Resilience in a Protected Area: Prospects for Fathom Five National Marine Park, Lake Huron, Canada

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Introduction

Building or maintaining resilience within a protected area is increasingly cited as a means to achieve long-term conservation goals in the face of climate change and other human impacts (e.g., Mumby et al. 2006; Cole et al. 2008; Pittock et al. 2008; Baron et al. 2009; Lemieux et al. 2011; National Park System Advisory Board Science Committee 2012). Although there is an established body of ecological and social–ecological knowledge related to resilience concepts, in application it is still conceptually and methodologically early in its development. Within this paper, we explore the applicability of a resilience-based approach to planning and management by using Fathom Five National Marine Park as a study area.

Resilience is a system property that describes the capacity to cope with disturbance and remain within the same regime, essentially retaining defining structures, functions, and feedbacks (Walker and Salt 2012). Furthermore, to support resilience in a protected area context, learning, cross-scale linkages, and adaptability are needed (Berkes et al. 2003; Fazey et al. 2007; Francis 2008). Resilient systems are more diverse, flexible, and prepared for change and uncertainty (Hughes et al. 2005). Resilience is founded on non-equilibrium dynamics, where systems can transition to alternate states and where system behavior and progression is described within an adaptive cycle involving phases of collapse, renewal, growth, and conservation (Holling and Gunderson 2002). Whereas a traditional management approach may focus on maintaining historic conditions (e.g., composition and abundance of native species) or promoting system efficiency (e.g., maximum sustainable yield, single stable state), a resilience-based approach focuses more on the desired system regime and maintaining functional and response diversity (Table 1 and Text Box 1) (Folke et al. 2004; Chapin et al. 2010). Resilience itself is neither inherently good nor bad. As noted by those studying degraded systems, being locked in an undesirable state due to high resilience would be perceived as bad (Carpenter et al. 2001). Thus, in managing for resilience there rests a

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Characteristic	Traditional	Resilience-based
Reference	Historic condition	Trajectory of change
Role of manager	Decision maker who establishes sustainable course; fixed targets/performance measures; disseminates information; maintains institutional structure; and, may respond to changing human values	Facilitator who engages stakeholders and shapes social-ecological resilience; adaptive/flexible targets; integrates across institutions and scales with some devolved/shared decision-making; and, responds to and shapes human values
Research	Reduces uncertainty before taking action	Increases flexibility for an uncertain future
Role of science	Species inventory, model predictable change, and maintain ecosystem composition	Complex social-ecological systems, adaptive cycle and panarchy, and maintains functional and response diversity
Community perspective	Waivers, dependent on individual disposition; and, people use and are part of protected area context	Improves through social learning and acceptance of complexity; and, people have responsibility to sustain protected area
Disturbance	May prevent or accept natural disturbances within historical range	Fosters disturbances that sustain function and structure
Establishment	For scenic value, representative features, scientific, economic or cultural reasons	To support ecosystem services, adaptation or mitigation to change, or build regional resilience

Table 1. Attributes of both a traditional and a resilience-based approach to protected area management (adapted from Chapin et al. 2009).

caveat that the intent is to maintain a resilient desired state and, where necessary, leverage out of a less desired one.

C.S. Holling's (1973) seminal work on resilience characterized several events of ecosystem change (e.g., lake eutrophication, fishery collapse) in the Laurentian Great Lakes. As described, when ecological resilience decreased the lakes became more vulnerable to disturbance and a sudden regime shift. Today, the lakes continue to be affected in complex and novel ways, and the drivers of change include: invasive species—as extreme as the introduction of a new species every 28 weeks (Ricciardi 2006); climate change (Cruce and Yurkovich 2011); governance effectiveness (McLaughlin and Krantzberg 2011); and contaminants (SOLEC 2009). It is a context that is particularly problematic for a protected area whose goals may be based on preserving historical conditions or where management practices are simply pushed beyond their adaptive capacity (Hobbs et al. 2010).

Fathom Five National Marine Park is a 114-km^2 freshwater protected area located on Lake Huron, Canada (Figure 1). It was first established as a provincial park in 1972 and in 1987 became the first site to be managed under the stewardship of Parks Canada's national marine conservation area (NMCA) program (Wilkes 2001). It provided us with a good study area to explore resilience because the site faces considerable management challenges from both the local (e.g., fisheries management, policy needs) (Parks Canada 2011) and Lake Huron scales (e.g., food web and nutrient cycling changes) (SOLEC 2009). To advance conservation efforts, we incorporated resilience-based concepts within a management cycle of assess, plan, and implement.

