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The Origin of NOAA's Integrated Ecosystem Assessment Program: A Retrospective and Prospective

Chris J. Harvey[a], David L. Fluharty[b], Michael J. Fogarty[c], Phillip S. Levin[d,e], Steven A. Murawski[f], Franklin B. Schwing[g], Rebecca L. Shuford[h,i], Christopher R. Kelble[j], and Mark E. Monaco[k]

[a]Conservation Biology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, Washington, USA; [b]School of Marine and Environmental Affairs, University of Washington, Seattle, Washington, USA; [c]Ecosystem Assessment Program, Northeast Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Woods Hole, Massachusetts, USA; [d]School of Environmental and Forest Sciences, University of Washington, Seattle, Washington, USA; [e]The Nature Conservancy, Seattle, Washington, USA; [f]College of Marine Science, University of South Florida, St. Petersburg, Florida, USA; [g]Science Information Division, Office of Science and Technology, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Silver Spring, Maryland, USA; [h]Marine Ecosystems Division, Office of Science and Technology, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Silver Spring, Maryland, USA; [i]New York Sea Grant, Stony Brook University, Stony Brook, New York, USA; [j]Ocean Chemistry and Ecosystem Division, Atlantic Oceanographic and Meteorological Laboratory, Office of Ocean and Atmospheric Research, National Oceanic and Atmospheric Administration, Miami, Florida, USA; [k]Marine Spatial Ecology Division, National Centers for Coastal Ocean Science, National Ocean Service, National Oceanic and Atmospheric Administration, Silver Spring, Maryland, USA

ABSTRACT

In response to calls for marine ecosystem-based management (EBM), the U.S. National Oceanic and Atmospheric Administration (NOAA) developed a multidisciplinary science support framework called integrated ecosystem assessment (IEA). The IEA framework and a national NOAA program for implementing that framework were the culmination of many efforts in the 2000s. At a recent workshop, five leaders from the early days of NOAA IEA development participated in a panel to discuss the history of the framework and program, and to provide recommendations for future work. Panelists intended IEA to be a call to action for scientists and agencies to support EBM, and they designed the framework to be adaptable, scalable, and non-prescriptive so that it could be applied to a range of issues. Panelists emphasized the complementary nature of the processes, tools, and products that make up IEA efforts, and also stressed the need to adapt the IEA approach to shifting management and governance structures. Finally, panelists offered a range of recommendations for future development of the IEA approach, including: (1) broadening the stakeholder base; (2) developing objectives and reference points in partnership with end-users; (3) increasing diversity of IEA practitioners to better reflect the communities that IEA serves; (4)

KEYWORDS

Communication; Ecosystem-Based Management; Engagement; Fisheries; Governance; NOAA Integrated Ecosystem Assessments; Spatial Scales

CONTACT Chris J. Harvey Chris.Harvey@noaa.gov Conservation Biology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 2725 Montlake Blvd E, Seattle, WA 98112, USA.

increasing development of readily updatable, real-time products; (5) carefully assessing and prioritizing the demands placed on IEA practitioners; (6) increasing collaboration across disciplines and resource sectors; (7) seeking opportunities to engage with emerging governance structures; and (8) strengthening support for IEA by effectively communicating its stories.

Introduction

Over the past several decades, support has grown for implementing ecosystem-based management (EBM) of the world's oceans (Fluharty, Langlet, and Rayfuse 2019). The goal of EBM is sustainable human activities across diverse sectors, while maintaining the functionality and resilience of coupled social-ecological systems. In 2010, the U.S. National Oceanic and Atmospheric Administration launched the Integrated Ecosystem Assessment (IEA) program to provide science that supports EBM. The program was the result of years of agency effort (EETT 2006; Fluharty, Langlet, and Rayfuse 2019; NOAA 2007) and parallel effort in the international community (e.g., Walther and Möllmann 2014), culminating in development of an IEA framework (Levin et al. 2008), a foundational paper to describe the framework (Levin et al. 2009), and allocation of program funds in 2010. Since its inception, the NOAA IEA program has engaged in partnerships supporting EBM approaches in five regions of the U.S. (Samhouri et al. 2014), and is playing a central role in implementation of NOAA's Ecosystem-Based Fisheries Management (EBFM) Policy (Link 2017; NOAA 2016).

In May 2019, NOAA IEA practitioners and partners gathered in Silver Spring, MD, USA for a workshop to commemorate the program's first decade. During the workshop, five architects of the NOAA IEA concept and program participated in a panel discussion of the program's history and future. The five panelists were Phil Levin, Steve Murawski, David Fluharty, and Mike Fogarty, the four authors of the seminal Levin et al. (2009) paper; and Frank Schwing, who was involved in EBM strategic planning within NOAA in the years leading up to the IEA program, and co-led the California Current IEA region at its inception. The discussion captured the panelists' perspectives on their original vision for the IEA program, and how it has evolved; the nature of IEA as a process and a product; connecting IEA-focused research to existing and emerging governance systems; the strengths and versatility of NOAA's IEA approach; and recommendations for advancing IEA and EBM in the future. The sections below are built around excerpts from the transcript of the panel discussion. Our hope is that the panelists' perspectives will inform ongoing and emerging integrative efforts to implement EBM.

