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# Action research to improve water quality in Canada's Rideau Canal: how do local groups reshape environmental governance?

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**ABSTRACT**

The historic Rideau Canal, spanning 200 km between the Canadian cities of Ottawa and Kingston, is a world heritage site and recreational waterway. The waterway presents a governance challenge, with multiple jurisdictions and agencies responsible for its management, making it difficult to establish a common vision to address environmental issues. Local stakeholders are concerned about toxic algal blooms in the downstream section of the Canal (the Lower Cataraqui region) because these blooms limit use of the system and pose a potential threat to human and environmental health. In the absence of a strategy to effectively manage water quality, a grassroots group called the Three Lakes Water Quality Group (TLG), has brought various stakeholders together to initiate transdisciplinary discussions and find solutions. This article presents findings from action research with the TLG. Specifically, it examines (1) the activities and concerns of the TLG in the governance arena, (2) the views of local stakeholders on social-ecological issues, (3) the potential of using collaborative systems thinking to capitalise on the TLG's activities. Our analysis is informed by interviews and a workshop. We recommend that the TLG mobilise collaborative systems thinking when meeting with other stakeholders to discuss raising awareness, enforcing policy and producing knowledge about water quality issues in the region. These findings have implications for the entire Rideau Canal and other historic waterways by revealing the potential of local residents to initiate dialogue and drive future co-governance efforts.

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## Introduction

This article examines the case of declining water quality in the southern reach of the Rideau Canal (RC) and the role of grassroots initiatives in reshaping governance, defined as "the means for achieving direction, control, and coordination of individuals and organisations with varying degrees of autonomy to advance joint objectives" (Imperial 2005, 282), in response to this problem. The RC is a National Historic Site and UNESCO World Heritage Site that spans 202 km across urban and rural land and waterscapes between Ottawa and Kingston (Canada). It is a complex system with a

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diversity of uses and stakeholders. The Lower Cataraqui (LC) region of the RC (Figure 1) has historically been susceptible to eutrophication, in part due to land-use changes linked to early colonisation and canal construction in the mid-1800s (Sonnenburg, Boyce, and Reinhardt 2009). In recent years, concerns about climate change and water management in Canada (Bakker and Cook 2011) and in the Lower Cataraqui region have compounded these problems, but there is limited ongoing research about social-ecological linkages that deteriorate water quality. In response, concerned residents from Cranberry Lake, Dog Lake and Colonel By Lake formed a group called the Three Lakes Water Quality Group (TLG) to address threats to water quality. This article examines the group's activities and presents findings from action research activities conducted in partnership with the TLG. Through systems thinking and qualitative research methods, we analyse perceptions and relationships among stakeholders with the goal of enhancing co-governance and facilitating collaborations. Co-governance, akin to multi-level governance, involves linking individuals and organisations within and across scales of governance (Schröter et al. 2014).

## *The case*

Large waterways are notoriously difficult to govern, due to hydrological properties, as well as ecological and socio-political complexity of connected land and waterscapes (Kim, Keane, and

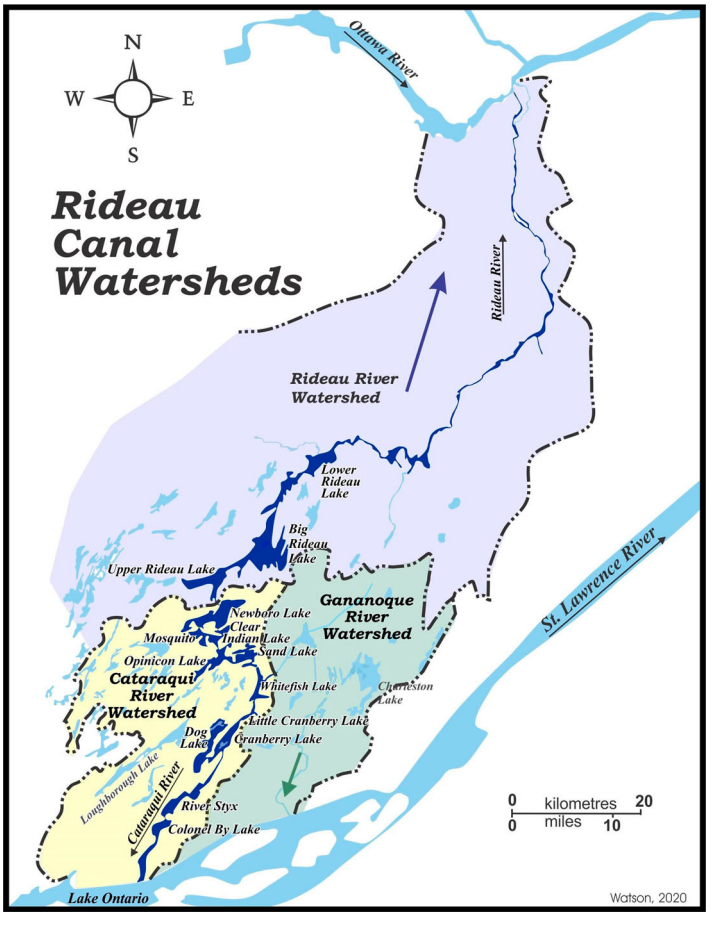


**Figure 1.** A map of the RC showing, in yellow, the Cataraqui Region watershed. Residents of the TLG are based in Cranberry Lake, Dog Lake and Colonel By Lake. Image credit to Ken W. Watson, used with permission.

Bernard 2015; Nguyen et al. 2016). Large waterways often cross jurisdictions, both horizontally (across various actors from the same level of social organisation e.g. municipalities linked by a waterway) and vertically (across levels of social organisations e.g. levels of government) (Young 2002; Armitage et al. 2009). Historic waterways, such as the RC, present unique challenges (see Lin et al. 2020).

While the Canal itself is managed by the federal government (primarily by Parks Canada), water quality is a provincial responsibility, meaning the Government of Ontario is a key stakeholder. There are also 13 municipalities and two Conservation Authorities that govern land use and development. A number of Indigenous communities in the region have direct consultative relationships with Parks Canada. In addition, other actors including property owners, visitors, local businesses, academics, lake and cottage associations, environmental and heritage groups, and recreational user groups have a stake in the RC. Specific stakeholder concerns, such as local water quality issues and algal blooms, can be difficult to address in fragmented contexts, especially when there are limited mechanisms for bottom-up communication (Bakker and Cook 2011; Cook 2014; Berardo, Turner, and Rice 2019).

