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Scenario analysis: An integrative and effective method for bridging disciplines and achieving a thriving Great Lakes-St. Lawrence River basin

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ABSTRACT

The Great Lakes-St. Lawrence River basin community is challenged in achieving a basin that thrives ecologically, economically and socially. Although natural science, social science, policy, and law literatures offer insight into understanding and developing policies for the Great Lakes-St. Lawrence River basin, these literatures are constructed in disciplinary silos. Scenario analysis supports an approach that transcends disciplines and embraces uncertainty. It facilitates dialogue among stakeholders and adds depth and diversity to the science-policy interface. We provide evidence for why scenario analysis is effective, why it was used in the Great Lakes Futures Project, and how its results can be used to complement and strengthen interdisciplinary scholarship and current management within the basin.

Introduction

The challenge of meeting the social, economic, and environmental policy needs of the Great Lakes-St. Lawrence River basin is shared among scholars, policy makers, and stakeholders at' the local, state/provincial, federal, and binational levels. Barriers to meeting these needs are encountered at many levels. Institutional fragmentation in the region is prominent and complicates effective ecosystem governance. Horizontal and vertical cooperation requires actions by two federal governments, two provinces, eight states, four region-wide institutions, over 120 First Nations and tribes, and thousands of local government jurisdictions and agencies (Hildebrand et al., 2002). To meet policy needs, it is critical to engage each of these actors, made difficult because they come from different sectors (government, non-government, industry, public, academic) and operate at different scales (from international to local).

Confounding effective cooperation further is the difference among academic disciplines, such as the approaches taken in science and policy studies (Sarewitz and Pielke, 2000). The inability of science to provide absolute certainty in its predictions (Allen et al., 2001; Ehrlich and Ehrlich, 1998) complicates its integration into policy, as social values often desire high certainty (Steel et al., 2004). Furthermore, language and methodological barriers often prevent common ground between science and policy. For example, "the scientific community tends to consider the 'resource' as the starting point and the policy maker often considers the 'social consequences' of resource use as a starting point" (McLaughlin and Krantzberg, 2006). In light of these complications, multiple tools are being used in natural science, social science, policy, and law in attempts to overcome these barriers.

Here, we argue that scenario analysis is an important, but underutilized tool in Great Lakes basin resource management. Scenario analysis is an effective and valuable methodology that complements and can leverage current management strategies because it: 1) transcends disciplines; 2) considers uncertainty; 3) creates a common language for the science-policy discourse; 4) considers multiple overlapping and interacting scales; and 5) can reveal important questions for future research. To support our argument, we present a case study of the Great Lakes Futures Project (GLFP) and how scenario analysis was used to reveal policy gaps and recommendations (Friedman et al., this issue).

Abbreviations: IAGLR, International Association of Great Lakes Research; IJC, International Joint Commission; ILM, Intuitive Logistics Model; IPCC, Intergovernmental Panel on Climate Change; GLFP, Great Lakes Futures Project; GLOS, Great Lakes Observing System; FFP, Forest Futures Project; USEPA, United States Environmental Protection Agency.

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Why current approaches are incomplete

Scientific approaches

Scientists often design, conduct, and publish research with results that could be directly integrated into policy action and synthesis. For instance, to maximize the social and ecological benefits of restoration initiatives, Allan et al. (2013) used a high-resolution assessment of 34 cumulative stressors across the basin to inform areas where restoration would provide the greatest payoff (Fig. 1). In another example, Bosch et al. (2013) analyzed the efficacy of sediment and nutrient loading agricultural Best Management Practices to inform managers and policy makers on necessary implementation strategies to substantially reduce Lake Erie nutrient loading. Scientists also have recommended strategies to be taken to protect, restore, and remediate the Great Lakes basin (Bails et al., 2005; Mortsch et al., 2003). Although these are valuable research enterprises, it is often challenging to integrate these relevant findings into policy action.

Scientists facilitate knowledge transfer into policy by making their data and research findings publically accessible. The Great Lakes Science-Policy Initiative, conducted by the International Association of Great Lakes Research (IAGLR) (IAGLR, 2003), indicated that such information repositories are essential for effective knowledge transfer. Examples of such databases include the United States Environmental Protection Agency (USEPA)'s Great Lakes Environmental Database and Storage and Retrial Data Warehouse, as well as the Great Lakes Observing System (GLOS). The Great Lakes Environmental Database is one that facilitates Great Lakes basin data entry, storage and accessibility (USEPA, 2013a: http://www.epa.gov/greatlakes/monitoring/data_proj/glenda/index.html), while the Storage and Retrial Data Warehouse provides a publically accessible repository of national water quality monitoring data collected by water resource management groups (USEPA, 2013b: http://www.epa.gov/storet/). Complementing these two databases is GLOS, founded in 2003 to provide a binational observing system that strengthens linkages between data users and providers in support of informed policy and decision making for the Great Lakes basin (GLOS, 2011). Although these databases provide a rich and accessible resource, the relevance of these data need to be translated, and translated appropriately, to decision makers for effective policy and practice.

