A perspective on successful implementation of ecosystem-based approaches to management and conservation in the Laurentian Great Lakes

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To celebrate the 1972 Great Lakes Water Quality Agreement, a conference was held on the evolution of the Ecosystem Approach during the past half-century to learn how to enhance successful implementation of ecosystem-based approaches for resource management, conservation, and societal problems worldwide. Among several conference workshops, one focused on the origins and history of ecosystem approaches, which was attended by 14 researchers with global expertise in conservation biology, ecology, economics, ecosystem modeling, limnology, resource and ecosystem management, policymaking, political science, and

Aquatic Ecosystem Health & Management, 27(2): 9–26, 2024.
ISSN: 1463-4988 print / 1539-4077 online. DOI: 10.14321/aehm.027.02.09

social science. This paper presents insights gleaned from this workshop on key needs for and challenges to effective implementation of these approaches. We identified six categories of needs and challenges, spanning from the initial phases of Ecosystem Approach development (e.g. setting clear goals; fostering stakeholder buy-in) to the final ones (e.g. adapting to change; maintaining program support). Setting clear goals aligned with a shared vision was identified as most critical to successful implementation and offered the fewest barriers. By contrast, 1) accounting for poorly understood governance structures and navigating administrative constraints, 2) sustaining support, and 3) gaining stakeholder buy-in were viewed as the biggest three challenges. Overcoming these challenges was viewed as critical to success, thus helping us understand why effective implementation of ecosystem approaches has remained difficult globally. Sound science (and overcoming associated hurdles; e.g. breaking down disciplinary silos) and effective communication were also mentioned by some. Using these findings, we assess the state of ecosystem approaches in the Laurentian Great Lakes Basin, concluding with recommendations on how to promote their successful implementation inside and outside of the Basin.

Keywords: socio-ecological systems, nature-based solutions, ecosystem-based fisheries management, biodiversity conservation, ecosystem services, ecosystem restoration

Introduction

Protecting our natural environment while concurrently preserving the ecosystem services upon which humanity relies has emerged as a worldwide imperative. Ecosystem-based approaches offer a means to solve natural resource management and biodiversity conservation problems, while also ensuring the sustainability of services valued by or essential to society. The use of ecosystem-based approaches to management, conservation, and societal problems (hereafter, EAs) has grown, leading to a diverse abundance of terminologies and literature on the topic (e.g. Kirkfeldt, 2019; Maron et al., 2018, Stephenson et al., 2021). While the seed concept of the “Ecosystem Approach” (Gillis, 1990; WCED, 1987) has blossomed into a diverse array of terms, including Ecosystem-Based Management (Slocombe, 1993), Green Infrastructure (Hauserman, 1995), Nature-Based Solutions (Eggermont et al., 2015), and Nature Contributions to People (Díaz et al., 2018), among many others (Stephenson et al., 2021), North American management still largely emphasizes the need to protect and rehabilitate ecosystems first and foremost. In turn, rehabilitating and protecting the structure, function, and natural dynamics of ecosystems can help prevent or solve societal problems and sustain ecosystems and their valued services.

Despite the urgent need to conserve and protect Earth’s ecosystems, our ability to successfully implement EAs (however defined) has varied globally (Hartig et al., 2020; Pitcher et al., 2009; Smith et al., 2017). While some initiatives have proven successful in both aquatic (Hering et al., 2010; Marshak et al., 2017) and terrestrial (Dombeck, 1996; Tolvanen and Aronson, 2016) ecosystems, implementation of plans designed to protect both the ecosystem and all of its services valued by society have had limited success (Dickey-Collas et al., 2022; Doswald et al., 2014). This lack of success even exists in the Laurentian Great Lakes (hereafter, Great Lakes), which can be viewed as a birthplace of EAs owing to the establishment of the Great Lakes Water Quality Agreement in 1972 (Hartig et al., 2020; Mackenzie, 1993). For example, implementation of a holistic, integrative approach that guides decision-making and considers all stakeholder values is not yet fully realized (Guthrie et al., 2019a; Guthrie et al., 2019b). The reasons underlying this lack of progress are varied, both in the Great lakes (Kellogg, 1998) and elsewhere (Dickey-Collas et al., 2022; Marshak et al., 2017; Waylen et al., 2015).

To help foster successful implementation of EAs globally, we (K. Minns, M. Munawar, and S. Ludsin) assembled a diverse group of scientists with experience in and knowledge of EAs in a workshop setting. Our goal was to identify vital needs for – and challenges to – successful implementation of EAs to support management and conservation decision-making. Given that the Ecosystem Approach and its evolution in the Great Lakes is the focus of this special issue, we discuss our findings in the context of these ecosystems. We first briefly relate the history of EAs in the Great Lakes basin. We then describe how input was solicited from workshop participants before summarizing our findings. We conclude by discussing the value of our findings to efforts aimed at implementing coordinated approaches to simultaneously manage natural resources, conserve biodiversity, and maintain societal access to valued ecosystem services in the face of continued anthropogenic stressors such as pollution, invasive species, habitat modification, and climate change.

Ecosystem approaches in the Great Lakes

During the 1950-1960s, awareness of environmental problems due to human activities grew worldwide, alongside growing appreciation of ecosystems as a central organizing concept (Bocking, 2013; WCED, 1987). In the Great Lakes Basin, that awareness centered on the rising impacts of nutrient pollution (i.e. eutrophication). Scientists were initially asked to develop models to understand the eutrophication process and guide efforts to control it, with a joint Canada-USA program to control phosphorus inputs, i.e. the Great Lakes Water Quality Agreement (GLWQA of 1972; Munawar and Hartig, 2020; Vallentyne and Munawar, 1993). Under the GLWQA umbrella, governmental organizations jointly identified 42 Areas of Concern (AOCs) with substantial impairment of their “beneficial uses” due to local human activities, with each AOC having a unique Remedial Action Plan (RAP) designed to rehabilitate it (Hartig et al., 1996). Later, Lakewide Management Plans (LAMPs) extended the hierarchy of efforts with the aim of assessing, restoring, protecting, and monitoring the health of each Great Lake and its watershed (IJC, 1987). An amendment to the GLWQA cemented these actions with a commitment to focus these efforts through an “Ecosystem Approach”, a concept being heavily promoted in the Great Lakes in response to eutrophication and a widening range of other anthropogenic stressors, including invasive species, overexploitation, and organo-chlorine and heavy metal contamination (IJC, 1987).