This article analyses findings from action research undertaken in partnership with the TLG as it tries to influence water quality governance in the lower region of the RC in the context of jurisdictional fragmentation. The TLG was created in the Fall of 2018 in response to the observed increasing frequency of algal blooms in the lakes. The group emerged in part because Cranberry and Colonel By lakes do not have lake associations, which represent the voices of local residents. The Dog Lake Association has a Water Quality Committee that has taken action to assess and monitor the state of water quality. This lake association has an organised structure, resources, and contacts with provincial health units, and the Ontario Ministry of Environment, Conservation and Parks. These resources have helped the TLG gain knowledge about the state of nutrients in the water and communicate it to the community.

The TLG is beginning to transform the environmental governance regime as they have initiated collaborations with Cataraqui Conservation (CC), the local Conservation Authority[1], and local scientists. However, the TLG also wants other stakeholders like farmers and Parks Canada to be involved. Their partnership with the CC is allowing this group to expand their network.

## *Action research: understanding and facilitating in research collaborations*

Action research in the social sciences involves activities that seek to simultaneously understand social phenomena, promote change led by the actors involved and facilitate specific outcomes based on these new understandings (Gloster 2000; Brydon-Miller, Greenwood, and Maguire 2003; Burns 2007; Elliott 2011; Klein 2012; Hall et al. 2013; Rauch et al. 2014; Bradbury 2015; Chevalier and Buckles 2019). In this case, we seek to understand how members of the TLG perceive the issue of water quality, as well as the governance system that they must navigate to exert influence. We also seek to facilitate their influence within the governance system through our collaborative research activities (described below). Given the social and ecological complexities of the water quality problem, our research is guided by the socio-ecological systems (SES) approach to integrated human and biophysical systems (Olsson et al. 2007). We are also guided by the adaptive co-management framework (ACM) that examines and promotes dynamic social learning, linking, and knowledge pluralism as important means for improving social-ecological governance (e.g. Armitage et al. 2007; Young 2020). Action research aligns with both these frameworks as (1) it implies collaborative work to position the actors who are being investigated at the centre of research activities (Daniel 2011), and (2) it is mobilised in research about environmental challenges (Blythe, Grabill, and Riley 2008; Wittmayer and Schäpke 2014; Reason and Canney 2015; Campos et al. 2016; Egmose 2016; Kušová and Těšitel 2017; London et al. 2018) and can foster change in SESs (Gloster 2000; Rogers et al. 2013).

According to the SES and ACM frameworks, the cross-jurisdictional fragmentation evident in the RC can be a significant obstacle to effective management, especially when communication and coordination amongst stakeholders, scientists and managers is lacking (Bakker and Cook 2011; Cook 2014; Berardo, Turner, and Rice 2019; Mancilla García, Hileman, and Bodin 2019). As we discuss later, this has certainly been the case for participants in the TLG, who are often confused about which agency has authority over a given issue or problem, and to whom they should direct requests and advocacy. Another significant obstacle is the nature of the water quality problem itself and how various actors perceive the problem taking shape over time (Saikkonen 2013). A number of knowledge gaps about the causes of eutrophication and algal blooms has led to finger-pointing amongst stakeholders. It is also unclear what role scientific knowledge and local knowledge can play in resolving this problem – uncertainties that are compounded by hierarchical governance structures.

To begin addressing these gaps and obstacles, we designed a series of action research activities to examine the perspectives of the TLG members on water quality in the LC, and to identify opportunities for the TLG to participate in governance, thus promoting adaptive co-management or co-governance processes and outcomes. These research activities described in the next section included interviews and a workshop based on systems thinking, which challenges actors to think about their role in dynamic systems (Boog 2003; Burns 2007; Ison 2008; Burns, Harvey, and Ortiz Aragón 2012; Lichtenstein 2015; Midgley 2015). The common objectives of these activities, however, have been to provide the TLG with an empirical assessment of the range of views on water quality and governance among members in its own group and the local community. We also provide recommendations to improve governance and water quality in the LC by including these views.

## Materials and methods

### *Approach to action research*

Action research initiatives often begin with a story. Ours begins with the launch of a four-year interdisciplinary research project on the environmental integrity and governance of two major waterways in Ontario, Canada, entitled: *Science to support management of Parks Canada's historic Rideau and Trent-Severn waterways to maintain and enhance ecosystem services* (Steven J. Cooke, PI) funded by the Natural Sciences and Engineering Research Council of Canada. This research initiative involves biologists, ecologists, engineers, and social scientists from multiple Canadian universities, working in partnership with scientists and managers at Parks Canada and other allies. In the initial stages of this research, the social science team had a series of preliminary exchanges with Manuel Stevens, a resident of Cranberry Lake and co-author of this paper. We began to attend community and NGO meetings in the region, including a science meeting co-hosted by the TLG and CC. After this initial meeting, we worked with the TLG, Holly Evans, Coordinator of Watershed Planning at CC, and Jyoti Kotecha, Associate Director for Research & Business Development at the Beaty Water Research Centre (Queen's University), to plan a workshop addressing water quality concerns. We also attended Lake Links 2019[2], a workshop at which we presented our research with Manuel. Part of our action research approach was to include local partners in further discussions, including authorship of this paper, to ensure recommendations reflect local needs. Our research activities received ethics approval from the University of Ottawa's Office of Research Ethics and Integrity.

### *Workshop using Collaborative Conceptual Modelling*

The initial discussions between the social science team and the TLG brought to light local concerns about water quality and lack of government responses to the problem, as well as uncertainties about the causes of recent changes. As a first step, the researchers and partners convened a workshop to conduct a knowledge mapping exercise based on Collaborative Conceptual Modelling (CCM). The aim of CCM is to articulate, extend and blend mental models of various participants to help

determine potential courses of action (Newell and Proust 2012). CCM aligns with the use of systems thinking (König and Ravetz 2018) in action research (Burns 2007), and with structured decision-making, which is a way of identifying key variables and mapping their relationships to inform environmental management (Gregory et al. 2012).

