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Original Article

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Implementation of integrated ecosystem assessments in the International Council for the Exploration of the Sea—conceptualizations, practice, and progress

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With increasing activities of multiple sectors in marine spaces, management of marine social–ecological systems requires more holistic approaches. Adopting such an approach, however, presents difficult institutional and disciplinary challenges. Here, we use the International Council for the Exploration of the Sea (ICES) as a case study on the implementation of ecosystem-based management (EBM) and integrated ecosystem assessments (IEAs). ICES includes EBM and IEAs in its Science Priorities and established IEA Working Groups (WGs) to carry out regional IEAs. But to what degree does this IEA WG work follow best practices? We examine policy documents, academic literature, and interview data from chairs of all IEA WGs. Results indicate mixed success. All groups acknowledge the holistic goals of IEA, and many use the IEA model as laid out by Levin *et al.* However, we found a significant variation in the degree to which the full model is applied. We identified two primary areas for improvement: (1) integration of social and economic issues and (2) involvement of stakeholders. We offer examples of how WGs have been making progress towards full IEAs, discuss how ICES can further support this transition, and suggest lessons with respect to the adoption of EBM and IEAs more broadly.

Keywords: International Council for the Exploration of the Sea (ICES), Integrated Ecosystem Assessments (IEAs), Social Science Methods, Semi-Structured Interviews.

Introduction

The range and magnitude of human activities in the marine environment are growing worldwide. Management of marine resources thus requires more holistic approaches to respond to increasingly high stakes for all marine sectors, scientific and political uncertainties, and urgency in decision making (Dankel *et al.*, 2012; Jouffray *et al.*, 2020). Integrated ecosystem assessments (IEAs) have increasingly been adopted to facilitate implementation of the broadly accepted goal of ecosystem-based management (EBM) and to provide ecosystem considerations to management decision making [Ash *et al.*, 2010; DePiper *et al.*, 2017; see also support for EBM in the Aitchi Targets connected to the Convention on Biodiversity (especially Goals C and D, on preserving ecosystems and enhancing ecosystem services) and are encouraged by the FAO, and international movements towards a growing Blue Economy, as supported by the World Bank and the United Nations Sustainable Development Goal 14; see also the UNDP–UNEP discussion of IEAs]. They are in active use worldwide, including in Norway (Ottersen *et al.*, 2011), Sweden (Hansen *et al.*, 2018), Canada (DFO Canada, 2002; Foley *et al.*, 2013: 622–623), the USA (Spooner *et al.*, 2021), and the International Council for Exploration of the Sea (ICES, 2013, 2015, 2017, 2020a, 2020c).

ICES fosters EBM science internationally and provides key scientific advice on the marine ecosystem to governments and

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international regulatory bodies managing the North Atlantic Ocean and adjacent seas. It embraced EBM beginning in 1999 and included it in the first ICES Strategic Plan in 2001 (Stange *et al.*, 2012; Wenzel, 2016). This and the 2012 adoption of IEAs (ICES, 2013; Walther and Möllman, 2013) marked a commitment to paradigmatic change for ICES. Traditional single-species management began moving towards managing stocks in an ecosystem context. This focus continues today (e.g. ICES, 2020c). However, the most radical aspect of this approach was acknowledging that humans are integral ecosystem components (e.g. MEA, 2005; Smith, 2007; Levin *et al.*, 2009; Ostrom, 2009; Paterson *et al.*, 2010; Levin *et al.*, 2014; re. Berkes *et al.*, 1998). As such, human uses of and benefits from the seas need to be incorporated into IEAs (e.g. Levin *et al.*, 2009, 2014), rather than simply treating humans as top predators in a marine ecosystem. The IEA, then, requires increased use of both ecological and social science data to provide ecosystem context and the synthesis of all data relevant for EBM. A paradigm shift of this magnitude presents a significant challenge and is one ICES has not yet fully embraced (e.g. ICES, 2020c).

Paradigmatic change is difficult for organizations. Moreover, adopting a holistic approach that requires integrating natural and social science as well as stakeholder input presents its own particular challenges (Gray and Hatchard, 2008; Levin *et al.*, 2009; Robinson *et al.*, 2012; Norris *et al.*, 2016; Burdon *et al.*, 2018; Djenontin and Meadow, 2018). ICES is of pivotal importance in fisheries and marine management in Europe and presents an important case of paradigm change. While Stange (2012) and others have explored the process by which ICES adopted the goal, the degree to which the approach is being effectively applied in practice has not been explored. The "Levin cycle" approach to IEAs (Levin *et al.*, 2009, 2014) is considered the gold standard for IEA (see "Literature Review"), and ICES IEA Working Groups (WGs) profess to be working towards this standard (see ICES, 2013, 2015, 2017, 2020a). Because of the importance of ICES for fisheries management throughout most of Europe and the northeast USA, as well as ICES' fisheries research leadership function internationally (see "Background on ICES IEA WGs"), the degree to which the ICES IEA WGs are actually meeting this standard is important to assess.

Here, we investigate the status of IEAs in ICES through their perception and implementation by the IEA WGs. We first present the IEA concept as understood in the literature and in ICES documents, identifying its key features. We then compare the concept to its perception and practice in IEA WGs through data gathered from interviews with IEA WG chairs. These data address two questions that illuminate the progress ICES WGs have made with IEAs. First, we ask to what extent do the IEA WGs follow the steps of Levin *et al.* (2009, 2014)? Second, to what extent do they consider the six IEA characteristics synthesized from the literature review, described below? This assessment rests on semi-structured interviews with WG chairs in 2018–2020. We asked WG chairs about their research processes and prompted them to identify needs for advancing their group's IEA. Based on these findings, we discuss recent changes within ICES that are fostering improved use of data from these IEA WGs. We also provide insights into current opportunities and challenges to the use of IEAs in ICES and more generally.

