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Research

Assessing social-ecological fit of flood planning governance

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ABSTRACT. Social-ecological fit demands that governance systems align with and function at the appropriate scales of social and ecological processes being governed. While multilevel social-ecological network analysis has been applied to assess fit in various contexts, it has not yet been applied to understand transboundary flood planning. We investigate the social-ecological fit of collaborative flood planning efforts in the St. John River Basin, located in New Brunswick and Quebec in Canada and Maine in the United States, focusing on two social-ecological fit challenges: shared management of ecological resources and management of interconnected resources. Our results displayed organizations have a tendency to collaborate with others located in the same sub-sub-basin and not with those working in different sub-sub-basins, indicating limited social-ecological fit of the collaboration network to flooding at the basin scale. Qualitative analysis identified collaboration provided increased knowledge and technical resources to engage in flood planning, but it was hindered by a lack of financial resources, time constraints, and a lack of shared commitment. Collaborative relationships among organizations working in different sub-sub-basins are essential for cohesive flood planning at the basin level, and in this case, there is potential for an increase in collaboration among ecological neighbors to govern for ecological connectivity.

Key Words: *collaborative governance; ERGM; flood planning; social-ecological fit; social-ecological network*

INTRODUCTION

Social-ecological systems (SES) research emphasizes the need for institutions to align with social, as well as ecological, processes and also take into account varying spatial and temporal levels (Young 2002, Folke 2007, Galaz et al. 2008, Ostrom 2010, Lebel et al. 2013). Failure of institutions to match the processes and levels of an SES may result in degradation of ecosystem services (Ekstrom and Young 2009), ineffective decision-making (Fischer and Ingold 2020), and/or unintended outcomes (Scheffer et al. 2001, Galaz et al. 2008). Consequently, the extent of congruence is conceived as the problem of fit, also referred to as institutional or social-ecological fit (Guerrero et al. 2015).

Fit has been variously conceptualized, described, and measured. In an early conception set out by the International Human Dimensions Program of Global Environmental Change in 1998, fit refers to the effectiveness of social institutions as a product of a fit with the social and biophysical landscape in which they operate (Folke et al. 1998, 2007). Interdependencies between ecosystems and institutions as connected complex adaptive systems elaborated fit to include patterns and interactions across spatial and temporal levels (Folke et al. 2007). The topic of fit has been approached with focuses on institutions (Ostrom 1990, Ekstrom and Young 2009, Lebel et al. 2013), policy outcomes (Meek 2013), collaborative governance (Bergsten et al. 2014, Guerrero et al. 2015, Sayles and Baggio 2017, Becker 2020), and collaboration structures (Bodin and Tengö 2012, Bodin et al. 2014, 2016). Epstein et al. (2015) present three generalized categories of fit between institutions and their contexts: ecological, social, and social-ecological (SE). Social-ecological fit, the focus of this study, refers to the degree to which institutions align with the SES under consideration by using indicators of sustainability; ultimately, seeking to arrive at specific institutional arrangements (Folke et al. 2007, Olsson et al. 2007, Epstein et al. 2015).

Social-ecological fit (hereafter "SE Fit") is highly contextual (Lebel et al. 2013, Epstein et al. 2015) and needs to be considered in relation to a defined SES (Bodin 2017). We, therefore, focus on the fit of a particular governance arrangement in relation to a distinct temporal and biophysical system. Specifically, we investigate the SE fit of collaborative governance to address flooding in the St. John River Basin, Canada.

Collaborative governance arrangements have the potential to enhance social-ecological fit (Bodin 2017). Collaboration can connect otherwise fragmented levels of government and non-governmental organizations to create cohesive action to match the geography of the environmental problem (Guerrero et al. 2015, Sayles and Baggio 2017, Hohbein et al. 2021). Collaboration among sectors can facilitate involving all necessary parties to tackle interconnected issues (Bergsten et al. 2019, Fried et al. 2022). However, collaboration patterns among involved actors may not fit the collective action problem and/or the underlying environmental issue (Bodin 2017, Bergsten et al. 2019). Problems of fit can undermine effective governance in various contexts (Bergsten et al. 2014, Guerrero et al. 2015, Sayles and Baggio 2017), including flood governance (Lebel et al. 2013, Becker 2020).

Flooding provides one example of an increasingly critical problem in current SES (Cornwall 2021, Davenport et al. 2021). Recent estimates place 1.47 billion people within direct exposure to flooding events (Rentschler and Salhab 2020), and climate change is forecasted to increase impacts of severe flooding in many regions (Tabari 2020, Hosseinzadehtalaei et al. 2021, Mohanty and Simonovic 2021). As flood governance requires responsiveness at both the basin and sub-catchment levels (Niemczynowicz 1999, Savenije and Van der Zaag 2008), it is well positioned to benefit from collaborative forms of governance (Fournier et al. 2016, Cumiskey et al. 2019, Becker 2021, Clegg et al. 2021). Collaborative approaches can connect a variety of

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sectors and stakeholders operating in different regions and at different administrative levels (Dieperink et al. 2018, Bottazzi et al. 2019). However, a reliance on collaboration to appropriately match the problem at multiple levels creates a potential problem of fit.