Implementation of RAPs and LAMPs has helped rehabilitate 7 of the original 42 AOCs and eliminated some of the listed beneficial use impairments (Canada 79 of 137; U.S. 90 of 255), with the assistance of successive updates to the GLWQA (Hartig et al., 2020). The rest of the AOCs remain degraded for one or more reasons, with all the Great Lakes facing dozens of anthropogenic stressors (Allan et al., 2013; Smith et al., 2015). Forward-thinking Great Lakes scientists pushed for adoption of an EA in the Great Lakes, which they defined as “… an integrated set of policies and managerial practices that relate people to ‘ecosystems’ of which they are part – rather than to external resources or environments with which they interact” (Vallentyne and Beeton, 1988, p. 58). This synthetic, holistic, anticipatory, and ethical approach envisioned during the 1980s has yet to be fully implemented. RAPs, which were designed to involve local stakeholders, scientists, and governing agencies in goal-setting and development of a collaborative strategy to remediate water quality impairments and rehabilitate specific AOCs, offer the closest approximation to an EA, with their non-multisectoral nature separating them from a “true” EA (but see Koops et al., 2009; Minns et al., 2022). Language has been added to the most recent (2012) amendment to the GLWQA agreement to continue to promote the concept of holistic, multisectoral approaches to management (Budnik et al., 2023), with the need for public engagement being further identified in the most recent assessment of the latest version of the GLWQA (IJC, 2023). Even so, a coordinated governance structure with regulatory power to mandate change and provide resources to sustain EAs is still lacking in the Basin. However, the recently signed (6 March 2024) memorandum of understanding among the Great Lakes Commission, Great Lakes Fishery Commission, and International Joint Commission (https://ijc.org/en/MOU-signing-IJC-GLC-GLFC), which is designed to advance shared goals like coordinating science and monitoring activities, offers a major step forward.

Thus currently, the Great Lakes can be viewed as still being managed by a multitude of approaches that range in 1) their focus on single ecosystem components or sectors (e.g. water quality, a fishery, or human health) to a suite of them (e.g. water quality, fisheries, and human health) within a single geographic location (e.g. a lake, a lake basin, or an embayment) and 2) their degree of engagement from federal, state, regional, and local organizations (Alsip et al., 2021; Kellogg, 1998; Lee et al., 1982; Mackenzie, 1993). Admittedly, these activities, which can be viewed as elements along a continuum of EAs (Budnik et al., 2023; Dolan et al., 2016), have led to some success in mitigating water quality impairments such as nutrient, heavy metal, and organic toxicant pollution (Bhavsar et al., 2010; Makarewicz and Bertram, 1991; Visha et al., 2015) and improving habitat for biota (e.g. Ludsin et al., 2001; Schloesser et al., 2014). We are unaware, however, of any truly collaborative, multisectoral (i.e. Ecosystem-Based) management plans operating in the basin at scale larger than an AOC (e.g. at the lake basin or lake scale). While the merits of operationalizing EAs at such a large spatial scale versus continuing to do so at a smaller spatial scale and hoping that restorative effects trickle up to the lake scale is debatable, successfully implementing holistic, integrative approaches to management has proven difficult even at small spatial scales (e.g. an AOC) both inside and outside of the Great Lakes Basin.

Workshop setting and approach

Given the elusiveness of effective EAs globally, as envisioned by scientists both past (Christie et al., 1986; Vallentyne and Beeton, 1988) and present (Budnik et al., 2023; Guthrie et al., 2019b), as well as more broadly (Dickey-Collas et al., 2022; Doswald et al., 2014), some of us (Ludsin, Minns and Munawar) organized a 1.5-day workshop to identify concrete ways to help enhance their successful implementation. Our workshop focused on the Great Lakes but with global context and application. The workshop—entitled "History & Origin of the Ecosystem Approach"—was held in Windsor, Ontario on 23-24 September 2022 as part of the Ecosystem Approach Conference celebrating the 50th anniversary of the GLWQA. Workshop participants consisted of 14 scientists (all paper co-authors) with knowledge of EAs in aquatic and terrestrial ecosystems across the world (Supplemental Table 1). Participants' collective expertise included aquatic ecology, conservation biology, economics, ecosystem modeling, limnology, natural resource management, policymaking, political science, and/or social science.

While our workshop consisted of many activities, a key one that we report on here was an exercise implemented at the conclusion of the first day. All participants (including organizers) were asked to respond to the two subsequent queries, with the following context provided beforehand:

> <u>Context provided:</u>
> *"Based on your personal experiences/ knowledge, answer the following questions about ecosystem approaches (EAs; however, you define them). This information will eventually be tabulated and incorporated into our planned documents (report/manuscript). Your responses will remain anonymous."*
>
> <u>Queries made:</u>
> 1. *Provide your top three (3) keys to effective implementation of the EA (however you define it).*
> 2. *Identify your top three (3) biggest barriers (challenges) to effective implementation of the EA (however you define it).*

These needs and barriers could have emerged from individual experiences, pre-workshop activities (reading, presentation generation), or workshop discussions. We summarize the key findings of this exercise, more fully developed during discussions on the second day and while drafting this paper.

