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Building Flood Resilience In Trans-Boundary Social-Ecological Systems: Adaptive Governance In The Lake Champlain Richelieu River Basin

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The management of water bodies that cross political, cultural, and ecological boundaries entails engaging with a level of complexity that requires creative, adaptive management strategies that build resilience throughout the system and contribute to increased capacity in the face of disturbance. To characterize the extent to which such complexity can be managed, this paper explores the application of the social-ecological systems framework, developed by Elinor Ostrom and operationalized by Brian Walker and David Salt, for assessing and managing resilience. Elements of this framework will be applied to the Lake Champlain Richelieu River basin, which is a freshwater basin that exists between the United States and Canada, in Vermont, New York, and Quebec. The paper will end with considerations regarding how adaptive management and governance can be employed as tools to build resilience in this region, particularly with respect to flooding and flood resilience.

Keywords: social-ecological systems; resilience; environmental planning

Introduction

The Lake Champlain Richelieu River basin spans physical, social, ecological, economic, and political boundaries. Lake Champlain's southern edge is located in central Vermont and New York, and beyond its upper edge in Quebec, the lake drains north into the Richelieu River. Surrounding tributaries, and the towns built around them, make up the greater basin. The lake is fed from tributaries that flow from the Adirondack Mountains and Green Mountains in New York and Vermont, respectively. Governance of this region is varied in scale and capacity; each political region has distinctly organized agencies, municipalities, and structures, as well as organizations, universities, and individual actors who have a stake in the management of ecological, as well as economic and social resources. The challenge of reckoning the complex governance structure within the basin is a primary, initial hurdle of the region's capacity to build resilience.