Scientists also participate in advisory boards and councils. For the Great Lakes basin, scientists communicate and translate science into recommendations for policy makers to inform policy needs around Great Lakes basin's management (IAGLR, 2003). Such boards include the Great Lakes Water Quality Board, the Great Lakes Science Advisory Board, and the Council of Great Lakes Research Managers of the International Joint Commission (IJC) (IJC, 2013a (http://ijc.org/boards/cglrm/), IJC, 2013b (http://ijc.org/en_/sab); Krantzberg, 2004). These boards provide mechanisms for informing policy with science. Although scientists do participate in these important advisory boards, effective communication is not guaranteed. As noted by Aumen and Havens (1997), a new type of scientist is needed, those that are "highly competent applied scientists possessing the desire, creativity, and

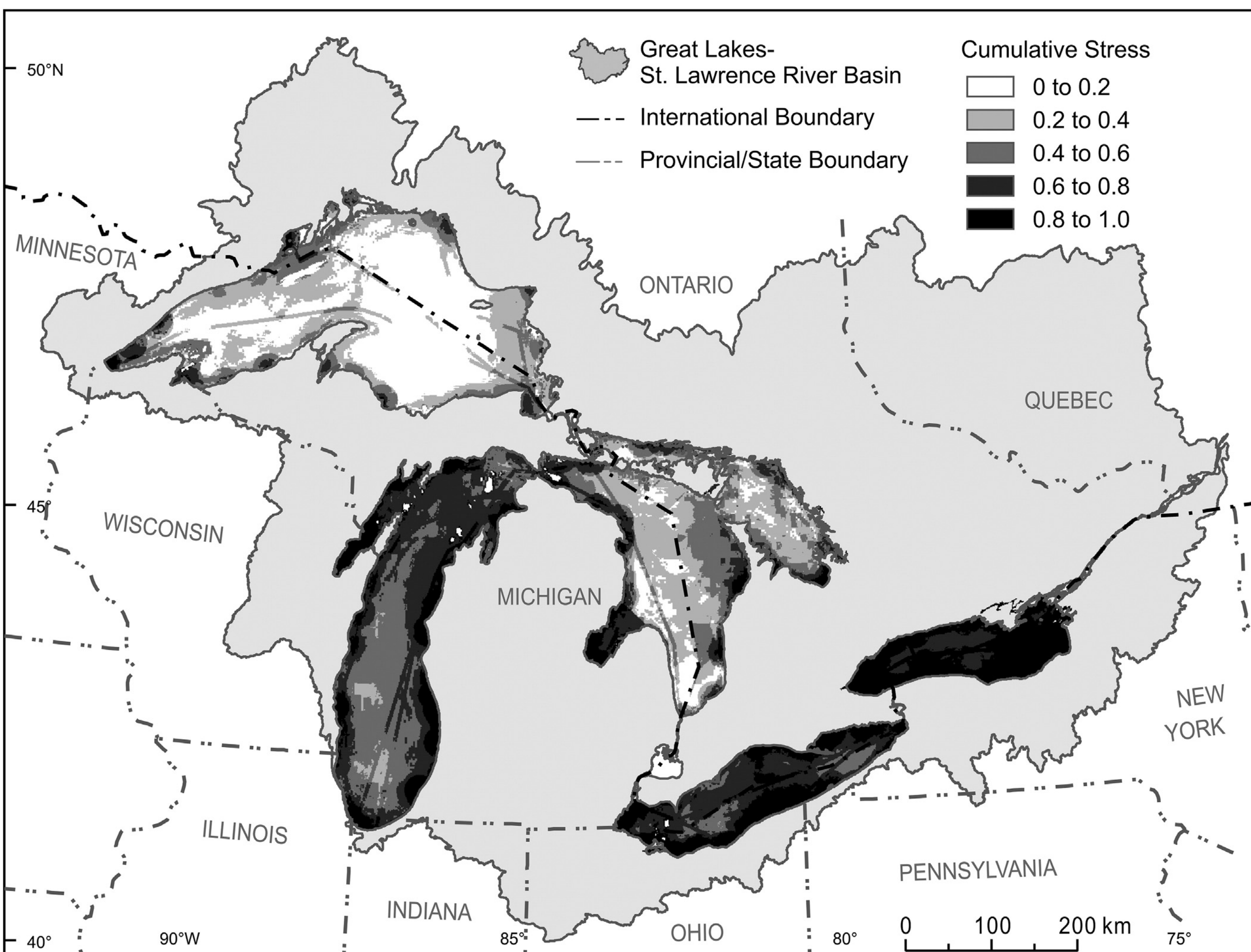

Fig. 1. Map of cumulative stressors for the Great Lakes-St. Lawrence River basin (data source: Great Lakes Environmental Assessment and Mapping Project, published in Allan et al., 2013).