The CCM framework involves multiple activities designed to elicit the views of individuals, while working towards a collaborative understanding of complex phenomena and opportunities for action (called "leverage points") (Newell and Proust 2012). The activities are organised around "steps" that are based on questions posed to the participants (see Figure 2). The steps are meant to be iterative, with the last step feeding back into the first. However, we limited our workshop to three hours to respect participants' time and only completed some of the activities. We followed the first three steps of identifying influencing factors that positively or negatively impact water quality, developing a timeline and mapping causal relationships in pairs. Then we completed step five which was developing a list of leverage points based on the first three activities. Steps four (What drives system behaviour?) and six (What futures can we see?) were omitted.

The workshop was held on June 18th, 2019 at the Battersea United Church, located in Battersea (Ontario, Canada) in the lower region of the Cataraqui watershed. With support from CC, the Beaty Water Research Centre, and the TLG, the research team invited participants based on their knowledge of local water quality and the region in general. The workshop was facilitated by two of the authors (Mistry and Beaudoin). The ten participants[3] who attended the workshop represented various stakeholder groups including: provincial and municipal government, academic scientists, a resident from the TLG, the Conservation Authority, a real estate agent, the owner of a campground and farmers. Before the workshop, participants received discussion questions, the agenda, a PDF of the workshop presentation, and a request to bring a dated study, event or information piece that has impacted water quality in the LC region.

The overarching question that guided the workshop was: *What can be done to maintain or improve water quality in the Rideau Canal?* Materials for the workshop included flipchart paper, blank paper, markers, tape, pens, sticky notes and media equipment for the PowerPoint presentation (projector and laptop).

For the first step, we asked participants to individually list the top five measurable factors they thought positively or negatively influence water quality in the LC region. Participants were encouraged to consider environmental, social, economic, cultural and political factors. The lists were posted on the wall for sharing. Next, participants collectively created a historical timeline of events impacting water quality. Each participant shared dated information, studies and events which were posted on the timeline. The timeline was set from 2000 to the present (mid-2019), but participants were encouraged to think beyond these temporal boundaries.

For the third step, we provided instructions on drawing causal maps and annotating relationships among measurable factors as positively or negatively correlated. First, each participant drew an

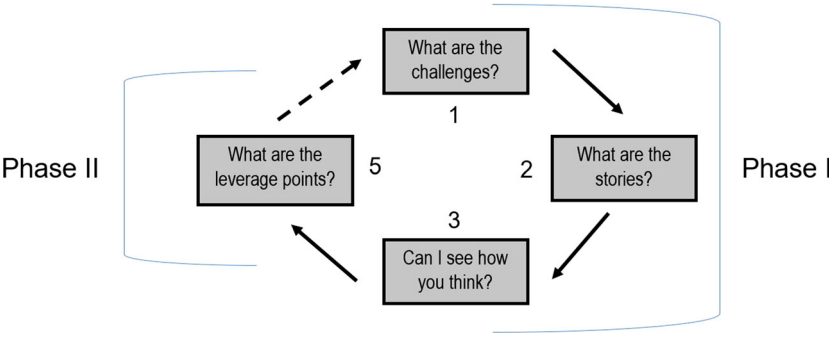


**Figure 2.** Collaborative Conceptual Modelling steps adapted from König and Ravetz (2018, 101).

individual map detailing their perspective of the relationships between factors impacting water quality. They were encouraged to consider the timeline and listing exercise. Next, participants were divided into pairs by the facilitators and combined their maps with their partner, generating a new map. Stakeholders from the same group or background were intentionally kept apart when creating pairs. We ended the workshop with an open roundtable discussion about leverage points.

Post-workshop data analysis included thematic coding to standardise the list of factors generated by each participant in the first activity to establish a frequency count. We also coded and aggregated the historical factors that participants provided in the timeline exercise. We synthesised the discussion around leverage points and grouped potential strategies by domain of action. The maps drawn by each pair of participants were recorded as adjacency matrices using MS Excel. We also thematically coded the collaborative maps and created a merged aggregate map representing the overall knowledge and causal logic of the group. The aggregated map was translated into a weighted, asymmetric matrix representing the frequency of relationships across maps. This matrix was imported in RStudio, an integrated development environment for the programming language R (R Core Team 2017). The packages "sna" (Butts 2019), "igraph" (Csardi and Nepusz 2006) and "FCMapper" (Turney and Bachhofer 2016) were used to create network graphs (see the Supplementary Material for code) and generate structural measures (e.g. density and centrality). These indices were used to describe the structure of relations in the aggregated map (Özesmi and Özesmi 2004; Papageorgiou and Kontogianni 2012; Stakias, Psoras, and Glykas 2013; Gray, Zanre, and Gray 2014; Giordano et al. 2017).

### *Interviews*

Following the workshop, we invited participants as well as other key stakeholders from the region for individual, semi-structured interviews lasting approximately 60–90 min. These interviews included questions on perceptions of environmental health of the RC (including water quality), as well as views on governance, collaboration and knowledge gaps. Between May 2019 and March 2020 we interviewed six participants from the LC region: three workshop participants, two members of the TLG, and one representative from CC. Interviews were conducted in person (five) and on the phone (one) by two authors of this paper (Mistry and Beaudoin). Please see the Supplementary Material for the interview questions. Data analysis included coding each interview transcript using a three-step inductive approach: (1) identifying codes, (2) grouping codes into master themes, and (3) assigning relevant quotations to master themes for later analysis (Thomas 2006).

## Results

### *Workshop results*

We begin with some general observations from the workshop. Overall, the fact that we brought different stakeholders together was seen as a strength, though the absence of Parks Canada (PC) was noted; they were invited but did not attend. Paul[4], a farmer and township councillor remarked, "the higher up the chain you go, the more difficult it is in order to convince somebody that, okay, I need to spend a half a day and go to something like this". This participant mentioned that PC may not have any staff working in the LC region with enough authority to represent the agency. Authorities that were represented at the workshop included the province, the township of South Frontenac and CC. The absence of Indigenous community representation, with whom we were unable to connect despite various attempts, was also noticed.

Participants thought the workshop could inform policy- and decision-making if the right people are in attendance and if the outcomes are presented in a rational manner. Some hoped that this type of activity (Figure 3) could occur again, especially if it is used in governance processes. However, one

participant thought there could have been a more concrete plan of action as an outcome of the workshop. Some participants were concerned about the lack of contact from other participants and hosts post-workshop and commented that a follow-up would be beneficial.