We are particularly interested in functional fit: the alignment of governance arrangement with the ecological and social-ecological processes and relationships in the system (Ekstrom and Young 2009, Epstein et al. 2015). The composition of the involved actors, along with their capabilities and priorities, can impact overall governance function and outcomes (Bodin and Crona 2009, Fliervoet et al. 2016, Baudoin and Gittins 2021). For example, Guerrin et al. (2014) assessed functional fit of an institution created to address flooding along the Rhône River, *Plan Rhône,* which largely failed to meet the outset floodplain restoration targets. Guerrin et al. (2014) identified immense oversight on behalf of the state in both understanding the interests of industry and local actors and designing effective implementation measures. As Guerrin et al. (2014) illuminated, governance outcomes can be impacted by the interests and willing participation of involved actors. Consequently, there is a need to substantially investigate how organizational attributes may impact operational abilities and subsequently functional fit (Alexander et al. 2017, Guerrero et al. 2021).

In building upon the growing body of SE fit scholarship (e.g., Guerrero et al. 2015, Bodin et al. 2016, Sayles and Baggio 2017), we examine functional fit in relation to the critical issue of flooding in the St. John River watershed. Specifically, we analyze SE fit through a multilevel network analysis and illuminate how collaboration contributes to functional fit or misfit. Focus is directed to the particular SE fit challenges of shared resource management and management of interconnected resources.

COLLABORATION IN FLOOD GOVERNANCE

Effective governance arrangements are essential to cope with uncertainties and emerging issues in a changing climate (Fischer and Ingold 2020). Concerted attention is being given to collaborative governance to meet this need, and collaborative governance has been applied in the context of water resources (Berardo et al. 2019, Sullivan et al. 2019, Hardy 2022), disaster response (McGuire and Silvia 2010, Nohrstedt 2018, Bodin et al. 2019), and climate change adaptation (Baird et al. 2016, Hamilton and Lubell 2018, Feist et al. 2020). Collaborative governance provides a mechanism to address complex social-ecological systems problems by involving diverse stakeholders, recognizing multiple sources and types of knowledge, facilitating social learning, and accounting for multilevel system dynamics (Ostrom 1990, Armitage et al. 2009, van Tol Smit et al. 2015).

Emerging flood governance literature emphasizes a need for more integrative and adaptive forms of governance with connections across multiple scales and sectors (Alexander et al. 2016, Bottazzi et al. 2019, Meng et al. 2019, Tran et al. 2020, Winter and Karvonen 2022). With the increasing importance of non-structural measures to address flooding, collaborative governance provides a means to understand and incorporate varying actors' interests and possible contributions (Meng et al. 2019, Blázquez et al. 2021). Driessen et al. (2018), describing the six main governance strategies that emerged from the European STAR-FLOOD project, also highlight the need for connectivity among multiple administrative levels. Collaboration can contribute to scale-matching by enhancing connections among the traditional government hierarchy and building relationships among the local governments and organizations within the basin (Thaler et al. 2017). Matczak and Hegger (2021), in a review of flood risk governance literature, identified the need for further empirical assessment of flood risk governance strategies, emphasizing the importance of conducting analysis within a SES perspective.

Flood governance faces inherent challenges as it often crosses multiple financial and strategic interests (Bottazzi et al. 2019). A review of research into peri-urban flooding found similar governance challenges in multiple cases, for example, difficulties with coordination among departments and actors, lack of resources, and having only technical plans (Winter and Karvonen 2022). Governance of transboundary watersheds face particular issues of coordination or cooperation challenges among an array of actors over a large geographic area with possible power imbalances (Armitage et al. 2015, Plummer et al. 2016), and collaboration is impacted by jurisdictional levels, institutional arrangements, major political boundaries, and natural river dynamics (Widmer et al. 2019).

METHODS

Study region

The St. John River is a 673 km transboundary river that originates in Québec, Canada, and Maine, United States, and flows through New Brunswick into the Bay of Fundy (Kidd et al. 2011). The watershed lies within the unsurrendered and unceded traditional lands of the Wolastoqiyik (Maliseet) people, who since time immemorial have referred to this river as the Wolastoq, the "good and bountiful river" (St. John River Society 2008). The watershed, covering over 55,000 km^2 in total, is distributed 51% in New Brunswick, 36% in Maine, and 13% in Québec (Kidd et al. 2011). The river forms part of the international boundary for the two nations and is steeped in cultural and historical significance (Kidd et al. 2011, Currie et al. 2020), such that in 2013, the river was designated as a Canadian Heritage River (Plummer et al. 2016).

The St. John River historically experiences two types of flooding: ice-jam flooding and open water flooding (St. John River Society 2008). While both flooding patterns have traditionally occurred and been manageable, there are notable instances of catastrophic floods in the region (i.e., 2008, 2014, 2018, 2019) causing damages estimated at or over 10 million dollars (Woodhall-Melnik and Grogan 2019). Record-breaking floods result in evacuation notices (Government of New Brunswick 2018) and a significant number of homes flooded (Insurance Bureau of Canada 2019, Woodhall-Melnik and Grogan 2019). As climate change has and is forecasted to alter precipitation patterns and increase extreme weather events broadly across Canada (Government of Canada 2019), climate change may exacerbate impacts of flooding on the landscape and local populations (CCA 2019). In recent years, flooding disasters have caused the greatest rise in natural disaster damages in Canada (CCA 2019). With the impacts of climate change already being experienced in New Brunswick (Department of Environment and Local Government 2018), an increased focus on improved flood planning as a component of broader climate change adaptation is highly warranted.