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capability to design, implement, and publish the results of high-quality research and monitoring in a team-oriented environment, and to participate directly in the application of those results in resource management." Thus, board participation does not necessarily guarantee an integrated approach for addressing and solving the complicated problems inflicting the Great Lakes basin.

Social science, policy and law approaches

Social scientists, political scientists, and lawyers also use various tools to understand effective environmental policy outcomes. The Advocacy Coalition Framework represents a foundational scholarly contribution in this respect (Jenkins-Smith, 1990; Sabatier, 1988; Sabatier and Jenkins-Smith, 1993, 1999). This framework, which inherently recognizes the complexity of the policy system, highlights the need to examine the role that science plays in policy formulation.

Policy and law studies consider the role of institutions in influencing environmental outcomes. In previous studies, domestic institutions in both Canada and the US were highlighted as key factors in explaining Great Lakes-St. Lawrence River basin environmental policy. Some studies examine the mix of intergovernmental policy tools—tools at the province or state and federal levels—as well as principal-agent relations to better understand innovative environmental outcomes (Rabe, 1999). Other studies examine the role of institutions and various policy implementation mechanisms as a key factor in explaining environmental outcomes in the Great Lakes basin (Botts and Muldoon, 2005; Johns, 2002, 2009). Divergence in environmental policy participatory opportunities also can be traced to varying domestic institutional frameworks (VanNijnatten, 2009).

Recognizing the importance of domestic institutions, social scientists study the links among these institutions in Canada and the US to illustrate key insights into environmental policy outcomes in transboundary watersheds such as the Great Lakes basin. By examining the interaction of the institutions and actors across international boundaries, scholars illustrate that sound transboundary environmental policy is more complex than suggested by domestically focused scholarship (Friedman, 2009, 2012). Much environmental policy engagement takes place at the subnational level across the international boundary, providing insight into engagement strategies for achieving good water governance. Successful transboundary collaboration on environmental issues takes place either through formal or informal mechanisms. Successful formal collaborations are institutionalized in a way that allows for equal representation of participants on both sides of a geographic or other type of boundary. In certain circumstances, informal collaborations work well because they offer flexibility to adapt to pressing challenges, but mission codification in terms of setting expectations, anticipating needs, establishing priorities, and achieving goals is critical to achieving environmental outcomes. Finally, whether formal or informal, both require the right mix of government participants at the table—federal, state, and local (Friedman and Foster, 2011).

The previously mentioned studies provide useful tools for understanding environmental policy outcomes in the Great Lakes basin; however, none capture the dynamic and rich processes of engagement crucial to policy planning, formulation, and implementation. In addition, although the Advocacy Coalition Framework incorporates long-term outcomes, it does not adequately deal with adaptive management and feedback mechanisms emphasized in science literature. Finally, the subnational work does not explicitly address the role that science plays in environmental policy formulation and implementation.

What is being lost in translation?

Although both science and policy perspectives provide useful ways to understand environmental policy outcomes in the Great Lakes basin, neither provide a strategic way to engage all necessary stakeholders across boundaries and disciplines, crucial to policy planning, formulation, and implementation. Furthermore, although these perspectives and mechanisms exist and are used, it is not guaranteed that they will be integrated appropriately.

This is where scenario analysis can play an important role. Scenario analysis can complement and enrich the current practices employed within the Great Lakes basin.

Scenario analysis: an integrative and effective method for the Great Lakes St. Lawrence River basin

Scenario analysis is a method that offers promise for solving challenges facing the Great Lakes basin because it has "the potential to link, and even integrate, environmental science and policy" (Alcamo, 2008). Scenario analysis provides a methodology to strengthen the science-policy nexus and inform management. It is a tool that allows researchers to work at the edges of disciplinary boundaries and to bridge the science-policy interface.