### *Activity 1: factors of influence*

Table 1 shows the eight categories of factors influencing water quality that were most frequently cited by participants in the individual listing activity. Nutrient and chemical inputs to the lakes was the most frequently cited factor (13). Participants sometimes listed multiple dimensions of a factor which we recorded as separate counts.

### *Activity 2: timeline*

The second activity involved collectively building a timeline of key events. Participants provided 21 events with approximate dates and four factors that had continuous impacts. These factors are development, the introduction of carp fish, increasing suckers and dog fish populations (although they are native, some participants were concerned with their increasing presence), water level fluctuations, and poor water flow overall. The lakes in the LC region were created in the 1830s through flooding for canal construction. According to participants, this significantly impacts the current state of lake water quality. The newer, shallow lakes warm up more quickly than deeper lakes in the summer, and now for longer periods throughout the year because of climate change. Additionally, these lakes have historically shown excess nutrients which participants believe makes them prone to eutrophication and algal blooms. Increased human activity in the past 20 years, such as intensified fishing and boating, are also seen as contributing to poor water quality. Figure 4 shows select items from the collective timeline, see the Supplementary Material file for the full list.

### *Activity 3: collaborative mapping*

The third workshop activity involved grouping participants in pairs and asking them to combine their individual maps into a collaborative map. The research team then combined these into an


**Figure 3.** An example of results from the water quality workshop.

**Table 1.** Most frequently cited factors by participants as influencing water quality in the LC region.

| Count | Eight most frequent factors cited by participants that influence the water quality in the LC region |
|---|---|
| 13 | Nutrient (loading, internal nutrients, septic systems, fertilisers, agricultural runoff) and chemical (mercury, pesticides, garbage) input, and its impact on pH levels |
| 9 | Development (canal construction affecting wetlands, cottage development, altering watershed drainage, buffer zones, human impact) |
| 8 | Water flow (upstream sources, fluctuating levels, flushing, shallow bodies, flooding) |
| 5 | Education (education, stakeholder awareness, increased popularity and interest, engaging programmes) |
| 5 | Governance (grassroots initiatives, political will, lack of response to reduce plastics and other contaminants, poor restriction of shoreline development by municipalities, water level regulations) |
| 5 | Ecology (biodiversity, invasive species, remediation and moving towards a "normal" ecology) |
| 4 | Climate change (extreme weather and weather swings, changes in atmospheres and plant growth, hot summers) |
| 4 | Tourism and recreation (Boating activity and traffic, speeding, sport fishing, overindulgence in tourism) |

aggregated map containing 47 factors (see Supplementary Material for a list of factors and their centrality measures). Unless otherwise stated, measures were generated with the R package "sna" (Butts 2019). Table 2 provides key measures from the aggregate map. The finding of low network density means that participants did not identify many direct connections among the factors. Centralisation scores refer to the extent to which a network is focused around specific central nodes.

Measures from fuzzy cognitive mapping (generated with the package "FCMapper", Turney and Bachhofer 2016) help us understand connections among the factors. The majority of factors are ordinary, meaning that they influence, and are influenced by, other factors. There are fourteen strong components in the final map, however, the largest component has 34 factors while the other 13 components have one factor each. This means that most factors strongly relate to each other while 13 (see Supplementary Material for component membership) are less connected to the rest of the network. We see this in the network map (Figure 5a) that has a dense cluster of interconnected factors in the middle and less connected factors on the outskirts.

Betweenness centrality of individual nodes (see Supplementary Material) can be used to identify bridges, which connect factors that may not otherwise be related to each other (Butts 2019). Boating, water level, nutrients, shoreline development and tourism are bridging factors in the system, as

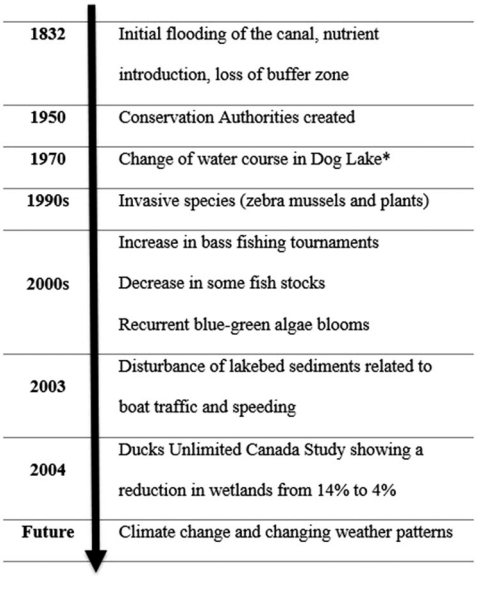


**Figure 4.** Selected items from the collective timeline. *Dog Lake over the years has become more stagnant due to a loss of flushing and poor water flow, changing its water course.

**Table 2.** Network measures for the merged map.

| Size | # of links | Network density | In degree centralisation | Out degree centralisation |
|---|---|---|---|---|
| 47 | 247 | 0.11 | 0.51 | 0.51 |
| Betweenness centralisation | # of transmitter factors | # of receiver factors | # of ordinary factors | # of strong components |
| 0.28 | 3 | 3 | 41 | 14 |

indicated by a betweenness centrality score of more than 100. The most central factors in the system are water quality, nutrients, boating, sediments, agriculture, shoreline development, atmosphere, water level, education and policy, as indicated by in and out degree centrality scores of 10 or more (see Supplementary Material).

