An Examination of Collaborative Governance for Complex Adaptive Systems in the St. John River Basin

By

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Abstract

Climactic changes are having devastating impacts on communities and improved collaborative decision-making is required to govern the changing social-ecological system. This research sought to expand understanding of collaborative governance as it relates to social-ecological complex adaptive systems by using a network perspective to examine governance network properties in relation to adaptive governance and social-ecological fit. The collaborative flood planning network in the St. John River Basin was collected and analyzed both independently and within a multilevel social-ecological network. Analysis displayed a broad range of organizations within the network, a tendency for transitivity, and limited social-ecological fit. While collaboration aids in adaptive governance in the basin, the network was strongly impacted by varying jurisdictional roles, responsibilities, and resources. This research contributes to the growing body of literature on network governance for social-ecological systems and further questions the role of top-down governance within collaborative arrangements.

Keywords: social-ecological systems, adaptive governance, social-ecological fit, social network analysis, exponential random graph models

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CAS	complex adaptive system
ERGM	exponential random graph model
NGO	non-governmental organization
SES	social-ecological system
SE fit	social-ecological fit
REB	Research Ethics Board
WWF-Canada	World Wildlife Fund – Canada

Chapter One: Introduction

Globally, wildfires (Abram et al., 2021; Burke et al., 2021; D. Wang et al., 2021), water shortages (Fleck & Udall, 2021; IPCC, 2019), and flooding (Cornwall, 2021; Davenport et al., 2021), among other disasters are having catastrophic impacts on communities. Governance and management choices made now can alter future impacts of environmental change (Fleck & Udall, 2021; IPCC, 2018). Recent estimates place 1.47 billion people within direct exposure to flooding events (Rentschler & Salhab, 2020). With populations across the development gradient exposed, flooding is a global problem in need of suitable governance.

Within Canada, the most recent 2021 Canada in a Changing Climate report, the *National Issues Report*, identifies large gaps in climate change preparedness, in particular to extreme events such as floods (Warren & Lulham, 2021). In recent years, flooding disasters have caused the greatest rise in natural disaster damages in Canada (CCA, 2019), and climate change is forecasted to further alter flooding patterns driven by both snowmelt and rainfall (Government of Canada, 2019). Canada appears to be early on in a shift from traditional models of flood management to a more adaptive approach, flood risk management (Henstra et al., 2019). A survey of Canadians in 2016 demonstrated a belief that responsibility for flood mitigation lies among multiple levels of government, NGOs, and individuals, with municipal governments and individuals as the most responsible (Henstra et al., 2019). Flood risk management is a rich framework designed to enhance broader stakeholder participation, coordination across scales, and strategy diversity to ultimately reduce or manage risk (Evers et al., 2016; Merz et al., 2010; Serra-Llobet et al., 2016).

Flooding provides one example of severe environmental change within the current sustainability crisis to explore broader system changes. Recognizing the interconnectivity and indivisibility of human and environmental systems through a social-ecological system perspective provides a platform from which to investigate holistic system properties (Berkes & Folke, 1998; Gunderson & Holling, 2002). Social-ecological systems can be further understood as complex adaptive systems (Levin, 1999; Levin et al., 2013). Ecosystems are complex systems with multiple stable states (Holling, 1973) and are deeply connected with human systems through non-linear relationships (Gunderson & Holling, 2002; Levin, 1998). Framing social-ecological systems (SES) as complex adaptive systems (CAS) has direct consequences for governance suggestions, as complex adaptive systems need to be governed and understood in an integrated manner to account for deep uncertainties (Dietz et al., 2003; Levin et al., 2013; Ostrom, 2009; Pahl-Wostl, 2009).

Attempts to address environmental concerns through "command and control" to reduce variation and uncertainty often resulted in unintended consequences (Holling & Meffe, 1996; Ostrom et al., 2002). Recognizing the deep uncertainties in complex systems led to suggestions of adaptive management (Gunderson, 1999; Holling, 1978) and ultimately adaptive governance (Dietz et al., 2003; Folke et al., 2005). Governance, referring to "the structures and processes by which people in societies make decisions and share power" (Folke et al., 2005, p. 444), includes interacting institutions, organizations, and networks (Chaffin et al., 2014; Kooiman & Bavinck, 2005; Lockwood, 2010).