Results and discussion

Overview of workshop responses

Many needs for and barriers to the successful implementation of EAs were identified in the exercise and subsequently discussed (Figure 1). To measure the importance of each need and barrier, we counted their occurrences. While we had asked participants for three needs and three barriers, we found some of the "needs" responses contained multiple ideas. In such cases (n=4), we split the response, leading to a total of 46 identified "needs". To facilitate understanding, we grouped these needs and barriers into six broad categories: 1) Setting & Planning Shared Goals; 2) Securing Stakeholder Support; 3) Accommodating Existing Governance; 4) Sustaining Programmatic Support; 5) Conducting Integrative Science; and 6) Facilitating Open Communication. We grouped findings this way owing to extensive overlap among the identified needs and barriers (Figure 1).

In taking this approach, we assumed that the frequency of occurrence in participant responses correlates with the magnitude of the challenge posed. While our approach has been used with success (e.g. Alexander and Haward, 2019; Fussell et al., 2016), a better approach could have had participants compile a complete list of needs and challenges as a group and then rank them afterwards. Even so, we feel our views represent the common challenges facing implementation of EAs, given that our participants represent a range of empirical experiences and disciplinary expertise (Dickey-Collas et al., 2022). The fact that the insights we present below align with previously identified needs and challenges inside and outside of the Great Lakes basin also supports the soundness of our results.

Category 1: Setting and planning shared goals

Proper goal setting and planning was the category seen as most vital for effective implementation of EAs (28% of the written responses; Figure 1). Three general sub-needs emerged from our responses: 1) set clear, measurable, adaptable, and achievable goals that properly align with the shared vision of stakeholders; 2) plan with a shared vision in mind; and 3) articulate the general goals and plan in a way that is understandable to all involved. Indeed, assessments of existing EAs have identified the need to set clear goals that are based on broad input by involved stakeholders in the ecosystem (Leslie and McLeod, 2007; Tallis et al., 2010). Such planning aligns with one of the global best practices for implementing EAs, the integrated ecosystem assessment approach (Levin et al., 2009), which has as a first step scoping with stakeholders to set clear objectives and goals. Embedded within the responses mentioning these three sub-needs were the assumptions that we will: a) learn or know what aspects of the ecosystem need to be considered and managed, as well as the spatiotemporal scales at which they operate (i.e. ecosystem scoping of pressures); b) understand what capabilities exist to support implementation plans (i.e. plan feasibility); c) design a plan that is clear and understandable to all (i.e. plan clarity); and d) identify and involve everyone who needs to be a part of the goal-setting process (i.e. stakeholder involvement).

Ecosystem scoping of pressures

To help collectively set goals and plan, many of us mentioned the import of spending time at the outset to identify the key problems that an EA should address. These problems may be ecological (e.g. poor energy flow within the food web, reduced abundance of a valued species), environmental (e.g. habitat loss, pollution), health-related (e.g. famine,

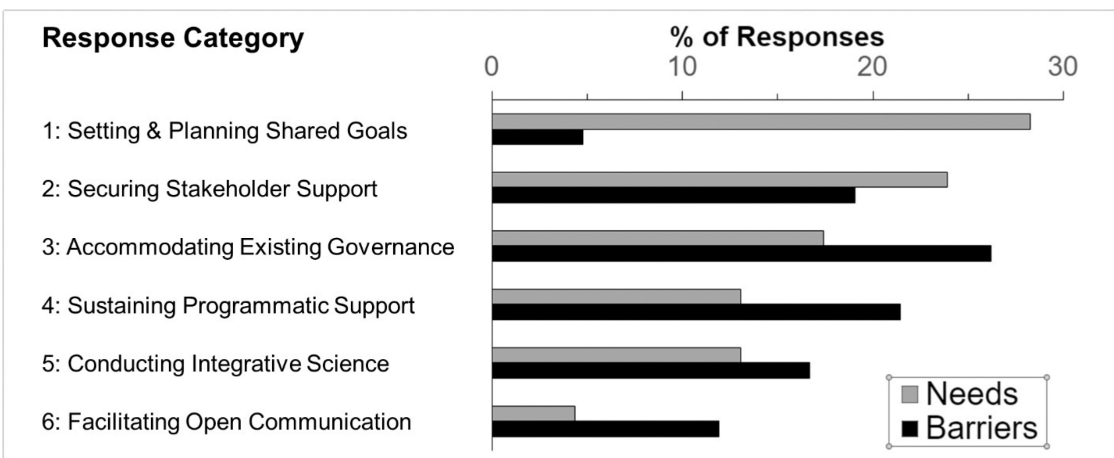

Figure 1. Workshop participant responses to writing exercise queries regarding the most important needs for (n=46) and barriers (challenges) to (n=42) effective implementation of ecosystem-based management approaches (however defined by the participant). Numbers preceding each category correspond to the categories mentioned in the main text.

contaminant exposure), economic (e.g. reduced tourism or food production), or sociopolitical (e.g. disputes over resource allocations or causes of an environmental impairment). All of these can degrade ecosystem services. While the exact nature of each problem will be context- and ecosystem-specific, identifying key impairments that might be addressed in any subsequent EA is important. Many responses also mentioned the need to identify and discuss the drivers (i.e. causal mechanisms) of those ecosystem impairments and the "negative interdependencies" that sustain them. Such drivers of impairment could include anthropogenic ecosystem stress (e.g. climate change, invasive species, pollution, habitat destruction, overexploitation). As we discuss below (see Category 6), the negative interdependencies that sustain them can arise from a lack of interactions among stakeholders (actors) in the ecosystem, resultant of poor governance or failed lines of communication.