Background on IEAs

IEAs developed as a framework to implement and assess the progress of EBM. EBM is "an adaptable form of management that brings together natural and social scientists, stakeholders and resource managers in both the science and management-decision process to build meaningful relationships and recognize the full array of interactions within an ecosystem, including humans" (Spooner *et al.*, 2021: 27). Ideally, the outcome of an IEA is a co-created product by experts in the relevant social, economic, and ecological areas, including stakeholders. An IEA is a tool to assess, for a specific ecosystem, its status, and the adequacy of its management implementation process. Moreover, it is not a one-time product but an adaptive process or cycle (see Figure 1). A cycle implies continuous evaluation with each cycle serving as an input for the next, allowing for updated indicators and stakeholder input and overall improvement over time. Additionally, because they are designed to assess progress in EBM, IEAs are inherently a management tool and should be tied to management objectives. Thus, IEAs are transdisciplinary projects.

Norris *et al.* (2016: 116) distinguish *multidisciplinary* research, where researchers from different disciplines work "independently or sequentially on separate parts of a common research problem", from *interdisciplinary research*, where researchers work "jointly to integrate disciplinary perspectives and address a common problem, but remain anchored in their home disciplines". *Transdisciplinary* research, meanwhile, has been defined in two ways, both of which incorporate the idea of interdisciplinary research but also transcend it. The first is researchers jointly developing a "shared conceptual framework that synthesizes and extends discipline-specific knowledge creating new models and language to address a common research problem" (Stokols *et al.*, 2008 in Norris *et al.*, 2016). The second is researchers working with "non-traditional research partners" (Norris *et al.*, 2016), including variously defined stakeholders, in a process of co-production of knowledge (e.g. Djenontin and Meadow, 2018). IEAs should aim for transdisciplinarity under both definitions, but as a first step should be at least multidisciplinary and preferably interdisciplinary.

Background on ICES IEA WGs

ICES' mission is "to generate state-of-the-art advice for meeting conservation, management, and sustainability goals" regarding marine ecosystems and the services they provide. ICES' research is done primarily by a network of ~6000 individual scientists. The scientists come mainly from the 20 ICES member countries, but also from >40 other countries worldwide (ICES Science Committee chair, Jörn Schmidt, pers. comm.). To adopt IEAs, ICES has created IEA-focused WGs, each conducting research for a regional sea or seas (now ecoregions; see Figure 2) and producing ecosystem overviews (EOs) in Europe and equivalent products in North America (the WG for the North Atlantic Regional Sea currently focuses on east coasts of the USA and Canada). In 2012, ICES began a series of workshops where the IEA WGs and others worked to develop the IEA concept for ICES (ICES, 2013, 2015, 2017, 2020a). Each WG chooses Terms of Reference (ToRs) for 3-year periods at a time. An ICES WG generally has two to four chairs who serve 3-year, often overlapping, terms. Since 2014, the IEA WGs have been under the IEAs

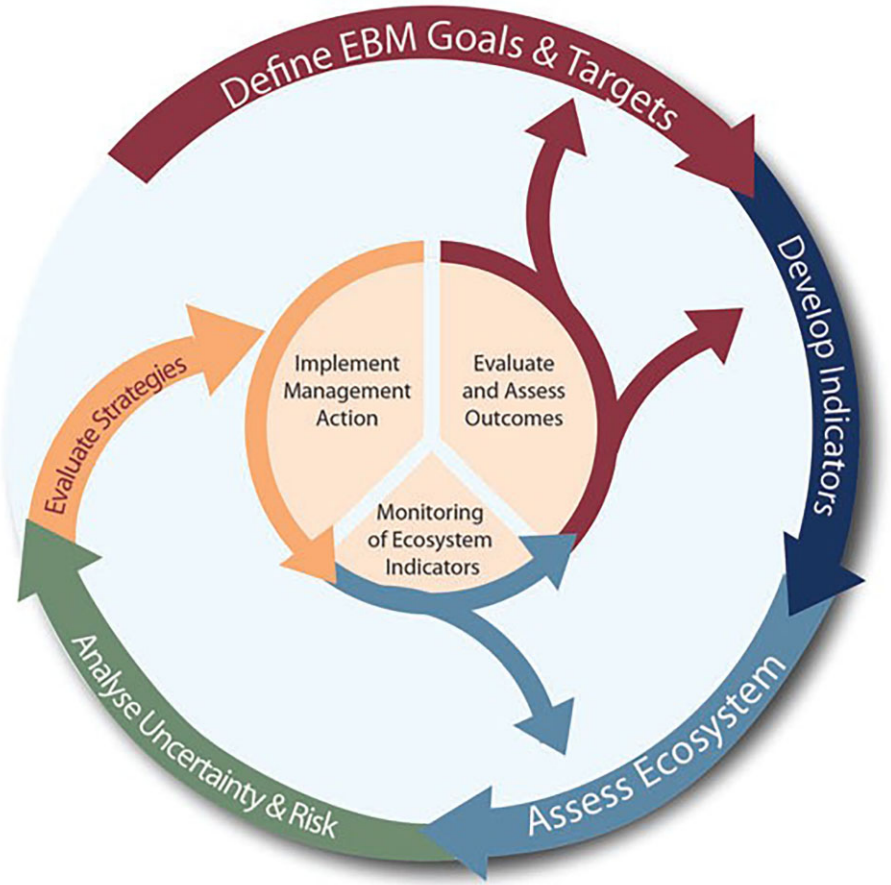

Figure 1. Conceptual schematic describing the cyclical, iterative nature of IEAs at the US NOAA. This figure is an update of the characterization of the approach depicted in Levin *et al.* (2009) and Samhouri *et al.* (2014: 1206). Used with permission of the NOAA IEA WG.