Scenario analysis can be conducted in different ways for different goals. Bradfield et al. (2005) recognized three schools in scenario analysis: the Intuitive Logistics Model (ILM); the La Prospective Model; and, the Probabilistic Modified Trends Model (Table 1). Although each school is strong in its own right, the qualitative ILM showcased by Huss and Honton (1987) is an excellent tool for bridging the science-policy-stakeholder interface. The ILM can be used to understand puzzling situations, develop strategy, and anticipate and conduct adaptive organization learning (Bradfield et al., 2005). Scenarios under the ILM are not restricted to a mathematical algorithm, but use logic and intuition to build internally consistent and flexible scenarios that can be tailored to meet the needs of the system to which it is applied (Huss and Honton, 1987). Therefore, the ILM approach is attractive for use in the science-policy field because it combines the right mix of technological sophistication, provides ease of use for a professional audience, and enables consideration of alternative futures as a function of known uncertainties (Bishop et al., 2007).

The ILM (Huss and Honton, 1987) of the Royal Dutch Shell/Global Business Network (Wack, 1985a,b) and Stanford Research Institute International (Huss and Honton, 1987) involves structured steps that can be customized to suit the specific system under analysis. As outlined by Huss and Honton (1987), the ILM of the Stanford Research Institute International involves: 1) analyzing decisions, strategic issues and concerns, and the overall scope of the scenario analysis; 2) identifying key factors that influence the outcomes of each decision in a system; 3) identifying key environmental forces that shape the key decision factors; 4) analyzing the history, trends, uncertainties and interactions of the environmental forces; 5) defining scenario logics or "organizing themes, principles, or assumptions that provide each scenario with a coherent, consistent and plausible logical underpinning"; 6) developing scenarios by combining scenario logic with environmental analysis; 7) exploring the implications of the scenarios on the key decision factors; and 8) exploring the implications of the scenarios on key decision strategies. Overall, the ILM of scenario analysis results in four distinct scenarios (a manageable number for decision makers) that facilitate informed strategic decision-making (Wack, 1985a,b).

We propose that scenario analysis, and in particular the ILM, is a valuable tool when designing policies for the sustainability of basins, particularly those that cross subnational and national jurisdictional boundaries, such as the Great Lakes basin. In the following, we detail how scenario analysis offers a holistic and participatory approach to help bridge the science-policy interface and foster sustainable transborder basin management.

[1] Scenario analysis is a rigorous approach to transcending disciplinary boundaries

Scenario analysis establishes an interdisciplinary, integrative, and innovative approach for analyzing and solving complex environmental

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Table 1
The Intuitive Logistics, the Probalistics Modified Trends, and the La Prospective schools of scenario analyses.

Aspects	Intuitive Logistics Models	La Prospectives Models	Probalistic Modified Trends Models
Methodology	A subjective, qualitative, and process oriented scenario analysis approach that is inductive or deductive in nature and heavily reliant on disciplined intuition.	A direct, objective, quantitative, analytical (with some subjectivity) and outcome oriented scenario analysis approach. Has room for subjectivity, but relies strongly on computer-analysis and mathematical modeling.	A direct, objective, quantitative, analytical (with some subjectivity), and outcome-oriented scenario analysis approach. Uses computer-based extrapolative forecasting and simulation models to generate future scenarios and the probability of their occurrence.
Scope	Broad or narrow	Narrow (generally) but considers broad driving factors.	Narrow
Qualitative or quantitative output	Qualitative A series of equally plausible and probable scenarios narratives, often accompanied by graphics and limited quantification.	Quantitative and qualitative A series of multiple and alternative scenarios, with probability indicators associated.	Quantitative Scenarios generally include: 1) baseline case, 2) upper quartile, and 3) lower quartiles, with probability indicators associated with each.
Advantages	• Flexible • All scenarios are equally plausible. • Embraces uncertainty. • Creates a space for, and relies upon, “remarkable” conversation. • Scenarios can generate implications, strategic options and early warning signals for the system under analysis. • Organization asking the question conducts the scenario analysis and engages experts in the process: builds capacity and lends familiarity to problem and scenario context.	• Scenarios accompanied by comprehensive analysis of possible actions and their implications. • Probability factor accompanies each scenario. • Uses mixed systems analysis and scenario tools to create a space for elaborate, complex and mechanistic scenarios. • Rich history of guiding policy and informing policy makers.	• Scenarios accompanied by an indication of how probable they are. • Specific methodologies outlined for the two approaches of this school: Trend Impact Analysis and Cross-Impact Analysis • Creates a space to understand the probability of events that could change future extrapolations based solely on historical data.
Limitations	• “Methodological chaos”: many protocols for developing this school's scenarios exist. • Need to avoid “first generation scenarios” which offer no insight over what is already known (Wack, 1985a)	• Proprietary analysis software often required. • External experts play the dominant role in the running of the analysis; capacity for organization asking the question is limited and their familiarity of the problem and scenario context not as intertwined in the process and outcome.	• Requires years of detailed and reliable data. • Proprietary analysis software often required. • External experts play a dominant role; capacity for organization asking the question is limited and their familiarity of the problem and scenario context is not as intertwined in the process and outcome.