The origins and blueprints of the NOAA IEA program

The way for the NOAA IEA program, which officially began in 2010, was paved by decades of evolving research and thought around EBM (Samhouri et al. 2014, Fluharty, Langlet, and Rayfuse 2019). The potential benefits of integrated management of resources had been outlined in numerous influential reports (e.g., EPAP 1999; Garcia et al. 2003; MEA 2005; Pew Oceans Commission 2003; USCOP 2004), and were recognized

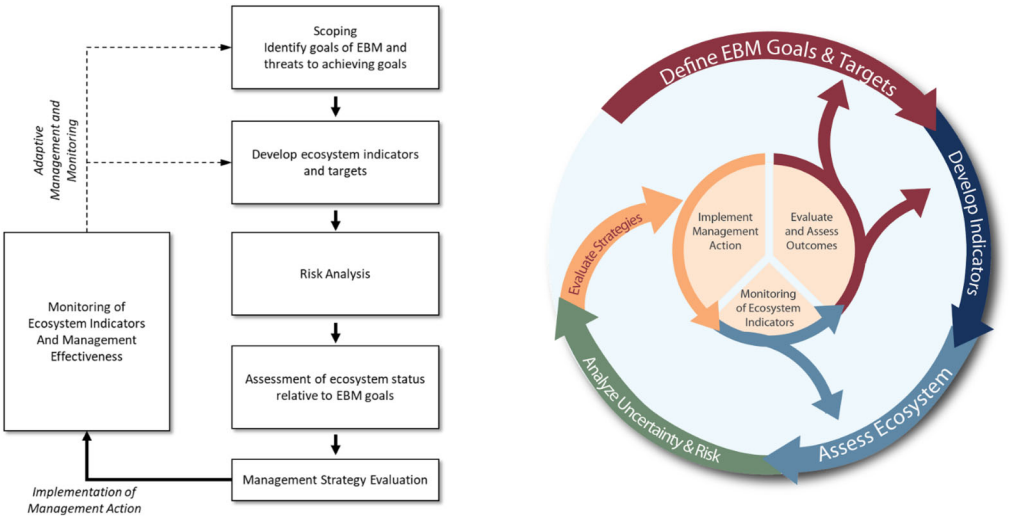

Figure 1. The NOAA integrated ecosystem assessment (IEA) framework. Left: IEA framework as originally depicted by Levin et al. (2008, 2009). Right: as currently depicted with additional detail in the management implementation steps, following Samhouri et al. (2014).

in a NOAA strategic plan (NOAA 2004). Based on that plan, in 2004 the NOAA Science Advisory Board convened an External Ecosystem Task Team (EETT), chaired by David Fluharty, to review NOAA's capacity to plan, conduct and apply ecosystem science in support of its management responsibilities (EETT 2006). The EETT found that aspects of NOAA's ecosystem science enterprise were well-positioned to support EBM. For example, many pieces of federal legislation supported NOAA mandates for marine EBM (e.g., McFadden and Barnes 2009). NOAA had also made considerable investments in ecosystem research, and NOAA's Ecosystem Goal Team had begun integrating ecosystem science resources and responsibilities across the agency (EETT 2006). However, the EETT identified several gaps, principally the need for a national vision for marine ecosystem science, complemented by regional plans to assess ecosystems and provide suitable advice. To close this gap, the EETT proposed that regional IEAs could compile, analyze and report information on historic, current and potential future ecosystem status and condition, in order to address important place-based issues (EETT 2006).

In response to the EETT recommendations, NOAA formed a Priority Area Task Team to further develop the IEA concept as a basis for coordinating ecosystem science efforts across the agency (NOAA 2007). Subsequently, research teams published an agency document (Levin et al. 2008) and a peer-reviewed paper (Levin et al. 2009) that explicitly defined an IEA framework as a way to organize biophysical and social science efforts and provide useful, EBM-relevant information and guidance. The approach, shown in Figure 1, consists of scoping, analysis and implementation steps that are meant to be collaborative among scientists, stakeholders, managers and policymakers. The approach is also iterative, with new information incorporated as ecosystem conditions and societal objectives change over time (Levin et al. 2008, 2009). NOAA implemented this framework in 2010 by creating a national office and regional IEAs for the Northeast Shelf, Gulf of Mexico, California Current, Alaska, and Hawai'i (Figure 2), each of which has directed efforts at a range of marine EBM issues (e.g., Levin et al.