Steering Group (IEASG) [these are the WG for Integrated Assessment of the Baltic Sea (WGIAB); the WG on Ecosystem Assessment of Western European Shelf Seas (WGEAWESS); the WG on the Northwest Atlantic Regional Sea (WGNARS); the WG on the Integrated Assessments of the Barents Sea (WGIBAR); the WG on the Integrated Assessments of the Norwegian Sea (WGINOR); the WG on Integrated Assessments of the North Sea (WGINOSE); the WG on Comparative Analyses between European Atlantic and Mediterranean marine ecosystems to move towards an Ecosystem-based Approach to Fisheries (WGCOMEDA); the WG on IEA for the Central Arctic Ocean (WGICA); the WG on Integrated Assessment of the Azores (WGIAZOR); the WG on IEA of the Greenland Sea (WGIEAGS); and the WG on IEA of the Northern Bering Sea-Chukchi Sea (WGIEANBS-CS); see Figure 2]. At the time of this study, the 11 ICES IEA WGs had been established for periods of >1 to >15 years, meaning some WGs predate the first IEA development workshop in 2012 and have had to consider how to alter their existing protocols and processes to adapt to the new mandates. Other IEA WGs were still in the process of acquiring members and beginning operational research related to their ToRs at the time of our interviews. The chairs themselves had been members of their WGs for anywhere from <1 to >15 years at the time of the interviews.

Methods

(a) Literature review

Because we are dealing with ICES WGs, a review of the ICES literature was important to indicate what elements and practices ICES sees as critical to IEAs. The IEA workshops (ICES, 2013, 2015, 2017, 2020a) also presented the content and achievement of IEAs over time. The academic literature provided a broader sense of the commonly accepted key components of an IEA. Those, it became clear, were the steps of the Levin cycle (Levin *et al.*, 2009, 2014). One or both of Levin *et al.* (2009, 2014) were cited by 78% of the articles/reports initially reviewed. To identify an overall IEA framework and potential interview questions, the overall review focused on: EBM definition, IEA definition, IEA goal, IEA implementation process characteristics, and the main message/key issues. We initially reviewed 16 journal articles and 4 ICES documents (see Supplementary Resource 1) in order to formulate our interview protocol. We also interviewed the then ICES Ecosystem Approach Coordinator (M. Dickey-Collas, 23 February 2018). We gathered other literature cited here continuously over the course of the project.

In addition to the steps of the Levin cycle, we identified six key characteristics of IEAs: (i) IEAs form a framework for exploring potentially conflicting objectives and trade-offs. (ii)

Figure 2. ICES IEA Groups and their Regional Seas Areas (see bracketed text below Fig. 1 for full names). Used with permission of the ICES Secretariat, N. B. WGNARS' Regional Sea extends to the east coast of North America.

They include a broad assessment of dynamics and relationships, rather than just status and trends of individual components. (iii) They include social, economic, and ecological elements. (iv) They consider humans as both impacting and being impacted. (v) They are iterative and adaptive for management. (vi) IEAs involve stakeholder input. These characteristics and their use in this paper are discussed further below, under (c) Analysis.

(b) Interviews

We chose semi-structured interviews because they allowed for (i) targeting specific topics while (ii) asking follow-up questions for clarity—or to explore issues raised by the interviewees. They also allow interviewees to frame answers in their own words and are the best option when "you want reliable, comparable qualitative data," "you won't get more than one chance to interview someone", and you are "dealing with high-level bureaucrats and elite members of a community—people who are accustomed to efficient use of their time" (Bernard, 2006: 212). To avoid conflicts of interest, authors did not interview chairs of a WG of which they were members. Multiple WGMARS members had previous experience with oral histories and other types of semi-structured interviews and this prior experience informed the group discussion on the appropriateness of this format for our study.

Pre-interview author meetings then allowed for consensus on the questions and the approach. Extensive discussion on specific interview questions in person, virtually, and via email, along with a test interview with one of the WGs, led to final clarification of concepts and approach. Once the questionnaire was finalized, the five social scientists on the project met to finalize the interview coding structure. All interview pairs included at least one social scientist, which assured that someone familiar with the interview format and strategies was involved and enhanced comprehension of discipline-focused responses. Further, the interview guide (see Supplementary Resource 2) ensured comparability across interviews and included open-ended questions covering the following six themes: Background of the Chairs and their definitions of IEA; Group Composition; IEA Processes within the WG; Audiences for the WG's output, including any provision of advice; Methodological Approaches; and Future Needs to Fully Implement IEA. We chose these topic areas because they represent important information about the ICES IEA WGs that are related to both the six characteristics summarized from the literature review and the steps of the Levin cycle. The answers also give a sense of the evolution of the IEA WGs over time.

We interviewed IEA chairs in 2018–2020, in person or over video, for ~1 h. Due to scheduling and time zone issues, we were not able to interview all the chairs of some WGs, but we did interview at least one chair from each WG. All interviews were in English. Each interview team included two individuals, a primary interviewer and a second person to ensure proper recording and taking notes if needed. In 2018, we interviewed chairs of the eight existing ICES IEA WGs: WGINOSE, WGIBAR, WGINOR, WGCOMEDA, WGEAWESS, WGIAB, WGNARS, and WGICA. ICES created three new IEA WGs (WGIAZOR, WGIEANBS-CS, and WGIEAGS) in 2019. We interviewed chairs of WGIAZOR and WGIEAGS in 2020.

However, WGIEAGS had only been in existence for such a short period that they were still setting up the WG, so that interview was not analysed. We did not interview the chairs of WGIEANBS-CS due to timing issues. Thus, our final database of IEA WG interviews includes 9 of the 11 current IEA WGs and 17 individual chairs (see Supplementary Resource 3).

All interviews were recorded, then transcribed via Trint© or F4Transkript© and reviewed by the interviewers for any obvious mis-transcriptions. Next, we sent transcripts to interviewees for their review and approval. This allowed for correction of less obvious mistranscriptions, such as can occur where all interviews were in English and many interviewers/interviewees were non-native speakers. However, no or only minor corrections were received. When transcriptions were approved or corrected and approved, or a month passed with no response (despite a reminder), we began the analysis process. The interviews were coded for the questions in our interview guide with MaxQDA© by one person for consistency. That person was one of the social scientists involved in the earlier coding discussions. A second person read all the interviews to assure that the MaxQDA© segments captured the proper context. Because there were only 11 interviews, we did not use any of MaxQDA's specialized tools. Rather, multiple researchers individually or in pairs read all text with a specific code to better synthesize the results. Finally, we did a simple keyword search of the transcripts for terms/phrases related to the Levin cycle steps and the key characteristics from the literature review.