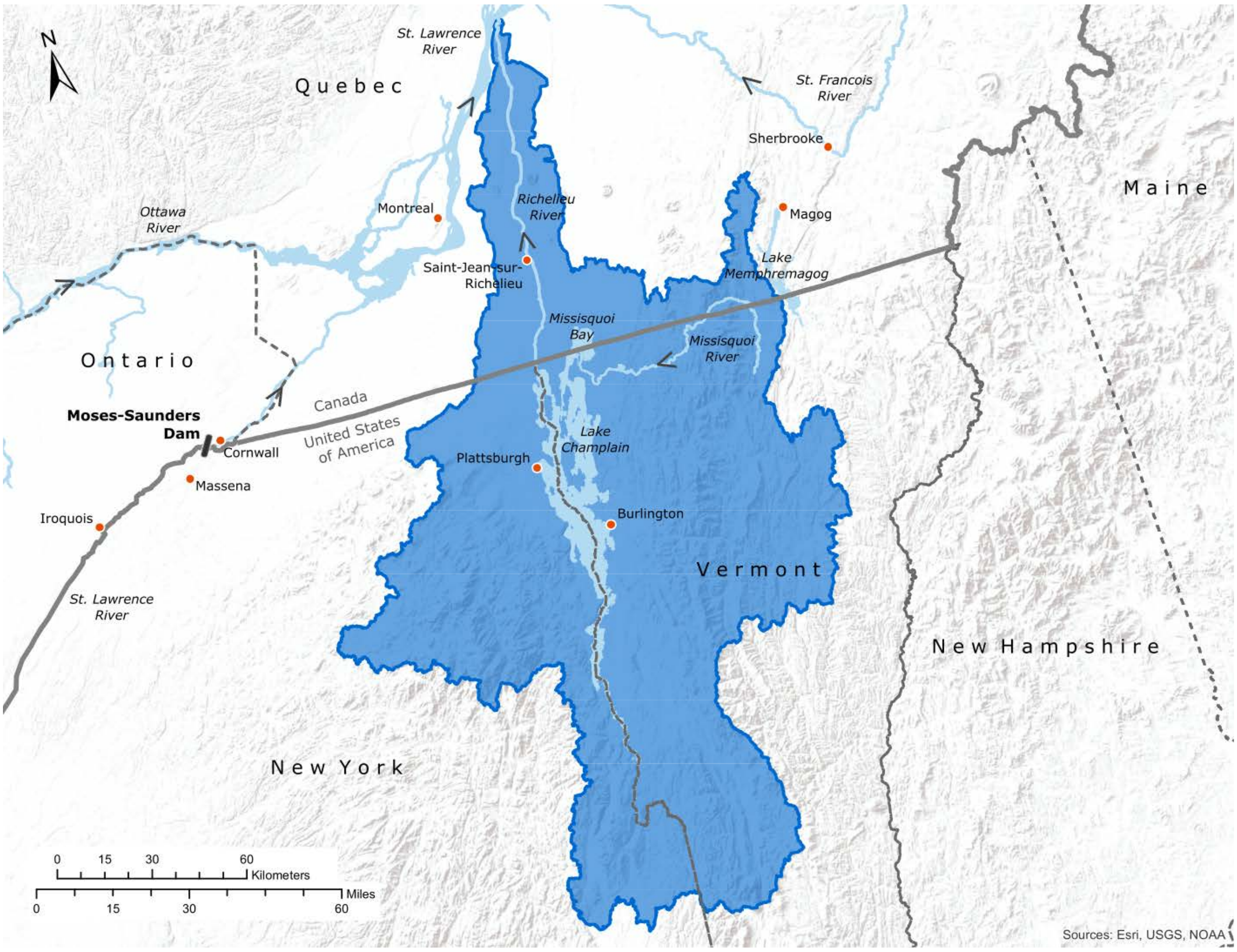

Figure 1. Map of the Lake Champlain Richelieu River Basin, retrieved from: International Joint Commission. (2018b). International Lake Champlain -Richelieu River Study Board. Retrieved from International Joint Commission website: https://www.ijc.org/en/lcrr

The social ecological-systems framework was developed by Elinor Ostrom in order to consider the interactions among resources units, resource systems, governance systems, and users within a related ecosystem. The framework, Ostrom posits, "is useful in providing a common set of potentially relevant variables and their subcomponents to use in the design of data collection instruments, the conduct of fieldwork, and the analysis of findings about the sustainability of complex social-ecological systems" (Ostrom, 2009, p. 420). Utilizing a resilience perspective to understand the dynamics of social-ecological systems is useful when considering how systems "persist through continuous development in the face of change and how to innovate and transform into new more desirable configurations" (Folke, 2006, p. 260). Cornerstones of social-ecological resilience include social learning and social memory, mental models and knowledge-system integration, visioning and scenario building (Folke, 2006).

Brian Walker and David Salt lay out the operationalization of assessing and building resilience in their books "Resilience Thinking" and "Resilience Practice."

Their framework seeks to categorize thresholds of the social-ecological system, defined as, "levels of controlling variables where feedbacks to the rest of the system change-crossing points that have the potential to alter the future of many of the systems that we depend on" (Walker & Salt, 2012b, p. 53) as well as the thresholds of potential concern, which are yet to be established levels. The resilience thinking described by these authors provides a series of assumptions essential to the analysis of social-ecological systems. They include the fact that the systems are self-organizing, and that there are limits to a system's self-organizing capacity. The systems have linked social, economic, and biophysical domains, move through adaptive cycles, and function across multiple scales (Walker & Salt, 2012). Adaptive cycles are heuristic models that pass through four phases, two of which, growth and exploitation, are considered to be fast moving, a slow-moving conservation phase, and a chaotic collapse and release phase. Panarchies are adaptive cycles operating at multiple scales, which is indicative of the complex nature of social-ecological systems (Walker et al., 2004

Walker and Salt developed a framework that assesses a social-ecological system through three lenses; specified resilience, general resilience, and transformability. The interaction of these different system capacities indicates the resilience of the system. The framework to best understand these interacting components, considered within the context of the social-ecological system of the Lake Champlain Richelieu River basin, can be found here:

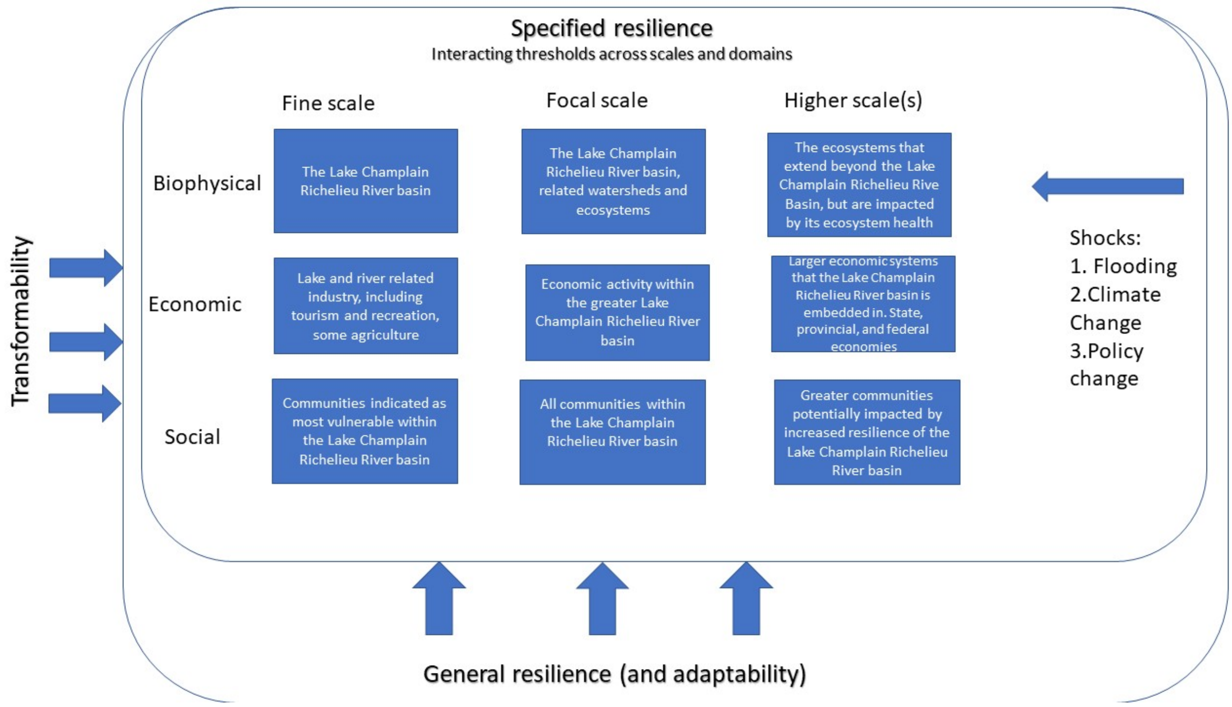

Figure 2. Specified Resilience, General Resilience, and Transformability of the Lake Champlain Richelieu River basin.

This framework will provide the basis for an analysis that explores the specified resilience, general resilience, and transformability of the Lake Champlain Richelieu River Basin as a social-ecological system, and will consider how the trans-boundary nature of the embedded political and social systems fits into this framework. Ultimately, the goal of this research is to assess the resilience of this system, propose tools for management, and consider how the framework can be adjusted to better accommodate systems with added complexity. All of these components will be considered through the lens of flood management, as flooding and fluvial erosion are the most destructive and prominent natural hazard to the region (Vermont Emergency Management, 2018).

1. Assessing Resilience

This section will categorize key components of the social and ecological thresholds that highlight the social, economic, and biophysical variables of interest when considering the resilience of the Lake Champlain Richelieu River basin.

1.1 Social Thresholds

The social system within the Lake Champlain Richelieu River basin consists of communities of varying sizes. The largest municipality within the basin is St. Jean-sur-Richelieu, which is a small city 40 km southeast of Montreal, and, as its name suggests, is along the Richelieu River. The population of the city, according to the 2011 Canadian census, was 92, 394, with a median household income of $55,412 and 40,411 private dwellings (Statistics Canada, 2018). The second largest city, Burlington, Vermont, has a population of approximately 42, 417 people according to the 2010 census, with 16,851 households and a median income of $37,078 (United States Census Bureau, 2019). Other large municipalities include Whitehall, New York, Plattsburgh, New York, and Venise-en-Quebec, Quebec in Canada. A breakdown of demographic information can be found here:

Table 1. Population of the LCRR basin

State/Province	County/Regional County/Municipality	Total Population	Density (people/square mile)
New York	Clinton County, NY	81.505	78.5
	Essex County, NY	37,587	22.6
	Franklin County, NY	15,884	14.5
	Warren County, NY	57,695	142.3
	Washington County, NY	38,145	69.4
Vermont	Addison County, VT	36,926	28.2
	Chittenden County, VT	160,510	299.1
	Franklin County, VT	48,625	76.7
	Grand Isle County, VT	6,945	84.9
	Lamoille County, VT	25,136	54.8
	Rutland County, VT	60,133	64.7
	Washington County, VT	58,963	85.8
Quebec	Brome-Missisquoi, QC	58,315	91.4
	Le Haut-Richelieu, QC	117,445	325.0
	Pierre-De Saurel, QC	51,025	221.2
	Rouville, QC	36,535	195.9
	La Vallee-du-Richelieu, QC	124,420	547.5

Note. Retrieved from: United States Census Bureau. "Population." *United States Census Bureau*, 2019, www.census.gov/topics/population.html.

Table 2. Income breakdown of US portion of LCRR basin

State	County	$9,999 & less	$10,000 -14,999	$15,000 -24,999	25,000-34,999	$35,000 -49,999	$50,000 -64,999	$65,000 -74,999	$75,000 & above
NY	Clinton	19.13	8.94	13.23	11.69	11.97	8.98	3.40	7.47
	Essex	17.21	8.72	15.64	13.57	13.57	8.91	3.87	7.86
	Franklin	19.32	9.05	14.21	12.18	14.38	10.47	3.04	7.62
	Warren	15.98	9.88	15.35	12.06	12.67	11.38	4.28	10.91
	Washington	17.54	8.63	17.09	12.29	13.24	9.12	2.98	5.76
VT	Addison	20.82	8.49	13.97	13.56	14.68	9.40	3.48	9.66
	Chittenden	19.78	7.86	12.67	11.12	13.64	10.13	4.01	14.18
	Franklin								
	Grand Isle	16.29	10.13	13.24	12.58	15.97	9.58	4.29	9.90
	Lamoille	17.09	8.31	13.04	12.72	16.08	9.98	4.54	11.91
	Rutland								
	Washington	15.55	9.78	16.23	14.43	15.36	8.07	3.17	10.31
		12.50	13.20	18.80	9.50	14.80	10.10	0.90	28.50
		13.70	4.10	17.90	12.20	12.20	15.90	2.90	16.90

Note. Retrieved from: United States Census Bureau. "Population." *United States Census Bureau*, 2019, www.census.gov/topics/population.html.

