3

EMERGENCE OF COMMUNITY SCIENCE AS A TRANSFORMATIVE PROCESS IN PORT MOUTON BAY, CANADA

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Introduction

In this chapter we focus on the emergence of *community science* as a key aspect of the necessary shift required to transform our current governance practices to achieve a better fit between a social-ecological system at the local community level and provincial level of decision-making. We examine this process in Port Mouton Bay (PMB), a small harbour in Nova Scotia, Canada (Figure 3.1) where the degradation of important lobster habitat motivated the community to create an innovative volunteer ecosystem-based monitoring program. Since 2006, a community-based

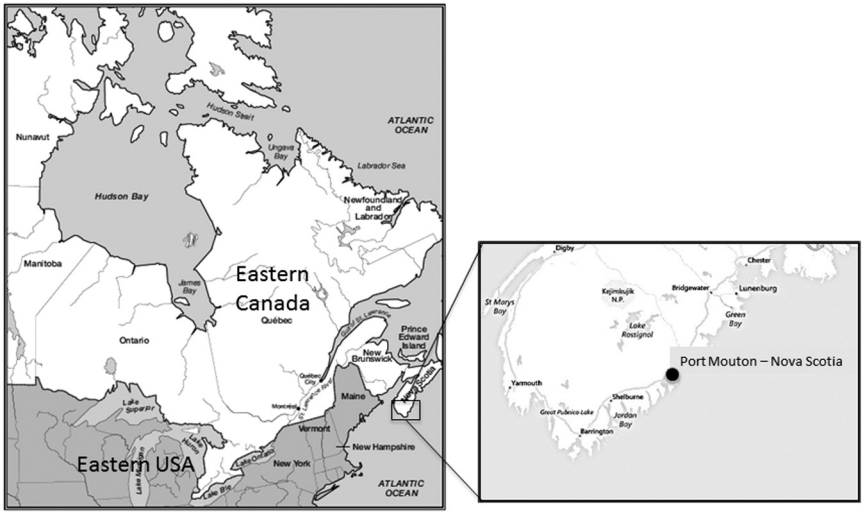
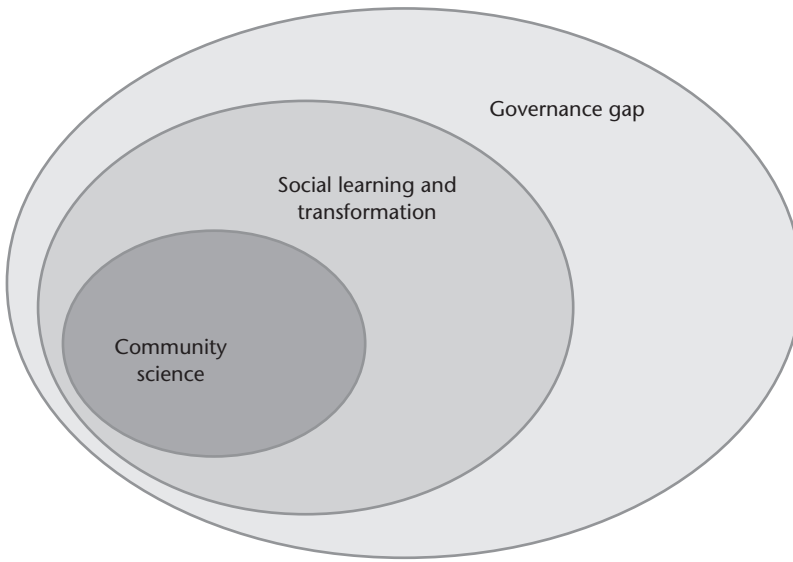


FIGURE 3.1 Port Mouton Bay location map

organisation, the Friends of Port Mouton Bay (FPMB), has developed a unique blend of scientific knowledge and local ecological knowledge in the process of co-producing an environmental assessment of the impact of finfish aquaculture in the Bay. Not only has the FPMB developed a new form of hybrid knowledge, they have also demonstrated the importance of engaged social learning as a transformative process that links knowledge together with collective action, across a social network over time.