Figure 5b shows that water quality was often cited to be directly influenced by shoreline development, water levels, human activity, boating, hydrology, nutrients and invasive species. Climate change strongly impacts water quality, and to a lesser extent invasive species and water levels, while it is itself strongly influenced by education. Education strongly influences chemicals, boating, agriculture, tourism, invasive species and fishing. To a lesser degree, it influences water levels, shoreline development, property value, policy, nutrients, hydrology and human activity. The only factors influencing education are political will and tourism. Education connects policy and climate change, as well as boating and invasive species. Tourism is a bridge in the network, connecting cottages, communities, algae and biodiversity to education, policy, boating and water quality. Boating also bridges property value and erosion to water quality. It is influenced by many factors like fishing, education, tourism, human activity, agriculture, shoreline development, lakes, hydrology and chemicals. Boating also influences depth, erosion, flushing, hydrology, water levels, nutrients and sediments. Water levels is another bridge that is often seen in a bidirectional relationship with water quality and agriculture and is influenced by climate change, education, nutrients and sediments. Nutrients is another bridge node with many factors influencing it, most notably chemicals and erosion. Shoreline development is central and has a direct, bidirectional relation with water quality. Erosion was frequently seen as influencing nutrients and water quality. It is influenced by

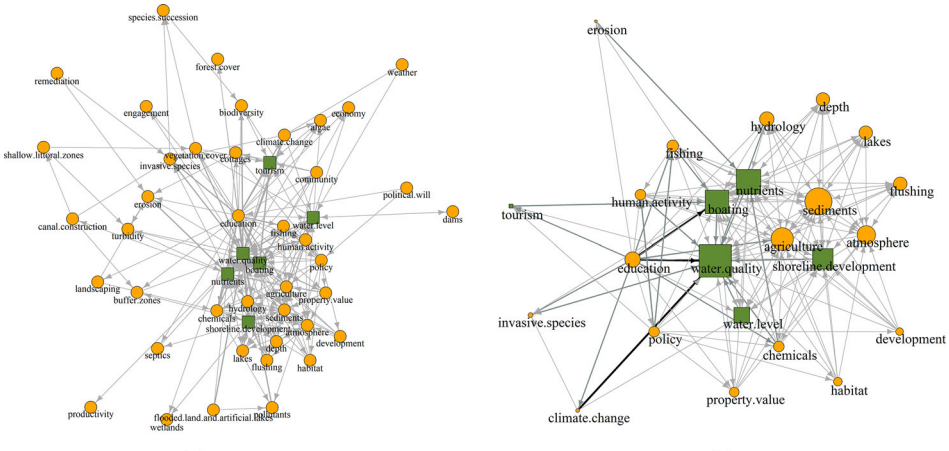


**Figure 5.** (a) Full graph: map of 47 factors influencing water quality in the LC region. The thickness of lines represents the frequency at which relationships were cited across the different pairs. Green squares have the highest scores of betweenness centrality. Graph generated in R with the "iGraph" package (Csardi and Nepusz 2006). (b) Central nodes graph: simplified map with 24 most central factors (in and out degree centrality scores above 5.0). Higher degree centrality is represented by larger node size. Thicker and darker edges indicate higher frequency at which relationships between factors were quoted by participants.

chemicals, development, education, fishing, human activity, lakes, property value, sediments and water levels.

Beyond these bridges, we see that policy influences boating practices and human practices which influence, and are influenced by, water quality. Both human activity and policy influence erosion. Nutrients, lakes, sediments, hydrology, flushing and depth are related in various capacities. Agriculture and development (including shoreline development) relate to water levels and water quality. Water levels are influenced by climate change and education. There is a bidirectional relationship between water levels and water quality, nutrients, agriculture, sediments and shoreline development.

### *Activity 4: leverage points*

The workshop ended with a discussion around possible actions to enhance water quality in the LC regions. Participants identified 21 leverage points during this discussion. Some emphasised the need to take a watershed approach and engage small communities. Setting reasonable targets to favour feasible expectations was also discussed. Additionally, gaining a better understanding of water quality by considering different knowledges could lead to solutions. Researchers could also focus on identifying the cause of seasonally early blue–green algae blooms, conducting a nutrient budget in the lakes, investigating the effects of climate change, and understanding differences in water quality over time and across the lakes.

Other concrete actions proposed include pushing cottages and septic systems further back from the lakes and revegetating the shoreline. Education, outreach, programming and raising awareness were discussed at length. These could take many forms, such as developing compelling stories to communicate with the public and gain support, conducting experiential education on the water, encouraging residents to take action and volunteer, and developing education programmes for farmers and residents using existing resources (e.g. the *Ontario Environmental Farm Plan* and the *Lake Links Lake Protection Workbook*). Finally, participants discussed the need for adaptive management practices and for municipalities to support preservation of the shoreline by creating new bylaws.

## *Interview results*

The results from interviews with six individuals familiar with the LC region covered themes of water quality and governance.

### *Water quality*

The overall environmental health of the canal was rated a median of 6.5 out of ten. Specifically, water quality in the region was perceived as poor by participants because of (1) eutrophication related to nutrient loading, (2) shoreline development leading to erosion and more septic systems, (3) climate change which leads to warmer water and changes in precipitation and water levels, and (4) human practices such as damming which increase stagnancy. As seen in Figure 6, these factors among others ranked relatively high as threats to the environmental health of the RC.

Given the history of lakes in the LC, which interact with new pressures like climate change, there are "algal blooms that we didn't used to see" according to Paul. Larger housing developments from an influx of permanent residents has led to increased human activity and changes in physical features, which are seen as degrading water quality. Algal blooms negatively impact property values, which Shannon from the Dog Lake Association and the TLG sees as "a good impetus to get people concerned". Some participants thought their neighbours do not realise the impacts of their behaviours on water quality. There are perceived differences in internal and external nutrient loading between the constructed and natural lakes.

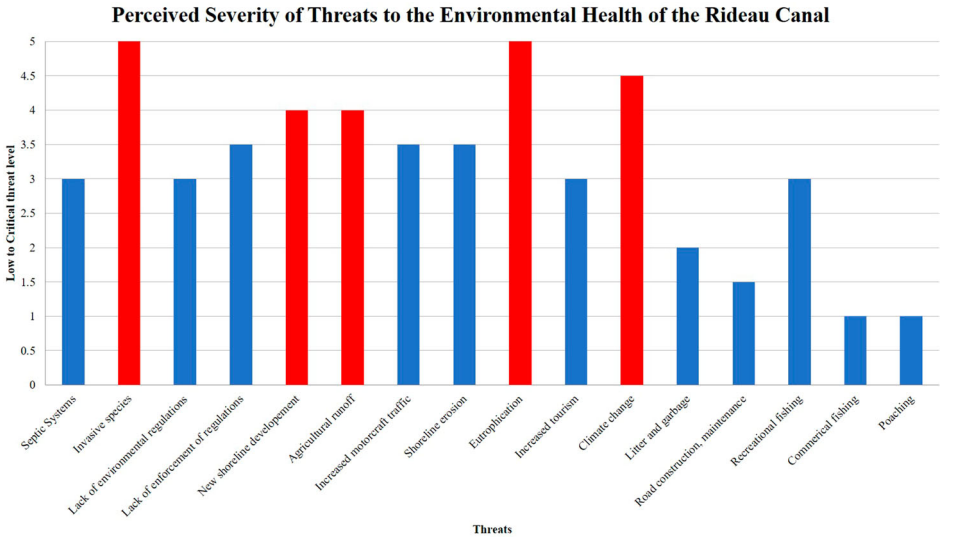


**Figure 6.** Perceived median severity of threats to the environmental health of the RC with red bars showing the most severe threats.