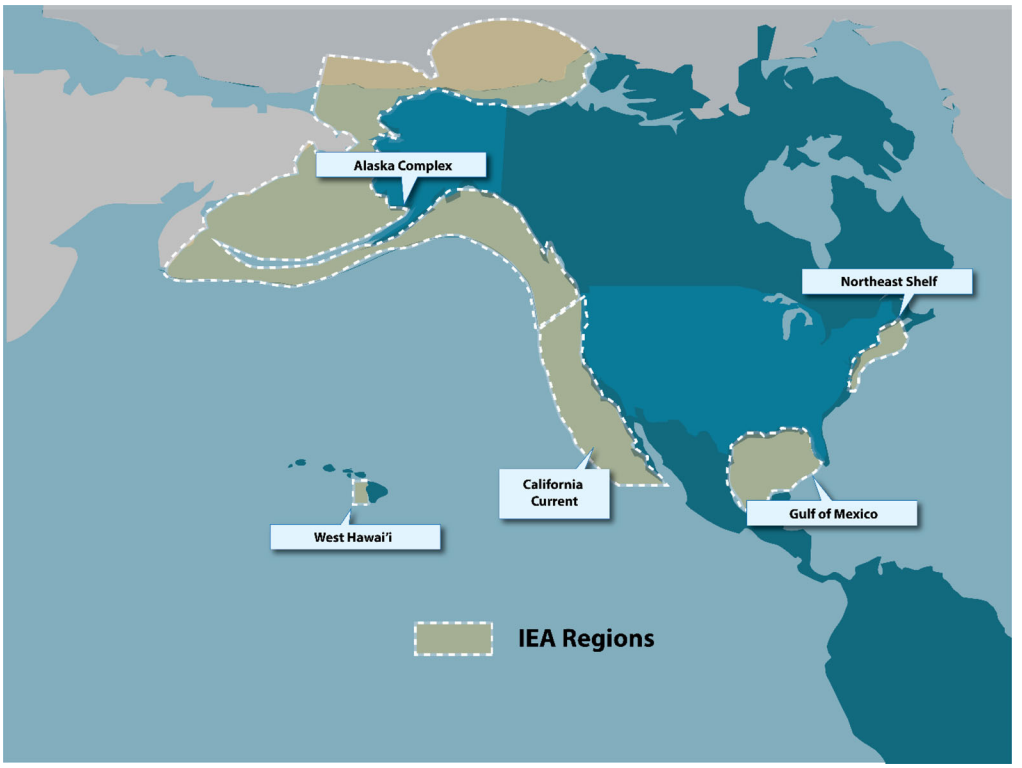

Figure 2. Map of the five NOAA IEA regions.

2014; Samhouri et al. 2014). The teams have also collaborated cross-regionally to develop IEA concepts and tools (e.g., Holsman et al. 2017; Samhouri et al. 2017; Williams et al. 2021), and the program has supported development of IEA efforts elsewhere in the world (e.g., Dickey-Collas 2014; Walther and Möllmann 2014).

Panelists' perspectives: the IEA vision and how it has evolved

The May 2019 panel discussion began with reflections on the panelists' original vision of the IEA approach. One theme was that the IEA concept was intended as a "call to action" for researchers and silo-ed management agencies to rise to the challenge of providing effective, integrative science support for EBM:

> **Mike Fogarty:** "One thing that we thought when we put forward the basic idea is that it would be a call to action, that we would provide a pathway for synthesis and integration. It wasn't meant to be overly prescriptive, but it had to have that five-element synthesis [i.e., Figure 1] in bringing together the pieces of the puzzle."

> **Steve Murawski:** "When [Vice Admiral Conrad] Lautenbacher was the NOAA Administrator [2001-2008], he was really interested in cutting across the different organizational line offices in NOAA, otherwise known as the 'cylinders of excellence.' This became one of the important goals of the NOAA Ecosystem Goal Team, to cut across the ecosystem enterprise. One of the things that emerged was the IEA program."

Of the approach itself (Figure 1), the panelists emphasized that they intended for the IEA framework to provide practitioners with the flexibility required to address diverse EBM issues. In particular, they explicitly avoided an approach that recommended a set series of methods, because ecosystem issues are too variable for overly prescriptive treatment (Levin et al. 2014; Samhouri et al. 2014). Rather, the IEA framework provides general guidance toward achieving issue-driven objectives:

> **Mike Fogarty:** "We recognized pretty early on that we needed something that was flexible and adaptable because the needs of each of the regions were going to differ in terms of both the problems that were to be solved, and the types and amounts of information available. That was baked into a lot of the thinking throughout."

> **Phil Levin:** "The reason why I think IEAs are persistent and why we continue to see success is because it's not prescriptive in terms of what is done. If it's done well, you don't say, for example, 'You need a marine protected area,' or 'You need this,' or 'You need to do that.' What it does is say, 'This is the goal we're trying to achieve.' Who cares how we get there? If we want healthy ecosystems, does it really matter if we use Tool X or Tool Y? We just need to get there. It's a process of getting from where we are to where we want to be, building a coalition that will allow us to move there, and finding a collection of tools to allow us get there."