Adaptive governance (Dietz et al., 2003; Folke et al., 2005), collaborative governance (Ansell & Gash, 2007; Emerson et al., 2012), and adaptive co-management (Armitage et al., 2008, 2009;

Olsson et al., 2007) all share the essential component of social connections among various governance actors and organizations. Collaborative governance arrangements, which integrate diverse stakeholders and nested institutions, may be apt to address problems within complex adaptive systems as they have the potential to account for multi-level and cross-scalar system dynamics (Armitage et al., 2009; Bodin, 2017).

Flooding requires cohesive action over a basin scale (Niemczynowicz, 1999). While matching the geographic scope of governance to the targeted issue is widely recommended (Cumming et al., 2006; Folke, 2007; Ostrom, 2010; Young, 2002), 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). Collaboration in a transboundary watershed is impacted by jurisdictional levels, institutional arrangements, major political boundaries, and natural river dynamics (Widmer et al., 2019). Problems of fit can undermine effective governance in various contexts (Bergsten et al., 2014; Guerrero, Bodin, et al., 2015; Sayles & Baggio, 2017b), including flood governance (Becker, 2020; Lebel et al., 2013).

Collaborative governance may provide a promising tool to address the current social-ecological systems crisis; however, as collaboration may not be suited for all contexts or collective action problems (Bodin, 2017), further research is needed to understand collaborative governance as it specifically relates to social-ecological complex adaptive systems.

1.1 Rationale

The potential for collaborative governance to contribute to achieving sustainability goals requires further research into understanding its application in complex adaptive systems through investigating the impacts of governance network structure. Collaborative governance, the primary focus of this research, has been defined by O'Leary et al. (2006, p.7) as "the process of facilitating and operating in multiorganizational arrangements to solve problems that cannot be solved or easily solved by single organizations." As such, there is a natural alignment between collaborative governance and network analysis, an analytical process that is built from nodes and relations. As formal and informal social networks are central attributes of governance arrangements, understanding network structure and properties assists in understanding the governance arrangement (Bodin & Prell, 2011).

In examining regional collaborative governance arrangements, particularly those with components of top-down government, understanding how network structures, organizational roles, and actor attributes impact governance function is an ongoing area of research (Alexander et al., 2017; Hamilton et al., 2020; Hamilton & Lubell, 2018; Locatelli et al., 2020; Sayles & Baggio, 2017b). For example, the balance between bridging structures (actors connected through an open two-path) and bonding structures (actors connected in a closed triangle) in a network may provide insight into the levels of trust and conflict in a network (Berardo & Scholz, 2010; Bodin et al., 2020; McAllister et al., 2017); however, a more in-depth understanding of in what contexts certain structures contribute to addressing collective action problems is needed (Bodin et al., 2020). Incorporating geographic or jurisdictional level attributes into the network analysis may provide further needed insight into the functionality of multilevel governance arrangements. Specifically, understanding how spatial level impacts tie formation and cross-level ties can contribute to a more robust understanding of ways to decrease geographic fragmentation (Hamilton et al., 2018; Hamilton & Lubell, 2018; Sayles & Baggio, 2017b). Further investigation of brokerage (an actor connecting two actors without direct ties to each other) differences among groups, in consideration of scale, organization type, and context is needed (Barnes, Kalberg, et al., 2016; Hamilton et al., 2020).

In contexts that incorporate both traditional top-down government as well as non-governmental organizations, it is valuable to understand the relative involvement of both (Fliervoet et al., 2016). For instance, municipalities can be components in top-down governmental structures but also engage in bottom-up collaborations (García et al., 2019). As a result, the formal and informal governance networks may overlap in network analysis, and mapping informal networks onto top-down formal implementation structures is an emerging area of research (McGee & Jones, 2019). An effective means of understanding and incorporating institutional constraints and the specific roles of governmental and non-governmental organizations into the network analysis of a collaborative governance system is invaluable for making practical governance recommendations for the studied system. For example, Becker's (2020) network analysis of flood risk mitigation within a catchment area found municipalities were connected via voluntary associations without decision-making power, identifying a problem of fit.