We treat the community and the bay as a social-ecological system, taking the view that the human components and the biophysical components of the system are linked with feedback relationships and should be analysed together (Berkes and Folke, 1998; Garcia and Charles, 2008). Three concepts frame our analysis of the Port Mouton Bay case and its implications for a broader set of coastal contexts: the problem of governance 'fit', social learning as a transformative process, and community science. The argument is that the three concepts are related in that community science can lead to social learning and social-ecological system transformation, and in turn address the governance gap (Figure 3.2). We expand on each.

The problem of *governance 'fit'* is defined as the 'failure of an institution or a set of institutions to take adequately into account the nature, functionality, and dynamics of the specific ecosystem it influences' (Ekstrom and Young, 2009). Galaz and colleagues (2008: 168) take the perspective that problems of fit are between biophysical systems (broadly defined) and governance systems of which institutions are a part. Fit is thus best conceived of as a 'bundle' of challenges, some of which are relatively well understood, such as the problem of spatial fit typified by



As community science expands, the social learning space expands and closes the governance 'gap' over time.

FIGURE 3.2 Community science, social learning and the transformation of governance fit

transboundary resources. However, some aspects of fit are a more recent concern, including problems of social fit, or the lack of congruence of different actors around a defined problem (Galaz *et al.*, 2008; Moss, 2012).

Social Learning is an important ingredient in helping actors at different levels (local, regional) deal with system complexity and problems of fit associated with many social-ecological systems (Armitage and Plummer, 2010). Social learning is defined here as the iterative action, reflection and deliberation of individuals and groups in ways that create shared experiences and which foster changes in understandings or perspectives aimed at resolving complex challenges (Diduck *et al.*, 2012; Keen *et al.*, 2005; Reed *et al.*, 2010). A key requirement is that the learning extends beyond the individual and becomes embedded in a broader social context through interactions among actors in a social network (Diduck *et al.*, 2012; Reed *et al.*, 2010). Social learning is considered important to bridge the knowledge gap that often exists in managing change processes in multi-level and multi-scale governance systems (Cundill and Rodela, 2012; Medema *et al.*, 2014). Transformative learning concerns the process *individuals* undergo when a shift occurs in their mindsets and perspectives through constructive discourse (Mezirow, 2003). Social learning engages a *social network* in the expanding transformative process of co-producing knowledge.

An increasingly important catalyst for social learning and the transformative process is the emergence of *community science*. Community science is a form of place-based social learning, one that is both a process and product of *collective* scientific inquiry at the community level. Indeed, its key characteristic is its social nature, based on social learning, collective action and commitment to transforming situations and conditions that are undesirable in some way. Community science is related to citizen science since by definition it is 'citizens' who are involved in doing 'community science', and both are based on principles of scientific hypothesis testing. However, there are significant differences. First, the term 'citizen science' says nothing about the social nature of the endeavour. While it can be a community-based activity, citizen science typically focuses on the involvement of individual citizens as volunteers in the collection of scientific data (e.g. birdwatchers contributing to monitoring of nesting sites). Second, citizen science is usually driven by professionals and experts. Community science in contrast is *led by the community*, with input into which experts may be engaged or chosen as partners, whether internal or external.

The key to community science lies in its roots in the place-based relationship between the community's experiential local ecological knowledge holders and instrumental scientific knowledge holders. In an iterative and cyclical transformation process, participants in community science blend both forms of knowledge in the practice of communication and learning about their local social-ecological system and the flow of ecosystem services.

Transformation in Port Mouton Bay: the emergence of community science

The emergence of community science in Port Mouton Bay was precipitated by multiple dilemmas arising from a finfish aquaculture lease first issued in 1995. Aqua Gem Farms (later Aqua Fish) anchored three temporary rainbow trout (*Oncorhynchus mykiss*) aquaculture cages in the inner harbour of Port Mouton Bay. A year later, lobster fishers observed crabs and lobsters migrating towards the finfish farm site, leading them to believe the lobster were attracted to the aquaculture feed settling on the ocean bottom. However, their beliefs changed in the second year and later when the operation increased in size and switched to Atlantic salmon (*Salmo salar*). After this, fishers noticed lobster migrations were shifting their traditional routes to avoid a wide area of sludge on the ocean bottom below the salmon net-cages (Gilbert, 2007). Fishers also observed a growing amount of greenish-brown algae fouling their lobster traps and thought there might be a connection with the declining numbers of mussels, clams, scallops and periwinkles in Port Mouton Bay (Gilbert, 2007).