(c) Analysis

We examined the extent to which each of the WGs followed the steps of the Levin Cycle and included the six characteristics from the literature review. Some of these characteristics clearly fell under a single step, while others were potentially appropriate under more than one step. To avoid duplication, we have placed these characteristics as follows. *Needs to consider humans as both impacting and being impacted* was placed under Scoping, as this is the step where the broad outlines and key components of an IEA process are established. We placed *Provides a broad assessment of dynamics and relationships, not just status and trends of individual components* under Indicator Development, as this is the step where appropriate quantitative and/or qualitative ecosystem status measures for a particular case are chosen. We placed *Provides a framework for exploring potentially conflicting objectives and trade-offs* under Management Strategy Evaluation, as that is the step where trade-offs are considered. We also placed *Must be iterative and adaptive for management* here, as this is the step where management concerns are explicitly addressed. *Must involve stakeholder input* was the most difficult to place in a single step, as ideally it is used throughout the cycle, from Scoping to Indicator Development to Risk Analysis to Management Strategy Evaluation to Monitoring and Evaluation. Ultimately, we placed it under Scoping to reflect the general understanding that transdisciplinary work can only succeed if it starts at the beginning and that scoping is about establishing the goals of management (Curtin and Prellezo, 2010; Leslie and McLoed, 2007; Sharpe *et al.*, 2020).

Results

Here, we present and compare data from 17 chairs, representing 9 ICES IEA WGs. The data represent answers to two questions that illuminate the status of IEAs in ICES. First, to what extent do the IEA WGs follow the steps of Levin *et al.*, (2009, 2014)? Second, to what extent do they consider the six IEA characteristics synthesized from the literature review? Of the nine IEA WGs interviewed, five linked their description of IEA structure and process explicitly to the Levin cycle. Two other WGs mentioned the idea of sustainability, specifically noted in Levin *et al.* (2014) as a goal of the IEA process. Below, we provide interviewee responses ordered by the five steps of the Levin cycle, with the six characteristics placed under these steps as described above under "Analysis".

1. Scoping

Levin *et al.* (2009) describe scoping as identifying specific objectives and threats to EBM to be addressed by the IEA. Levin *et al.* (2014) define this step as articulating the objectives to be addressed by the IEA process, defining the spatial scale of the IEA, and conceptualizing the ecosystem and the IEA.

Chairs of three WGs said their objectives and indicators come from the European Union's Marine Strategy Framework Directive (MSFD; European Commission, 2008). The chair of a fourth similarly noted, "instead of developing objectives ourselves we defaulted to look at what managers through regulations had suggested was the objective of management".

- Needs to consider humans as both impacting and being impacted

Chairs of three IEA WGs spoke of humans primarily as impacts on the ecosystem. For example, a chair from one WG saw the objective of IEA as estimating "the current state of the ecosystem, including impact from human activity". A chair from another WG defined IEA as "ensuring that those [human] activities don't go beyond the boundaries of what the ecosystem can sustain". A chair of a third WG noted, "[I]t is in the overall evaluation of … the status of the ecosystem … including to what extent that status is influenced by human activities, human pressures". A chair of a fourth WG, in contrast, described investigating qualitative models that include both biological and economic indicators for fisheries.

- Must involve stakeholder input

Including stakeholders can help track how humans impact and are impacted by ecosystem changes and management responses. IEA WGs vary considerably in whom they consider as stakeholders. A chair of one WG described stakeholders as "the people using our tools". A chair from another WG included the shipping sector, green NGOs, and indigenous communities. A chair of a third WG described their stakeholders as including fishers' organizations and government ministries (e.g. fisheries, environment, and climate). A chair from a fourth WG took a broader view: "[T]ypically … the stakeholders that we have are fisherman, fishing organisations; … but what about the ordinary people that like to go swimming in the ocean, … dive or snorkel?" And a chair from a fifth WG summarized: "The stakeholders would be ministries representatives, NGOs and other organisations that have activities in the ecosystem and have to follow the policies…". A chair of a sixth WG stated: "We do interact with stakeholders, particularly the [regional fishery management bodies that] are very stakeholder and industry-driven". Yet, the chair of a seventh WG felt that "getting stakeholders involved would be important, but it's not within the framework of the ICES WG".

There are also different views on appropriate types of stakeholder involvement. A chair from one WG saw stakeholders as

data sources where other data are lacking (e.g. fishers providing historical fishing effort and foodweb interaction data). A chair from another WG mentioned potentially doing cognitive mapping with stakeholders and noted some connections to general water management and staff from federal ministries. A chair from a third WG is working with management bodies that include open fora with fishers to choose specific studies that will be of use to management.

- Must include social, economic, and ecological elements

Most members of the IEA WGs, and all but two of the chairs, were natural scientists. A chair of one WG stated: "[In] the last couple of years, we wanted to include more the human dimension, where we have to some extent tried to cooperate at least loosely [with] social scientists". The majority of WGs plan to include socio-economic research, but must look outside for the necessary expertise. Two rely on cooperation with research institutions. Two others plan to draw on other ICES WGs, with one chair noting: "[W]e were happy to hear that there are some developments within ICES now …; [with] other WGs … defining these social indicators and potentially guiding us where to look for information". One limiting factor for incorporating socio-economic expertise is that IEA WGs are composed of members of different nations that may lack common priorities for social/economic issues. The range is captured in two quotes: This is "one of the most diverse WGs I have ever worked with in my career" versus a WG characterized as "coming mostly from fisheries", where "fisheries" meant biology and ecology.

Furthermore, the WGs express varying degrees of urgency in adding social scientists. A chair of one WG noted: "For these three years … we didn't decide on ToRs that really [integrate] … socio-economics. But for the next 3-year cycle, our idea is to try to expand a bit these questions". A chair from another WG stated: "I think from the perspective of IEAs, in the future we will want to involve economists and specialists on the climate". A chair from a third WG expressed apprehension: "It can be too much pressure, caused by the elevated expectations. … This will be very difficult". But a chair of fourth stated: "[T]his last year, we have made the attempt to link some of the questions that we are asking in our WG with fisheries economists…exciting". And a chair from a fifth WG noted: "We have an economist here who is now heading up probably the most concerted effort forward based on employment insurance and economic things like that; I never would have explored it before. So it has been a real eye-opening experience".