Additionally, there is a need to understand governance ‘fit’, as governance should align with both social and ecological processes (Folke et al., 2007; Young, 2002), and failure to fit both contexts may result in unintended outcomes and ecosystem service degradation (Ekstrom & Young, 2009). The identification of gaps where institutions fail to fit the systems they are supposed to manage is essential for locating governance gaps in relation to key system dynamics (Ekstrom & Young, 2009). There is a need for a broader understanding of social-ecological fit at regional scales (Bodin, 2017).

Social-ecological (SE) fit for collective governance arrangements can be assessed through a network perspective that conveys connections among actors and between actors and ecological structures (Bodin, Alexander, et al., 2019; Bodin & Tengö, 2012; Ekstrom & Young, 2009). However, there is a need for research on if and how the SE fit of a collaborative network structure impacts capacity to address collective action problems (Bodin, 2017). Network patterns in combinations with institutional settings impact outcomes related to SE fit, as different settings with different actors will produce different governance behaviours (Duit & Galaz, 2008). One dimension of fit, functional fit, demands governance arrangements and institutions align with the ecological and social-ecological processes and relationships in the system (Ekstrom & Young, 2009; Epstein et al., 2015). As the capabilities of the collaborative governance arrangements, and subsequent governance outcomes, may be impacted by the formal responsibilities and capacities of the individual actors in the network, there is an additional need to consider how organizational attributes may impact functional fit (Alexander et al., 2017). There is also a potential for qualitative analysis to understand which institutional conditions contribute to SE fit (Epstein et al., 2015).

1.2 Study Purpose, Research Aims, and Objectives

This research is responding to the need to further understand with contextual nuance and specificity the application of collaborative governance to address environmental challenges. The purpose is to advance understanding of collaborative governance as it relates to social-ecological complex adaptive systems. This research specifically employs a network perspective to examine network properties to further our understanding of how they relate to adaptive governance and social-ecological fit. The empirical portion of the investigation is grounded in the context of the collaborative flood planning network in the St. John River Basin.

It is divided into three main research aims.

Research Aim One: Identify and describe the flood planning network

Research Aim One addresses the necessity of first understanding the composition of the flood planning network within the embedded institutional context. Henstra et al., (2019) described Canada as in an early shift towards flood risk management, which incorporates a diverse set of institutions and organizations. Research Aim One provides an empirical example of the extent of involvement of varying organizational types in flood planning in Canada.

Research Aim Two: Analyze the network in reference to adaptive governance scholarship

Social networks are an essential component of adaptive governance to create a cohesive system comprised of diverse institutions functioning across different jurisdictional and spatial levels (Dietz et al., 2003; Folke, 2006; Folke et al., 2005). As the structure of the governance network impacts function (Bodin & Crona, 2009), investigating specific network properties related to collective action dilemmas, organizational type, and geographic scale, can provide an enhanced understanding of the application of adaptive governance. Research Aim Two is associated with four objectives:

Objective One: To understand the centrality and transitivity in the collaboration network

Following Berardo & Scholz's (2010) risk hypothesis that organizations will seek bridging relationships in low-risk dilemmas and bonding relationships when risk increases, understanding the relative impact of centrality (tendency to connect to popular nodes) and transitivity (tendency for three nodes connected in a closed triangle) in the network provides insight into the nature of the collective action problem and the perceived risk of collaboration.

Objective Two: To analyze the impact of geographic scale and homophily (tendency to form ties with alike nodes) on collaboration structures

Collaboration among and between government and non-governmental organizations, as well as among and between organizations operating within different geographic levels, may impact the functionality of the network (Fliervoet et al., 2016; Hileman & Lubell, 2018; Locatelli et al., 2020). Collaborative ties may be impacted by organization level (Hamilton & Lubell, 2018; Sayles & Baggio, 2017b), and differences in activity based on geographic scale will shape the multi-level governance arrangement. Homophily in a network can contribute to both enhanced information sharing and trapping information in network communities (Crona & Bodin, 2011; Prell et al., 2009).