Social-ecological network analysis

There is an emerging use of social-ecological network (hereafter "SEN") analysis for empirical assessments of SE fit (e.g., Bodin et al. 2014, Alexander et al. 2017, Wang et al. 2019, Barnes et al. 2019). A SEN perspective allows for the identification of interdependencies between social actors, which facilitates an analysis of the characteristics of any present collaborative governance arrangements (Bodin and Tengö 2012). SE fit has been assessed through a multilevel network approach, where both the collaborative governance arrangement and ecological system are described as separate but interconnected networks comprised of nodes and connections between them (Bodin and Tengö 2012, Guerrero et al. 2015). The connectivity of these networks can be analyzed to identify specific patterns among and between the social and ecological nodes that can be attributed to the enhancement or hindering of fit (Bodin and Tengö 2012, Bodin et al. 2016).

Data collection and network construction

Establishing network boundaries

In this study, organizations were chosen as the node level (Fliervoet et al. 2016, Baird et al. 2016), and network boundaries were established through a nominalist approach with the assistance of key informants knowledgeable in collaborative flood planning efforts in the basin (Berardo et al. 2020). Key informants are individuals in social positions that provide specialist knowledge of particular value to the researcher beyond that which could be provided by ordinary individuals (Payne and Payne 2011). Network boundaries were set as including all organizations that are involved in some capacity in flood planning the St. John River Basin. This included multiple levels of government (federal, provincial, regional, and municipal) with jurisdictions in the basin and Indigenous self-government, as well as non-governmental actors, such as watershed organizations, research, and industry (Baird et al. 2016). An initial list of organizations was provided by the key informant at WWF-Canada and was supplemented by web-based research by the student researcher. Three key informant interviews were conducted to verify this list of organizations involved in collaborative flood planning in the St. John River Basin in Spring 2020. As such, a combination of a position-based approach and a relation-based approach was used to identify relevant social nodes in the social network (Scott et al. 2015). In total, 136 organizations were identified throughout New Brunswick, Québec, and Maine. Organizations included various levels of government, Indigenous self-government, non-governmental organizations, watershed organizations, research, and industry. A contact list of individuals within the identified organizations was compiled based on community partners' past work and contextual knowledge of the basin, as well as web-based research by the student researcher. This research sought to identify high-position individuals within the organization with potential knowledge about their organization's flood planning activities. Multiple individuals were identified from large organizations (Fliervoet et al. 2016). The ecological network was restricted to the St. John River Basin.

Network gathering

To address our first objective, we constructed a SEN using data collected from a sociometric survey conducted in August and September 2020. The social-ecological network is composed of three layers: the social, the ecological, and the social-ecological layer.

Layer 1: Actors' collaboration

The questionnaire was developed to collect descriptive information, network data, and qualitative data on impacts and barriers to collaboration. A questionnaire was distributed with an introductory letter via email to the identified individuals and was active from August 18th to September 30th, 2020. The questionnaire was available in both English and French to account for the bilingual nature of those living and working in the river basin. The initial invitation was followed by two reminder emails from the student researcher. After the second reminder email, the key informant from WWF-Canada followed up with contacts, by either phone or email, for which he had direct contact information.

Participants, responding on behalf of their respective organizations, were asked to identify through recognition which organizations they communicate and collaborate with for flood planning (Baird et al. 2016). With the substantial number of possible collaborating organizations, recognition provided a better method than recall to collect a complete network (Marsden 1990). Respondents were asked to select the organizations they collaborate with when making flood planning decisions. Collaboration was defined as the regular professional sharing of human, financial and/or technical resources, engaging in joint activities, and organizing joint activities (Alexander et al. 2017, Bodin et al. 2019). Respondents were encouraged to consider all flood planning activities conducted since 2018 when answering.

We received complete responses from 53 organizations. As four organizations indicated they were not affected by flooding, the potential responses were reduced to 132, resulting in a 40% response rate. Responses from multiple individuals in the same organization were coalesced into a singular response using the maximum value reported (Baird et al. 2016). The collaboration network was restricted to only responding organizations and symmetrized to create an undirected network using the minimum symmetry rule, i.e., the responses were transformed into a matrix where reciprocated collaboration was considered an undirected tie (Fliervoet et al. 2016, Bodin et al. 2020).

Layer 2: Ecological

The ecological layer was constructed from the sub-sub-basins of the St. John River Basin, smaller hydrologically defined areas within the St. John River Basin. Links between sub-sub-basins were determined by downstream flow and indicated by an undirected network (Sayles and Baggio 2017, Widmer et al. 2019). The information for the ecological network was sourced from the Natural Resources Canada National Hydro Network (Government of Canada 2020) and the United States Department of Agriculture Geospatial Data Gateway (USDA-NRCS 2020). The Canadian data was described as sub-sub drainage areas and the American data was hydrologic unit code 8s.