Fishers' perceptions of loss of ecosystem services were substantiated by their local community science, which was later corroborated by a retired federal Department of Fisheries and Oceans (DFO) scientist who reviewed scientific sediment monitoring data at the first aquaculture site. His report discussed the cumulative effects of organic material settling on the ocean bottom underlying the open-net pen cages, resulting in anoxic and hypoxic conditions and the release of large quantities of dissolved nutrients in the water column which could explain the nuisance algae over a widespread area (Hargrave, 2009). Community science generated data on metal contamination in the sediments and in the sea-surface microlayer (Loucks *et al.*, 2012). These conditions likely contributed to the loss of mussels, scallops, kelp and eelgrass beds and Irish moss, both adjacent to the fish cages and at distance (Loucks *et al.*, 2014). These findings are comparable to ecosystem losses that lobster fishers sustained after salmon aquaculture cages were introduced in New Brunswick (Marshall, 2001; Wiber *et al.*, 2012); but see Walters (2007) for a dissenting view.

The observations of local marine species decline and changing lobster migration patterns signalled a serious change in the flow of ecosystem services (e.g. food production) and socio-economic benefits for the community of Port Mouton Bay. Some 28 per cent of the local community (pop. ~429) depends on the fisheries resource sector for some part of their livelihood and almost every family has some connection with lobster fishing, either past or present. Historically, people from the local villages fished groundfish such as cod and haddock in the summer and lobster in the autumn, winter and spring. Groundfish populations are only partially recovering from collapse in the early 1990s, while lobster fishing remains an important livelihood for many of Nova Scotia's coastal communities (Charles, 1997). It is significant that fishers in Port Mouton Bay still fish lobsters in the areas first delineated by their ancestors according to the location of their early village wharves, an

affirmation of the important rules-in-use that have guided local fishers for more than two centuries.

In the Port Mouton Bay social-ecological system, the size and distribution of traditional lobster fishing territories reflect the location of lobster habitat and seasonal lobster migration patterns. Hand-drawn maps of lobster fishing locations in the 1940s illustrate the approximate location of lobster fishing areas that are still used, and confirm that lobster migration patterns are relatively slow to change (unpublished records in DFO data files cited in FPMB, 2008). However, when these migration routes do change (because of the siting of aquaculture farms, for example), a series of cascading collective action dilemmas are triggered. One local lobster fisher describes this process more generally:

> Up until about 15 years ago this was one of the best, if not the best, harbours for fishing. In the Spring we pulled in 700 or 800 pounds of lobster a day. Now I fish outside…. Nobody fishes the inside harbour anymore. That's pushing all the fishers out, so there's more competition…. More boats in less space. We're not getting near those numbers anymore.
>
> *(G.E. Broome cited in Ediger, 2007)*

The use of lobster fishing territories in Port Mouton Bay can be traced back to the 1700s when fishing families first settled the area. These fishing spaces continue to be handed down within the same families whose ancestors originally settled the local villages. Fishers still refer to an area in Port Mouton Bay as the 'safe haven', a sheltered place where lobster traps are set for protection during storms and a type of lobster spawning commons. Much like a marine protected area, the fishers share the practice of conservation by not gill-net fishing in the location of the most important spawning habitat. However, in 2006, a second finfish aquaculture site was proposed in the same location as the 'safe haven'. Concerned with the dilemmas arising from the first finfish aquaculture site, the community created the Friends of Port Mouton Bay (FPMB) to monitor their bay and protect the flow of ecosystem services.

While no new aquaculture applications have been approved since the first aquaculture site lease was issued in 1995, the Friends of Port Mouton Bay have yet to experience a governance and regulatory process that adequately takes into account the nature, functionality and dynamics of their local social-ecological system. Decisions on aquaculture made by successive provincial governments have not yet linked the livelihoods and well-being of the community of Port Mouton to the productivity and health of the bay and its lobster fishery. Rather, support for aquaculture development has exacerbated a growing disconnect among provincial (and in some respects national) policy and the place-based livelihoods and marine ecology of Port Mouton Bay. This problem of fit has had the unintended consequence of displacing fishers from their traditional fishing territories and eroding an effective informal local governance arrangement (see below) that previously supported the stewardship of local lobster spawning grounds.