Two notably important ideas were not mentioned in our responses for this category. First, the need to identify and consider potential tradeoffs is critical, given that stakeholder values and goals can conflict (e.g. tradeoffs often exist between water quality vs. fisheries production), which can give rise to wicked management landscape (DeFries and Nagendra, 2017; Sinclair et al., 2023). Second, we did not discuss how to identify the aforementioned negative interdependencies or tradeoffs. To this end, they can be identified by implementing survey instruments, holding small or large focus-group sessions, or building mechanistic models based on science or expert opinion (Hobbs et al., 2002; Mollmann et al., 2014; Stori et al., 2019; Tallis et al., 2010). Done well, these activities could help identify many things that need to considered in the planning and goal-setting process, including: *(i)* benefits that ecosystem services provide society (e.g. income, food, health, well-being); *(ii)* key interdependencies within the ecosystem (and potential threats); *(iii)* potential tradeoffs that exist or can arise with EA implementation; and *(iv)* the spatial and temporal scales at which planning and management should occur.

Plan feasibility

To execute effective implementation of an EA, some form of plan is needed that is ideally agreed upon and recognized by all key stakeholders. Such a plan would describe the goals (as noted above) and the high-level actions needed to achieve those goals. We noted that plan feasibility must be considered early in the planning process (in relation to goal-setting), with needed consideration of governance, communication, science, monitoring, plan evaluation, decision-making processes, and adaptation to future change within the ecosystem. While not mentioned in the workshop responses in this context, uncertainties in plan implementation and the ecosystem should be considered, especially given the typical long time of plan implementation (Tallis et al., 2010) and likelihood of ecosystem non-stationarity (Litzow et al., 2019). Some of us warned of the need to avoid getting lost in the minutia of terminology and metaphors early on (e.g. Nature-based Solutions, Ecosystem Approach, Green Infrastructure, etc.), which can hamper the planning process. Instead, the focus should ideally be on how best to understand, assess, and implement useful behavioral or management changes (i.e. ones that mitigate ecosystem impairments and overcome negative interdependencies). Done properly, the process of evaluating plan feasibility would consider existing governance structures, including existing policies, rules, institutions, and governing bodies (Alexander and Haward, 2019; Leslie and McLeod, 2007; Link et al., 2019), as well as operational indicators, monitoring, and scientific models (including how to adapt them or identify more appropriate replacements). These evaluation approaches should also consider the spatial and temporal scales associated with all plan elements (Fraker et al., 2022; Leslie and McLeod, 2007; Tallis et al., 2010), avoiding scale mismatches. For instance, as efforts to implement an EA in the Bay of Biscay showed (Borja et al., 2019), insufficient time allocated to compiling and digesting existing information on the ecosystem and properly defining goals, indicators, and policies will lead to failure.

Plan clarity

Communicating the plan in a manner that can be understood by all stakeholder groups was deemed important. Doing so can help overcome the last remaining barrier identified in this category, which is avoiding confusion by making the plan clear. We agreed on the need to clearly define concepts and principles in existing EAs or related approaches (e.g. Nature-based Solutions: Cohen-Shacham et al., 2019; NOAA Fisheries Ecosystem-based Fishery Management Implementation Plans: NOAA Fisheries, 2024; Conservation Commission of Western Australia Forest Management Plan: CCWA, 2013). The use of clear, consistent language and terminology, combined with examples to make concepts more concrete, was also encouraged. This approach could both help achieve local implementation success and facilitate adaptation of the proposed plan or elements of it (e.g. operational framework) in different ecosystems for new environmental problems or with novel audiences (e.g. new stakeholder groups). Beyond clearly articulating key principles of the proposed plan, we felt that clearly explaining how progress will be achieved is essential. Identifying progress milestones and concrete ways to achieve goals will make the plan less esoteric (i.e. less "pie-in-the-sky") and in turn reduce confusion, help ensure that those in charge of plan implementation know what they are supposed to achieve, and improve stakeholder buy-in. When setting goals, we encourage creation of some near-term milestones that can be easily reached to help build momentum thereby fostering sustained support for the proposed plan. Such "easy wins", however, are typically actions that closely conform with existing practices and that can be delivered quickly and thus should not be the sole focus. Finally, organizers also need to address difficult issues and set relevant milestones in the planning process, to avoid losing plan support in the future as new challenges arise. Ultimately, the time taken to clearly define both short-term and long-term goals, combined with effort to ensure plan feasibility and engage appropriate stakeholders, will go a long way in helping enhance the success of any EA to management or conservation.

Stakeholder involvement

Workshop survey responses identified the need to include stakeholders in the planning process, a concept long recognized as fundamental to EA success (Leslie and McLeod, 2007; Levin et al., 2009; Mackenzie, 1993; Tallis et al., 2010). Unfortunately, the importance of democratically including relevant stakeholders early in the process is not always recognized. By including stakeholders in all phases of EA development, including conceptualization, implementation, monitoring, and evaluation, collaborations and partnerships can be established to help overcome two key barriers that we identified: 1) identifying a clear, shared vision with appropriately set goals and 2) justifying the approach being taken, including its focus, spatiotemporal scales, and endpoints. In turn, subsequent planning, implementation, assessment, governance, and future adaptation can be facilitated (Leslie and McLeod, 2007; Tallis et al., 2010). Including all key stakeholders as early as possible can also help avoid later questions such as "Why are we doing this?" or "What are we trying to achieve?".

Category 2: Securing stakeholder support

The second most important category of needs identified was securing stakeholder support for the planned EA. Getting stakeholder "buy-in" was noted in about a quarter of the identified needs in our exercise, with about 20% of the responses to identified barriers also referencing it (Figure 1). Related to this need is obtaining input from stakeholders in all steps of an EA process. This includes soliciting the opinions of relevant stakeholders from both private and public sectors (e.g. ecosystem user groups, non-governmental agencies, industry, regulatory and management agencies) within both the local and regional communities. Engaging with stakeholders is considered a best practice in EA design and implementation, owing to its value in helping establish a shared vision with known tradeoffs (Levin et al., 2009). Thus, planners of EAs should work diligently to gain stakeholder support.