2. Indicator development

Levin *et al.* (2009) define this as identifying and validating appropriate indicators; Levin *et al.* (2014) describe it as selecting and defining appropriate ecosystem indicators and reference levels.

Three (EU) WGs mentioned the MSFD as describing or providing the impetus for indicator creation; one stated: "after the MSFD was introduced with this demand of implementing indicators for the different 11 descriptors of the oceans, there have been various parameters that have been identified … that managers should look at over time and in the next several years". Of these three WGs looking at MSFD, one chair also noted: "For the last meeting, we looked at the SDGs because they have some indicators suggested". Meanwhile one chair is wary of using indicators, in part because this WG's regional sea is currently data poor.

- Provides a broad assessment of dynamics and relationships, not just status and trends of individual components

Chairs of three WGs noted that they have been using conceptual modelling to understand broad relationships in the ecosystem (e.g. foodweb connections, fishing pressure, and economic impacts), sometimes with qualitative modelling software. Chairs from six WGs mentioned the importance of understanding system dynamics (though the system referenced was often marine only). A chair of one of these WG noted: "[W]e often looked at the trend of time series without evaluating what was good and what was not good. But now, as part of the MSFD, you have different indicator time series and there have to be thresholds defined or targets defined to say, ok, the system is in a good state or in a bad state". However, of these six, four stated that for now their process was actually more an Integrated Trend Analysis, a precursor to an integrative assessment (Möllmann *et al.*, 2014).

3. Risk analysis

Levin *et al.* (2009: 0025) define this as assessing "the risk to the indicators posed by human activities and natural processes". Levin *et al.* (2014: 1201) define it as evaluating the risk of exceeding reference points or indicators that is "posed by human activities and natural processes".

Chairs from seven WGs specifically mentioned risk analysis. One WG chair noted the use of [a specific tool] for risk assessment, adding "but I don't know if we can go farther". Another WG is beginning to work with regional management bodies on defining risk to evaluate trade-offs. Chairs from a third WG said they were planning to "subject these indicators to a formal analysis and risk assessment and MSE", even though they did not yet have social indicators—noting they would add social and other additional indicators to the process as they were able. A chair from a fourth WG mentioned the importance of developing indicators to, among other things, conduct a risk analysis. Chairs from two other WGs specifically said they were not doing risk analysis because they lacked the necessary personnel or it was otherwise "too difficult". A chair from another WG said simply "when it comes to risk, that is more related to human activities", and his group was at that point focused on the marine ecosystem.

4. Management strategy evaluation

Levin *et al.* (2009) describes this as using ecosystem-modelling frameworks to evaluate the impact of different management strategies in order to identify which are most likely to meet stated objectives. Levin *et al.* (2014: 1202) describes this as using "simulation and analytical or conceptual modelling" to evaluate which management strategies may help to achieve the stated ecosystem objectives.

Chairs from a total of seven out of the nine IEA WGs mentioned planning for or conducting MSEs. The same chair who mentioned using indicators for risk analysis also mentioned their importance for MSE. Chairs from four WGs thought they were probably ready to start trying some MSE or scenario analysis, with one adding that doing so might require adding "some economists and social people". A chair from a fifth said they had recently completed an MSE for a single stock fishery. A chair from another WG considered they

were not yet ready for MSEs, but expected to do them in the future.

- Provides a framework for exploring potentially conflicting objectives and trade-offs

As one chair noted, "The IEA is an approach with which knowledge is gained and processed in a synthesised way to be able to tackle the ecosystem-based management issues such as trade-offs between sectors and essentially arrive at sustainable management for the system as a whole, including humans". Altogether, chairs from four WGs mentioned exploring trade-offs. They also referred to the difficulty of addressing normative issues and clarified that it is rarely a case of objectively "good" vs. objectively "bad" uses. For instance, within the fisheries sector, is employment or profitability "better"? More broadly, among fishing, energy production, marine sanctuaries, or military use, what is "best"? A chair of one WG noted, "in economics, at least, … some approaches … have been developed to [assess trade-offs]", but explained that these only apply if you have weights for the various options. That chair later described work with regional management bodies on evaluating trade-offs, noting, "as of right now we are still struggling with how you would actually implement some sort of interdisciplinary or transdisciplinary analysis at that level. And I think that the predominant reason for that is that managers are loath to provide the weights across these objectives … especially if there is a trade-off across management bodies".

5. Monitoring and evaluation

Levin *et al.* (2009) describes this as continuous monitoring and evaluation of ecosystem indicators to be sure the system is staying within its desired state. Levin *et al.* (2014: 1202) describes this as continuous monitoring and assessment "to determine whether management strategies improve ecosystem services and sustainability and quantifies (sic) the trade-offs that have occurred since implementation of the management strategy".

Chairs from seven IEA WGs specifically used the terms "monitoring" and "evaluating". They spoke primarily of quantitative evaluations and monitoring key properties, e.g. "…both [diversity and stability] are important properties to … monitor in the ecosystem". All WGs monitor both physical and biological properties "to understand processes". In many cases, the WGs have found it important to sub-divide their regional sea into separate functional areas and then "identify what kind of monitoring data sets are available associated with those strata". A chair of one WG noted: "[W]e often looked at the trend of time series without evaluating what was good and what was not good. But now, as part of the MSFD, you have different indicator time series and there have to be thresholds defined or targets defined to say, ok, the system is in a good state or in a bad state". A chair of another noted: "[W]e want to take account of the other impacts, not only fisheries but also other activities … and evaluate the state of the ecosystem".