Adapted from Bradfield et al. (2005), unless otherwise noted.

problems (Alcamo, 2008) through the consideration of drivers of change across disciplines (Schwartz, 1996). The identification of the multiple and transdisciplinary drivers of change occurs early in scenario analysis and involves identifying drivers impacting a system or decision, from categories such as society, technology, economics, policy, and the environment (Schwartz, 1996). Fundamental to the success of this phase, and the overall process, is the diversity of stakeholders involved—it is important to engage key experts, decision makers, and those with valuable perspectives and varied backgrounds, including outsiders and those with “common sense wisdom” (Schwartz, 1996). This brainstorming phase often considers the drivers known to influence a system, examines their historical and future trajectories, and considers their interactions.

A recent example of how scenario analysis can be used to analyze complex environmental problems is demonstrated in Canada's Forest Futures Project (FFP). The FFP analyzed scenarios around the possible future states of Canada's forests and forest sector into the year 2050 by exploring major drivers of change, including: Canadian wood supply, global forest products demand, industry profitability, technological innovation, society's forest values, potential conflicts over resources, shifting demographics, invasive species, Aboriginal empowerment, governance, geopolitics, air pollution, global energy supplies, and global climate change (Duinker, 2008). To develop these drivers, stakeholders from academia, government, industry, non-governmental and Aboriginal memberships, other experts and interested stakeholders were engaged and provided extensive input on the process to inform the alternate futures (Frittaion et al., 2010, 2011).

By including and engaging stakeholders within the driver analysis phase, scenario analysis not only transcends disciplines but also incorporates rigour by engaging multiple viewpoints. This supports a collective understanding of the problem under analysis and, as stated by Van der Heijden (1996), “allows both differentiation in views, but also brings people together towards a shared understanding of the situation, making decision making possible when the time has arrived to take action.”

[2] Scenario analysis enables the consideration of uncertainty

Uncertainty is often viewed as a barrier to bridging the science-policy interface. The ILM of scenario analysis mitigates this barrier by identifying key uncertainties, which then become the “axes of analysis” for the system being studied and frame the alternate future scenarios (Huss and Honton, 1987). These key uncertainties, or “axes of analysis” are specific to each scenario analysis and are identified by carefully reviewing and ranking the identified drivers of change impacting the system under question (Maack, 2001; Wilson, 1998). This process involves open dialogue among scenario analysis participant stakeholders about certain (predictable) versus uncertain (unpredictable) forces (Ogilvy and Schwartz, 2004), of high versus low impact (Van der Heijden et al., 2002). Certain or predictable forces include those unlikely to change significantly in the future that can be predicted with confidence (Oglivy and Schwartz, 2004; Van der Heijden, 1996). These include demographic change, limits to growth, actor logic and motivation, and culture (Van der Heijden, 1996). In contrast, uncertain or unpredictable forces are those that are generally uncontrollable (Peterson et al., 2003), including forces such as abrupt climate change (Alley et al., 2003), market prices, demand for export goods, and changes in political values (Maack, 2001). The ultimate goal for this phase of the ILM of scenario analysis is to select two critical forces or combination of forces (Schwartz, 1996; Van der Heijden, 1996; Wack, 1985a), which become the axes of analysis that frame four alternate and divergent future scenarios.

The FFP scenario analysis provides an example of how of such “axes of analysis” can be generated and used to frame four alternate futures.

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Based on their 13 drivers and engagement of many different stakeholder groups, the FFP came up with two axes of analysis based on two highly influential and highly uncertain factors: societal values for forests versus environmental change (Duinker, 2008). Each axis had contrasting endpoints. For example, the societal values for forests axis were buttressed by two divergent end points, where values were "competitive, commodity oriented, individualistic- a from the forest mentality" versus "cooperative services-oriented communitarian-a for the forest mentality (Duinker, 2008). In contrast, the environmental change axis was buttressed by an environment that experienced "unpredictable and eventful changes, beyond adaptive capacities" versus "predictable and gradual change, within adaptive capacities" (Duinker, 2008). These two axes of analysis for the FFP framed four alternate future scenarios, scenarios from which specific management questions regarding Canadian forestry could be addressed.

The value of incorporating uncertainties in the ILM methodology is immense, and as a result, capacity for strategic decision-making is built, rather than crippled (Schwartz, 1996) and those involved learn by anticipating perceived uncertainty (Tapinos, 2012). As a result, explicit attention is given to uncertainties without trying to change them into certainties (Goodwin and Wright, 2010). Decision makers and managers benefit from a deeper understanding of uncertainty and associated risks by participating in the scenario analysis; often scenarios focus on key uncertainties that differ from those identified as obvious to participants at the onset (Wack, 1985b). Such a benefit was illustrated when scenarios helped Royal Dutch Shell navigate the leanness and restructuring that became a reality for the oil industry in the 1980s (Wack, 1985b).