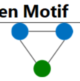
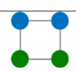
Layer 3: Social-ecological

Respondents were asked to indicate from a labeled map all of the sub-sub-basins their organization conducts flood planning within (Guerrero et al. 2015). These responses were used to create the social-ecological layer (Widmer et al. 2019), where the nodes are organizations and sub-sub-basins, and links represent an organization conducting flood planning in a specific sub-sub-basin.

Multilevel exponential random graph model

We used Exponential random graph models (ERGM) to analyze social-ecological fit under Objective 1. ERGMs are a class of statistical models used to model the observed overall network data structure as the result of accumulative and local social processes that can be represented through smaller configurations (also called "motifs") within the network (Lusher et al. 2012). In multilevel networks, these smaller configurations are specific connections among and between social and ecological nodes (Fig. 1). In our case, drawing upon decades of SES governance literature, we chose motifs that have been associated to the enhancement or hindering of social-ecological fit (Fig. 1) (Guerrero et al. 2015, Bodin et al. 2016, Pittman and Armitage 2017, Widmer et al. 2019, Barnes et al. 2020). The observed social-ecological networks are treated as the dependent variable and the smaller configurations (or motifs) as the explanatory parameters. Multiple motifs can be considered simultaneously to understand a network and are assigned a parameter value and standard error. The magnitude and direction of the parameter value convey if a motif is over or under-expressed in the network in comparison to comparable randomly generated networks. Standard error is used to determine statistical significance. As motifs are nested, they are understood in conjunction, with lower order motifs providing a baseline for proper interpretation of more complex motifs.

Fig. 1. Selected motifs to assess social-ecological fit.

Chosen Motif	Social-ecological Fit Challenge
 TriangleXAX	Shared management of ecological resources The closed common pool resource triangle indicates organizations working in the same sub-sub basin collaborate, preventing ineffective management (Bodin et al. 2014, Guerrero et al. 2015).
 C4AXB	Management of interconnected resources Collaboration among organizations working in connected sub-sub basins would indicate coordinated flood planning through the basin (Bodin and Tengö 2012, Guerrero et al. 2015).

Blue nodes indicate organizations and green nodes indicate ecological components. MPNet codes are indicated.

The multilevel SEN was analyzed though multilevel exponential random graph models to address two SE fit challenges: 1. shared resource management and 2. management of interconnected resources (Guerrero et al. 2015) (Fig. 1). The ecological network and the social-ecological network were fixed to purposefully explore and understand the choices of collaborating organizations (i.e., who they chose to collaborate with) given their social-ecological connections and the ecological complexity (Pittman and Armitage 2017). Many actors in the region have mandated areas of responsibility for flood planning, and as such, the social-ecological network connecting organizations to the river was not a product of actor choices.

The multilevel ERGM was fitted in MPNet to the observed social-ecological network (Wang et al. 2014) following a sequential process, where beginning with baseline terms, additional terms were only added after the model converged. Baseline terms are lower order configurations that are nested within other configurations that aid in model fit and interpretation. A motif was determined to be significant when the parameter estimates were twice the standard error (Lusher et al. 2013). Model goodness of fit is included in Appendix 1.

Qualitative analysis

To address the second objective, qualitative information was collected to develop a more comprehensive understanding of the benefits of, and difficulties within, the collaborative governance arrangement, and to assist in the interpretation of the ERGM motifs (Pittman and Armitage 2017, Alexander et al. 2017). The questionnaire collected qualitative responses on collaboration to understand the adequacies of, and barriers to, collaboration (Cohen et al. 2012). Respondents were asked to describe how collaboration affects their ability to conduct flood planning. Additionally, respondents were presented with a list of common challenges to collaboration (Cohen et al. 2012, Guerrero et al. 2015, Hermansson 2016) and asked to select and then rank any of the challenges they have experienced.

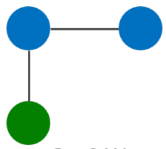
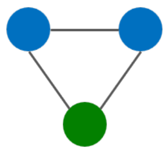
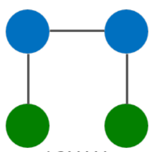
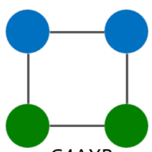
The coding process for the responses to the open-ended question asking respondents to describe how collaboration affects their ability to conduct flood planning was both deductive and inductive. A codebook was developed based on current literature on known stimuli or hindrances to functional collaborative governance (Honadle 2001, Ansell and Gash 2007, Emerson et al. 2012, Krause 2012, Emerson and Gerlak 2014, Mattor et al. 2020), and the researcher was open and aware of emergent themes in rounds of coding (Saldaña 2013). This allowed the findings of the benefits and barriers to collaboration within the St. John River Basin flood planning network to be grounded in existing theories and from the respondents themselves. Once coded, the number of each theme was summed (Krippendorff 2013). Open coding was used to understand additional commentary about flood planning in the St. John River Basin.