- Must be iterative and adaptive for management

Five IEA WGs specifically use the word "cycle", referring to the Levin cycle, indicating they planned an iterative process. At least some WGs see their role as contributing to adaptive management. For instance, a chair from one explicitly noted: "IEA is not just a description of the ecosystem. It answers a question". That chair later noted limitations, saying: "for the [sub-region of a regional sea] they [regional managers] have identified which part of the system is most at-risk from their perspective, and then you build a model that kind of identifies the appropriate scale. So we are going to develop a list of five specific questions we could answer with the information and the expertise available to us. If and when they identify which one of those they actually want to address, then you build an appropriate model at the appropriate scale".

But the degree to which the IEA WGs see themselves as providing advice to managers varies. A chair from one WG stated: "We started before the Levin cycle was suggested. […T]hen IEA was more of a loose concept; … and now our WG has turned more into trying to fit our work into the IEA framework". A chair from another noted: "I have been working for a long time in fisheries biology and population dynamics applied to fish stock assessment to give advice for the fisheries management. And these have been evolving in a way that we want to take account of the other impacts, not only fisheries but also other activities of the ecosystem". A chair from a third WG said an IEA "is a good way to synthesise information, both knowledge and information to really assess the ecosystem.… Develop the scope, indicators, the risk analysis, the status, for the management".

Discussion

Key areas and issues

The IEA approach as defined by Levin *et al.* (2009, 2014) prescribes a sequence of steps as illustrated in Figure 1. This means that the steps are interrelated, each building on the previous steps in a progressive, iterative process. Issues at early stages accordingly have implications for later stages and possibly, without intervention, the continuing cycle. Here, we discuss the current state of progress of ICES IEA WGs towards prescribed IEA approaches.

1. Challenges to scoping remain

Scoping involves conceptualizing the ecosystem to help identify management objectives and threats. Ideally, this includes all those stakeholders whose livelihoods and economic, social, and cultural well-being are impacted by advice and regulations (here, e.g. fishers, aquaculture businesses, offshore energy companies, dredging companies, and the military (CBD, 2000); Beddington *et al.*, 2007; Dickey-Collas, 2014; Long *et al.*, 2015; ICES, 2019a). These stakeholder analyses should be conducted prior to each new cycle (Levin *et al.*, 2019, 2014; Samhouri *et al.*, 2014; Burdon *et al.*, 2018; Ballesteros and Dickey-Collas, 2023). Ideally, moreover, the IEA process begins with stakeholders participating in formulating conceptual frameworks and research questions, and collecting data, then jointly analysing and interpreting results with scientists (Wiber *et al.*, 2004; Röckmann *et al.*, 2015; Ingram *et al.*, 2018). Currently, ICES IEA WGs vary with respect to how they define stakeholders, their degrees and modes of involvement with them, and their understandings of the points at which stakeholders should be brought into the process. The successful incorporation of stakeholders into ICES work, other than traditional recipients of advice related to stock assessment, still represents a challenge (Dickey-Collas and Ballesteros, 2019, 2021; Ballesteros and Dickey-Collas, 2023).

2. EBM feedback loops not fully achieved

Levin *et al.*'s (2009, 2014) characterization of EBM as complex socio-ecological interactions, including impacts and services, is commonly represented as a set of feedback loops within and across the social and ecological parts of the overall system, see, e.g. Figure 1 in Bograd *et al.* (2019). Many IEA WGs do link their IEA to EBM in a way that potentially does this. Their objective is, as one chair stated, to "synthesise … all the scientific information… to inform decisions in the context of ecosystem-based management". Or as stated by a chair from another WG, IEA is "a framework in which you just try to consider as many of the interactions in a system as possible… to make sure you are not missing any issues". However, in practice, some WGs display classical ecosystem thinking, by incorporating humans into marine ecosystem analyses in a limited, unilateral way, e.g. as described in "Results" under "Scoping" (see also Bundy *et al.*, 2008). The IEA WGs, in general, are still at the level of following a "general workflow" that was catalogued in WKIDEA (ICES, 2017: 3): (1) Data collection; (2) Data analysis; (3) Conceptualization; (4) Model development; (5) Scenario development; (6) Scenario testing (assessment)—with steps (5) and (6) not always present yet, even for some of the longstanding WGs.

3. Challenges to true interdisciplinarity

Moving beyond the focus on impacts and feedback loops discussed above requires new data and expertise. Most IEA WGs lack both. We have noted the wide variation in stakeholder involvement across the WGs. Our interviews also reveal that, generally, little economic and especially social data is yet used actively by the IEA WGs. Some WGs view their mostly natural science work as a first stage, and have the ambition of working more with social scientists in the future, a process that would progress multidisciplinarity, but not ensure inter- or transdisciplinarity. Few WGs have a plan for moving beyond incorporating a limited number of human impacts into their IEAs. In general, this suggests that not very much has changed for many of the IEA WGs since Dickey-Collas (2014: 1177) remarked that they "seem most confident and happiest when working in the core ICES disciplines of fisheries and the ecology of marine vertebrates and copepods". **WKCONSERVE (ICES 2020a)** argued that the first step towards including social and economic aspects in ecosystem analysis is to include social scientists in the WGs. Many social scientists are prepared for this endeavour (Kraan and Linke, 2020). However, looking at the history of incorporation of social science in NOAA (Abbott-Jamieson and Clay, 2010), the incorporation of sufficient numbers of social scientists into ICES WGs (and ICES leadership) will potentially take years, if not decades. Empirical findings in the EU further suggest that "interdisciplinarity is an extensive learning process taking place on three levels: between individuals, between disciplines, and between types of knowledge" (Haapasaari *et al.*, 2012: 1). Moreover, the learning process could be facilitated "by agreeing to a methodological epochè and by formulating a global question at the outset of a process" (*ibid.*). ICES might consider whether to sponsor such an effort, alone or in coordination with other national and international bodies.

Beyond this, without a base level of funding from ICES, the participation of additional disciplines will be slow to come, resulting in the multiplication of difficult tasks for ICES WGs—with no appreciable increase in funding, expertise, personnel, or work hours. So far, stakeholder workshops (e.g. ICES, 2016; ICES, 2020b) have generally been funded by research grants. This can make continuous involvement of stakeholders difficult.