Overall, the ILM method of scenario analysis embraces uncertainty, thereby providing a tool to incorporating uncertainty into the science-policy dialogue.

[3] Scenario analysis creates a common language among science-policy-stakeholder representatives, adding diversity and depth to the science-policy discourse

Scenario analysis provides a method that enhances communication among scientists, policy makers, and stakeholders. Engagement across stakeholder groups is important because it broadens knowledge bases and enhances mutual learning (Swart et al., 2004). The engagement of scientists, policy makers, and stakeholders in developing alternate future scenario stories facilitates communication among them because these stories are constructed in a common language to all participants (Go and Carrol, 2004) that allows room for diversity and creativity (Bensoussan and Fleisher, 2008).

Scenario narratives are developed after the two axes of analysis are identified. These alternate plausible futures depict what can unfold within a system by considering the future of each driver in isolation and in conjunction. In doing this they effectively communicate the ramifications of current decisions and strategies under the alternate futures. As argued by Jarke et al. (1999), scenario analysis provides the "ideal medium for participatory design", because it allows participants to express their goals and visions in a common language, breaking down the traditional language barriers that often complicate communication between disciplines.

A particular strength of scenario analysis is its ability to foster genuine conversations about the future (Chermack et al., 2007). Schwartz (1996) argues that the language of math and science cannot capture the important, complex, and often imprecise questions about the future. Instead, future questions should be explored in the dialogue of stories and myths, because "stories have a psychological impact that graphs and equations lack. Stories are about meaning; they help explain why things could happen in a certain way. They give order and meaning to events" (Schwartz, 1996). The very inclusion of narratives in scenario analysis adds depth to the process because when information is presented as a story, it facilitates learning, promotes relatable stories, and provides context (Hull, 1993). This influences human thinking, imagination, and decision-making (Kearns and Sutton, 2013; Sarabin, 1986), important factors when bridging the science-policy interface. By describing futures as narratives, important qualitative factors are revealed and incorporated in the process, including values, behaviors, and institutions, facilitating broad perspectives, which can add depth to futures generated through mathematical modeling alone (Swart et al., 2004).

[4] Scenario analysis can be customized and applied at local, regional, national, bi-national, continental, and global scales

Scenario analysis is an effective tool because it offers an approach to assessing co-determinants of change across local, regional, and global scales (Swart et al., 2004). Scenario analysis protocols can be scaled down to specific river basins. Peterson et al. (2003) illustrate this in their application of the global Millennium Ecosystem Assessment scenario analysis protocol (global) to the Northern Highlands Lake District of northern Wisconsin (regional). Scenario analysis narratives can also be developed to generate customized strategies for alternate futures. Abildtrup et al. (2006) downscaled the Intergovernmental Panel on Climate Change's (IPCC) Special Report on Emission Scenarios (IPCC, 2000) to understand climate change impacts on European agricultural land use. In taking this approach, Abildtrup et al. (2006) built on the foundation of and remained consistent with the IPCC Special Report on Emission Scenarios; however, they were able to apply the scenarios to localized questions around agriculture for specific regions in Europe. Although the use of a specific scenario analysis protocol across different scales must be appropriate to the goal of the analysis (Biggs et al., 2007), the ability for this approach to make such scale linkages facilitates the understanding of global to regional interactions on a system and develops a space for holistic approaches to complex issues across different spaces and times (Raskin et al., 1998).

[5] Scenario analysis is a foundation for research and can be combined with other approaches to leverage effective resource management

Although different approaches can be taken in scenario analysis (Bradfield et al., 2005; Huss and Honton, 1987), and futuring exercises in general (Futures Academy, 2008, http://www.thefuturesacademy.ie/futures/methods), the ILM of scenario planning is effective because it creates a unique space to explore unanticipated ideas, ideas that can lead to novel solutions to basin management. For instance, scenario analysis brings to the surface hidden assumptions and risks and reveals key uncertainties within a system (Wack, 1985b). As stated by Wack (1985b) "scenarios can effectively organize a variety of seemingly unrelated economic, technological, competitive, political, and societal information and translate it into a framework for judgment—in a way that no model could do. Decision scenarios acknowledge uncertainty and aim at structuring and understanding it—but not by merely crisscrossing variables and producing dozens or hundreds of outcomes. Instead, they create a few alternative and internally consistent pathways into the future. They are not a group of quasi-forecasts, one of which may be right. Decision scenarios describe different worlds, not just different outcomes in the same world". As a result, organizations and managers can acknowledge the alternate plausible futures and develop strategies for dealing with such futures.