Table 3. Income breakdown of Quebec counties in LCRR basin

Regional County Municipality	Under $10,000	$10,000-19.9999	$20,000-29,000	$30,000-39,999	$40,000-49,000	$50,000-59,000	$60,000-69,000	$70,000-79,000	$80,000-89,000	$90,000-99,000	$100,000 and over
Brome-Missisquoi	11.09	18.54	16.48	14.09	11.42	0.82	5.41	3.61	2.29	1.55	4.88
Le Haut-Richelieu	10.51	17.51	15.38	13.55	11.84	0.88	6.18	4.67	2.76	1.73	3.95
Pierre-De Saurel	11.85	20.37	16.05	13.46	10.82	0.72	4.96	4.49	2.82	1.62	3.53
Rouville	9.61	16.08	15.04	14.46	13.63	0.97	6.82	4.56	2.51	1.64	3.45
La Vallee-du-Richelieu	9.35	13.18	11.46	11.25	11.44	0.95	7.63	6.55	4.68	3.15	8.52

Note. Retrieved from: Statistics Canada. "Census Program." *Statistics Canada*, 2018, www12.statcan.gc.ca/census-recensement/index-eng.cfm.

Population and income distribution are important social thresholds, since both indicate vulnerability, particularly to flooding. Regions with high population density, coupled with proximity to floodplains, can increase the potential for regime shift following disaster. Income is indicative of a vulnerability that reduces the resilience of individuals, households, and communities, and makes them more susceptible to the impacts of flooding.

Low-lying homes within the floodplains of the Richelieu River and Lake Champlain were inundated with water following spring flooding in April and May of 2011. Many homes, primarily in Quebec, were evacuated, and some were destroyed. In May, when the flood stage reached its maximal water level, the military of Canada was called in to assist in the evacuation of civilians in the town of St. Jean-sur-Richelieu. In Vermont, 500 individuals were evacuated and 500 homes were impacted by Lake Champlain and subsequent tributary floods. 124 individuals were evacuated in New York, with 929 homes affected. Quebec bore the brunt of the damage, though, with 1,651 individuals evacuated during the length of the flooding event, and 2,375 homes affected. Known thresholds within the social realm, then, are the damages brought on by the flood stage moving beyond 100 feet and affecting the low-lying homes (Federal Emergency Management Agency 2018a; Federal Emergency Management Agency 2018b).

In order to establish a list of prominent flooding events in the Lake Champlain Richelieu River basin, an analysis of disaster declarations from the Federal Emergency Management Agency (FEMA) was conducted. Disaster declarations were considered if they occurred in the New York counties: Clinton; Essex; Franklin; Warren; and Washington. In Vermont, declarations of disaster were considered if they occurred in the following counties: Addison; Chittenden; Franklin; Grand Isle; Lamoille; Rutland; and Washington.

In Vermont, FEMA disaster declaration data indicates the occurrences of 25 distinct flooding events on the Vermont side of the Lake Champlain Richelieu River basin, beginning in 1973. Each flooding event is also associated with a cause. Four events are associated with ice jams and occurred between December and January, ten events are associated with snowmelt and occur between March and June, and eleven flooding events occurred between July and September and were associated with heavy rain (Federal Emergency Management Agency, 2018b).

Across the lake in New York, FEMA disaster declaration data indicates the occurrences of 12 distinct flooding events, beginning in 1976. Two events occurred in January, six occurred between March and June (caused primarily by snowmelt), three events occurred between July and September (caused by heavy rainfall), and one event occurred in November (Federal Emergency Management Agency, 2018a).

In both Vermont and New York, there are no more than nine disasters declared in a given decade, with Vermont declaring nine disasters in the 1990s, and New York declaring five. New York and Vermont also possessed very little overlap with respect to disaster declarations, indicating disproportionate effects of snowmelt, ice jams, and heavy rainfall on opposite sides of Lake Champlain. Shared disasters include the spring and fall floods of 2011, as well as June 2013, September 1999, June 1998, January 1998, January 1996, and July/August of 1976 (Federal Emergency Management Agency, 2018).