Assessing resilience

A protected area is composed of diverse and interacting biophysical elements and associated actors and institutions. To assess resilience, there is an initial need to scope, describe, and bind these into relevant issues, components, and scales. For our assessment of Fathom Five we completed the Resilience Alliance practitioners' workbook *Assessing Resilience in Social–Ecological Systems* (Resilience Alliance 2010). It acted as a guide to determine resilience *of* what, *to* what, and *for* whom (Carpenter et al. 2001; Lebel et al. 2006). A review of relevant literature and discussions with park staff and other experts was required. The assessment highlighted important aspects of resilience, including:

- Identification of the key structures, functions, and feedbacks that define the desired state;
- An understanding of the current state and trajectory of the park's ecosystems;
- Recognition of elements that guide system recovery, including connectivity, sources of replicates, and functional diversities;
- Disturbances, disturbance regimes, and cross-scale influences;
- Governance structures, ownership, and potential constraints; and,
- Patterns of visitor use.

Box 1. Resilience, ecological integrity, and the NMCA Act

From the guiding legislation for Fathom Five: "Marine conservation areas shall be managed and used in a sustainable manner that meets the needs of present and future generations without compromising the structure and function of the ecosystems…" (Canada 2002: Section 4(3)). This is a shift from the more familiar "ecological integrity" endpoint, as is found in national and provincial parks in the region (see Government of Canada 2000; Government of Ontario 2006). As defined in the Canada National Parks Act, ecological integrity is "a condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change and supporting processes" (Canada 2000: Section 2 (1)).

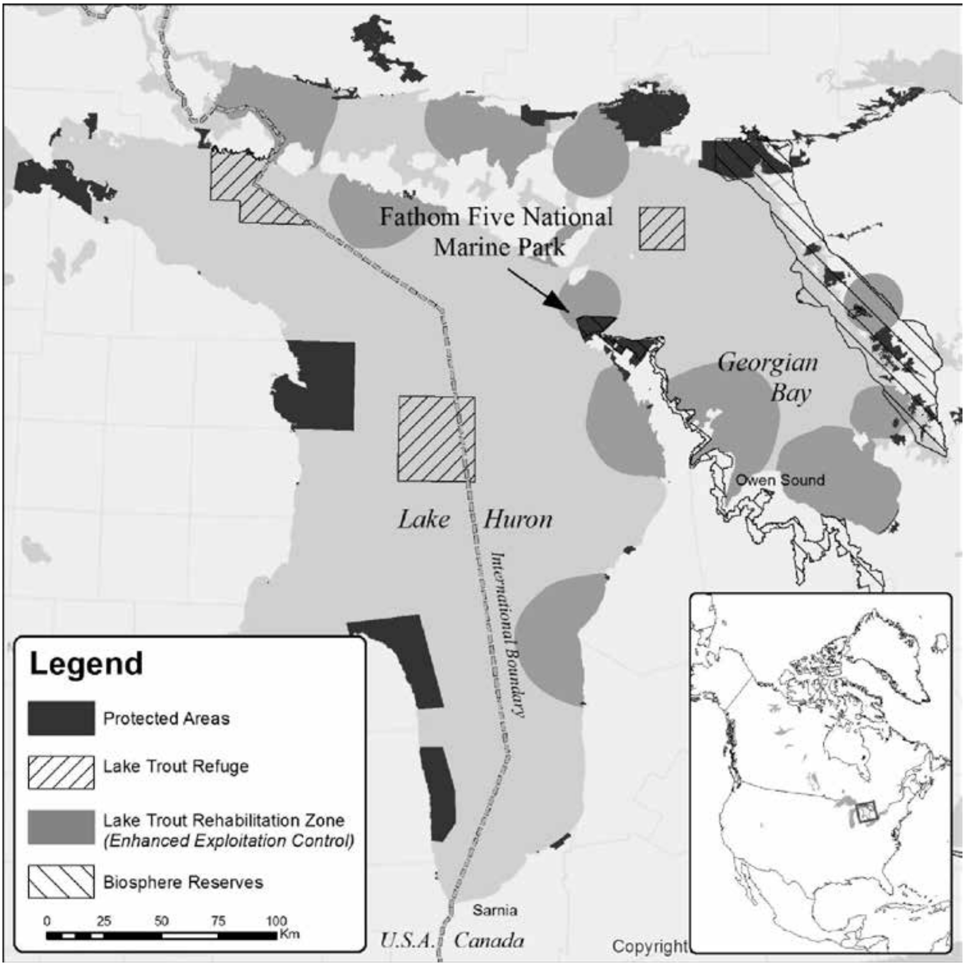
Resilience, especially its concept of persistence, may sound complementary to achieving ecological integrity, and it can with some qualification. Since many ecosystems face escalating uncertainty and novelty, efforts defined by maintaining the "composition and abundance of native species" may confront significant challenges, both socially and ecologically (Fluker 2010). In contrast, resilience is less focused on the persistence of a single species, and more reflective of an insurance metaphor by maintaining functional diversity, response diversity, and natural processes (Folke et al. 2004). Therefore, resilience appears to reinforce the expectations of the National Marine Conservation Area (NMCA) Act, including sustainability and the maintenance of structure and function (not specifically composition), and with qualification can also augment ecological integrity goals.