Objective Three: To assess the impact of geographic scale on brokerage (a node connecting otherwise unconnected nodes) in the network

Differences in brokerage roles may influence knowledge flows (Levy & Lubell, 2018; Locatelli et al., 2020) and management priorities (Hamilton et al., 2020). Understanding brokerage roles by geographic scale provides insight into connections across levels while also providing insight into devising interventions to facilitate greater connections among distinct groups (Hamilton et al., 2020).

Objective Four: To assess if municipalities are brokers in the network

Research has displayed municipalities occupy unique roles within water governance and often work with both other formal government agencies and community-based organizations (García et al., 2019). This objective assesses this property from a unique network perspective.

Research Aim Three: Assess the collaborative governance arrangement for the principles of social-ecological fit to address the problem of flooding

Research Aim Three is associated with two objectives:

Objective One: To analyze SE fit through a multilevel network approach

A multilevel network approach allows for the investigation into specific motifs, small scale internal network structures, such as those denoting collaboration, shared resource usage, and social-ecological scale-matching that have been shown to improve SE fit (Barnes et al., 2017; Guerrero, Bodin, et al., 2015).

Objective Two: To understand how collaboration contributes to functional fit or misfit

Qualitative data was collected to understand the benefits and barriers to collaboration. Understanding the dynamics that influence collaboration and functionality in the governance network assists in assessing the SE fit of the governance arrangement.

1.3 Thesis Organization

This thesis is organized into five chapters. The first has set out the rationale for this study and outlines the research purpose, aims, and objectives. Chapter Two presents a literature review that begins with describing essential theoretical components for understanding collaborative governance opportunities for complex adaptive systems. The first section synthesizes scholarship on the subjects of social-ecological systems and complex adaptive systems, with an emphasis on their conceptual integration and impact on governance. The impact of these theoretical framings is further explored through a discussion of adaptive governance and subsequently collaborative governance. The following section discusses the use and insights provided by network analysis in governance research. The final section reviews the literature on social-ecological fit, with a specific focus on the use of network approaches. Emphasis is placed in each section on literature significant to improving governance for sustainability. Chapter Three presents the methods of this study, including a description of the study region, the data collection and analysis process and procedures, network limitation, and study limitations and delimitations. Chapter Four presents the findings of this research. Findings are presented by research aim and objective. Results for each objective are presented and then discussed in sequence. Chapter Five concludes the thesis with a synopsis of key findings for each research aim and objective, and a summary of key contributions and recommendations for future research.

Chapter Two: Literature Review

The literature review describes essential theoretical components for understanding collaborative governance as it relates to social-ecological complex adaptive systems. There is a specific emphasis on how the social-ecological complex adaptive system framing provides a basis to investigate collaborative governance through a network perspective. The first section synthesizes scholarship on the subjects of social-ecological systems and complex adaptive systems, with an emphasis on their conceptual integration and impact on governance. The impact of these theoretical framings is further explored through a discussion of adaptive governance and subsequently collaborative governance. Governance is further explored through a review of the application of network analysis to understand the governance of social-ecological systems and of the role of governance network structures in developing social-ecological fit. Emphasis is placed in each section on literature significant to improving governance for sustainability.

2.1 Social-Ecological Systems

The social-ecological systems (SES) perspective presented by Berkes and Folke (1998) argued that any delineations between human systems and ecosystems are artificial, as humans are embedded in and coevolving with the biosphere. At the time it was presented, this integration of the natural and social sciences was uncommon in both disciplines and provided a novel perspective. Social-ecological systems are non-linear systems with interactions between slow and fast variables, and critical feedbacks nested across various scales and levels (Allen & Starr, 2017; Berkes & Folke, 1998; Cash et al., 2006; Gunderson & Holling, 2002). Scale refers to the dimension used to measure a phenomenon (temporal, spatial, jurisdictional, etc.) and level to the unit within the dimension (Cash et al., 2006). For example, jurisdictional levels may consist of municipalities, regional government, and a federal government. Cross-scale then refers to interactions across measurable dimensions, such as temporal and spatial, and cross-level to interactions within a single scale. Variables exist within different scales, as some may change slower or faster in time and exist in smaller or broader areas (Crépin, 2007; Walker et al., 2006). Some variables within SES change quickly and are often of direct relevance to resource users, while other variables may change slowly and have a controlling influence on the system (Crépin, 2007; Walker et al., 2012). Non-linear interactions among these variables, operating at different speeds and over possibly distinct spatial areas, may trigger whole system changes (Gunderson & Holling, 2002; Scheffer et al., 2001).