As mentioned in Category 1 above, the need to include stakeholders in the EA planning process is a fundamental tenet of EAs. Stakeholder appreciation for the many goods and services ecosystems provide can increase pro-environmental behavior (Whitburn et al., 2020), such as support for EAs. Stakeholder involvement can also contribute to the legitimacy of EAs and their sustainability, especially when stakeholders participate in EA goal-setting and construction for local efforts (Bouleau et al., 2018). Early participation by a broad array of stakeholders has several advantages.

Participation by stakeholders with diverse backgrounds, knowledge, and lived experiences can help improve knowledge inputs, ensure that a broad set of options are discussed, and can integrate stakeholder values into decision-making, which determines how priorities and tradeoffs are evaluated (Beierle and Konisky, 2001). Such tradeoffs are especially likely to emerge in large, complex ecosystems spanning multiple authorities and providing multiple ecosystem services (e.g. Great Lakes; DeFries and Nagendra, 2017; Sinclair et al., 2023). Early involvement by stakeholders can also help identify their existing expertise and capabilities, which can facilitate proper assignment of responsibilities among them. In this way, someone, or the appropriate organization, can be held accountable for each component of the plan to be implemented.

Unfortunately, securing, and sustaining stakeholder support and participation is a common challenge in collaborative environmental governance (Holifield and Williams, 2019). One barrier to securing adequate support relates to a common tendency to selfishness and shortsightedness (Ridley and Low, 1993). By selfishness, we are referring to the general unwillingness of individuals to self-sacrifice for the benefit of the collective whole. By contrast, shortsightedness refers to individuals undervaluing the long-term when making decisions. The framing of processes can help to counter these tendencies (e.g. Lawrence and Haasnoot, 2017). Unfortunately, due to societal expectations, governing bodies are often pressed to quickly find 'optimal' and 'efficient' solutions, which typically are at odds with equitable, inclusive, and adaptive processes that foster ecosystem resilience. Ecosystem rehabilitation, which often underlies the need for EAs, can take several years to several decades. Therefore, getting buy-in and associated funding support from elected decisionmakers and policymakers can be difficult because their election cycles operate on shorter timescales. Practical constraints not unique to EA implementation can also impede meaningful stakeholder engagement. Holifield and Williams (2019), for example, found that the majority of stakeholders involved in Great Lakes AOCs acknowledged a lack of time, awareness, interest, and funding as serious barriers to recruiting and sustaining stakeholder participation.

The existence of these barriers reinforces the need to communicate openly, frequently, and transparently with stakeholders while investing in relationship-building to maintain stakeholder networks (Holifield and Williams, 2019). Such discussions, which can occur in small- or large group settings (e.g. workshops, public forums, public seminars), within formal or informal settings (e.g. meetings vs. social gatherings), or through online communications (e.g. discussion boards, blog sites, e-mail, social media), are essential to securing and sustaining stakeholder buy-in (Cooke et al., 2013; Tallis et al., 2010; Holifield and Williams, 2019). Such interactions offer a means to: *(i)* recognize and discuss plan benefits, potential tradeoffs, and other risks; *(ii)* understand and alleviate stakeholder concerns; and *(iii)* identify and adapt to new ideas or priorities. In return, stakeholder buy-in and trust can be built.

Category 3: Accommodating existing governance

The third category of responses concerned accommodating existing governance structures, which includes accounting for existing organization hierarchies and scales (local, regional, and national) and paying attention to and navigating governing processes. Here, we refer to governance as encapsulating all the mandates, venues, processes, enforcement, and decisions by which decisions are made to manage ecosystems, their uses, and the pressures they face. Whereas the percentage of needs exceeded the percentage of barriers in the previous two categories, the opposite was true for this and all remaining categories (Figure 1). In fact, this category had the highest percentage of barriers (~26%) relative to all others, with its need also being noteworthy (~17% of the responses).

Good governance is essential for effective EA implementation (Alsip et al., 2021; Cohen-Shacham et al., 2019; Jones and Taylor, 1999; Link et al., 2019; Mackenzie, 1993; Pelletier, 2010; Wondolleck and Yaffee, 2022). Some of the pillars of governance include sufficient investment in building collaborations, partnerships, and capacity to allow for integrated management both in the short-term and long-term. We identified as critical needs *(i)* formal agreements to sustain these pillars of governance and *(ii)* ensuring that the operational framework is not only sufficient to meet agreed-upon goals at the outset but sufficiently flexible so that it can be updated and remain relevant to changing societal challenges, including potential shifts in goals that might occur and even conflict with the original ones. The need for flexible and adaptive governance structures is especially critical given that ecosystems are complex and nonstationary due to human-driven environmental change (Alsip et al., 2021; Leslie and McLeod, 2007; Marcek et al., 2021; Tallis et al., 2010), each of which can drive stakeholder priorities on issues such as biodiversity loss, human health, disaster risk, and food and water security (Pelletier, 2010; Tolvanen and Aronson, 2016). Collectively then, a responsive, effective, and participatory governance structure that is transparent, accountable, trustworthy, and integrated at both the local and higher levels, is essential to effective EA implementation both in the short-term and during future periods of change.