Structure, function, and composition can be characterized at all scales, from genetic to landscape. Structure includes biomass, density, diversity, spatial patterns, trophic groups, and ecosystem configuration (Minns et al. 1996). Function includes physiology, behavior, competition, energy flow, nutrient flux, and disturbance regimes (Minns et al. 1996). Composition refers to the species within the ecosystem.

Here follows a brief description of the current state and drivers for the interconnected offshore, coastal, and governance systems as discovered through the assessment (Table 2). This provided the context for resilience thinking.

Offshore assessment. Much of the recent change in the offshore ecosystem is coincident with invasive dreissenid mussel (*Dreissena rostriformis* and *D. polymorpha*) colonization (Nalepa et al. 2009; Barbiero et al. 2011). Although recent declines in the invasive sea lamprey (*Petromyzon marinus*) and alewife (*Alosa pseudoharengus*) fish population have created favorable conditions for native lake trout (*Salvelinus namaycush*) and cisco (*Coregonus* spp.) recovery, abundance across all trophic levels is generally low or declining (Dobiesz et al. 2005; OMNR 2010). For instance, four of the six deepwater cisco species are extinct or extirpated (Roseman et al. 2009), and, by feeding on benthic invertebrates, these fishes played an important function in energy and nutrient transfer to the pelagic environment

Figure 1. Lake Huron's protected area and enhanced fisheries management context.



Desired State	← Drivers →	Less Desired State
	Offshore	
native benthic diversity and lake trout-cisco community	nutrient and energy pathways colonization / extinction phase cycle of ecosystem temperature	dreissenid dominance and alewife-salmonie community
	Coastal	
low turbidity and sub/emergent vegetation	nutrient and energy pathways coastal development phase cycle of ecosystem colonization / extinction lake level fluctuations	high turbidity and algal biomass
	Governance	
legitimate, accountable, adaptive, and regionally integrated	politics and policy cultural beliefs and values population and demographics socio-economics problem-solving ability	lacks authority, limited mandate support, and little regional integration

Table 2. Alternate states and system drivers in Fathom Five. A decrease in resilience can make a system more vulnerable to disturbances. This can result in a regime shift when a threshold to a new basin is crossed. For example thresholds, see the Resilience Alliance threshold database (www.resalliance.org) and the Stockholm Resilience Centre regime shift database (www.regimeshifts.org). Currently, within Fathom Five the offshore is transitioning to a less-desired state, coastal is in a desired state, and governance is in a less-desired state.

(Eshenroder and Burnham-Curtis 1999). The dramatic decline of the benthic crustacean *Diporeia* spp. has also contributed to this break in traditional energy and nutrient cycles (Nalepa et al. 2009; Barbiero et al. 2011). It appears the offshore ecosystem of Fathom Five is transitioning to a resilient and less-desired state.