As an illustration of the approach's flexibility in practice, the Mid-Atlantic Fishery Management Council and the Northeast IEA team recently developed a decision-making framework for managing summer flounder (*Paralichthys dentatus*). Collaborators adapted the IEA framework such that the initial step was a risk assessment to identify key priorities, which informed subsequent scoping and conceptual model development that will be used to evaluate management alternatives (Muffley et al. 2021).

The non-prescriptive approach of IEA is in the spirit of the Magnuson-Stevens Fishery Conservation and Management Act [16 U.S.C. §1801, *et seq.*], the U.S. legislation that frames many of NOAA Fisheries' mandates, particularly as revised in 2007 just before the inception of the IEA program:

> **Steve Murawski:** "My early impression was that the whole concept was going to be a lot more prescriptive rather than permissive. One of the interlocking parts of this was the revision of the Magnuson-Stevens Act. At the time, there was an Administration draft that was heavily laden with ecosystem prescription. That got some traction, but Senator [Ted] Stevens felt that it was *too* prescriptive, so the red pencil came out … In retrospect, the blowback from Senator Stevens probably reflected everybody's uncertainty about a more prescriptive Magnuson-Stevens Act. The way it evolved actually is probably pretty good, because you all have a pretty good track record of doing IEAs as 'coalitions of the willing,' and you have examples at different spatial scales that show that IEA is a viable concept."

As for the proper spatial scales of IEA implementation, panelists offered several perspectives on their initial vision. The earliest concept was that IEAs would be large-scale, and could generate valuable, wide-ranging, but potentially unwieldy products:

> **David Fluharty:** "My own memory of what we on the EETT were thinking was a regional scientific enterprise that was integrating around an ecosystem that was being assessed. I had the sense that IEA regions would be fairly large, and that an IEA would be one synthetic product. I was trying to envision how many pages would this thing be, and would anyone be able to lift it? The other part was, who was going to pick it up? Could we do scoping on a regional scale so that there would be buy-in from the heads of the natural resource agencies and the coastal zone management groups and all of the potential

end users? We thought that would be a big process that would define the objectives, and then the report would come out and serve all."

Once the NOAA IEA program was implemented, however, practitioners began to follow the guidance of Levin et al. (2009, 2014) and scale IEA applications according to management needs, available research funds and capacity (Harvey, Kelble, and Schwing 2017; Samhouri et al. 2014). IEA applications in the different regions thus range from individual communities and small coastal regions (e.g., Ingram, Oleson, and Gove 2018; Rosellon-Druker et al. 2019) to large marine ecosystems, and are generating not just large ecosystem status reports, but a variety of products and tools tailored to specific users and needs (Muffley et al. 2021; Samhouri et al. 2014; Spooner et al. 2021; Williams et al. 2021).

In the previous quote, the panelist reflected not only on issues of scale, but also the challenge of engaging managers and stakeholders as active participants in an IEA process. It is these partners, after all, who identify the societal needs and management objectives that determine matters of scale. Several panelists commented further on the importance of drawing meaningful and lasting connections to end-users:

Mike Fogarty: "One of the things that I would redo or rethink is exactly how we were going to connect with the customer. The science is superb but if it's going to make the translation into implementation, it's got to have a real customer that's interested in a product, is going to support it in legislative and budgetary processes, and use it."

Frank Schwing: "I was at a conference a few months ago, and one of the things the keynote speaker said was, 'There are a lot of problems facing society today. We need science to address *every single one*.' As scientists we often come up with a solution and then go searching for a problem that it will fix, and I think instead we need to reach out to the public and say, 'What is your problem? Help me understand that, and help us figure out a way that we can use science to address it.' Looking at it from that end of the telescope is better than saying, 'Hey, we've built a nice tool,' putting it out there, and expecting that someone will come along and use it."

This challenge of successfully engaging customers in management, stakeholder communities and the broader public has arisen frequently over the NOAA IEA program's first decade. In many cases, IEA scientists focused simultaneously on relationship-building with customers and on tool development. This was often done under the general notion that moving toward an ecosystem approach was desirable, though not necessarily with specific management needs or explicit legislative mandates in mind. As IEA-customer relationships have grown, issue-based scoping has become easier, with partnerships collaborating to identify specific problems, define objectives, and refine tools to better meet those objectives (e.g., Muffley et al. 2021; Spooner et al. 2021; Williams et al. 2021).