Understanding and addressing the non-linear nature of SES requires "new and appropriate" tools (Berkes & Folke, 1998). This SES framework used an ecosystem view that explicitly included social systems and intertwined two previous resource management streams (Berkes & Folke, 1998). The first was a systems approach that strove for adaptive management and emphasized component connections and feedbacks (Holling, 1978). The second, recognizing the importance of the social sciences in improving resource management outcomes, emphasized institutional and property components. Responding to flaws in historic resource management practices, the framework presented a structure to analyze resource management systems, emphasizing how local knowledge can function as a bridge between dynamic ecosystems, management practices, and the broader institutions (Anderies et al., 2004). Berkes and Folke (1998) hypothesized that the well-being of social and ecological systems were closely linked, and knowledge of resource management systems can promote resilience to reduce the potential for disturbances to impact the structure or function of the system. Their SES framework was later applied in navigating change to promote sustainability, leading to the identification of key resilience principles (Biggs et al., 2012; Colding & Barthel, 2019; Folke, 2006; Gunderson & Holling, 2002).

Anderies, Janssen, & Ostrom (2004) define a social-ecological system as "an ecological system intricately linked with and affected by one or more social systems" (p. 18), where both ecological and social systems are broadly described as "independent systems of organisms". SES are further characterized by social systems where relationships between components are impacted and mediated by components of the ecological system, and cooperation is required to cope with disturbances (Anderies et al., 2004). Interactions can be described at the most elementary level as a combination of four entities connected through eight distinct links. The resource, resource user, public infrastructure, which includes both physical and social capital, and public infrastructure provider, all affected by institutional rules and external environments, are connected both directly and indirectly through component dynamics (Anderies et al., 2004).

SES present social systems embedded in and thus inseparable from and co-evolving with the biosphere (Berkes, 2017; Folke et al., 2016). The social systems of SES are products of economics, politics, history, culture, and institutions, and the governance of SES is a component, not an external factor, of the system (Chaffin et al., 2014; Folke et al., 2011). SES are nested within the overall global dynamic and can be defined at various levels based on the biophysical or social subsystems, such as a river system or state jurisdiction. Different levels are intrinsically connected to those both above and below. For example, a state may be divided into smaller regional jurisdictions but is also a component of a larger, federal jurisdiction (Berkes, 2017). Such SES are described as nested complex adaptive systems with interactions across scales (Allen & Starr, 2017; Gunderson & Holling, 2002; Levin, 1998).

2.2 Complex Adaptive Systems

Fundamental components of SES research are based on an understanding that SES are complex adaptive systems (Berkes & Folke, 1998; Folke, 2016; Levin et al., 2013; Olsson et al., 2004). Framing SES as complex adaptive systems (CAS) allows for better recognition of the interconnectedness between human systems and ecosystems, and consequently for better understanding of the dynamic interactions within the systems (Levin et al., 2013; Norberg & Cummin, 2008). Additionally, this framing provides a rationale to understand broader SES, and specifically governance arrangements within SES, as networks.

Systems refer to interconnected but independent parts that exchange energy, matter, and information (Costanza et al., 1993). Complex systems are defined by non-linear connections that result in complex feedback loops across time steps, which may have thresholds and limits (Costanza et al., 1993). Such systems reduce the effectiveness of traditional scientific methods to accurately deduce cause-effect relationships and extrapolate system properties from a few, selected components (Costanza et al., 1993). Understanding SES as CAS refutes assumptions of linear dynamics made throughout historic resource management practices, which often, in the attempt to control a few selected variables to reach an economic or social goal, degraded the overarching system (Folke, 2007; Holling & Meffe, 1996; Norberg & Cummin, 2008).