Pushing back with a transformative process in Port Mouton Bay

The initial goals of the Friends of Port Mouton Bay (FPMB) community science monitoring programme were to document ecosystem sensitivity to nutrient enrichment in Port Mouton Bay and to prevent the siting of aquaculture leases in locations with low flushing rates. The fishers' experience with aquaculture waste accumulation, declining lobster catches and the production of nuisance algae are strong indicators that Port Mouton Bay's ecosystem has low capacity to assimilate the nutrient rich wastes that accumulate from salmon aquaculture net pen cages in shallow basin formations. This initial emphasis on ecosystem conditions in the Bay has since become more comprehensive.

Comparable to what Freire (1970) called 'true dialogue', and in response to the growing disconnect identified above, the FPMB gathered in community meetings to discuss their situation and reflect on future actions. These group conversations became the foundation for building strong relationships and collective action within a widespread social network that included scientists and civil society. When reflecting back on these 'early' days, people explain how these meetings helped create a sense of shared community strength and cohesion (Pottie, personal communication, 7 August 2013). During one pivotal meeting, two oceanographers who were part of the local community asked the local fishers, 'How does this Bay work?'

The question initiated a conversation between the local scientists and fishers about the Bay ecosystem, revealing the fishers' knowledge of the biophysical properties influencing water circulation. The fishers knew from experience that the bottom of the Bay was shaped in a series of shallow basin-sill formations. They described their observations of the water movements as 'going in circles' rather than going out to sea. The oceanographers recognised this pattern as a function of the bathymetric influence on the water column and surface water. When shown bathymetry maps for the Bay, the fishers' local ecological knowledge of the Bay matched perfectly with the bathymetric contours, validating their understanding of the relationship between the shape of the ocean bottom and the movement of the currents.

Building on this initial conversation, the fishers and scientists conducted simple oceanographic experiments to determine the water circulation pattern in the location of the proposed fish farm site. They used marked current drogues (an apparatus that has an underwater sail and a marker float) and tracked the position of the drogues by following the current markers in a fishing boat throughout the full tidal cycle of 12.5 hours. The shared experience created a unique opportunity for the fishers and the scientist onboard to observe each other's data-gathering methods and ask clarifying questions about their assumptions. Consequently, several new scientific questions emerged from their conversations, which, in turn, informed another series of community science studies. With these initial knowledge exchanges, the fishers and scientists were able to cross-validate each other's knowledge with their shared experience and methods of learning. As a result, a high level of mutual trust and respect was established early on in the evolution of the Port

Mouton Bay voluntary marine monitoring programme, resulting in a knowledge co-creation and continuous social learning. These processes reflected the key components of community science.

> The fishermen described the depositional basins and slow currents except in times of storms. We suggested a sea-bed drifter validation experiment to confirm this pattern and supplied the seabed drifters. The fishermen deployed the drifters in advance of the next nor'easter storm (that occurred in late January 2007 that year). The community volunteered to walk the shorelines to find drifters and report the identification number, position, and date located.
>
> *(This took place from February to April 2007.) (R. Loucks, personal communication, 10 October 2013)*

The next step in the community science effort, the sea-bed drifter experiment, was designed to answer the locally important question: Is there a risk that finfish farm waste can pollute adjacent beaches and shoreline habitats? Carters Beach, a habitat for the endangered piping plover shorebird, is located in close proximity to the existing fish farm lease. Its significance was recently recognised by the Nova Scotia Department of Environment as a potential nature reserve for the protection of its unique sand dunes (NSDE, 2012). The monitoring required a dedicated community effort throughout the cold months of winter, yet the community was fully engaged in the process.