## *Governance*

Participants were asked to evaluate the performance of the current governance regime ("How would you rate the performance of the current governance regime in achieving the following goals?"), with results provided in Figure 7. The current regime was seen as very good in promoting tourism, protecting historical heritage, facilitating economic development, and managing water levels. The areas of very poor performance included controlling invasive species, maintaining water quality, enforcing environmental regulations, planning for the future and reconciliation with Indigenous groups in the region.

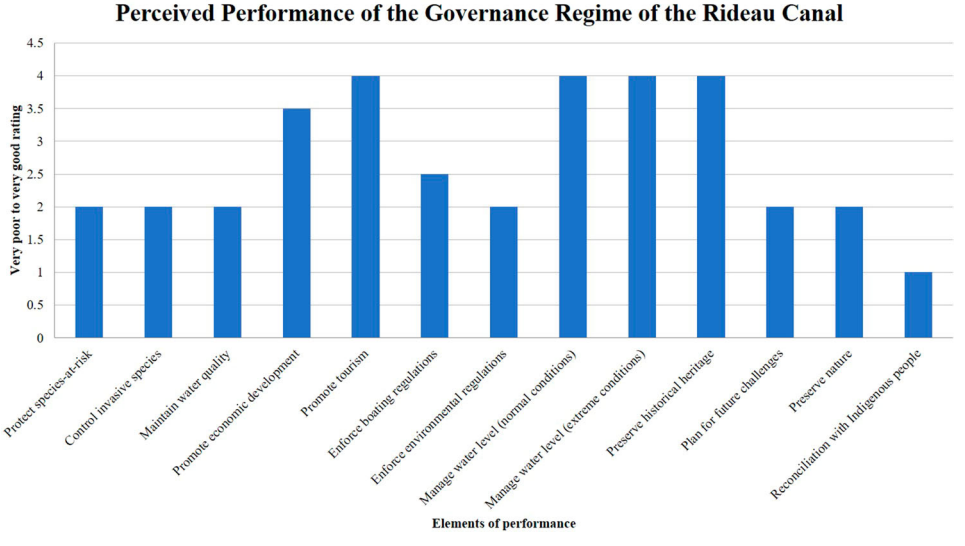


**Figure 7.** Perceived median performance of the governance regime of the RC.

Participants were also asked to discuss the overall effectiveness of governance. Here, we heard a range of views. Some viewed the governance structure as effective in fulfilling current mandates but think it could improve. Some talked about the need to improve relations and communications between government agencies and communities. We also heard about inconsistencies in the effectiveness of different levels of government that relate to a lack of coordination. Some participants questioned the ability of authorities to address environmental concerns. Generally, participants wanted more focus on the environment in the governance of the RC.

A number of participants who had experience working with or for municipal and federal governments think the governance regime is ineffective due to fragmented yet overlapping jurisdictions, as well as a lack of capacity to enforce existing regulations. The multiple levels of government render the regime ineffective since "there's nothing that's coordinated between federal, provincial and municipal" (Paul) governments. Participants viewed the Conservation Authority as the most effective agency within the governance regime, and the federal government as the least effective. Daniel, a graduate student at Queen's University, thinks climate change exacerbates poor water quality management. He does not "think there's enough initiatives to preserve the water quality". Sean also noted that PC is "very much focused towards fun, enjoyment and recreation". There is a focus on permitting and regulations among PC, CC and municipalities, but with limited scope.

Although townships and municipalities were said to be more communicative and engaged with stakeholders than other authorities, municipal involvement is inconsistent along the entire canal. The provincial government's concerns with water quality relate strictly to human health and, despite their presence at some TLG meetings, many participants felt they were not very engaged. Overall, participants identified gaps in environmental regulation, coordination of mandated responsibilities and regular communication with different departments and stakeholders. People related these gaps to a lack of funding, capacity, working relationships and political will.

Participants see the federal and municipal governments as good partners in collaborations related to education and awareness, though the province is engaged in local water sampling efforts. Interviewees appreciated existing programmes and partnerships, however, they believe that the community should be more involved in informing decisions. They see a lack of governmental action so "it's going to have to come from the citizens, … saying that we need some sort of governance structure or to address issues which affect the whole canal" (Sean). There is interest in valuing local knowledge, and residents want to play a bigger role in the monitoring and reporting about the state of their lakes. Although the community is engaged in programmes such as Lake Partners and shoreline naturalisation programmes, the communication of results and visible outcomes is lacking. Additionally, these programmes may not engage new residents arriving from urban settings. The TLG members would like to see transparent communications and meaningful actions from the provincial and federal governments.

All participants wanted democratic processes and decision-making that includes a variety of perspectives and knowledges to inform decision-makers. Suggestions offered by participants to tackle water quality issues stemming from governance include conducting CCM workshops more frequently with different people, hosting annual meetings or conferences, or creating an independent body dedicated to the RC. They want to see PC take leadership and greater interest in environmental issues, even if water quality is not officially the remit of PC.

## Discussion

We engaged in action research with the TLG to investigate local understandings of water quality and perspectives on governance, and to provide recommendations for how this knowledge can be mobilised to improve environmental conditions and governance processes. Overall, our research revealed convergence in views on both natural and social systems. In this section, we look at (1) the activities and concerns of the TLG, (2) converging perspectives about water quality and (3) potential points of intervention. We include recommendations for the TLG and the field of co-governance.

### *Activities and concerns of the TLG*

Overall, participants thought the environment of the Lower Cataraqui region was moderately healthy, but water quality was identified as an area of concern that could be improved. Shared concerns around algal blooms motivated residents to create the TLG as a vehicle for collaborative action, demonstrating the potential for community groups to shape governance at a local scale. The TLG advocates for more scientific research on water quality, but also recognises the value of local knowledge (Maclean 2015). There is also cooperation within the TLG for information sharing and organisational support.