To the north, in Quebec, Public Safety Canada's Canadian Disaster Database (CDD) has recorded 40 flood events in Quebec, occurring between 1928 and 2014. Floods of consequence that encompassed the entire Lake Champlain Richelieu River basin include both the spring and summer floods of 2011, and August of 1976. Flooding most likely also occurred during events in Vermont and New York, but was not categorized as a disaster. The Canadian Disaster Database considers an event a disaster if 10 or more people are killed, 100 or more people are affected, injured, infected, evacuated, or homeless, if there is an appeal made for national or international assistance, if it proves to be historically significant, or if there is significant damage or interruption of normal processes such that the community affected cannot recover on its own (Public Safety Canada, 2018).

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Additional thresholds of interest within the realm of social and community life in the Lake Champlain Richelieu River basin include the implications of flooding on agriculture and other economic ventures. There is little data to express the financial and social burdens of flooding, which would make these categories of potential concern. Media sources did note that the overload of nutrients from lake flooding affected the soil quality and therefore the capacity of farms to produce at a normal rate. The tourism and recreation industries in Burlington, VT and Venise-en-Quebec suffered during the floods, although the economic cost of this degradation is not well documented. The interconnected nature of the social lives of inhabitants along the Lake Champlain Richelieu River basin highlight the need for a resilience management approach that considers the widespread effects of flooding on every aspect of life in the region.

1.2 Ecological Thresholds

The Lake Champlain Richelieu River flooding event of 2011 was deemed a hundred-year flood, meaning the region had not experienced an event of a similar magnitude in recent or recorded memory. Prior to 2011, the highest recorded level that the lake had reached was 99.64 feet. On May 23rd, 2011, the maximal water level reached 103.5 feet. Typically, projections point to any floodwater beyond 100 feet as a serious risk to the low-lying communities and ecosystems (Lake Champlain Basin Program, 2019). While the flood levels had serious implications for the social system along the basin, it also had an adverse effect on a variety of ecological factors.

Phosphorous and other nutrient loading accounts for the over-fertilization and subsequent water quality issues associated with Lake Champlain.

Sources of phosphorous in the Lake Champlain Richelieu River basin include point and non-point sources, which indicate whether or not the runoff has come from a pipe. Non-point phosphorous sources in the region, which account for over 90% of the lake's phosphorous load, include agricultural land, urban and developed land, and forested land. The implications of phosphorous loading include harmful algal blooms, which can adversely affect animals and plants, and can affect the use of the lake by the fishing and recreation industries (Lake Champlain Basin Program, 2019).

The established threshold for phosphorous in Lake Champlain varies based on a variety of factors including depth and land use, but by and large the standard that phosphorous should not exceed is about 10 micrograms/liter. During the flooding events of 2011, washout caused a spike in non-point source phosphorous loading, exacerbating the negative water quality of the lake (Lake Champlain Basin Program, 2019).

Additional thresholds of interest that can indicate vulnerability include the fish stock of the lake, the effects that flooding have on biodiversity and habitat, the introduction and prevalence of invasive species, and the overall state of ecosystem health with respect to how it handles development and disturbance.

1.3 Adaptive Governance

The role that governance structures play in the establishment and retention of resilience of social-ecological systems is an imperative component of a resilience assessment. To determine the state of a governance structure's resilience first requires the acknowledgement of how "even though some similarities can be identified, societies and ecosystems are also fundamentally different in many ways" and an awareness that "the notions of resilience...may have wholly different meanings depending on how the social system was configured to begin with and from whose viewpoint the resilience is assessed" (Duit et al., 2010, p.365).

The response to this variation is a greater consideration of complexity. Ultimately, the need for new governance models to improve society's ability to handle processes of complex change are necessary, though difficult to develop and even more difficult to implement (Duit et al., 2010).

One such answer to the problem of integrating adaptive governance into social-ecological systems resilience comes from Karpouzoglou et al. (2016), who conducted a literature review on the subject of adaptive governance and capacity building. The major findings from their study indicate that there must be a "focus on governance capacity to adapt to change and self-organize," and a "collective search for solutions to societal problems." They also emphasized the need for "indigenous and scientific knowledge integration, learning by doing, and policy and management as experiments." Finally, they call for "mixed hierarchies and matching ecosystem management with the appropriate governance scale" (Karpouzoglou et al., 2016, p.5).

In an applied sense, these findings require mainstreaming a social-ecological systems perspective. Fischer et al. (2014) advise prioritizing attention paid to long-term drivers that gradually shape social-ecological systems, a commitment by governments and society at large to support the development of a stronger science-society interface, and the interactions among power relations, equity, justice, and ecosystem stewardship to be better understood (Fischer et al., 2014).