> All through February and March, people walked the shores and inspected for stranded drifters, but none were found. In late March a single drifter was found on a beach. We were quite excited until we inspected it and found it to be a different color than those released. At a public meeting in late March, we commiserated with the searchers about the absence of found drifters, but there hadn't been any large storms in the search period – until April 8th. On that day a very large nor'easter was experienced and afterwards the searchers found several drifters on shores and beaches. It was concluded that sediments released and deposited in Port Mouton Bay could accumulate during mild weather and later be transported to the shores by storms.
>
> *(R. Loucks, personal communication, 10 October 2013)*

Another example of knowledge co-production by local lobster fishers and local scientists was the lobster study, initiated by the fishers to answer the question: Is the finfish farm having a detectable effect on the traditional lobster migration patterns on which the traditional fishing territories are located? To address this, the fishers collected lobster catch data in five regions that reflected the traditional lobster fishing territorial boundaries. After seven years of data gathering, their findings show that the lobster catches were lowest in the regions adjacent to the fish farm in years the fish feeding was in operation (Loucks *et al.*, 2014). While this finding was

not so surprising, the study also confirmed that the lobster catches significantly declined in the far-field regions, specifically during the fish feeding years. Interestingly, in the three years the fish farm feeding operations ceased between 2009 and 2011, the lobster catch rates began to increase in the far-field regions, but not in the region where the fish farm was immediately located. However, the catch rates in all regions declined once the fish farm resumed feeding operations in 2012 (Loucks *et al.*, 2014).

Looking at the process of engagement over the last nine years, we can see that restoring the governance 'fit' is a gradual step-by-step process of social learning and transformation. Table 3.1 describes the community skills, strategies and emerging opportunities that evolved with the community science transformative process. As evident from Table 3.1, the Friends of Port Mouton Bay have been acting collectively since 2006. This has required an enormous community effort of voluntary time, energy and financial cost to prevent the leasing of a second aquaculture site in the bay, and to seek a reversal of the approval for the first aquaculture site location. The ability of the Nova Scotia Minister of Fisheries and Aquaculture to make decisions that can potentially perpetuate a series of cascading collective action dilemmas in coastal areas unsuitable for aquaculture is an obvious weakness in the current fisheries and aquaculture regulatory framework and one that goes against the findings of a recent province-wide independent aquaculture review panel process (Doelle and Lahey, 2014). Indeed, an outcome of this review by the Nova Scotia Ministry of Fisheries and Aquaculture is the potential transformation of the provincial aquaculture regulatory framework (Doelle and Lahey, 2014).

The recommendations of the Doelle and Lahey (2014) final report have the capacity to catalyse significant shifts in the Nova Scotia provincial aquaculture policy. Still, the long-term impacts of this review are yet to be fully determined. So far, the report has not facilitated a significant shift and, in fact, the licence for one of the aquaculture facilities in Port Mouton Bay was extended. However, it is worth noting the following text in the panel report about the FPMB community science:

> In our view, the study [i.e. the FPMB community science] … raises questions about the interaction between fin-fish aquaculture and lobster populations that should not be ignored. They are questions that are particularly important in Nova Scotia, where the lobster fishery is vital to the economy of coastal communities and the province more broadly. The fact that considerable work is left to be done by the scientific community before we will have clear answers to these questions is not a reason for inaction but rather for action that will ensure that this work is undertaken. The Friends of Port Mouton Bay have done tremendous work to try to fill information gaps that are of significant general interest, and it is critical that their work lead to further research in this area.
>
> *(Doelle and Lahey, 2014: 28)*

Currently, there is a window of opportunity that the new aquaculture siting criteria and licensing process will integrate the values of economic prosperity, social well-being and environmental sustainability in the site assessment process. Acknowledgement in the panel report that aquaculture should have a low level of adverse environmental and social impact that decreases over time is an indication that the experience in Port Mouton Bay is both undesirable and unacceptable for future aquaculture development.

> We have concluded that a fundamental overhaul of the regulation of aquaculture is called for. We have concluded that this overhaul should be guided by the idea that aquaculture that integrates economic prosperity, social well-being and environmental sustainability is one that is low impact and high value. By this we mean aquaculture that combines two fundamental attributes: it has a low level of adverse environmental and social impact which decreases over time and it produces a positive economic and social value from the use of coastal resources which is high and increases over time.
>
> *(Doelle and Lahey, 2014: xvii)*

Revisiting governance fit, social learning and community science: challenges and lessons

There are clearly many accomplishments in the small community of Port Mouton Bay, in drawing on the community's sense of place and strong social cohesion to develop effective community science, and then in using this to push, sometimes successfully, for policy change. At a local level, the community illustrates the reality that increasing the fit between ecosystems and governance systems is inextricably linked to (1) building an integrative perspective on social-ecological systems and (2) aligning management, protection, monitoring and knowledge sharing across multiple scales (Galaz *et al.*, 2008). However, the process of social learning and production of community science in Port Mouton Bay is an illuminating example of the enormous effort and time it takes to co-produce local community scientific knowledge and fit this into existing government regulatory frameworks. The required commitment of time and energy may be a limiting factor in other cases.