Some of the most successful engagement between NOAA IEA regions and customers has come through production of ecosystem status reports, which summarize the status and trends of biophysical, economic and social indicators and conditions in a system (Slater et al. 2017). These reports, which were pioneered by NOAA's Alaska Fisheries Science Center in the 1990s, are highly valued for the general ecosystem context they provide to decision-makers. However, they are time- and labor-intensive, and the effort required to produce them may come at the expense of higher-level IEA products like risk assessments. What is key, one panelist emphasized, is that ecosystem status reports

should stem from strategic partnerships between IEA teams and end-users who have formal plans for using them, such as Fishery Ecosystem Plans developed by many Councils (Marshall et al. 2018). That strategic connection can justify the effort required for the reports:

> **Phil Levin:** "There is value in doing reports as part of a strategy. EBFM has become a centerpiece of the IEA program, because there is a customer in the Councils, and there is information that the IEA program can generate that they want. Some members of the Pacific Fishery Management Council have complained to me, 'This ecosystem status report is awesome … what do I do with it?' That's where the Fishery Ecosystem Plans intersecting with the IEA becomes a very useful thing and moves beyond a report to 'I have information, now I can use this information in a process.'"

A recent example of this strategic approach is the Mid-Atlantic Fisheries Management Council's use of indicators in the ecosystem status report generated by the Northeast IEA team to underpin an ecosystem-scale risk assessment framework for much of the U.S. East Coast (Gaichas et al. 2018). We can further anticipate indicators from these reports to be used in identifying ecosystem reference points, which are a priority under the NOAA EBFM Policy (NOAA 2016).

The final aspect of the original IEA framework and vision that the panelists discussed was management strategy evaluation (MSE), which Levin et al. (2009) proposed as the penultimate step before implementation of management actions (Figure 1). MSE involves using operating models to simulate alternative management strategies, compare the potential effectiveness of those alternatives, identify tradeoffs, and assess the role of underlying uncertainty (Punt et al. 2016). While MSEs have been adopted recently by Fishery Management Councils, these applications have largely originated outside the IEA context. These MSEs tend to focus on single-species management (Haltuch et al. 2019), with rare exceptions such as the New England Council's ecosystem-level MSE applied to Atlantic herring (*Clupea harengus*) as both a target species and forage species (Goethel et al. 2019).

Panelists encouraged further use of management evaluation tools that include at least multispecies if not full ecosystem considerations in the process. NOAA IEA scientists are making progress in developing operating models that can support ecosystem-scale MSEs, particularly by building MSE capabilities into end-to-end ecosystem models (e.g., Kaplan et al. 2020). However, panelists also encouraged IEA practitioners to employ a diversity of approaches in this penultimate step, offering that the early IEA documents may have been too constraining:

> **Phil Levin:** "Using the term 'management strategy evaluation' [in Levin et al. 2008, 2009] is a regret of mine. I actually changed this in later papers to 'evaluate management strategies' [e.g., Levin et al. 2014; Figure 1, right]. Mostly, it seemed people were getting stuck on doing full-blown closed-loop, formal, ecosystem-scale MSEs, a feat that requires extremely high technical capacity. There are lots of ways to analyze strategies besides MSEs … in retrospect, we could have written that section a little broader. Doing so would have perhaps made it less daunting. It may have also helped make it more inclusive, especially toward social sciences."

NOAA IEA teams have identified other management strategy analysis tools, such as scenario analysis (Levin et al. 2014) and qualitative network models (DePiper et al. 2017), that are not as technically arduous as a formal MSE, and that readily incorporate

social science information. These alternative approaches may help IEA practitioners within and beyond NOAA explore this step and avoid feeling as if they have fallen short of the full potential of the IEA approach.

Process vs. Products

In the previous section, and throughout the panel discussion, panelists frequently alluded to IEA "tools" and "products," while also emphasizing that IEA is a "process." The distinctions are more than semantic, because IEA practitioners must convey to managers, stakeholders, and organizational leadership that IEA is envisioned as an ongoing, iterative process (Figure 1), and does not necessarily conclude upon delivery of a product like an ecosystem status report (Harvey, Kelble, and Schwing 2017). This prompted several audience questions about how the panelists regarded the importance of "process vs. products" in their vision of IEA. Panelists contended that this is a false dichotomy: processes and products, and the tools used to complete both, are inseparable elements that are essential to successful IEA implementation. Products inherently reflect the process and tools that produce them. This is especially true in the IEA framework, which is collaborative (i.e., the products are tailored to end-user needs) and also iterative (i.e., tools and products from one iteration are applied to the process of subsequent iterations). Many NOAA IEA outcomes embody this idea; for example, social-ecological conceptual models developed via participatory scoping and engagement processes increase collective knowledge and engender stakeholder trust and investment in future management applications of those models (e.g., Ingram, Oleson, and Gove 2018; Rosellon-Druker et al. 2019).

While it is philosophically appealing to regard IEA as an interdependent blend of process, tools, and products, audience members raised the concern that tracking the NOAA IEA program's overall progress is difficult because advancing a process is difficult to quantify through performance metrics. Panelists concurred, but encouraged IEA practitioners to meet this challenge:

> **Steve Murawski:** "If you work for NOAA, somewhere in your food chain you have a senior executive. In the annual guidance that the senior executives get, they're supposed to focus on outcomes, and not outputs. But, doing the process is probably as important as the outcome, because it brings so many elements together, and I think it builds confidence. Those things are hard to quantify, but they're actually the shining proof of all of this because they build enduring relationships. Imbuing performance metrics with the idea that you're bringing along these communities is hyper-important for the credibility of the eventual output that you're generating."