Two common governance challenges shaped the socio-politico-ecological conditions that led to the emergence of the TLG. First, the lack of capacity and restricted mandates at the federal and provincial level (Carbonetti, Pomeroy, and Richards 2014) led to gaps in effective management, leaving resident concerns unaddressed. Second, the misalignments between ecological and socio-political systems (Mancilla García, Hileman, and Bodin 2019; Sayles and Baggio 2017) provided an opportunity for residents to self-organise and bridge the gaps. Frustrated by jurisdictional fragmentation, but also overlapping responsibilities, residents became a collective to voice their concerns. In this context, the TLG took it upon themselves to co-host science meetings with CC which "was fabulous because you get to know faces … and I think that's the way to go. That's the way we're going to get things done" (Shannon).

Collaborative management and governance are relational matters (Young 2020). While the complexity of the current governance regime can leave residents feeling powerless, it also offers an array of potential partners at multiple levels: local, municipal, watershed, provincial and federal. Grassroots efforts can thus navigate jurisdictional fragmentation by identifying the most accessible and interested authority to partner with to influence higher-level decision-making. Collaboration in this case has been mostly horizontal, occurring across groups at the regional level such as between the TLG, Dog Lake Association and CC (Young 2002; Armitage et al. 2009; Young 2020). However, vertical linkages that facilitate flows of communication from local users to higher-level authorities are also needed to grant decision-makers access to local knowledge and address the challenges brought on by jurisdictional fragmentation (Berardo, Turner, and Rice 2019). Overall, vertical and horizontal partnerships within community contexts help build social capital where it is weak, helping create opportunities for change (Warner 2001; Berardo, Turner, and Rice 2019). Thus, the TLG's emergence shows that when top down approaches are insufficient and ineffective in addressing local environmental concerns (Bakker and Cook 2011; Cook 2014; Berardo, Turner, and Rice 2019), residents emerge as local leaders that create relationships with other local and regional groups.

Furthermore, this action research project expanded our capacity as researchers to participate in multiple activities and develop meaningful relationships with members of the community. According to Burns (2007), action research takes time as it is a multi-stranded inquiry process where various "strands" (i.e. activities) interact and converge to reveal opportunities such as a partnership with the TLG. Framing this project as action research allowed us to mobilise knowledges and empowered actors to participate in environmental governance rather than being mere research subjects (Hall et al. 2013).

Beyond collaboration, we must be aware of power asymmetries relating to who participates in governance and in grassroots initiatives that influence governance. Three of the members of the TLG were over 65 years old, had graduate degrees, and were employed as professionals prior to retiring (professor, Parks Canada planner, nurse). They lived on the lakes in primary residences and seasonal cottages, which is a costly endeavour that not everyone can afford. These demographics align with what the authors observed working with other lake associations in Ontario and Quebec, but also with those reported in the literature (see Ibrahim et al. 2017). Therefore, the opportunity to start a grassroots initiative may not be as accessible as the TLG case makes it out to be. People must have the time, resources and knowledge to organise and create partnerships. Although this

is a common limitation of collaborative governance (Young 2020), these demographics suggest there is an aging population that can invest time and resources in local efforts, which can guide future initiatives (Burns 2007), perhaps involving youth. However, inclusivity is important to develop systemic understandings using diverse perspectives (Burns 2007). More specifically, we recognise that Indigenous communities have an interest in the region but that their voices are missing.

Regarding the structure of the TLG and their relationships, we recommend that they develop stronger vertical links with higher-level authorities. To increase the TLG's capacity to influence governance, these linkages should enable bottom-up flow of information and include feedback mechanisms (Berardo, Turner, and Rice 2019). This could be difficult given the limited resources, restricted mandates and lack of staff holding leadership roles in the LC region at PC and the province. Beyond local partnerships, results from this action research project could be used by the TLG and CC as evidence in specific policy- and decision-making processes related to water quality. We also encourage the TLG to pursue a diversity of local partnerships that include youth, early career conservation researchers (see Jeanson et al. 2020), and Indigenous voices.

### *Converging perspectives about water quality*

Efforts to improve water quality must consider social-ecological linkages as the interconnectedness of social and ecological factors influences the presence of algal blooms. There is a need to pay "more of a holistic attention […] to environmental issues" (Sean). Poor water quality in the LC region relates to various human activities, such as the historical flooding of swamps and uplands to create lakes during canal construction, development and boating, land-use management, and the lack of planning for climate change. The guided activities in our workshop helped inform a systemic and shared understanding of water quality concerns that can be used for action, and improved public understanding of systems thinking (Hall et al. 2013).

The story about water quality in this region is that shallow water levels and excess nutrient inputs from erosion, shoreline development, agriculture and boating exacerbate the recurrent algal blooms seen since the 2000s. Education could focus on naturalised shorelines as ways to improve water quality, which would increase property values. CC could also focus their education programmes on different sources of nutrients as there are diverging perspectives about which factors contribute to severe algal blooms. This uncertainty indicates a need to investigate the proportion of nutrients originating from different sources to set evidence-based policies and regulations. Although differing views have caused some tensions between groups, such conflicts have the potential to guide collaborations towards common goals (Medema, Wals, and Adamowski 2014; Mancilla García, Hileman, and Bodin 2019). Community groups, governmental authorities and researchers need to disseminate "knowledge out in a way that's not threatening but is informative" (Emilie of the TLG and Dog Lake Association).

Although integrating a diversity of knowledge in decision-making processes is not a panacea and has costs (Gray et al. 2012), the convergences of participants' perspectives reveals indirect interconnections among social and ecological components. For example, the relationship between algae and water quality is not direct but is mediated by climate change, water levels, education, tourism and the economy. This and other structural relationships demonstrate the complexity of this SES and the need for a multi-pronged approach. For example, education influences water quality directly, but also indirectly by influencing levels of chemicals and nutrients, which loop back to water quality. Overall, this view of stakeholders' perceptions of water quality in the LC helps us identify points of intervention in the system.