2. Managing Resilience

The ultimate objective of undertaking a resilience assessment is to yield a resilient management approach, which, bound to the development of adaptive management policy, requires an understanding of where many potential management scenarios fit within the adaptive cycle, as well as when management structures would be most useful. This section of the resilience assessment will provide a series of tools and options for management, as well as a conception of how such tools can be integrated into an adaptive management plan for the Lake Champlain Richelieu River basin. One specific consideration for addressing flooding in particular in the Lake Champlain Richelieu River basin is to make sure that any tools utilized can be shared as a resource across the state and national borders that comprise the basin, which will require increased levels of collaboration and communication on the part of practitioners, and will need to be cognizant of the diverse, multi-faceted governance that exist throughout the Lake Champlain Richelieu River basin. Literature on trans-boundary water management will be analyzed, and then contextualized within the scope of the watershed of interest.

2.1 Tools and Options for Management

At present, some of the management options being utilized to deal with flooding on the trans-boundary Lake Champlain Richelieu River basin include localized efforts to mitigate the impact of flooding, including sandbagging around neighborhoods and roads that are particularly vulnerable to damage. A current flood mitigation program is currently being developed by the International Joint Commission, a trans-boundary, bi-national water management agency, which will provide insight into management proposals, as well as a ground for criticism of where the proposal could further develop protocols for building resilience in the social-ecological system.

When considering tools and options for management that acknowledge the prevalent, known thresholds previously described, there are a variety of measures that can be taken in order to build up resilience programs: management, financial interventions, governance, and education.

Management of resources, specifically in the trans-boundary Lake Champlain Richelieu River basin, develops complications with respect to the conflicting nature of having multiple states and countries vested in a certain systematic mode of operating. In Quebec, there is a community-wide desire to mitigate flooding in order to protect riverside homes and businesses. Across the border, where flooding causes less of an immediate problem to the lakeside communities in Vermont and New York, there is a greater vested interest in maintaining the water quality, since there is a substantial tourism and recreation industry. Were any type of structural program implemented in order to control water flow into Quebec, there would likely be a water quality implication upstream in Lake Champlain.

So how is such a conflict mediated in order to develop a resilience management strategy that is satisfactory to the continued economic, social, and environmental success of all facets of the region? Mark Zeitoun and Naho Mirumachi describe the challenges associated with treaties meant to establish cooperation between entities, such as the Boundary Water Treaty that created the International Joint Commission. They write that, "International agreements are generally seen as the pinnacle of cooperation...and emphasize 'once cooperative water regimes are established through treaties, they turn out to be impressively resilient over time" (Zeitoun and Mirumachi, 2008, p.303) and acknowledge that there must be work done to "move beyond the notion of cooperation as treaties to a more dynamic view of trans-boundary water cooperation as an on-going and non-linear process in which state and non-state actors establish, challenge, modify, and legitimize multi- layered governance structures" (Zeitoun and Mirumachi, 2008, p.303).

Best management practices for the Lake Champlain Richelieu River basin, while not explicitly categorized as an area of conflict like many of the trans-boundary water systems described in the previously described article, can benefit from this shifting management paradigm. Jens Newig and Oliver Fritsch note that their analysis, "suggests that a highly polycentric governance system comprising many agencies and levels of governance yields higher environmental outputs" (Newig and Fritsch, 2009, p.197).

In the Lake Champlain Richelieu River basin, it is important to draw in the various NGOs who direct their attention towards flood mitigation, water quality, and other issues at the nexus of social-ecological issues. In Vermont, the Lake Champlain Basin Program, Lake Champlain International, and 350VT have vested interest in the maintenance of Lake Champlain's ecosystem health. In New York, the organizations that direct attention towards Adirondack State Park play a substantial role in the conservation of the area's natural resources, and in Canada, NGOs tend to direct their attention towards mitigation of natural hazards. For example, following the 2011 flooding event in Quebec, a car salesman named Michel Fecteau developed the organization SOS Richelieu, which grew out of a desire to active local social networks to aid in disaster relief. Fecteau was later elected mayor of St. Jean-sur-Richelieu, which is one of the most effected flooding locations in the Lake Champlain Richelieu River basin (Rukavina, 2017).

Along with NGOs, there must be an integration of local municipalities and governments, including planning boards, government agencies, and community groups. Additionally, there should be an integration of universities, and space for public input. In the current International Joint Commission iteration, there is substantial input from professionals from local universities and government agencies, as well as representation from larger national organizations like the United States Geological Survey and Environment Canada, but little input from groups with localized information and investment. Primarily, interaction with local stakeholders is facilitated through engagement with study membership.

There is also a challenge that has to be mediated in order to effectively manage the region in a cooperative way, which is the social disconnect between the United States and Canada.