Furthermore, even when knowledge is scalable, a significant governance gap persists between the practice of environmental assessment (e.g. the community's monitoring of the bay, in this case) and the protection of ecosystem services (through governmental policy and action). As Wilson (2006) observed, the mismatch of ecological and management policy scales creates a barrier limiting the ability of regulators to respond to fine-scale ocean ecosystem changes that lead to the erosion of fish habitat and subsequent loss of livelihoods at the local community level. This mismatch has a parallel in terms of the social part of the social-ecological system; its mismatch with policy scales, often arising from differences in values and motivations, creates large differences between community and government directions (Garcia *et al.*, 2014). This is reflected, for Port Mouton Bay, in the dichotomy

TABLE 3.1 Community skills, strategies, emergent opportunities and transformative process in Port Mouton Bay, 2006–2015

Community skills	*Strategies*	*Opportunities*	*Outcome*
(2006–ongoing) (1) Facilitating hybrid knowledge building and social innovations; community science	Publish 29 local scientific reports on FPMB website; invent new monitoring methods; community members conduct interviews with local fishers; local scientists design research programmes with local fishers; research results published on website and in peer-reviewed scientific journals	Evidence of loss of ecosystem services; evidence of copper in the micro-surface layer creates opportunity for more provincial scientific assessment; journal publications increase legitimacy and validity of community science	The FPMB dialogue with scientists grows at multiple levels (NS Dept of Environment, NS Dept Fisheries & Aquaculture, ex DFO fisheries scientists, National Parks scientists, NGO scientists, university scientists); journal publications are presented as valid evidence for NS Aquaculture Review Panel (2014)
(2007–ongoing) (2) Visioning and strengthening sense of place	Local music composer and musicians collaborate to produce song on Port Mouton Bay, SES; boundaries articulated and celebrated through music, visioning and values dialogue (2012)	Provides new opportunity to re-embed values and identity connections affiliated with place; strengthen community norms of marine stewardship and caring for each other within social-ecological system	Shifts the dominant perception of the SES boundary to include the marine ecosystem and social system of all adjacent communities and residents; builds community resilience; broadens the sense of place for all who live around Port Mouton Bay, including newcomers

(2007–ongoing) (3) Political engagement and local voice in municipal governance; local voice in province-wide coalition	Local municipal councillor (and local business owner) is member of Friends of Port Mouton Bay; FPMB share their science via website and model a new norm of information transparency	Opportunity for dialogue to expand across NS	Municipal leaders voice concerns to Minister of Fisheries and Aquaculture; pressure from provincial coastal community network pushes aquaculture as an election issue (2013); moratorium on new aquaculture sites and Doelle-Lahey aquaculture regulatory review panel announced and completed
(2009–ongoing) (4) Scientific collaboration and networking (2012–ongoing); university scientists partner with FPMB and begin co-designing research projects and publications	FPMB featured in Community Conservation Research Network case study (2012); community partner in OceanCanada Partnership (2014); FPMB join international eel grass monitoring project (2015)	Provincial election platform provides a new opportunity for engaged dialogue	Regulatory review process includes members of FPMB on Roundtable, Scientific Advisory Committee; local ecological knowledge is recognised as a valid knowledge contribution to scientific evidence of aquaculture marine ecosystem impacts
(2012–ongoing) (5) Scaling up information sharing; linking across diverse communication platforms	University research partnerships create opportunities for increasing local research and knowledge mobilisation; FPMB featured in Silver Donald Cameron film *Salmon Wars*; story of FPMB presented as case study in university courses and conferences	Opportunities to make sense of the situation grow as knowledge feedback loop links community with outside researchers (i.e. reviewing research papers and designing new research questions); community resilience builds for 'staying the course'	As the community engages in university research partnerships, a new domain for learning and sharing knowledge about local marine ecosystem stewardship is created

between the science-based community goals of the FPMB and the policies adopted by the provincial government.