Given that process and products are intertwined, panelists emphasized that tracking progress requires new thinking about how performance is measured:

> **David Fluharty:** "You don't have a lot of times where there's a piece of paper that comes out that has the descriptions of the involvement of the groups that you're working with, and the agencies you're working with, and what you've done for them, as an accomplishment. If you can capture that, then I think the process is going to work really well. Documenting what you're doing as part of the process, the problems you're solving and the people and communities you're helping—I think that's key. That speaks well of it to the people who are controlling the purse."

In fact, at the same IEA workshop in May 2019, one of the most resonant voices was a commercial fisherman from the west coast of Florida, who told members of NOAA leadership about his collaboration and cooperative research efforts with the Gulf of Mexico IEA team during the extremely severe red tide event of 2018–2019 (e.g., Weisberg et al. 2019). The fisherman emphasized the mutual exchange of information and development of trust built through this process. One effective performance metric of the process, then, may be the testimony of members of the public whom IEA teams collaborate with and serve. This input can be gathered through formal means such as surveys, focus groups, semi-structured interviews or sentiment analysis (e.g., Lennox et al. 2020; Moon et al. 2019; Mukherjee et al. 2018).

Further ideas on tracking the progress of IEA processes, products and tools may be derived from NOAA's EBFM Policy implementation plan (NOAA 2016), which directs NOAA regions to identify "milestones" of progress toward achieving EBFM goals and objectives. The guiding principles of the EBFM Policy closely follow the steps of the IEA framework (Figure 1), and thus many regional milestones could provide a basis for performance metrics of the IEA program. These should include performance metrics related to goals and objectives in the social and economic domains, building off work led by the California Current IEA to incorporate human wellbeing into ecosystem management (Breslow et al. 2016). In fact, Breslow et al. (2016) identify several human wellbeing attributes (e.g., transmission of knowledge, voice and participation in management, sense of connection to the environment) that can be connected to the aforementioned collaboration and trust built between fishermen and IEA scientists during the recent Gulf of Mexico red tide event.

Connecting the IEA approach to governance

A recurring theme in the panel discussion was how the IEA process relates to, or is shaped by, governance structures that support management. The connection between governance and IEA spans the full history of the NOAA IEA program. This is appropriate given that the NOAA IEA program is federally funded and is thus bound to legislation and/or executive orders intended to promote the public good. Panelists noted how governance structures influenced their own thinking about the early IEA framework, and how changes in governance may have affected opportunities for IEA implementation:

> **Mike Fogarty:** "The original IEA papers talked a fair bit about connecting with what were, at that time, unspecified governance structures, and the importance of having mandates for us to make this a reality. The year after we published Levin et al. [2009], President Obama signed the Executive Order [EO 13547[1]] declaring the National Ocean Policy, and I felt, 'this is the governance structure that will fit perfectly with what we want to do.' It's going to be multi-sectoral, it's going to bring in a heavy emphasis on stakeholder involvement in the process, it was really perfect for what we had envisioned. We always knew that the National Ocean Policy was vulnerable because it was implemented as an Executive Order rather than a piece of legislation, and of course it's come to pass that it fell victim to the fact that it was an Executive Order."

Executive Order 13840[2] in 2018 repealed the National Ocean Policy and terminated the Policy's multi-jurisdictional Regional Planning Bodies, which had been tasked with developing sustainable, multi-sector use plans for ecosystems within U.S. waters. E.O.

13840 provides the opportunity for Regional Ocean Partnerships to be organized and led by nonfederal partners, with the option for federal participation. Panelists encouraged IEA practitioners to take advantage of such opportunities, because given increases in multisector ocean uses and added stressors such as climate and ocean change, the need for integration is growing:

> **Steve Murawski:** "The urgency [for regional planning] has really accelerated. It used to be that energy development was only in the Gulf of Mexico and Cook Inlet [Alaska], but now with renewables it's pretty much everywhere. So that's a giant footprint of another federal agency [U.S. Bureau of Ocean Energy Management]. There's a notion that you could get regional governance and multiple agencies at least sitting at the table to negotiate; it's so much more important."

This illustrates a key challenge: governance systems are complex and by no means static, and very often have inertia toward managing single sectors rather than accounting for multiple sectors (Drakou et al. 2017). To make their products relevant and useful, IEA practitioners must adapt to that complexity and dynamism while continuing to provide robust, enduring science.