4. Clarification needed of IEA role in the management system

In ICES, there is a clear divide between those WGs involved in producing management advice (i.e. stock assessment WGs, which provide advice requested by ICES member countries) and those whose work does not directly contribute to advice, (e.g. IEA WGs, though this is changing, see below). This has undercut the evolution of the IEA groups, since the IEA process itself is closely tied to producing management advice. The disassociation of the IEA from ICES advice is exemplified by the ICES 2020 Annual Report (ICES, 2021c, pp. 6) and the Guide to ICES advisory framework and principles (ICES, 2023b—which do not list IEAs as products. This contrasts with, for example, the EOs that have been requested through the ICES Advisory Committee (ACOM), by "member countries, international commissions and organisations, and fisheries and ecosystem management bodies". As a result, in general, the WG chairs described the impetus for IEA work as coming from within the WG itself, though this is slowly beginning to change (ICES, 2019, 2021a, 2021b).

Multiple chairs expressed a need for greater ICES involvement in clarifying the procedures and easing the implementation of the IEA process. One chair stated this as: "…if ICES wants to push this strongly, then dedicated WGs, hopefully organised under ACOM, should pursue this and do this on a routine basis; similar to the fish stock assessments…", with dedicated personnel. Another WG chair noted: "If policymakers were interested in IEA then there would be a budget". Advancing and sharing scientific understanding of marine ecosystems and the services they provide—and using this knowledge to generate state-of-the-art advice to meet conservation, management, and sustainability goals—requires dedicated annual funding, at a minimum for "benchmark" meetings, which discuss methods in an iterative way (re. those for stock assessment WGs). Benchmark meetings have the additional benefit of not being limited to scientists, but also including stakeholders.

Ways forward for ICES

ICES has attempted to make the organizational changes necessary to accommodate producing the new EBM-oriented work. It undertook a series of organizational and process changes that support the adoption of EBM (Stange, 2012) and created eco-regional IEA WGs. It also created the IEA Steering Group to facilitate interaction and learning among the IEA WGs. In addition, it has recently created a "pipeline" process (ICES, 2019) to include new elements in EOs, including adding in 2021 reports of fishing activity and effort by fishing port (e.g. ICES, 2021d). It also has launched Viewpoints, to provide "unsolicited advice" that highlight ICES' capacity to provide "evidence-based analyses of emerging topics related to the state and sustainable use of the seas and oceans". These are all steps towards literally putting humans on the map and creating avenues for adding social and economic analyses to future EOs.

However, ICES could better facilitate operation of at least some governance processes through setting stakeholder

involvement as the clear policy of the organization. ICES has opened many groups to stakeholder engagement and observation and regularly engages with the EU fisheries advisory councils (Dickey-Collas and Ballesteros, 2019). The current Stakeholder Engagement Strategy (ICES, 2023a) reflects ICES' efforts to facilitate stakeholder involvement. It could go further by encouraging increased use of scenario planning, participatory processes, and case studies (Link *et al.*, 2017) in ICES work. Moreover, though the stakeholder strategy recognizes stakeholders as instrumental in meeting "knowledge needs", it does not explicitly discuss stakeholder roles in establishing management goals. One step forward would be to update the ICES Science Plan (ICES, 2020c) and other policy documents to make clearer the significance of links between impacts and services (and human and ecological components of the ecosystem (**re. DFO, 2002**); Link *et al.*, 2015; Denit, 2016; Harvey *et al.*, 2021).

Greater involvement with stakeholders by ICES will of course bring complexity. Establishing management objectives is an inherently political exercise. This may be why the Levin IEA process developed in the USA where establishing management goals legally requires collaboration between NOAA and the stakeholder-driven Fishery Management Councils. As Dickey-Collas and Ballesteros (2019) point out, involving stakeholders more deeply into ICES work, including as co-authors of reports, could be seen by some as a challenge to the neutrality and hence authority of ICES scientific work. Nonetheless, the inclusion of stakeholders is now an established principle of EBM and ICES is developing guidance for ensuring the integrity of scientific information submitted to ICES by data providers (see upcoming report of WKEnsure, held in February 2023).

Additionally, the lack of social science expertise has contributed to the IEA WGs' difficulties in seeing how to incorporate the human dimension into their work. Research on integrated management has highlighted the importance of training in the production of truly interdisciplinary and transdisciplinary work (Alexander *et al.*, 2019; Stephenson *et al.*, 2019). In the ICES context, where the organization does not itself supply the core personnel engaged in the work, workshops have played key roles in training and education (Fuller *et al.*, 2023). WKTRANSPARENT (ICES, 2021b), for example, focused on advancing the interdisciplinary contributions to the ICES EOs and WKCCMM (ICES, 2022) provided training to support inter- and transdisciplinary science through the use of qualitative conceptual models. These and other work (e.g. ICES, 2019, 2020c, 2021a, 2021b) could together move ICES towards a more coupled approach for impacts and benefits.

However, participation in workshops remains voluntary, and depends much on the ability of those interested to dedicate several days out of busy professional calendars. In addition, while ICES publishes the results of all workshops, and workshops have in the past built on each other, it is unclear to what extent there is a formal protocol for following up on such workshops. EBM and IEA require a change in the processes of requesting, producing, and using advice and assessment (Möllmann *et al.*, 2014). Ultimately, until ICES member states request advice on social and economic impacts, ICES alone will not and cannot provide the necessary support to conduct full IEAs. Remedying this situation requires ICES leadership, political will beyond ICES, individual initiative, and a willing scientific community (Olsen *et al.*, 2014). The ICES leadership may be able to encourage ICES members to fund the participation of social scientists throughout the system of ICES expert groups (WGs and workshops) to a greater degree than is now the case. The IEA WGs might also benefit from regular funded benchmark meetings, as noted above (e.g. see 2021 ToRs for WGs and WKs under the ICES Fisheries Resources Steering Group).