At their core, CAS are systems of interacting components, where interactions are complex (non-linear) and components can learn or change in a manner that promotes adaptive behaviour. These relationships between elements can be considered as networks that are nested at various temporal and spatial hierarchical levels (Holland, 1995; Levin, 1999). System networks connect changes in individual behaviours or collective action to the broader system, driving macroscopic properties (Levin et al., 2013). The system is heavily influenced by the dynamic interactions and relationships among elements and between the sub-system and the broader system (Duit & Galaz, 2008; Preiser et al., 2018), and as such cannot be isolated from the broader environment (Juarrero, 2002). CAS must be studied in an integrative manner as the deconstruction of a CAS into individual components would ignore many of the processes that heavily shape the overall dynamic (Berkes et al., 2003; Levin, 1999).

2.3 Governance

At the broadest definition, governance "can be seen as the totality of theoretical conceptions on governing" (Kooiman, 2003, p. 4), where governing includes all actions and interactions among public and private actors addressing social concern and opportunities, and attending to or establishing functions for institutions. "Institutions" include norms, rules, laws, and policies (Chaffin et al., 2014). Governance has been academically defined and investigated by a range of social science fields, such as public administration and management, and international development and trade (Kooiman, 1999; Rhodes, 1997). Among the various definitions and classifications, there is a commonality of building blocks of rules and system qualities, cooperation, and arrangements and methods (Kooiman, 1999). Good governance, as emerging from international development aims, emphasizes participation and representation for all, accountability, efficiency, and responsiveness to system changes (Weiss, 2000). Within a SES context, governance has been described as a core subsystem of a broader social-ecological system comprised of organizations, network structures, rules, and monitoring processes (Ostrom, 2009); with good governance as a "prerequisite for effective management"; and government effectiveness as the "combination of governance quality and institutional capacity" (Lockwood, 2010, p. 755).

More tangibly, governance refers to the system of institutions, organizations, and networks involved with governing (Chaffin et al., 2014; Kooiman & Bavinck, 2005; Lockwood, 2010). Environmental governance is a said system explicitly concerned with influencing environmental actions and outcomes (Bulkeley, 2005). Lockwood, Davidson, Curtis, Stratford, & Griffith (2010) identify eight good governance principles explicitly for environmental governance: legitimacy, transparency, accountability, inclusiveness, fairness, integration, capability, and adaptability. Armitage, de Loë, & Plummer (2012) identify five core issues of environmental governance with associated policy implications. Recognizing the importance of fit and scale, for instance, then demands horizontal and vertical connections among institutions and actors to address scale mismatches. Furthermore, an emphasis on the necessity of knowledge of the complex system, and the specific value of the co-production of knowledge, calls for investigation of what organizations can function as bridges to assist in distributing information and conveying complex ideas (Armitage et al., 2012).

Within SES, interactions among governance organizations and institutions, as well as their relations with the broader system, impact system sustainability, as governance decisions can vastly alter the resource system and its relied upon the components and outcomes (Berkes & Folke, 1998; Ostrom, 2009). As such, governance designed for SES must account for the full system of actors, institutions, and networks (Dietz et al., 2003; Folke et al., 2005). Following the definitions of governance and management presented by Folke et al. (2005), governance will be used to describe structures of decision making, and management as the operationalization of said decisions.

The following sections will describe the components, forms, and analysis of governance for social-ecological systems that will allow for a discussion of specific governance network properties that can assist in achieving sustainability goals.

2.3.1 Governance of Complex Adaptive Systems

Environmental governance embedded within SES functions as a link between system components and influences system trajectory (Berkes, 2017; Chaffin et al., 2014). Consequently, governance of SES needs to acknowledge system characteristics and be able to cope with uncertainty (Dietz et al., 2003; Pahl-Wostl, 2009).

Specifically framing SES as CAS has tangible implications for governance structures and decisions (Levin et al., 2013; Preiser et al., 2018). CAS characteristics, such as non-linear relationships, feedbacks, multilevel and cross-scale interactions, emergence, and self-organization, need to be explicitly considered (Cash et al., 2006; Levin et al., 2013; Young, 2017). Non-linear connectivity reduces the ability of governance systems to define rigid system boundaries and processes (Young, 2017). CAS are composed of variables operating across different spatial and temporal levels; consequently, both governance and system analysis need to acknowledge and adequately account for the different speeds and locations of subsequent interactions (Cash et al., 2006; Folke, 2006). As CAS are open systems, the effects of external variables should be considered as the boundaries imposed on the system will be largely a product of the perspective of the observer (Berkes, 2017; Preiser et al., 2018). Interactions with external variables also make assessing CAS context-specific (Preiser et al., 2018).