Accommodating existing governance structures can unfortunately be difficult, especially if they lack the many needed attributes of success (e.g. trust, transparency, stakeholder equity, efficiency, budget stability, contemporary technologies). Even so, such shortcomings must be acknowledged and navigated until necessary changes are implemented. Such navigation may prove challenging, however, particularly when this structure and their outcomes (e.g. socio-ecological planning and decision-making) are heavily influenced by dominant producer interests that are self-serving (Carter, 2021). In most socio ecosystems, obstacles (e.g. "sticking points"; Waylen et al., 2015) will also exist, which can arise from poorly organized government structures, past decisions, regulatory or market context, lack of trust, or even cultural attributes of society (Pelletier, 2010; Rowbottom et al., 2022). Failure to appreciate these "sticking points" and recognize that any EA plan will not start from nothing or operate in an institutional vacuum can hamper planning and implementation (Pelletier, 2010; Rowbottom et al., 2022; Waylen et al., 2015). Thus, we should remember that we always start from a situation of past decisions ("residual legacies") and that institutional and governance cultures can shape implementation, with the old ways of doing business often sowing the seeds of the ecosystem challenges that we currently face. Furthermore, because economic and political pressures and processes can drive governance conditions (Pelletier, 2010), planners need to consider these broader pressures and processes both in the short-term and long-term.

A related problem for most ecosystems, including the Great Lakes, is the lack of a venue or forum at which different governing bodies can meet to discuss how to fix poorly performing governance structures and how to manage existing conflicts or tradeoffs that might emerge across sectors (e.g. taxa, ecosystem uses). Discussions without all interested and effected parties involved will result in *de facto* decision-making that is not transparent or as thoughtful as it might be otherwise. Given that agencies operating in "silos" can impede effective ecosystem management (Carter, 2021; Ehler and Douvere, 2009; Randrup et al., 2020), establishing venues or forums to force inter-agency interaction and decision-making is critical.

Category 4: Sustaining programmatic support

As with governance considerations (c.f. Category 3), which concerned accommodating existing structures, the percentage of mentioned barriers (~21%) exceeded that of mentioned needs (13%; Figure 1). Generally, these barriers consisted of the lack of sustained operational capacity to pay for the time needed to fully understand existing governance structures and stakeholder opinions at the outset, as well as the needed research, monitoring, and enforcement activities over the long-term.

The most stated need was a clear, unequivocal commitment to the EA by all organizations and institutions involved in the process. Such commitments include funding for governance, monitoring, personnel, science, and potential future adaptation. The Great Lakes highlight how such commitments can confer benefits. For example, restoration of many beneficial-use impairments in AOCs under RAPs, which embody an EA, has accelerated during recent decades owing to sustained funding from programs such as the Great Lakes Legacy Act, the Great Lakes Restoration Initiative, the Great Lakes Protection Initiative, and the Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health

(Hartig et al., 2020; Tuchman et al., 2018). Thus, we suggest EAs be designed to be persistent, which requires vigilance to ensure that all aspects of the plan are implemented and sustained, including governance, science, monitoring of the ecosystem and stakeholders, enforcement, and the capacity to adapt. Creating the mechanisms to provide support for such governance, scientific, citizen intelligence, and monitoring can also help avoid the "shifting baseline" syndrome (Alleway et al., 2023; Soga and Gaston, 2018), which can hamper achieving planned goals. Most certainly, the Great Lakes AOC clean-up efforts (Hartig et al., 2020; Ridgway et al., 2018) could be examined for lessons on how to implement successful and collaborative EAs locally.

We identified many factors that could undermine sustained support for EAs. These include a lack of sustained operational capacity to pay for the time needed to fully understand existing governance structures and stakeholder opinions at the outset, as well as for the needed research, monitoring, and enforcement activities over the long-term. A lack of suitable funding, which can arise from many sources, is the most conspicuous problem that has hampered development of effective EAs (Gutrich et al., 2005; Schweizer et al., 2021). For example, competing programmatic demands within the institutions or agencies with EA implementation or oversight responsibilities can cause a shortage of support in the short-term or lost support in the long-term as new priorities arise (Hodge and Adams, 2016). Further, because management of ecosystem components is often attempted by multiple organizations that are often using different processes or approaches, competition for funds can occur, which can undermine efforts to develop integrated, coordinate plans, as well as result in inefficiencies in the application of resources. Political changes (e.g. elections) and the economic landscape (e.g. markets), both internal and external to the ecosystem, can also degrade both short-term and long-term support for EAs (Knights et al., 2014; Lusser and Riglar, 1999). For instance, degradation of the Newfoundland and Labrador cod (*Gadus morhua*) fisheries and inability to implement effective ecosystem-based fisheries management plans were strongly swayed by commercial fishing industry influences on political decision-making (Davis, 2014). These barriers reinforce the need to: (i) understand existing governance structures (see Category 3); (ii) identify all stakeholder values and priorities so that suitable compromises are made (see Category 2); and (iii) clearly articulate EA goals and processes (see Category 1) in the short-term and long-term.

Category 5: Conducting integrative science

A strong transdisciplinary science program that includes monitoring, research, and assessment is critical to any effective EA (Boesch, 2006; Cohen-Shacham et al., 2019; Hartig et al., 2020; Leslie and McLeod, 2007; Levin et al., 2009; Tallis et al., 2010). Hence, the mention of Conducting Integrative Science (this Category) was unsurprising. Responses in this category were similar to those in Category 4 (Sustained Programmatic Support) with 13% of the "Needs" and about 17% of the "Barriers" (Figure 1).