Coastal assessment. There is growing concern with sustained low lake levels, which is now approaching twelve years as compared with a maximum period of five years during the past century (e.g., Sellinger et al. 2008; IJC 2009; Millerd 2011; Midwood and Chow-Fraser 2012). Non-native species, including round goby (*Neogobius melanostomus*), common carp (*Cyprinus carpio*), and Eurasian watermilfoil (*Myriophyllum spicatum*) are present and have the potential to impact some coastal areas (e.g., GLANSIS 2012). The cumulative or direct impact of adjacent coastal development and domestic nutrient inputs remains unknown. In spite of this, the coastal ecosystem of Fathom Five appears to be in a resilient and desired state (Parks Canada 2011).

Governance assessment. Issues of legitimacy and effectiveness are the foremost challenges to governance in Fathom Five. Fisheries and water quality are managed without park involvement (e.g., see Table 10 in Parks Canada 2011). The transfer of ownership of the water column and lakebed to Parks Canada as per the establishment agreement (Canada and Ontario 1987) has yet to occur, and as a result the site is not scheduled under the NMCA Act. A park advisory committee representing a cross-section of public interest groups exists; however, this committee has no decision-making authority or role in goal setting, implementation, or evaluation (Werhum 1994). Fathom Five is within the traditional territory of the Saugeen Ojibway Nations, and consultation and management processes are currently being negotiated. The archipelago is recognized as a lake trout rehabilitation zone (Figure 1); however, there are no additional measures such as fish sanctuaries or gear restrictions in place (OMNR 2010). The park boundary is considered inadequate in terms of representing either the Georgian Bay or Lake Huron marine regions (Beak Consultants Ltd. 1994). There is little demonstrated engagement in lake-wide initiatives, such as those stemming from the Great Lakes Water Quality Agreement (IJC 2012a). In practice, management concerns and actions are clearly focused on a park scale (Parks Canada 2011). Governance in Fathom Five appears to be in a resilient and less desired state.

Planning for resilience

Planning involves identifying a desired state and developing strategies to reduce vulnerabilities, increase adaptive capacity, and monitor system feedbacks. Table 2 summarizes our perspective of the desired state for the three systems and Table 3 provides our recommended planning strategies and actions for each.

Desired state. A degree of uncertainty and a plurality of perspectives on the desired state are to be expected. It is an open and ongoing discussion, influenced by changing social values, system novelty, management institutions, and other factors (Olsson et al. 2006; Hobbs et al. 2009). To illustrate the challenge, Sloan (2004) presents an interesting dilemma involving a choice between the recovery of sea otter (*Enhydra lutris*) or northern abalone (*Haliotis kamtschatkana*) in Gwaii Haanas NMCA and Haida Heritage Site. These species represent

Table 3. Recommendations to strengthen resilience by reducing vulnerability, increasing adaptability, and navigating change in Fathom Five.

System	Scale Below (specific sites)	Focal Scale (Park)	Scale Above (Lake Huron)
Offshore	• Establish lake trout and whitefish spawning refuges. • Restore and protect lake trout and cisco populations (e.g., stocking).	• Research and monitor disturbances, functional, and response diversity. • Restore and protect lake trout-cisco community. • Develop a sustainable fishery in collaboration with First Nations and other government departments. • Re-assess boundary adequacy.	• Meaningfully engage on lake-wide coordinating policies and programs. • Conduct a regional representativeness and network analysis of offshore ecosystems. • Express conservation and resilience concerns. • Integrate with "State of the Lake" monitoring.
Coastal	• Engage landowners in learning, monitoring, and area planning opportunities for place-based conservation. • Restore sites degraded by development. • Protect coastal wetlands from development.	• Research and monitor disturbances, functional, and response diversity. • Manage coastal connectivity (e.g., reduce stranding barriers, prevent phragmites colonization). • Assess boundary adequacy. • Assess cumulative impacts from coastal development.	• Meaningfully engage on lake-wide coordinating policies and programs. • Conduct a regional representativeness and network analysis of coastal ecosystems. • Support stewardship activities, including restoration and conservation incentives. • Integrate with "State of the Lake" monitoring.
Governance	• Conduct scenario and desired state exercises, with resilience as a goal, for areas of local interest. • Develop mechanisms for ecosystem stewardship at specific sites, including social learning and involvement of adjacent landowners and commercial operators. • Promote sense of place.	• Evaluate governance, including vulnerabilities related to legitimacy, adaptability, capacity, and participation. • Develop a communication and learning strategy related to NMCAs and resilience. • Demonstrate place-based conservation. • Assign adaptive management targets. • Recalibrate management objectives in terms of resiliency and ecosystem change. • Report on ecological services and promote the site as a source of knowledge and well-being.	• Establish regional partnerships with initiatives focussed on broader social-ecological stewardship issues. • Examine regional social networks, strategic policies, and opportunities for involvement. • Coordinate access to information and knowledge. • Participate in regional land-use and lake-wide planning. • Support NMCA policy development and include resiliency concepts.