The governance gap, apparent in poorly designed Nova Scotia regulations, is also evident at the national level. Recent changes in Canada's Fisheries Act, and federal cutbacks in funding for local-level ecological monitoring and ecosystem assessment, have widened the governance gap (Hutchings and Post, 2013). While several new 'Fisheries Protection Provisions' aim to protect the 'sustainability of the ongoing productivity of fisheries' (Rice *et al.*, 2015), the large spatial scale at which fisheries productivity is assessed is incapable of incorporating the results of habitat monitoring in a smaller location like Port Mouton Bay. Indeed, the risk of harming ecosystem services at the local community level is not even a measureable consequence in the most recent Canadian fisheries protection legislation. Similarly, the interconnection between social and ecological systems is not articulated in the amended Act as an important aspect of sustainability.

Given these challenges, what lessons can be drawn from the social learning and community science in Port Mouton Bay? More broadly, what can be learned about ideas of transformation and its links to governance fit? First, the timing of transformation is critical, especially when a change in the dominant world view in government regulatory frameworks is required for the shift to occur. Second, the process of transformation requires many leaders engaged within the social learning process. Third, the role of community agency is vital in the co-production of community science and shaping the broader context within which more opportunities for transformation can arise. Fourth, the collective sense of place connection is critical for building community resilience in Port Mouton Bay and integral to the co-production of community science. Without a strong collective sense of place, it is unlikely that transformation would occur. We discuss each of these below.

The timing of transformation

Transformation, or transformability, is described as the capacity 'to create untried beginnings from which to evolve a new way of living' (Walker *et al.*, 2004; Goldstein, 2009) analysed the specific resilience that arises after disasters, noting that disturbances and crises of various kinds may provide windows of opportunity to transform social-ecological systems, including the role of informal and community-based knowledge networks. Dorado (2005), in her analysis of social movement literature, defines opportunity as 'the likelihood that an organisational field will permit actors to identify and introduce novel institutional combinations and facilitate the mobilisation of resources to make it enduring' (2005: 413).

One key window of opportunity for transformation in Port Mouton Bay emerged during a 2014 provincial election, and corresponding government commitment to review the role of aquaculture in the province. Consistent with Dorado's (2005) notion of opportunity, the Friends of Port Mouton Bay social learning process and expanded social network helped to create an appropriate context within which the Nova Scotia provincial aquaculture policy was reviewed. The freely

accessible online community science reports facilitated a high degree of legitimacy for the pre-election announcement of a temporary moratorium on new aquaculture lease applications and the subsequent province-wide aquaculture regulatory review panel. And as noted earlier, the submission of research findings to the panel review influenced the final report recommendations. Still, time is a malleable concept when thinking about transformative changes, and any positive outcomes associated with the election and the panel review are still short term. The institutionalised barriers to transformative change are not easy to transcend even in a context where capacity to do so is relatively high.

The role of many leaders

While the social network is well documented as a key organisational structure for social learning (Armitage *et al.*, 2007), the *leadership* style emerging in the Friends of Port Mouton Bay is somewhat unique. There are no formal organisational structures, no assigned, elected or appointed leaders, no staff, no budgets or strategic plans. Rather, there is a self-organising web of relationships within the community and beyond, through which knowledge is shared and continuously reflected upon. Some individuals naturally gravitate to leadership roles depending on circumstances, although the 'flat' organisational structure remains. Community members voluntarily walk the beaches and shorelines to take photographs of contaminated beach sand, gather sludge samples for sediment tests, and participate in eelgrass monitoring and lobster habitat studies. When they need money to send samples for laboratory tests, they either fundraise or donate the money themselves. When a leadership role is required, the appropriate leader for the situation is encouraged to take on the task.