Another challenge has been the perception that EBM represents a paradigm shift that could threaten existing governance structures, and this perception can generate resistance to consideration of IEA products. One panelist contended that the IEA approach can work in parallel with existing legislative mandates, and used the regional Fishery Management Councils, which were established by the Magnuson-Stevens Act, to illustrate:

> **Steve Murawski:** "The fact that you have parallel processes going on—one [IEA] that's more organic and one [a Council] that's more prescriptive—shouldn't necessarily be threatening because I don't think the Council system will be tossed aside for IEA. I think they're reinforcing, and you need to make that message that you're not advocating a revolution … I think we can live in that dual universe, and communicating the note that it's not threatening to the existing paradigms is important."

The Councils have long been customers of NOAA IEA products, and those partnerships have produced many synergies in support of EBFM (e.g., Muffley et al. 2021; Slater et al. 2017; Spooner et al. 2021). Another panelist noted that the data generated by marine ecosystem monitoring programs, and high-quality analyses done under the IEA umbrella, are assets that are resilient to vacillations in public discourse and changes in legislation and administrative orders:

> **Frank Schwing:** "One of the things that comes out from the new Executive Order [13840] on ocean policy, as well as some congressional legislation, is treating data as an asset. Evidence-based policymaking is a new act that has been signed into the law of the land[3]. I think we can use these drivers to essentially do what we've been doing and what we continue to do, and to recognize the importance and value of data: facts matter, and fact-based decision-making is an important thing."

The versatility and strength of the IEA approach

The NOAA IEA program has passed its tenth year, which connotes the versatility, strength, and value of the approach, along with the tenacity of its practitioners. The

panel organizers asked the panelists for their impressions of why the IEA approach has endured. One source of strength derives from broader context: the widespread crescendo of support for EBM over the past several decades effectively set the stage for starting an IEA program ten years ago:

> **Steve Murawski:** "I think the enduring positive aspect of IEAs is that at the time there was a lot of talk about EBM … The timing was right to get a lot of this energy around a NOAA product. It was the logical next step to this interest in ecosystems, and I think that's been borne out in the ten years since then … It's set up the next ten years pretty well in terms of worked examples of how IEA doesn't threaten the status quo, it actually helps bend traditional approaches based on single issues with a broader view of how ecosystems respond."

As the general appetite for EBM has grown, emerging generations of scientists worldwide have been immersed in the theories underlying it and have become professionally invested in EBM tenets, practices and skillsets (e.g., Drakou et al. 2017). These include taking interdisciplinary approaches; viewing people as essential components of ecosystems (and partners in successful EBM) rather than external actors or stressors; and utilizing broad integrative frameworks and tools to explore the benefits, risks and tradeoffs of different management approaches to achieving ecosystem sustainability. These new generations are infusing IEA science with energy, creativity, and new and powerful research tools:

> **David Fluharty:** "I think a really enduring part of IEA is that we 'caught the wave' with people who were capable of absorbing the message and feeling that it was right and then trying to figure out how it could be implemented. They took the IEA concept to heart and worked to implement it in ways not prescribed or imagined in the beginning."

Another panelist declared that the strength of the IEA approach comes not from its originality, but rather that its root concept is a commonly used approach that can be adapted to virtually any walk of life, and thus it is already tempered for use in applications like EBM:

> **Phil Levin:** "The versatility is that it is incredibly unoriginal and boring. Honestly. Have you read Levin et al. [2009]? It's absolutely boring. How versatile is the process? I'll tell you: there is a new sewer coming in down the street from me. What's the process you use to put in a sewer? That's the process [Figure 1]. That's what you do for any public policy: you do a little scoping, you do some risk assessment, you figure out what's going on, and then you move forward! There's *nothing* new here! Maybe it's a slightly new application, but that's why I feel like it's versatile: because it's boring."

Looking ahead: recommendations

At the close of the discussion, panelists were asked to make recommendations for the IEA enterprise as it moves into its next ten years. Some essential recommendations for the NOAA IEA program have been discussed so often over its first decade (e.g., increase funding; increase research capacity across the social sciences; improve integration of biophysical and social sciences; expand to regions that do not yet have IEA programs; Hicks et al. 2016; Levin et al. 2016; Samhouri et al. 2014) that they were perhaps accepted as given and were not mentioned by the panelists. Alongside these established

needs, the panelists offered recommendations that emphasize engagement with end-users, making products more readily applicable, and ways to sustain and expand the program:

1. **Connect with the broader public, and not just with managers.**

Frank Schwing: "Don't consider government resource managers as our sole customer. There's great potential with the public. Every region should be reaching out to businesses, decision-makers, and communities in terms of, again: what's your problem, how can we help provide science to support it?"

2. **Engage with stakeholders and customers to develop operational ecosystem objectives and ecosystem reference points.**

Mike Fogarty: "I want to emphasize the central importance of having clearly defined objectives from the customer. There's an infinite number of pathways you could follow with any of this, but if you have these directions from the customer, then you can move on."