potentially mutually exclusive desired states with different social and ecological values. It is a choice between otters and kelp forests or abalone and "urchin barrens," with the former better representing historic conditions and the latter specific fishery values. Similar debates exist within Fathom Five; for example, stocking non-native pacific salmon versus a full focus on native species recovery (Crawford 2001), or debating on the need to regulate lake levels or not (IJC 2011, 2012b).

To move forward, planners need to be aware of biases and assumptions and be open and prepared for such questions as: "who decides"; "why is one state better than all the others"; and, "what if there is disagreement" (Nadasdy 2007). Much is hindered by uncertainty, but this can be reduced by incorporating active learning and adaptability within a resilience framework (Fazey et al. 2007).

Opportunities to explore diverse perspectives and alternative desired states could be facilitated through visioning (Olsson 2007) or future scenario exercises (Peterson et al. 2003). An active research and learning program that incorporates social and ecological sciences and adequately educates and informs decision-making is essential. However, this may be challenging to implement, as is evident at Fathom Five. For instance, most social indicators in the recent State of the Park report (SOPR) are not reported due to a lack of knowledge (Parks Canada 2011) and the ecological indicators provide limited insight when compared with other government initiatives, such as the State of the Lake report (SOLEC 2009) or the Binational Partnership (EPA and EC 2008). Since the SOPR is developed as the key document for informing the planning process, its content matters (for details see, Parks Canada 2008). Knowledge of emerging issues or trends is also central to the identification of desired state. For instance, at Fathom Five knowledge of visitor carrying capacity (*sensu* Manning 2007) or valuation of ecosystem services (*sensu* MEA 2005) would be informative and guiding.

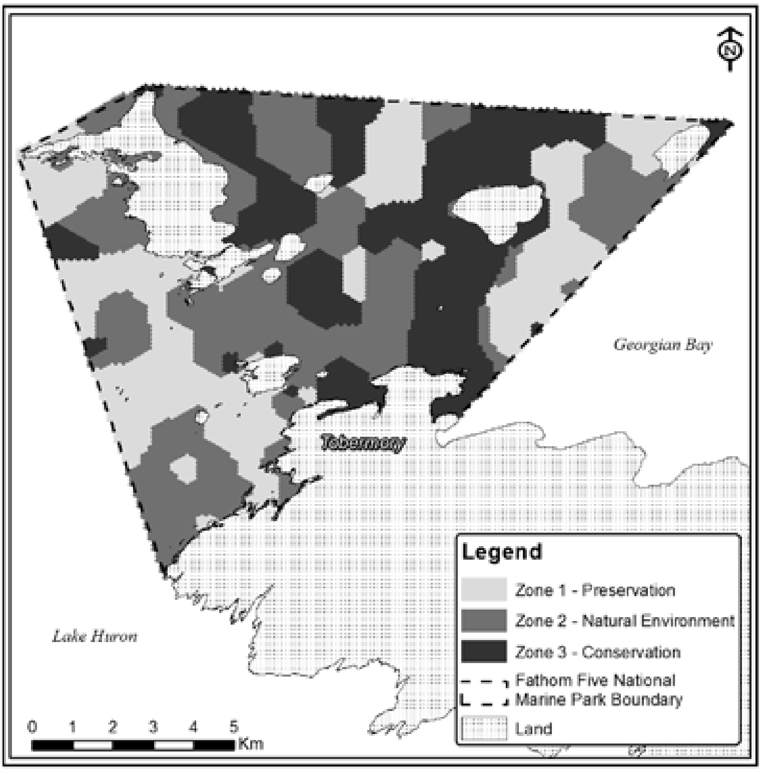
Based on our assessment of the offshore, the dominance of invasive dreissenid mussels has virtually eliminated any prospect of restoring this ecosystem to a historical composition. Although a degree of reconciliation and acceptance of system novelty is required, we feel there still exists an opportunity to actively navigate the transition and maintain structural and functional elements for energy and nutrient transfer from the benthic to pelagic realm. To this end, the desired state focuses on maintaining lake trout–cisco communities. Of note, other areas on Lake Huron that have established fish sanctuaries have witnessed native fish recovery and progress towards a more desired and resilient state (Reid et al. 2001; Madenjian et al. 2004).