RESULTS

Results from the investigation are presented in correspondence with the two research objectives, starting with outcomes regarding SE fit through a multilevel network analysis. The multilevel exponential random graph model was fitted to the social-ecological network to investigate two SE fit challenges: shared management of ecological resources and management of interconnected resources. The five configurations shown in Figure 2 include both the baselines (Motifs A, B, and D) and the motifs of interest (Motifs C and E). As motifs are nested within each other, including baseline motifs in the model is essential for proper interpretation of higher-level motifs. Motif A is a baseline parameter and it is significant and negative, indicating that the tendency to form collaborative ties in is lower than would be expected by chance, which is anticipated for a collaboration network.

Motif C corresponds to the first SE fit challenge of shared management of ecological resources. Motif B presents a baseline for the tendency of actors with ties to the ecological network to also have social ties; the parameter is positive and significant, meaning actors with ties to the river are likely to collaborate. Motif C is the closed common pool resource triangle, and the positive and significant parameter indicates a tendency of actors who

Fig. 2. Multilevel exponential random graph model estimates. MPNet codes are provided for each motif. * indicates significant effect.

Motif		Parameter estimate	(standard error)
A	 EdgeA	-3.5934	(0.2030)*
B	 Star2AX	0.1211	(0.028)*
C	 TriangleXAX	1.1475	(0.245)*
D	 L3XAX	-0.0615	(0.016)*
E	 C4AXB	-0.1592	(0.112)

work in the same sub-sub-basin to collaborate. Interpreted together, organizations with ties to the river are likely to collaborate and are further likely to collaborate with those working within the same sub-sub-basin.

Motif E corresponds to the second SE fit challenge of management of interconnected resources. It is non-significant, meaning the closed square configuration occurred in the network within a range expected by chance. However, the baseline configuration (Motif D) provides an indication of the occurrence of this challenge. It depicts two collaborating actors working in different sub-sub-basins. It is significant and negative, indicating actors do not tend to collaborate when working in different locations.

The second research objective sought to illuminate how collaboration contributes to functional fit or misfit. The responses to the open-ended question provided insight into the impacts of collaboration on flood planning activities, as well as barriers and shortcomings of collaboration. Nearly three-quarters of respondents, (71% or 41 respondents), indicated collaboration affected the ability to conduct flood planning, with 29% (17 respondents) indicating it does not.

Respondents who indicated that collaboration affected the ability to conduct flood planning were then asked to describe how. These descriptions were coded, and their frequencies are presented in Table 1. Knowledge was the most frequently mentioned effect of collaboration on flood planning. Within the theme of knowledge, respondents expressed the benefits of collaboration for increasing access to new information and enhancing understanding within their flood planning efforts. For example, a respondent from a watershed organization reported, "*We learn a great deal from our partner organizations; we share one another's planning information and approaches*." Further illustrative of this theme, a regional government respondent observed, "*thankfully we are able to share expertise with some of our partner organizations, which helps compensate for our own weaknesses ... the communities we collaborate with have a much greater understanding of the situation within their jurisdictions.*"

Table 1. Deductive code frequencies of responses to the question: "How does collaboration affect your ability to conduct flood planning?"

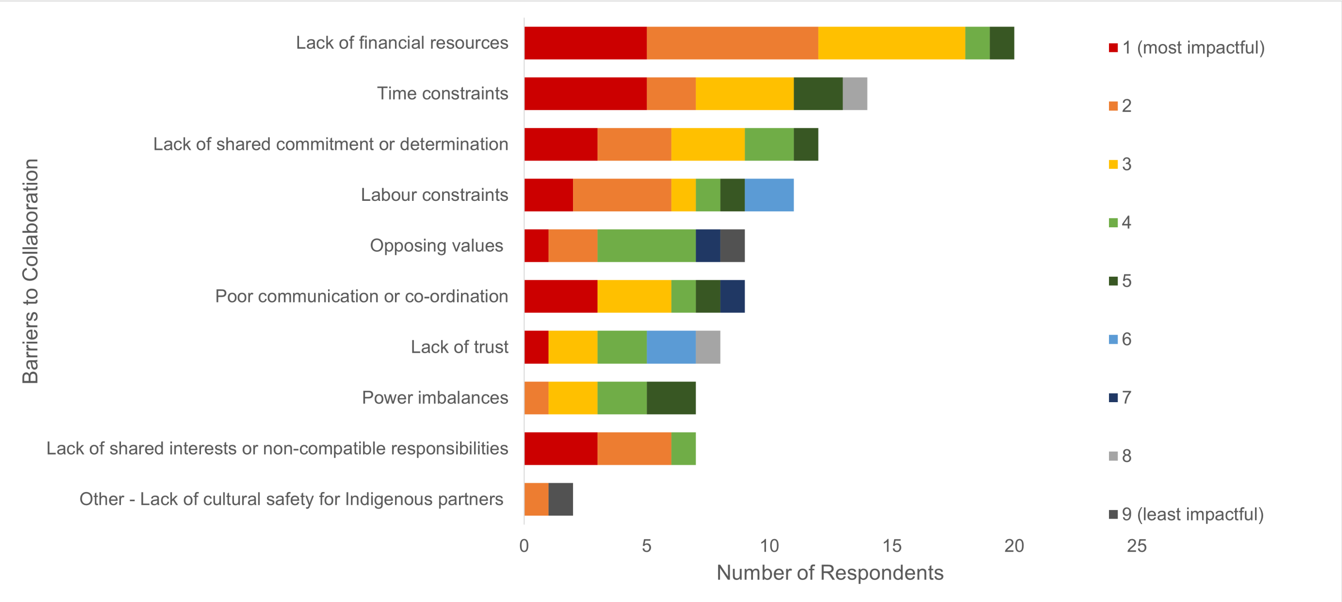
Code	Count
Knowledge	16
Technical resources	9
Funding	5
Implementation	5
Authority	3
Employee time & training	3
Leadership	2