We recommend that the TLG follow-up with other workshop attendees to build trust and meaningful relationships that will facilitate environmental co-governance. They should use the maps to identify central factors that represent converging views (in this case, agreement that education, boating practices, shoreline development and nutrients are key factors that influence water

quality) to facilitate future research. To guide change in the system, groups across reaches must work together. Systems level thinking is particularly salient in waterways where what happens in adjacent reaches has a strong influence on a given reach (Nguyen et al. 2016). In other words, failure to work across the system will mean that local initiatives may be unable to achieve the results they desire (e.g. if water quality is being driven by upstream forces). We also recommend that future conversation include stakeholders beyond the LC region to scale up their influence and improve systemic understandings of water quality issues.

### *Identifying points of intervention*

The collaborative systems thinking workshop was useful for participants to learn from and connect with others that share their concerns. The causal mapping activity presented an opportunity to network and create a sense of ownership and empowerment, especially when identifying leverage points (McKenna and Main 2013; Rauch et al. 2014). This workshop mobilised existing knowledges to create potential pathways towards improving water quality.

Three areas of action were identified from the workshop discussion on points of intervention: determining the sources of nutrient loading, investigating temporal and spatial differences in environmental health, and sharing stories or creating an educational narrative to engage property owners and politicians. This action research project allowed us to identify potential steps that are tailored to the local context. Work in the three areas of action should come together to influence policies and regulations.

Our data show that the Conservation Authority is an effective actor in implementing education programmes and raising awareness given their emphasis on stewardship through direct interactions with stakeholders. The map reveals that water quality could improve if residents and visitors are educated about the use of chemicals and nutrients on their properties, the protection of wildlife habitat and forest cover, limiting the spread of invasive species, best practices for boating and fishing, and shoreline development regulations. As such, non-compliance of environmental regulations could be improved through, for example, voluntary education programmes for new homeowners and landowners that emphasise the benefits of shoreline vegetation.

From the map we can see there is a need to balance tourism, shoreline development and economic development with environmental protection to prevent further deterioration of water quality. For instance, even if PC is not responsible for water quality, they are responsible for water level management which impacts water quality and ecosystems (Bakker and Hilt 2016; Gownaris et al. 2018). Government agencies should be mindful of their impact and could use causal mapping to identify mitigation strategies (e.g. balance navigation needs and water quality). The aggregated map reveals actionable leverage points authorities can use to design policies and programmes, such as effectively communicating with property owners concerned about poor water quality impacting their property values.

The collaborative workshop made it evident that a nutrient budget study is necessary to understand and improve water quality. The Beaty Water Research Centre, with whom we organised the workshop, is writing a grant application for a nutrient budget. The TLG is also moving forward by educating property owners with support from Dog Lake Association and CC. Researchers are working to fill the knowledge gaps about the water quality in the LC region and the RC. The frustration of concerned residents has incited action research through many "strands" (Burns 2007) such as collaboration, local action and academic research.

Community residents have developed trust with their partners through this collaboration, which is important for water management because it enables them to act collectively and reach broader audiences (Kim, Keane, and Bernard 2015). These relationships can be capitalised to effectively tackle more difficult issues, like reaching unengaged residents (Carr and Heyman 2012). CC and the TLG have created a small network, which is a key feature of successful co-governance according to the ACM literature (Imperial 2005; Olsson et al. 2007; Lundmark, Matti, and Sandström 2014).

However, the TLG must expand this network by building relationships with more influential actors to cultivate change.

Remaining barriers to regulatory and policy change include the lack of system-wide considerations from governments and lack of attention from uninterested stakeholders. The lack of capacity and funds also makes it difficult for governments to justify certain actions. However, this case highlights many opportunities to compensate for such gaps. Self-organising groups such as the TLG can gather expertise and direct government representatives and politicians to areas that require attention. Through this route, residents can help create a vision for the region that reflects their realities and values, which is a characteristic of co-governance (Davidson and de Loë 2016). Montgomery et al. (2016) note that while some stakeholders provide stability and capacity, change needs to be initiated by the public. Therefore, resident action should not substitute government inaction, but rather incite government involvement to co-produce programmes with locals (Montgomery et al. 2016). Involving municipal governments early could trigger the involvement of the province and PC. Providing specific actions, such as concrete leverage points, and presenting them to authorities whose mandates align with those actions could facilitate coordination with these authorities.

Building on the central factors of the map, we recommend that the TLG consider the three areas of action that emerged from the workshop discussion. We also recommend that the group work with governmental actors in a second CCM workshop to address a refined research question based on the results of previous activities to find clarity in the solutions required (Burns 2007). This would complete the iterative aspect of the CCM approach (Newell and Proust 2012).

## Conclusion

The governance of the RC needs to shift toward being more systemic and inclusive for water quality to improve in the LC region. We recommend that the TLG mobilise collaborative systems thinking when meeting with other stakeholders to effectively address water quality issues in the region. We would like to acknowledge the efforts of the TLG and their leadership which has demonstrated the potential for action research to contribute to flexible ACM processes, helping to shape the trajectory of co-governance in the region and the entire RC.

Our findings and recommendations have implications for the field of co-governance. We recommend a regional approach to compensate for gaps in governance. This aligns with research showing that watershed level management is the most effective at protecting water resources (Sayles and Baggio 2017; Berardo, Turner, and Rice 2019). Residents should identify effective actors, such as Conservation Authorities, that are well-positioned to become network coordinators, engage stakeholders and host CCM workshops. Higher level authorities should seek to work with regional networks to lower transactional costs through access to local and scientific knowledge. They should support bottom-up initiatives and create channels of communication.

This case study reveals how action research can amplify existing local efforts to address gaps in complex governance regimes by enabling community members to participate in democratic, evidence-based processes. It also shows the need for flexibility in ACM processes where outputs from multiple co-existing informal activities can be used as reliable sources of local knowledge to inform decisions. In an era of participatory governance, this research contributes to the evolution of environmental co-governance.

## Notes

1. In Ontario, Conservation Authorities "are community-based watershed management agencies, whose mandate is to undertake watershed-based programs to protect people and property from flooding, and other natural hazards, and to conserve natural resources for economic, social and environmental benefits." (Conservation Ontario n.d.)
2. https://watersheds.ca/lake-links/.
3. Evans and Stevens were participants, and Kotecha was an observer.

4. Every participant in the workshop consented to having their names and occupations appear in publications. Nevertheless, we assign pseudonyms to participants while accurately reporting their occupation or group membership.

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## Data availability statement

Data available within its supplementary materials found here: doi:10.6084/m9.figshare.c.5123894.

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