For the coast, planning efforts are directed towards monitoring and maintaining structure and function, reinforcing the need to identify sources of biodiversity and maintaining connectivity to different lake level scenarios. Much of the coast is already in a desired state, as characterized by low turbidity, submergent and emergent vegetation, and little development.

The focus for governance is on leveraging out of a less-desired state, mostly through partnership and networking initiatives (e.g., IUCN WCPA 2008). Desired state for governance was based on the expressed elements of leadership and regional cooperation in the Fathom Five management plan (Parks Canada 1998) and on general attributes of good governance (Gunderson et al. 1995; Francis 2008).

Park zoning. Zoning is a spatial planning process often undertaken to support conservation goals and reduce user conflicts within a protected area. The current zoning plan for Fathom Five (Parks Canada 1998) does not have any zones that fully protect aquatic ecosystems in the park. We explored a zoning concept that explicitly attempts to strengthen resilience by spatially prioritizing protection needs (Figure 2). The decision-support tool Marxan with Zones (Watts et al. 2009) provided a platform by which to define and service zoning in a complementarity-based approach. Resilience-based features were selected for the analysis, including ecosystem structure (e.g., benthic complexity and composition, deepwater, ice coverage, currents, coastal wetlands, shoreline complexity and exposure), ecosystem function (e.g., spawning and breeding areas, areas of high nutrient and energy

Figure 2. An example of a "best solution" generated by Marxan with Zones. Using resilience-based representativeness, replication, and connectivity targets for key structures and functions. This is only a proof of concept and does not represent a final or approved plan. The results highlight the importance of protecting lake trout–cisco habitat and coastal wetlands within a Zone 1 Preservation area. The Zone 2 Natural Environment and Zone 3 Conservation areas provide for ecological sustainable uses, recognizing the social benefits and values of facilitating meaningful experiences (for zone descriptions see Parks Canada 1994).



flow), and social structure (e.g., visitor use nodes). Conservation target values were assigned in terms of resilience-based needs for representativeness, replication, and connectivity. Cost layers included coastal development, commercial shipping, and fishing areas. The Marxan approach provides a potential link to an adaptive management design (*sensu* Holling 1978). The conservation targets form a prediction of change and benefit, thus providing a quantitative measure of management effectiveness, to be monitored, evaluated, and adjusted in an iterative manner.

As a "proof of concept," the method was successful. However, to receive a high degree of legitimacy and acceptance in its implementation, future iterations will need to be reinforced through a public and partner planning process. The Great Barrier Reef Marine Park Authority credits their communication strategy and level of public engagement as key to their success in increasing the area of no-take protection zones from 4.5% to 33% of the park (Kenchington and Day 2011).

Regional scale

Resilience, in part, is predicated on an understanding of cross-scale linkages (Resilience Alliance 2010), and therefore, planning efforts need to consider larger, regional-scale influences. Although Fathom Five remains somewhat isolated from regional initiatives (e.g., EPA and EC 2010), Figure 1 illustrates the existence of other protected areas and the potential for a more systematic approach to networking and partnership. The Georgian Bay Littoral Biosphere Reserve (www.gbbr.ca), 80 km to the east, presents an example of an integrated regional vision which maintains an aquatic ecosystem focus. An alternate concept to biosphere reserves is a network of protected areas that function collectively with corridors or stepping-stones to facilitate species or process movement (e.g., Wildlands Network; www.twp.org), IUCN WCPA 2008). This could be particularly relevant for coastal wetland or spawning shoal connectivity. Future Marxan zoning exercises could be undertaken at a larger scale to help promote a resilient network concept (e.g., IUCN WCPA 2008, Green et al. 2009), as well as address boundary adequacy and representativeness issues (Beak Consultants Ltd. 1994). Networks also have the benefit of facilitating informed contributions to planning, building knowledge bases for research and monitoring, and engaging curiosity or stewardship interests in a learned fashion. UNESCO's knowledge societies (2005) concept may be guiding in this regard.