Conclusion

The ICES experience is not unique. The EBM approach is broadly recognized and is being widely implemented by a variety of methods (e.g. Levin *et al.*, 2009, 2014; Arbo and Thy, 2016; Long *et al.*, 2017; O'Higgins *et al.*, 2019; Ehler, 2021). There has been progress, but EBM generally, and IEAs more specifically, have seldom been fully implemented, and not just in ICES (Link and Browman, 2017; Gaichas *et al.*, 2018; Karnauskas *et al.*, 2021; DePiper *et al.*, 2021). Surveys of EBM implementation (Lachapelle *et al.*, 2003; Long *et al.*, 2015, 2017; Rodriguez, 2017; Alexander *et al.*, 2019) suggest a series of barriers to implementation. These and other studies point to issues such as *conceptual ambiguity* (Long *et al.*, 2017; Smith *et al.*, 2017), *how and when to involve stakeholders* (Röckmann *et al.*, 2015; Smith *et al.*, 2017; Aminpour *et al.*, 2021), *the relationship of EBM to management and policy objectives* (Link and Browman, 2017; Murphy *et al.*, 2021) and *the need for guidance and training* (Alexander *et al.*, 2019; Stephenson *et al.*, 2019). The difficulty of fully integrating humans into IEA is illustrated by the lingering questions of how to deal with stakeholders and persistent difficulties in integrating socio-economic knowledge into processes that have focused in the past on marine ecological systems (Abbott-Jamieson and Clay, 2010; Robinson *et al.*, 2012; Kline *et al.*, 2017; Olsson and Jerneck, 2018; Alexander *et al.*, 2019). Much progress has been made, but more is needed. We recommend three key focus areas as a start: (1) the use of conceptual modelling to help visualize the specific ecosystem under study, (2) dedicated funding for stakeholder engagement, and (3) an emphasis on bringing in more social scientists who can both facilitate stakeholder involvement and provide basic sociocultural and economic research and indicators.

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Supplementary data

Supplementary material is available at the *ICESJMS* online version of the manuscript.

Author contributions

PMC: conceptualization (helped to flesh out the initial idea); design and methodology (helped fashion and review the interview questions); participating in performing experiments or the collection of data (co-conducted and transcribed three interviews); analysis of the findings (analysed literature review data, reviewed coding of specific sections, performed keyword search on all interviews); and drafting and revising the manuscript (involved in all drafts, lead on the series of final drafts leading to initial submission, responsible for most text in the final post-submission revision, wrote final revised version for submission, prepared response to comments, responded to final reviewer comments accompanying acceptance letter).

JF: conceptualization (helped to flesh out the initial idea); design and methodology (helped fashion and review the interview questions); participating in performing experiments or the collection of data (co-conducted and transcribed four interviews, including the initial test interview, conducted the interview with the ICES Ecosystem Approach Coordinator); analysis of the findings (analysed literature review data, did initial coding of all interviews); and drafting and revising the manuscript (involved in reviewing and providing suggested text/revisions for all drafts leading up to initial submission)

JLB: conceptualization (helped to flesh out the initial idea); design and methodology (helped fashion and review the interview questions); participating in performing experiments or the collection of data (co-conducted one interview); analysis of the findings (analysis of the literature review data, reviewed coding of specific interview sections); and drafting and revising the manuscript (involved in reviewing and providing suggested text/revisions for all versions, including the initial submission, the revised submission, and the final submission)

LG: conceptualization (helped to flesh out the initial idea); design and methodology (helped fashion and review the interview questions); analysis of the findings (analysis of literature review data, reviewed coding of specific sections); and drafting and revising the manuscript (revised and commented on most drafts leading to the initial submission).

DJD: conceptualization (helped to flesh out the initial idea); design and methodology (helped fashion and review the interview questions); participating in performing experiments or the collection of data (co-conducted one interview and transcribed two); analysis of the findings (reviewed coding of specific sections); and drafting and revising the manuscript (revised and commented on most drafts leading to the initial submission).

MS: conceptualization (helped to flesh out the initial idea); design and methodology (helped fashion and review the interview questions); participating in performing experiments or the collection of data (co-conducted three interviews); and drafting and revising the manuscript (revised and commented on early drafts leading to the initial submission).

JF: analysis of the findings (reviewed coding of multiple specific sections); and drafting and revising the manuscript (revised and commented on all later drafts leading to the initial submission).

SL: design and methodology (helped fashion and review the interview questions); participating in performing experiments or the collection of data (co-conducted 1 interview).

JS: design and methodology (helped fashion and review the interview questions, participating in performing experiments or the collection of data (co-conducted and transcribed one interview), and drafting and revising the manuscript (provided comments on early versions and provided background information on ICES' structure and function).

KNN: conceptualization (helped to flesh out the initial idea); design and methodology (helped fashion and review the interview questions); participating in performing experiments or the collection of data (co-conducted and transcribed one interview).

DG: design and methodology (helped fashion and review the interview questions), and drafting and revising the manuscript (provided comments on some drafts leading to initial submission).

RG: conceptualization (participated in early discussions); design and methodology (helped fashion and review the interview questions), participating in performing experiments or the collection of data (co-conducted and transcribed 1 interview).

ARF: design and methodology (helped fashion and review the interview questions), participating in performing experiments or the collection of data (identified the initial articles for the literature review), analysis of the findings (initial structuring and analysis of the literature review data), and drafting and revising the manuscript (commented on early drafts).

IE: design and methodology (helped fashion and review the interview questions), analysis of the findings (checking coded interviews for text with specific codes and commenting on findings).

CR: conceptualization (first suggested the project), design and methodology (helped fashion and review the interview questions), participating in performing experiments or the collection of data (co-conducted one interview), analysis of the findings (final structuring and analysis of the literature review data), and drafting and revising the manuscript (revised and commented on most drafts leading to the initial submission).

Data availability

In order for the interviewees to be able to speak freely, we did not ask them to allow the interviews to become public. In fact, you will see below that we do not assign quotes to specific chairs or even specific IEA WGs. The data will be shared on reasonable request to the corresponding author, pending permission from the interviewees.

Conflict of interest

The authors confirm they have no conflicts of interest.

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