The second and third most frequent themes expressed by respondents described how collaboration has increased the capacity of many organizations within the St. John River Basin to conduct flood planning by providing increased access to technical resources and funding. Respondents identified collaboration was beneficial for "*data sharing*" (Municipal Government respondent) and improving "*process and information set*" (Municipal Government respondent). More specifically, an NGO respondent indicated they "*use flood map data from our collaborators to complete risk and vulnerability assessments*."

Collaboration was also recognized as a mechanism for organizations to gain authority and enhance implementation. As the St. John River Basin is a transboundary river situated in a traditional hierarchical governance environment, no one organization holds purview over the entirety of the basin. For example, a federal agency respondent wrote, "*Our agency can only touch pieces of this issue, collaboration brings different partners and funding sources to the table*." Non-governmental organizations in particular described how collaboration enhances implementation efforts. For instance, "*collaboration allows our work and planning tools we develop to be adapted for use directly in flood planning*" (NGO respondent) and "*the more we collaborate (share human, financial, technical resources) the better our engagement tends to be, leading to more and better on-the-ground implementation of projects, i.e., restoration efforts.*" (NGO respondent)

Respondents were asked to indicate if there have been challenges collaborating with others. Slightly over half of respondents, 53% (31 respondents), indicated there have been challenges

Fig. 3. Selected and ranked barriers to collaboration. A rank of 1 indicates the most impactful barrier and a rank of 9 indicates the least impactful barrier.



collaborating, with 46% (27 respondents) indicating there have not been challenges. If respondents selected "yes," they were asked to select and rank barriers to collaboration experience while conducting flood planning (Fig. 3).

Lack of financial resources was the most selected barrier to collaboration overall, and both financial and time constraints were equally selected as the most impactful barriers. This theme is poignantly illustrated by a municipal respondent who adamantly expressed, "*we have limited human, financial and or technical resources to effectively collaborate*." Furthermore, a watershed organization respondent described that "*collaboration is essential but difficult to do when government departments mostly operate in a silo, and most non-profits depend on one or more silos for funding*." There is an evident impact of financial resources on collaborative relationships in the St. John River Basin, as it is both a benefit of and a barrier to collaboration.

A lack of shared commitment or determination was the third most frequent barrier selected, and this observation may be partially explained by the numerous organization types with differing jurisdictions, authorities, and resources interacting:

> *Forestry approves harvest plans on Crown Land that too often results in clear-cuts, resulting in faster snowmelt in Spring and reduced ability of the forest to absorb and slow down the meltwater, but they are not at the table when the River Watch organization has to deal with the freshet, even though forestry practices contribute to the problem. I see lots of busy organizations in the Spring dealing with the freshet and flooding, but not the same focus on preventative actions. Coordination of the private companies and numerous government departments operating in a watershed is, shall we say, challenging, for a watershed organization without some legislative support*. (watershed organization respondent)

Opposing values, lack of trust, lack of shared interests, power imbalances, and non-compatible activities were additional barriers to collaboration that were identified less often and with a range of rankings. Specific contextual attributes, such as the respondent's identified lack of cultural safety for Indigenous partners, was written in by two respondents with high variability in impact for collaboration ranking.

DISCUSSION

Our finding that organizations are likely to collaborate with those working within the same sub-sub-basin aligns with previous multilevel social-ecological network studies (Guerrero et al. 2015, Bodin et al. 2016, Pittman and Armitage 2017, Widmer et al. 2019, Barnes et al. 2019). This social-ecological closure has been associated with positive ecological conditions (Barnes et al. 2019). As acting independently regarding a shared resource can lead to ineffective management or overexploitation (Ostrom 1990), numerous network studies (e.g., Guerrero et al. 2015, Bodin et al. 2016) have further quantitatively demonstrated the utility of collaboration to enhance shared management. Collaboration within a sub-sub-basin can help minimize contradictory autonomous flooding adaptation approaches (Winter and Karvonen 2022).

Our result, that actors working in different sub-sub-basins tend to not collaborate, points to a potential shortcoming in flood governance. This result indicates flood planning in separate sub-sub-basins occurs largely independent of activities in other sub-sub-basins. There is, therefore, the potential for an increase in collaboration among ecological neighbors to govern for ecological connectivity (Bergsten et al. 2014, Bodin et al. 2016).