There is a lack of understanding amongst Americans in the Lake Champlain Richelieu River basin, particularly in the more heavily populated region in Vermont, about the implications that flooding has on the Canadians along the Richelieu River. Following a media review of the flooding event in the region, results showed that there were substantial news stories on the Canadian news services regarding the health, economic impacts, and environmental degradation associated with the floods, while the American news services only briefly covered the fairly limited damage that the flooding caused in Burlington, Vermont.

A useful strategy for building the resilience of the basin is the creation of a diversified educational program that seeks to build a sense of empathy amongst the basin residents that do not experience the worst effects of flooding. There are a variety of educational strategies that could be facilitated by the governance structures in Vermont and New York that engage with building the resilience of the region to flooding, including the government departments involved, including the Department of Environmental Conservation, along with university actors involved with the project. For the immediate present, the development of story-telling educational programs for engaged citizens would provide the opportunity for the community to develop a stake in the larger wellbeing of the entire Lake Champlain Richelieu River basin.

Over a longer period of time, the integration of basin-wide, place-based education programming would be an effective tool for perpetuating the continued conversations around management of the region, and ultimately contribute to a substantially increased resilience due to raised awareness. Place-based education has the capacity to, "help students develop stronger ties to their community, enhances students' appreciation for the natural world, and creates heightened commitment to serving as active, contributing citizens" (Sobel, 2004, p.6).

Funding for these programs should be diversified and represent the widespread investment of varied stakeholders, including local and national government, local and national organizations, municipalities, and universities. Similar to how management programming is developed via a collective of scientists and professionals from the International Joint Commission, funding could be controlled through a similar avenue.

2.2 Adaptive Management

When considering a framework for implementing the strategies and tools outlined above, with the shared goal of management and resilience, adaptive management and adaptive governance, respectively, are useful tools for integrating programs. A framework for adaptive management is laid out by Byron K. Williams, in which he addresses the necessary state a system must be in to benefit from adaptive management, as well as components of an adaptive management program. To begin, the system must fulfill a set of criteria. The system must be "dynamic, changing through time in response to environmental conditions and management," there must be "environmental variation [that is] only partially predictable," and the system, "is subjected to periodic and potential management interventions that potentially vary over time." Finally, "effective management is limited by uncertainty about the nature of resource processes and the influence of management on them" (Williams, 2011, p.1348). This accurately describes the Lake Champlain Richelieu River system.

From there, the framework calls for two phases, both of which involve the critical process of learning in order to further develop the system's capacity to adapt to changes, which will be significant in the coming years, when climate change increased unpredictable patterns of ecosystem function, weather, development, and more.

To effectively implement an adaptive management program, Williams notes that there must be a commitment to learning from the past and moving towards change. He explains how, in a management program that seeks to be adaptive, "little attention is given to the institutional barriers to its implementation, and little effort is expended on redesigning organizational structures and processes to accommodate an adaptive style of management" (Williams, 2011, p.1352). There would need to be, at the very least, an acknowledgement by project leadership that there needs to be a commitment to often reconsidering the actors involved in the program, and any potential new programs that could be integrated that would represent new perspectives. This is exemplified by the resilience-focused management of the trans-boundary Columbia River Basin. The Columbia

River Treaty was created in 1964 to allow for the co-management of the Columbia River's dams. The treaty's stakeholders have maintained dedication to integrated changing values and uses, as well as new concerns like climate change into the management of the basin, which was made evident by the Columbia River Symposium of 2009, when all such concerns were addressed (International Joint Commission, 2018).

Another form of this type of programming is adaptive governance, which acknowledges that, "a society's ability to manage resilience resides in actors, social networks, and institutions" (Lebel et al., 2006, p.6). Some of the recommendations laid out in Lebel et al. (2006) include participation and deliberation, polycentric and multi-layered institutions, and accountable and just authorities. In essence, the management programming is secondary to the ability to the individuals and groups in charge of managing the system in question to be adaptable, progressive, and understanding of what is required to maintain a cohesive understanding of the social-ecological system (Lebel et al., 2006).

Going forward, there are a variety of tools that contextualize the thresholds within the scope of adaptive management planning. A framework that would be best suited to implementing programming that is grounded in resilience thinking while also addressing thresholds of concern is proposed by Ryan Plummer and Derek Armitage, who developed a resilience-based framework for evaluating adaptive co-management. Their framework notes that adaptive co-management requires consistent evaluation of performance and outcomes, as well as foundations for multi-site comparisons. This, paired with understanding of the processes, livelihoods, and ecological systems, and the way that those components are embedded, contribute to social-ecological resilience and sustainability.