Scenario analysis results can be further analyzed using a variety of science and social science techniques, such as the social science based Q-Sort and Delphi methods. Q-Sort methodology can be used to understand multiple viewpoints surrounding an area of discourse (Clare, 2013), to understand "decision structures" (Durning and Brown, 2007), and lead to consensus or compromise in difficult policy discussions (Brown et al., 2007). Delphi methodology is similar to Q-sort in the sense that it examines areas of discourse, but it is a systematic approach that collects anonymous expert opinion, involving a series of

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designed and incremental questionnaires (Linstone and Turoff, 1975), to examine consensus and convergence of opinion around specific questions or problems (Landeta, 2006). Each approach, and others, can be applied to the results of a scenario analysis to inform natural resource strategies under the divergent and alternate futures of the analysis.

Applying scenario anaysis to improve policies within the Great Lakes: the Great Lakes Futures Project

It is evident that transboundary water issues are becoming increasingly critical to address, as demand for safe and sustainable water increases, particularly in light of climate change. For this reason, the goal of the GLFP was to suggest areas of governance and policy reform to achieve a sustainable Great Lakes basin by conducting a future scenario analysis. The GLFP was a scenario analysis of the Great Lakes basin that included the airshed, watershed, and water bodies, for a time period spanning the past 50 years, the present, and the next 50 years (1963–2063). The GLFP future scenario analysis was not about prediction (i.e. visible manifestations, trends and combinations, and causal relationships); that would have relied on sufficient knowledge to build formal models to predict the future and related uncertainties. Rather, the GLFP future scenario analysis explored different assumptions about how causal relationships worked and could result in different outcomes (i.e. scenario logic, characteristics, and storylines). In order to consider alternative futures, the GLFP created stories about the future that were not impossible to achieve and considered the following questions: What forces are driving changes? What are the key uncertainties associated with these drivers? How could these forces diverge the future from its current path?

The GLFP resulted in outcomes that illustrate the value of scenario analysis as an approach to support research, management and policy decisions within the Great Lakes basin. Here we illustrate these outputs and the important lessons they revealed over the course of the GLFP.

1. Increased knowledge and awareness related to the drivers of change, the main uncertainties and the barriers to achieving sustainability within the Great Lakes-St. Lawrence River Basin.
   The first step of the GLFP was to examine the current state of knowledge around the history, current status and future drivers of change for the Great Lakes basin. Informed by expert opinion through a consultative workshop, eight drivers of change, including: economy (Campbell et al., this issue), energy (Kelly et al., this issue), geopolitics and governance (Jetoo et al., this issue), demographics and societal values (Méthot et al., this issue), water quantity (Maghrebi et al., this issue), climate change (Bartolai et al., this issue), invasive species (Pagnucco et al., this issue), and biological and chemical contaminants (Cornwell et al., this issue) were examined within the GLFP. This truly transdisciplinary approach created a space for understanding the range of factors impacting the future sustainability of the Great Lakes basin. By doing so, it embraced a holistic and "systems" science approach by: (1) working across multiple disciplinary fields; (2) considering of multidisciplinary problems as a whole rather than as a collection of individual disciplines; and (3) unifying and bridging the often-independent disciplines of classical science (Kilr, 2001); all of which are important factors for managing such a complex system as the Great Lakes basin.
   The GLFP identified critical uncertainties of high impact for the Great Lakes basin. Informed by the development of the eight drivers of change and stakeholder engagement, the two main uncertainties (or "axes of analysis") for the basin were selected: "human capacity for change" and "balanced environment and economy" (Laurent et al., this issue). By identifying the critical uncertainties for the basin, and involving decision makers and managers in the process, the GLFP unveiled risks and uncertainties that were potentially unknown to its participants, uncertainties that will be important to consider when designing future research and policy directions for the basin.
   The GLFP identified four alternate and divergent futures for the Great Lakes basin: "Thriving and prosperous: How we rallied to confront collective challenges" (Comer et al., this issue), "Living on the Edge: How we converted challenges into profitable opportunities" (Steenberg et al., this issue), "Trying hard to adapt to a chaotic world: How complex challenges overwhelmed our best intentions" (Orr et al., this issue), and "Out of Control: How we failed to adapt and suffered the consequences" (Kalafatis et al., this issue). By developing the four alternate futures, GLFP participants were able to explore the implications of each future for the basin, implications that will require important decisions and strategies for management as well as important indicators to ensure that the desired future is moved towards.
   Finally, the GLFP revealed the current barriers and gaps preventing a "thriving and prosperous" ecological, economic, and social future for the Great Lakes basin. Through stakeholder engagement, the following six gaps and barriers that affect the management and sustainability of the basin emerged: 1) Great Lakes policies are fragmented vertically and horizontally across scale and jurisdiction; 2) Great Lakes policies are fragmented substantively, and lack a holistic approach; 3) Policy implementation is hindered by inadequate capacity, accountability, and enforcement; 4) Adaptive management remains elusive; 5) There is a collapse of Canadian support for investment in Great Lakes research and education; and 6) The Great Lakes basin lacks a shared vision for the future (Friedman et al., this issue).
2. Opportunities for bridging the current barriers and gaps within the Great Lakes-St. Lawrence River basin policies.
   The GLFP's future scenarios created a space to consider whether current policies are leading to a "thriving and prosperous" future (Comer et al., this issue), and if not, what changes were needed. Considerations for policy change that resulted from the discussion of these futures with Great Lakes stakeholders included: "seeking out opportunities to develop strategies, plans, and practices that are place-based and require shared responsibility for the Great Lakes basin; creating and building upon existing mechanisms that embody ecosystem health as a foundation that leads to innovation and societal well-being; developing and monitoring indicators of comprehensive basin health; strengthening existing and creating new Great Lakes experiential programs; and, developing stakeholder-driven planning and visioning that is legitimized by political leadership both before and after planning occurs to nurture a Great Lakes "citizenship" or "identity" (Friedman et al., this issue).
3. New, effective relationships in an interdisciplinary network of scholars who will continue to conduct research, education, and engagement on sustainability issues within the Great Lakes-St. Lawrence River basin and worldwide.
   The GLFP engaged Canadian and US academic, government, non-governmental, and business organizations, as well as graduate students and young professionals from Canadian and United States universities. The GLFP demonstrated the value of innovative international and interdisciplinary research networks for engaging faculty, students, stakeholders and decision makers to solve some of the most pressing issues of our time. It created and catalyzed new transboundary teams to initiate research and teaching programs focused on the Great Lakes basin. It resulted in four international workshops; the participation of over 50 Canadian and American volunteer faculty mentors and graduate students on international research teams; the submission of the papers for this special issue; the submission of joint grant submissions to the National Science and Engineering Research Council of Canada, the Social Sciences and Humanities Research Council of Canada, and the US National Science Foundation; the acquisition of funds for a second phase of the GLFP through the Network of Centres of Excellence—Canadian