Phil Levin: "Operational objectives are not something that the IEA program is necessarily responsible for, but [we should be] working with end-users to develop operational objectives. [An early criticism of IEA was] there were no reference points, like stock assessments have reference points. Well, to have reference points, you have to have objectives … without objectives and reference points, it's really hard to actually do stuff."

3. **Increase the diversity of IEA practitioners to better match the communities we serve.**

Phil Levin: "We certainly don't reflect the communities within which we work … there's a huge literature on diversity in the workforce, and how it promotes creativity and productivity. I think that's so important, that NOAA looks like the communities we wish to serve. Also, there's an environmental justice angle: are we just serving certain portions of the world who have power and voice, or are we able to serve indigenous communities, communities of color, and all communities in an equitable fashion?"

4. **Transition static IEA products like ecosystem status reports into continuously updated, accessible products.**

Frank Schwing: "When we first started out, the product was literally a piece of paper. You had a static map or a static graph or something like that. Our capabilities have evolved so much, particularly with machine learning and interactive capabilities, so the ability for an individual user to make their own customized product on the fly has great potential. I would challenge you moving forward: how do we convert from generating static products to products that literally get updated every time the person goes online to see whatever they wanted to see?"

5. **Assess and prioritize the many demands occurring at different levels of governance.**

David Fluharty: "The question of 'when is an IEA approach needed?' has come up many times, but we have had little critical discussion of what the threshold should be to justify a full-fledged investment into an IEA process. In my view, IEAs are most useful in complex decision environments where there could be a high degree of conflict or competing interests, not for problems that can be solved by a single agency or with negotiations

among a few affected interests. Given scarce resources, it would be useful to assess the demand for full IEAs based on some set of indicators or criteria, then ask how spending should be prioritized by the IEA program. Going beyond that would be how to obtain more resources to satisfy the demand, and/or foster more investment by partners in performing IEA as a matter of course."

6. Collaborate across boundaries, sectors and silos.

Frank Schwing: "We need to find a way to translate IEA to our sister agencies. If we're truly going to do ecosystem-based management, they have to learn the process implemented for EBFM and adopt it. How do we provide them with that example test case to help bring them on board so that they're doing ecosystem-based energy management, ecosystem-based transportation management, things like that?"

Steve Murawski: "[IEA] originally was viewed by skeptics as a 'fish thing,' but it never was intended to be that way, because it's so cross-sectoral … when you see the examples that have worked, they're about place-based management. So, they're very consistent with the mandates of other NOAA line offices [beyond NOAA Fisheries] and other legislation [beyond the Magnuson-Stevens Act]."

7. Anticipate, and engage with, emerging governance structures as a means of adapting to changing mandates.

Mike Fogarty: "We should be keeping our eyes open for where that next governance structure might take place and the form it might take, and reach out during the formation stages of that structure … whatever may or may not replace the Regional Planning Bodies, it's going to be really important for us to understand how that's evolving and reach out to the people involved to let them know what we can hope to provide."

8. Communicate the story of the IEA approach and program, as a means of increasing agency support.

Steve Murawski: "I think you need to tell your story, because it's a really good story, and that can be a launching point for how you 'level up' the budget. [In the] budget justification that was put together before the original IEA, one of the questions was, 'has this ever been done before?' We said no, it had never been done before. Now it *has* been done, and with a lot of different examples of how it's done. So now the platform to advance a budget initiative is much more solid … if the people that run NOAA can carry this message, then by telling your story, it's going to become their story, and they'll advocate for it."

It is essential that members of the NOAA IEA program heed these recommendations as the program enters its second decade. Doing so will expand the reach, elevate the value, and enhance the sustainability of the program, and ultimately improve the EBM enterprise as a whole, with lasting benefits to society and to marine resources. These perspectives may also help in regions beyond U.S. waters: IEA approaches are currently being used to inform management of marine resources in many countries and transboundary ecosystems (e.g., DePiper et al. 2017; Möllmann et al. 2014; Pedreschi et al. 2019; Skern-Mauritzen, Olsen, and Huse 2018; Walther and Möllmann 2014) and will guide management as human activities expand in the Arctic Ocean (Logerwell and Skjoldal 2019). Marine social-ecological systems face an array of complex, dynamic challenges that will require ongoing, rigorous, integrated science advice. The IEA approach

can help to provide that service, and the experiences and insights described here and elsewhere (Dickey-Collas 2014; Harvey, Kelble, and Schwing 2017; Levin et al. 2014; Samhouri et al. 2014; Walther and Möllmann 2014) may enable new practitioners to implement their own IEA processes more successfully.

Notes

1. https://obamawhitehouse.archives.gov/the-press-office/executive-order-stewardship-ocean-our-coasts-and-great-lakes
2. https://www.whitehouse.gov/presidential-actions/executive-order-regarding-ocean-policy-advance-economic-security-environmental-interests-united-states/
3. Foundations for Evidence-Based Policymaking Act; Public Law 115-435.

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