Management of interconnected resources through collaboration has presented a challenge across numerous SE fit studies (Guerrero et al. 2015, Bodin et al. 2016, Widmer et al. 2019; Pittman & Armitage 2017 for an exception). SE fit for interconnected resources is often harder to achieve than coordination or collaboration for a common pool resource (Guerrero et al. 2015, Pittman and Armitage 2017, Widmer et al. 2019). For example, Widmer et al. (2019), who investigated SE fit of collaborative water quality governance within the Rhine River catchment area, identified a similar challenge in collaboration connecting interconnected sub-catchments.

With relation to flooding, the coordination among upstream and downstream actors is of substantial importance, as action, or lack thereof, upstream can alter the risk and impacts of flooding downstream (Westerberg et al. 2017, Dieperink et al. 2018). For example, Dieperink et al. (2018) describe the case of Kingston upon Hull, UK, where upstream storage could reduce flood risk to over 8000 properties downstream. As a result of this dynamic, a regional partnership approach was employed to ensure coordination among upstream and downstream communities (Dieperink et al. 2018). Connections among upstream and downstream municipalities are an important component of flood governance (Driessen et al. 2018). Within the St. John River Basin, the Upper Basin is less densely populated and experiences lesser impacts of flooding than the Middle or Lower Basins. Upper Basin flood planning, or lack thereof, impacts peak flows downstream (Kidd et al. 2011), and as such, communicative and collaborative relationships are needed to connect Upper Basin actors with Middle and Lower Basin actors. Collaborative relationships among organizations working in different sub-sub-basins are essential for cohesive flood planning at a basin level (Galaz et al. 2008, Becker 2020).

The management of interconnected resources through collaboration may be particularly impacted by challenges associated with differing actor jurisdictional levels, working across political boundaries, country-specific regulations, upstream and downstream dynamics, and institutional arrangements (Widmer et al. 2019). As a transboundary river, the St. John River Basin is subject to many of these challenges. Organizations actively engaging in flood planning in the Basin vary greatly in organization type, jurisdiction, authority, spatial level, and access to resources. Engagement of actors beyond formal government and connections between administrative levels has been found in other flood governance regimes (Fournier et al. 2016).

It is plausible multiple organizational and contextual attributes may intersect to decrease collaboration among organizations working in different sub-sub-basins. For example, a lack of capacity may make it difficult for municipalities to collaborate, especially in the lesser populated Upper Basin. Becker (2020) identified multiple interacting factors, such as regulation and normative behaviors, that reduced the fit of municipalities to collectively address flooding.

Qualitative results from this study complemented the social network analysis to explicate how collaboration contributes to the functional fit or misfit. Respondents reported that collaboration affected the ability to conduct flood planning, specifically describing seven influences. The multiplicity of influences is consistent with findings by Emerson et al. (2012:14), who conceptualized the capacity for joint action to be the product of four necessary components of “procedural and institutional arrangements, leadership, knowledge, and resources.”

Beyond the capacity for collective action, collaborative governance and management approaches can provide a mechanism for combining different types of knowledge (Plummer et al. 2012, van Tol Smit et al. 2015, Feist et al. 2020), coproduce knowledge (Armitage et al. 2012), and enhance knowledge exchange (Olsson et al. 2007, Bodin and Crona 2009, Kuehne et al. 2020). A lack of organizational capacity, such as lack of personnel or technical knowledge base, may decrease the fit of institutions in river basin governance (Lebel et al. 2013), and the assurance of sufficient resources is a critical element in building flood resilience (Driessen et al. 2018). Responses suggest collaboration has increased the capacity of many organizations within the St. John River Basin to conduct flood planning by providing increased access to technical resources and funding. While collaboration can provide access to additional resources, the end goal is collaborative action or implementation of governance decisions (Mattor et al. 2020). Here, collaboration was reported to bolster authority to make decisions for and take action over a broader geographic region. Collaboration can provide a mechanism to better align the institutions with authority with the extent of the ecological process (Lee and Baggio 2021) and enhance implantations through partnerships with other agencies (Laurian and Crawford 2016). The intersection of benefits provided by collaborative relationships can contribute to functional fit, although those relationships are not without challenges.

Results from this study also shed light on the challenges of a collaborating approach to flood planning, in line with common collaborative governance barriers of financial, time, and labor constraints (Cohen et al. 2012, Guerrero et al. 2015, Hermansson 2016). Inconsistent access to necessary resources may hamper SE fit by impacting both internal organization action and the ability to commit to collaborations. A lack of shared commitment or determination was the third most frequently identified barrier.

Considering more than half of respondents experience barriers to collaboration and almost one-third indicated collaboration has not affected their ability to conduct flood planning, there is much room for improvement in current network dynamics. Challenges (e.g., limited capacity, government silos, conflicting priorities, inconsistent activity, and an absence of leadership) explain the absence of collaboration among organizations working in different sub-sub-basins; however, they also provide evidence to support the frequent assessment that guidance from top-down government may be beneficial to collaborative governance arrangements broadly (Schneider et al. 2003, Huntjens et al. 2010, 2012, Kuehne et al. 2020) and to support SE fit specifically (Bergsten et al. 2014, Guerrero et al. 2015).