The identified needs within this category aligned with many mentioned earlier. For example, similar to the need to identify and understand current stakeholder perceptions, values, and priorities (see Categories and 2), we highlighted the need to fully understand the structure and function of the focal ecosystem, as well as learn how changes in the ecosystem influence services provided to society and human well-being. Our observations centered on needs mentioned in previous studies, including developing monitoring programs and transdisciplinary models of the ecosystem for describing and predicting ecosystem conditions, as well as accounting for uncertainty in model predictions (Jones and Taylor, 1999; Leslie and McLeod, 2007; Mollmann et al., 2014; Tallis et al., 2010). These models would ideally operate at spatial and temporal scales relevant for management and conservation planning (Fraker et al., 2022; Leslie and McLeod, 2007; Tallis et al., 2010; Weinstein et al., 2021). Inherent to development of such models is the need for communication and collaboration among scientists with different skillsets (e.g. monitoring network developers, theoretical and empirical modelers, statisticians) or within different disciplines (e.g. citizen, physical, chemical, biological, and social scientists). Through such integration of science, mechanistic and predictive models may be developed that can accommodate changes to the ecosystem (e.g. due to subsequent anthropogenic change) and provide forecasts with measured uncertainty (Jones and Taylor, 1999; Leslie and McLeod, 2007; Mollmann et al., 2014; Tallis et al., 2010). These models should also consider the human dimension, as the state of local economies and social impacts often resonate more with stakeholders than that of the ecosystem (Link et al., 2023). Because ecosystems and stakeholder values and priorities can vary with time (Alleway et al., 2023; Soga and Gaston, 2018), we also identified the need to review and update all science components explicitly and regularly. This need aligns with earlier ideas regarding goal development and planning (see Category 1). Likewise, while not mentioned during workshop discussions, making the science process transparent by openly sharing data and other information (e.g. modeling outputs) is important, as it can help build trust (akin to ideas presented in Category 2).

Among the noted barriers to effective science integration, most identified ecosystem knowledge gaps as being important. These gaps spanned many realms. First, insufficient understanding of ecosystem processes is widespread, including among the best-monitored, most widely studied ecosystems on the planet (e.g. Great Lakes: Sterner et al., 2017; Chesapeake Bay, USA: Boesch, 2006). Second, a consensus emerged that our general inability to know how any ecosystem might respond to known and potentially new (emerging) threats is problematic. Both ecosystem non-stationarity (Bakun et al., 2010; Marcek et al., 2021) and ecological surprises (Paine et al., 1998) hold the potential to undermine even the best-laid plans. Inability to understand and reliably project the influence of climate change was an example mentioned in many responses, along with our inability to predict invasive species impacts or the impact of changing socioeconomic conditions. The third information gap focused on an inability to properly assess ecosystem services (sensu Plummer, 2009). Collectively, these responses highlight that planning for the unknown is difficult and that filling gaps critical to developing robust mechanistic and predictive models of ecosystems, including their socioeconomic and environmental components, in critical to EA success.

Many ideas to explain these knowledge gaps were offered, including a lack of funding, necessary technologies, and scientific expertise to properly monitor or manage the ecosystem (also see Hahn et al., 2022). Further, a perception was shared that scientists operating in silos may not be organized to interact in an efficient, systematic manner amongst themselves or with other stakeholders (e.g. resource managers). Such isolation can impede development of useful models and monitoring programs to assist with decision-making and prevent adaptive management from occurring (Carter, 2021; Ehler and Douvere, 2009; Randrup et al., 2020). As discussed below (Category 6), these identified barriers highlight the need for mechanisms to support science and facilitate the integration of scientists from diverse backgrounds with those eventually using the information they produce.

Importantly, some workshop respondents noted that, although science gaps will always exist, we do have enough understanding on general principles of how ecosystems function to make well-informed management decisions. Thus, we need to avoid using the trap of asking for “more science” as an excuse for inaction (Dickey-Collas et al., 2022). This notion is especially relevant *i)* when considering that sufficient directionality and magnitude of general understanding exist in most ecosystems to make improved management decisions and *ii)* in ecosystems where urgency is required, the consequences of inaction could be grave.

Category 6: Facilitating open communication

The final category of needs and barriers concerned the value of open communication. While only mentioned in ~4% of the needs’ responses and ~12% of the barrier responses (Figure 1), we view this category as important and one that should not be overlooked. As we discuss below, communication is integral to meeting the needs and overcoming the many barriers mentioned in the preceding categories. The message from those workshop respondents identifying this need was for clear, open lines of communication—which includes a willingness to listen—within and among institutions and agencies during all phases of EA plan development and implementation.

To achieve such lines of communication, the “silo” phenomenon previously mentioned with respect to governance and management (see Category 3) and science (see Category 5) must be eliminated. These silos were the most identified barrier within this current category and the greatest cause for the failure of communication within both ecosystem sectors (e.g. end users, scientists, and governing agencies) and participating organizations. Examples of “within-group” silos mentioned were those existing among disciplinary scientists, a problem noted elsewhere (Boesch, 2006). However, they can also exist within large governing organizations, where resources and associated decision-making are often organized around specific policies (e.g. nutrient pollution, organic contaminants, biodiversity; Carter, 2021; Ehler and Douvere, 2009; Randrup et al., 2020; Waylen et al., 2015). As noted earlier, eroding these silos to create open lines of communication in which all stakeholder views are considered can avoid de facto planning and decision-making and help overcome barriers identified in preceding categories.

Two other barriers relating to open communication were identified. The first relates to the varying jargon and language across disciplines, which is especially prevalent in the literature surrounding EAs (Escobedo et al., 2019; Kirkfeldt, 2019; Maron et al., 2018; Stephenson et al., 2021; Waylen et al., 2014). These variations in jargon and language can cause uncertainty that undermines efforts to achieve interdisciplinarity, stakeholder buy-in, and effective, coordinated governance (Stephenson et al., 2021). Thus, as with planning goals, the language and framing used to communicate and “sell” the plan need to be carefully considered (Bekessy et al., 2018). The second barrier is the social, political, and economic context that limits transparent consultation and engagement with local communities and stakeholders. A lack of engagement with and support from local communities can in turn reduce the stakeholder buy-in needed to promote acceptance of changes arising from EAs (Leslie and McLeod, 2007; Mackenzie, 1993; Tallis et al., 2010; Weinstein et al., 2021). These two barriers reinforce the need to fully evaluate how information is communicated and learn how decisions are made at all levels within all groups involved.