Ultimately, the framework calls for the following means of evaluation of an adaptive co-management schematic. First, they call for the identification of ultimate parameters of concern. In their case, enhanced livelihoods and ecological sustainability, and in the case of the Lake Champlain Richelieu River basin, perhaps the added component of cross-border interactions and public engagement would also be included. Next, first order, second order, and third order parameters are established. This allows for prioritization of programming, with considerations of what is tangible and intangible. The use of a tool like this would mediate issues of trans-boundary disconnect and challenges related to differing values, since the achievement of overcoming those issues could be integrated into the framework (Plummer and Armitage, 2007)

3. Governance and Resilience in the LCRR Basin

In Lebel et al. (2006), their central question is, "how do certain attributes of governance function in society to enhance the capacity to manage resilience?" (Lebel et al., 2006). They define governance as, "the structures and processes by which societies share power, shapes individual and collective action...it includes laws, regulations, discursive debates, negotiation, mediation, conflict, resolution, elections...and other decision-making processes" (Lebel et al., 2006, p.4). Alternatively, Brondizio et al. (2009) writes that governance systems are, "construed as a form of social capital that communities establish and rely on to guide human-environment interactions in a variety of settings" (Brondizio et al., 2009).

When considering how governance systems can contribute to the development of resilience, there are certain attributes that are considered to be particularly impactful to the management of resilience. Lebel et al. (2006) highlight public participation, polycentric institutions, and accountability as major components of managing resilience. Public participation, specifically through the lens of deliberation, lends to the alignment of priorities between citizens and scientists, experts, and decision-makers (Lebel et al., 2006). Polycentric institutions also play an important role in the maintenance of resilience. They are described as, "arrangements that are nested, quasiautonomous decision-making unites operating at multiple scales…spanning from local to higher organizational levels, polycentric institutions provide a balance between decentralized and centralized control" (Olsson et al., 2006, p.2). Finally, accountability lends to the maintenance of resilience through mechanisms such as, "transparency, independent monitoring, polycentricity, separation of powers, legal resources" and have social justice as a goal (Lebel et al., 2006).

Garmestani and Benson explore some other means of achieving and monitoring resilience, with specific attention paid to panarchy as a tool for characterizing the "cross scale dynamics of social-ecological systems and a framework for how governance institutions should behave to be compatible with the ecosystems they manage" (Garmestani and Benson, 2013, p.1). Through their framework for resilience-based governance, Garmestani and Benson explore panarchy's role in adaptive governance, noting that the panarchy model can be used to, "reconceptualize social-ecological systems in a manner that has the capacity to better match governance to the environment" (Garmestani and Benson, 2013, p.6).

While the tools laid out as frameworks for integrating governance and resilience are often made through theoretical frameworks and conceptualizations, there are issues with the translation of these ideas into practice. Olsson et al. (2015) note that there are types of resilience: bounce back, bounce back and transform, and that each type has a descriptive and prescriptive capacity. They also critique how resilience theory "suggests that 'critical changes in social-ecological systems are determined by a small set of three to five key variables'" and that a better means of creating strong foundations for resilience are to "search for integrative theories that combine disciplinary strengths while filling disciplinary gaps" (Olsson et al., 2015, p.8).

4. Discussion and Conclusions

Beyond the traditional aspects of assessing resilience, there is further information that can be gathered from exploring the more intricately developed social networks and phenomenon that exist within the Lake Champlain Richelieu River basin. For instance, there is value to quantifying the relationships that exist within communities, and whether or not those ties can be utilized to build resilience. Additionally, the idea of activating social memory, or restoring it, can be useful in galvanizing support for issues related to hazard mitigation and increased resilience. For instance, in the case of the 2011 flooding of the Lake Champlain Richelieu River basin, the experience varied across borders; Quebecois experienced weeks of devastating floods, ruined homes, monetary loss, and implications for mental and physical health. To the South, while flooding affected communities along the lake, there was substantially less damage. Tropical Storm Irene's impact just four months after the spring floods is far more prominent in the memories of Vermonters and New Yorkers. So, how is such an event standardized to a non-traditional community, as with the Lake Champlain Richelieu River basin? Further research is required to explore perceptions of flooding and vulnerability across the basin, which has the potential to yield public education campaigns, programming, and ultimately a widened perspective. Additionally, this region represents a potential frontier for research into integrated, adaptive management of trans-boundary social-ecological systems and their subsequent resilience.

The exercise of attempting to understanding the nuances of complex social-ecological systems on a community scale comes to a head at the Lake Champlain Richelieu River basin. In this space, there is a dispute that has the privilege of cooperation on multiple governance scales as well as support through the International Joint Commission to explore how to utilize governance and community structures to better understand and build on current knowledge and perceptions. In many ways, the work currently being done to enhance the resilience, particularly to flooding, of the Lake Champlain Richelieu River basin can provide insight into how to utilize public input to develop the solutions, and how to active a sense of community around natural rather than social and political boundaries. This initial investigation into assessing and managing resilience is only the first look into how creative, dynamic frameworks can be applied to this region to ultimately develop its capacity to adapt and exist in a sustainable way.

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