While network analysis is a powerful tool to understand aspects of SE fit, inherent methodological limitations are with the approach that need to be discussed. These considerations are particularly important, although not consistently addressed, in investigations of collaborative governance (Guerrero et al. 2020). Research regarding collaborative governance is impacted by how the boundaries of a collaborative governance network are established and defined (Cohen et al. 2012, Berardo et al. 2020, Guerrero et al. 2020), with the latter being especially important as it is multifaceted and comprised of various interactions (Berardo et al. 2020). Missing data from non-responding actors within the network boundaries is a limitation of this research and network analysis in general (Kossinets 2006, Smith and Moody 2013). The choice of missing data treatment is critical (Krause et al. 2020). We chose to delete non-responding actors to analyze a full sub-set of the network and use an analytical method, ERGMs, that is more robust to missing data (Robins et al. 2004). We also chose to investigate an undirected collaboration network to only assess reciprocal collaboration (Fliervoet et al. 2016, Bodin et al. 2020); this required considering the ecological network as undirected in the multilevel ERGM. We acknowledge that this choice removed the possibility of considering upstream-downstream dynamics in the analysis, which can be impactful in flood planning for planning processes and power dynamics (Widmer et al. 2019).

CONCLUSION

The research examines the social-ecological fit of collaborative governance arrangements for flood planning in the St. John River Basin, Canada. Analysis of the multilevel SEN displayed limited SE fit of the collaboration network to flooding at the basin scale. Collaboration may be contributing to SE fit for flood planning as organizations within the same sub-sub-basin demonstrated a tendency to collaborate. However, organizations working in different sub-sub-basins demonstrated a tendency to not collaborate, impeding the ability of the network to cohesively govern the basin. This research has contributed an additional example of a multilevel SEN assessment of fit at the regional scale and is the first instance this method has been used to assess SE Fit to flooding at the basin scale.

Qualitative responses conveyed collaboration increased access to knowledge, technical resources, and funding. The intersection of the benefits of collaboration are likely contributing to the capacity for joint action (Emerson et al. 2012) and potentially to implementation efforts throughout the basin (Laurian and Crawford 2016, Lee and Baggio 2021). However, respondents indicated multiple impactful barriers (e.g., a lack of financial resources, time, and shared commitment) that likely combine and interact to shape the investigated relational patterns (Cohen et al. 2012). Understanding the challenges to collaboration, such as limited capacity and government silos, provides a nuanced and contextualized interpretation of the misfit of the flood planning network.

More broadly, this research contributes to ongoing discussions about top-down governance in relation to collaborative arrangements. Kundzewicz et al. (2018) suggest flood governance is strengthened when top-down and bottom-up approaches are combined. Dieperink et al. (2018) suggest more research is needed to understand hierarchal steering in flood governance. Both Bergsten et al. (2014) and Guerrero et al. (2015) in SE fit studies suggest some extent of top-down governance can be helpful "to guide and facilitate the establishment of collaborations that better align with the different constraints inherent in the biophysical characteristics of the managed ecosystems" (Guerrero et al. 2015). However, the limited SE fit assessed in our study suggests further research is needed to enhance understanding of how effective network governance forms and operates in contexts where hierarchical government is dominant. More research is also required to further understand how hierarchical and collaborative modes of governance co-exist and in what contexts it is effective. Further assessments and comparisons of heterarchical structures across contexts can contribute to this (Shurety et al. 2022). A future avenue of research is to explore the possibility and the application to use SE fit as an indicator of collaborative governance performance across various SES.

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Data Availability:

The data/code that support the findings of this study are available on request from the corresponding author, B.M. None of the data/code are publicly available as data analysis is ongoing. Data will be made available through Brock University Dataverse. Before any data was collected, an application was submitted to and approved by the Brock University Social Science Research Ethics Board (REB 19-200 - BAIRD).

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Appendix 1. Goodness of fit

Statistics	Observed	Mean	StdDev	t-ratio
EdgeA	90.0000	91.7360	8.919	-0.195
Star2AX	725.0000	728.3540	89.989	-0.037
TriangleXAX	124.0000	122.8440	21.873	0.053
L3XAX	1226.0000	1192.7720	241.283	0.138
C4AXB	226.0000	220.3140	43.398	0.131
stddev_degreeA	2.0666	2.2995	0.294	-0.792
skew_degreeA	0.4246	1.0155	0.433	-1.364
clusteringA	0.0833	0.0934	0.032	-0.319
stddev_degreeX_A	4.2720	4.2720	0.000	-1.000
skew_degreeX_A	-0.2023	-0.2023	0.000	1.000
stddev_degreeX_B	10.4147	10.4147	0.000	-1.000
skew_degreeX_B	-1.2065	-1.2065	0.000	-1.000
clusteringX	0.4290	0.4290	0.000	-1.000
stddev_degreeB	1.3102	1.3102	0.000	-1.000
skew_degreeB	1.1171	1.1171	0.000	-1.000
clusteringB	0.0000	0.0000	0.000	NaN

Mahalanobis distance = 2562844972465013

Maximum qasi-autocorrelation in absolute value = ∞