Summary and conclusions

Our workshop identified critical needs for and challenges to successful implementation of ecosystem-based approaches for resource management, conservation, and societal problems (EAs), which can help with future planning and implementation in the Great Lakes basin and beyond. While dozens of ideas were presented in the writing exercise and discussed, they generally fell into six categories of needs including: 1) properly setting and planning clear goals that are collectively agreed upon and evaluate potential tradeoffs; 2) soliciting and securing input and support from all relevant stakeholder groups; 3) taking the time to identify, understand, and accommodate the existing governance structure; 4) securing sustained programmatic support that can adapt to changing conditions and priorities; 5) developing an integrative science program that involves monitoring, research, modeling, and evaluation, and which accounts for change within the ecosystem and provides estimates of uncertainty in predictions; and 6) developing clear, transparent lines of communication within and among stakeholders groups (e.g. end users, scientists, governing agencies, and decision-makers; see Figure 1). A scan of the current literature on EAs reveals that none of these ideas can be considered novel (Alexander and Haward, 2019; Dickey-Collas et al., 2022; Jones and Taylor, 1999; Leslie and McLeod, 2007; Link et al., 2021; Marshak et al., 2017; Pelletier, 2010; Tallis et al., 2010; Weinstein et al., 2021; Wondolleck and Yaffee, 2022). However, the ensemble of ideas gathered here offer a useful set of guidelines that could enable the development of effective EAs in any ecosystem, including in the Great Lakes.

The Great Lakes recently celebrated the 50th anniversary of the 1972 Great Lakes Water Quality Agreement (GLWQA), which set the stage for EAs in the basin. While the GLWQA is in-of-itself not an EA, it led to the development of successful Remedial Action Plans (RAPs) across the basin, which may be viewed as a localized EAs. Unique RAPs were implemented in 43 geographically distinct Areas of Concern (AOCs) around the Great Lakes basin, with these plans successfully mitigating many beneficial-use impairments (e.g. safe water for drinking and swimming; clean beaches) in a few of these AOCs (Alsip et al., 2021). RAPs were designed to involve local stakeholders, scientists, and governing agencies, with some oversight and involvement by regional agencies. While some RAPs have been successful in restoring and revitalizing Great Lakes AOCs and most are still working toward AOC rehabilitation, numerous positive lessons have emerged from their implementation that are transferable to management in other ecosystems across the globe (Alsip et al., 2021; Hartig et al, 2019; Hartig et al., 2020). For example, they show a willingness of stakeholders and agencies to support agreed-upon objectives and embrace the Ecosystem Approach, which is considered vital to sustaining ecosystems and their services in the face of continued anthropogenic change. We also see considerable value in the RAP process as an approach to implement the GLWQA, especially its 1987 amendment, which formalized the Ecosystem Approach as a fundamental principle in the basin (IJC, 1987). This amendment moved the basin closer to achieving a holistic, integrative management approach that acknowledges the Great Lakes as a socio environmental system like was envisioned by early proponents (Christie et al., 1986; Vallentyne and Beeton, 1988).Thus, the RAP process highlights a positive step forward towards EA implementation.

Despite the success of RAPs in some regions of the Great Lakes, their inability to rehabilitate the majority of AOCs shows that implementing a collaborative plan to resource governance can be challenging. Thus, if a more holistic and integrated approach to ecosystem-based management is to occur in the Great Lakes, we need to overcome many of the challenges discussed above. Based on our workshop responses, setting clearly-defined goals (see Category 1) was found to be of highest import (based on frequency of workshop participant responses). However, this category also posed the fewest challenges (see Figure 1). Thus, we conclude that the two general areas requiring most attention are: 1) soliciting and securing input and support from all relevant stakeholder groups (see Category 2) and 2) taking the time to identify, understand, and accommodate the existing governance structure (see Category 3). The import of these two areas is especially critical when considering that proper goal-setting (i.e. Category 1) hinges on overcoming barriers associated with getting stakeholder buy-in and navigating governance.

Insufficient time at the workshop did not allow us to discuss ways to overcome these two barriers. Thankfully, however, the literature is ripe with ideas on how to do so. Learning how to successfully engage stakeholders in the planning and implementation of EAs has long been a topic of study, with much of what we know deriving from literature focused on marketing and political theory (Bekessy et al., 2018; Hofer and Kaufmann, 2022; Reed, 2008). As an example, Toomey (2023) highlights limitations in several traditionally used approaches to altering stakeholder behavior regarding the environment (e.g. climate change), calling them “myths”, and instead offers new ways to approach this task that rely on findings from cognitive science. Similarly, the EA literature has shown the value of a strong, coordinated, and transparent governing structure, which is both adaptive and flexible (Bodin, 2017; Cvitanovic et al., 2015; Link and Marshak, 2021; Stephenson et al., 2021). We also appreciate Wondolleck and Yaffee’s (2023) “bricks” and “mortar” concept as it emphasizes the need for both functioning infrastructure in an interlinked hierarchical manner (i.e. bricks) and the mortar to hold the bricks together, which includes effective leaders who can communicate and bring energy and buy-in to the plan and that are transparent and trustworthy. While only taking care of these two needs alone cannot ensure successful EA development, our workshop findings suggest they are a key place to start.

Finally, we strongly support further studies and deliberations like this one to compare and integrate experiences from different ecosystems and stakeholder perspectives. Such endeavors offer a means to share vital information on the achievements and shortcomings of EAs, as well as identify which needs and challenges apply to all ecosystems versus only a subset. We are optimistic that the information presented herein will further facilitate EAs both within and beyond the Great Lakes basin by helping to identify and prioritize needs and avoid challenges that are difficult to overcome. Thus, our collective goal of advancing successful EA implementation globally can be advanced.

Acknowledgements

We thank Richard Budnik for helping organize the workshop at the outset. We thank AEHMS and the University Windsor for organizing and hosting the conference. Technical assistance provided by Catherine Febria and Jennifer Lorimer was much appreciated.

Supplementary material

Supplementary material for this manuscript is available on-line at the publisher's website

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