As a result, there are many leaders at work and no one leader is in control. Everyone is welcome to participate in community meetings and all information is posted on the website by a local volunteer. Information is continuously shared with local community members, outside scientists, academic advisors and government agents. Collective action, communication and reflection occur simultaneously as community science, leading to a subsequent stage of action. Transformation is embedded in the iterative and reflexive knowledge-gathering process within a web of tightly knit community relationships and among social network members. The focus in Port Mouton Bay now is not just on natural science issues and monitoring in the Bay, but a series of related social aspects – brainstorming ideas for economic development, and considering ways to generate value-added in the fishery. These issues also lead to community science activities, particularly where they are embedded in a communication process that includes social learning at the community scale.

The role of community agency

The practice of community agency in this case study is also a key lesson for leveraging windows of opportunity. The collaboration between local fishers, scientists

and community members to transform their individual types of knowledge into a hybrid form of knowledge, community science, demonstrates a high level of agency underlying the community's actions. The process of sharing this knowledge both inside and outside the community across a growing social network also demonstrates that high level of agency. One lesson to be learned from this case is that community science, especially when peer reviewed and supported by other scientists, is a strong form of community agency.

Community resilience and connection to place

Berkes and Ross (2013) identify a number of characteristics of community resilience. Many of these were observed in this case study on Port Mouton Bay, and included people-place connections, shared values and beliefs, high level of skills and learning, social networks both within the community and extending outwards beyond the community, governance that includes local political engagement, and collaborative institutional processes. As illustrated in Table 3.1, these characteristics emerged in Port Mouton Bay as strategies and self-organising skills consistent with the community resilience literature that documents the importance of agency and scaling up community processes for transformative change (Westley *et al.*, 2013).

Also consistent with Berkes and Ross (2013), the co-production of knowledge (community science) and the communication of this knowledge reflect specific skills and strategies to respond to the disturbance of finfish aquaculture on local lobster habitat. The ongoing transformation in Port Mouton Bay is both an interior and exterior process of iterative reflection and action. Local community members have clearly articulated their collective values and re-affirmed their strong identity as a lobster fishing community. Community science emerges from the strong sense of connection to place which resonates with local ecological knowledge holders and scientific knowledge holders. These community members, in an iterative and cyclical transformation process, blend the two forms of knowledge in the practice of learning about their local social-ecological system and what impacts the flow of ecosystem services.

Conclusion

The events in Port Mouton Bay since 2006 mark a deliberate transformation originating from the efforts of the local people towards social-ecological resilience and better governance. These changes, which have developed and drawn upon community science and shared learning, are compatible with broader trends towards ecosystem-based management and local stewardship (Charles, 2012). The ongoing challenges and lessons learned from this case study re-affirm what the literature has already articulated about the complexity of social-ecological systems and the cross-scale linkages that can unintentionally unravel and disturb locally designed collective action agreements, resulting in cascading collective action dilemmas. In this case, the poorly designed Nova Scotia provincial aquaculture regulations permitted

a finfish farm in a location where low tidal flushing rates are unsuitable for the accumulating sources of fish waste that can potentially impact a wider and wider area of lobster habitat.

However, the lack of rigorous environmental assessment is not unique to Port Mouton Bay. Recent changes in the federal Fisheries Act and cutbacks in funding for local-level ecological monitoring have widened the knowledge gap between political decision makers and local communities experiencing the loss of ecosystem services (Hutchings and Post, 2013; Shirk *et al.*, 2012; Bonny *et al.*, 2009). The problem of the knowledge gap and governance 'fit' is a growing trend throughout Canada and North America, and perhaps elsewhere in the world. In response to this gap, community groups are mobilising to monitor threats to local ecosystem processes in an effort to reduce the decline of ecosystem services and sustain their level of human well-being (Conrad and Hilchey, 2011).

Several key factors have contributed to the ongoing transformative efforts in Port Mouton Bay since 2006, and include issues of timing, the role of many leaders, the practice of community agency, community resilience and a strong sense of place identity. In the attempt to resist the persistent unravelling that can occur when local social-ecological systems are disrupted by outside forces, a community organisation, the Friends of Port Mouton Bay, played a critical role in bridging the governance gap with community science. In this context, community science has been both a process for and product of transformation that blends local ecological knowledge with scientific methods of observation within a process of social learning. The result in Port Mouton Bay is the ongoing transformation towards a new way of learning, reflecting and taking action within the community and beyond.

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