Monitoring

Recent research has revealed that there are leading indicators within ecological time-series data of abrupt and surprising changes due to a loss of resilience, including an increase in variance, change in skewness, rise in autocorrelation, and decrease in return rates (e.g., Carpenter and Brock 2006; Guttal and Jayaprakash 2009; Scheffer et al. 2009; Dakos et al. 2011). While many studies have been able to show retrospectively that such a transition occurred, methods to predict change, allowing for actions to either prevent or actively navigate a transition, have been more difficult to develop (Andersen et al. 2009; Biggs et al. 2009).

The current monitoring program for Fathom Five (Parks Canada 2011) does not explicitly address resiliency or leading indicators of regime shifts. We did, however, explore increasing variability further by completing a control chart analysis (Anderson and Thompson 2004; Morrison 2008) of the parks coastal fish community. Our data were limited to the past eight years (2005–2012) and was only beginning to generate tighter confidence limits for expected stability in variability. An exceedance in variability would be viewed as a potential leading indicator of a regime shift. The changes may be due to increased lake levels, colonization/loss of macrophyte-dependent species, or invasive species. Further monitoring and analysis is required, but the method showed promise for interpreting multivariate environmental data and informing managers of potential concerns. In reality, it may takes decades of research and monitoring, as it did with lake (Scheffer and Carpenter 2003) and coral reef systems (Hughes et al. 2010), before sufficient understanding of system indicators and thresholds is available to help manage for resilient desired states.

We also encourage expanding the monitoring measures and discourse beyond visitor metrics to those that link social–ecological values and benefits, such as "healthy parks, healthy people" (Maller et al. 2008) and "quality of life" (Costanza et al. 2007). As with ecosystem services (MEA 2005), this may help to deepen the appreciation and importance of Fathom Five and identify grounds for networking and support for resilience.

Implementing a resilience-based approach

Implementation includes organizing and managing for resilience (Table 3). Institutional rigidity, struggles translating plans into actions, and weak or insular management structures are general concerns with any organization (Gunderson et al. 1995). Given the complexity, uncertainty, and origin of some of the park issues, an adaptive management approach to promote learning and experimentation with new policies, partnerships, and institutions may be beneficial (e.g., fisheries management, *sensu* Holling 1978). As a model, the Great Barrier Reef embraced the need for transformation and overcame similar barriers. Through leadership and innovation, they were able to coordinate the scientific community, increase public awareness, broaden stakeholder engagement, and navigate the political system for support at critical times (Olsson et al. 2008). They essentially developed a resilience-based approach to cope with uncertainty, risk, and change. The IUCN has also addressed some of these issues by developing best practices for management planning (Thomas and Middleton 2003), guidelines for legislation (Lausche 2011), methods for establishing networks (IUCN WCPA 2008), and approaches to assess management effectiveness (Pomeroy et al. 2004; Hockings et al. 2006).

Conclusion

A resilience-based approach provides perspective on system disturbances, drivers, alternate regimes, and cross-scale interactions (Resilience Alliance 2010). With this understanding, we feel there is an opportunity to better manage towards a more resilient and desired state. The desired state is variable and adaptive, and defined by key structures, functions, and feedbacks.

Management efforts aim to prevent undesired regime shifts and support post-disturbance recovery with functional and response diversity (Folke et al. 2004; Chapin et al. 2010). To fully embrace resilience requires a management structure that supports social learning, experimentation, trust-building, and a mandate to take action (Prato 2006). Managers of protected areas should feel confident that those willing to look through its lens can make the concepts and methods of a resilience-based approach operational.

It is an opportune time for Fathom Five to consider incorporating resilience within its planning and management processes. The NMCA program is in a period of growth, there is growing interest in Great Lakes protected areas (e.g., Hedges et al. 2011; IJC 2012a), and the Fathom Five management plan is about to be opened for review. The concepts and methods we explored here appear to be promising and we are hopeful that even though the Great Lakes continue to face escalating uncertainties and change, Fathom Five can effectively achieve its long-term conservation goals by maintaining and building resilience.

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