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Water Network; and the expertise to adopt a similar approach to solving freshwater resource issues globally.

The GLFP evolved into a significant initiative, serving as a model for international, interdisciplinary, and multi-stakeholder research collaborations that engage in rigorous inquiry and have both scholarly and policy impact.

4. Innovative training for the next generation of Great Lakes scholars and stakeholders through engagement of almost 30 graduate students in the GLFP

Aumen and Havens (1997) recommend seven key areas of training for developing a "new cadre" of scientists necessary for bridging the science-resource management-policy interface. The GLFP supported these recommendations in the following ways: 1) exposed participating students to the scenario analysis tool; 2) exposed students, depending on which phase and driver they were involved in for the GLFP, to the critical importance of conducting high-quality science, regardless of whether it was basic or applied; 3) enabled students to develop skills for bridging the gap that presently exists between research and the decision-making process; 4) enabled students to develop excellent oral and written communication skills and to present their results to each other, to experts in the field, and to diverse stakeholder groups; and 5) provided intern-like opportunities for students that wanted to go above and beyond their commitments to their own thesis projects and be a part of this transborder and transdisciplinary project. Overall, regardless of whether one had disciplinary training in the sciences, social sciences, law, policy, or economics, participating students within the GLFP participated in a project that provided opportunities for their growth as leaders in the field of Great Lakes basin management, fostering the next generation of the "knights of the Great Lakes table".

Building on the experiences and findings of the GLFP, the next steps are to work with decision-makers and end-users to overcome the barriers to sustainable management of the Great Lakes basin. The second phase of the GLFP, The Great Lakes Futures Project-Action Plan for Sustainability will build on the strong foundation of the GLFP by targeting the science-policy interface, using insights into the consequences of current policy decisions to work with stakeholders and develop strategies to support future sustainability for basin. Using the basin as the model, this research will facilitate the uptake and measurement of the consequences of the GLFP policy recommendations, thereby enable learning to inform adaptive management and develop an action plan for sustainability.

Conclusion

Scenario analysis provided an effective tool for engaging stakeholders in the Great Lakes basin to identify and address barriers in meeting its science-policy requirements to achieve a "thriving" future shared among the Great Lakes basin community at large. By incorporating scenario analysis into the science-policy dialogue for the Great Lakes basin, opportunities were created to bridge the important and valuable approaches inherent to the sciences, social sciences, policy studies, and law.

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