Governance of CAS should seek to govern for the complexity rather than seek to eliminate it, as decisions that ignore core components of CAS often lead to poor SES outcomes (Carpenter et al., 2015; Ostrom, 2009). Governance decisions should attempt to balance levels of redundancy, heterogeneity, connectivity, and modularity to encourage desired system changes (Levin et al., 2013). Governance of CAS extends beyond that for “complex systems”, as the capacity to accommodate limited predictability does not equate to coping with thresholds and tipping points (Duit & Galaz, 2008). Resource governance regimes often create internal logics that exclude alternative approaches (Pahl-Wostl, 2007). For example, governance in prediction and control regimes, characterized by centralized and hierarchical authority, is non-compatible with greater stakeholder participation (Pahl-Wostl, 2007). Consequently, the structure and corresponding rationale of the governance system will impact governing methods and SES outcomes (Pahl-Wostl, 2009).

Traditional views of the complete separation of governance and management regimes from "pristine" ecosystems fail to address the presence of feedback loops, nested hierarchies, and uncertainties (Waltner-Toews et al., 2003). Command and control regimes follow such a reductionist understanding (Holling & Meffe, 1996) and fail to account for the characteristics of CAS (Pahl-Wostl, 2009). In particular, central bureaucracies often struggle to cope with uncertainty and respond to rapid social-ecological changes (Millennium Ecosystem Assessment, 2005).

Furthermore, environmental governance regimes inherently govern some common pool resources. Although previously framed as the tragedy of the commons (Hardin, 1968), such arguments that only centralized government or private property could sustain common resources have been surpassed by governance scholars demonstrating successes of diverse governance arrangements (Armitage, 2008; Dietz et al., 2003; Ostrom et al., 2002). However, in the absence of effective governance, resource sustainability is put in jeopardy, as many resource use problems are due to governance failures (Dietz et al., 2003; Pahl-Wostl, 2009).

Consequently, it is evident previous attempts to govern for environmental control failed to account for inherent connectivity and uncertainty in SES. Command and control also struggled to respond to rapid changes and address nested problems at the appropriate scales. Failure to account for interconnections among components and subsequent inability to react to the unpredicted effects led to changes to entire ecosystems (Scheffer et al., 2001). Alternative forms of governance that emphasize SES context and responsiveness to unpredictability are needed to sustainably address problems in complex adaptive social-ecological systems (Berkes, 2017; Chaffin et al., 2014). As many of these problems can also be framed as commons problems, with multiple users drawing upon the same resource, uncoordinated governance can lead to ineffective or exploitive management (Ostrom, 1990). Watershed governance, among these commons problems, will suffer if separate jurisdictions manage independently of each other without coordination (Sabatier, 2005; Swatuk & Wirkus, 2018).

Suitable governance regimes for common pool resources should emphasize layered institutions, social networks, and learning capacity (Chaffin et al., 2014; Dietz et al., 2003). Governance arrangements with a variety of organizations and institutions, connected through networks, and functioning at different governance levels will additionally be better suited to account for the connectivity and uncertainty within SES (Armitage et al., 2009; Bodin, 2017).

Over a decade of research on governance for complex adaptive social-ecological systems largely discusses three non-mutually exclusive threads: adaptive governance, collaborative governance, and operationalization through adaptive co-management (Berkes, 2017). All threads hold a commonality of collaboration among diverse parties, which is where this research is positioned. As this research is emphasizing modes of governance, both adaptive governance and collaborative governance will be described in the following sections.

2.3.2 Adaptive Governance

Adaptive governance emerged from a need to cope and respond to pervasive uncertainty and complexity in SES (Dietz et al., 2003; Folke, 2006; Folke et al., 2005). Dietz et al. (2003) argued that effective commons governance requires rules that evolve to cope with biophysical uncertainties, changing social conditions, and resulting feedbacks. This governance requires, at minimum, the capacity to evolve and respond to system feedbacks, as governance arrangements should compensate for a lack of ideal commons characteristics. As such, adaptive governance was presented as "managing diverse human-environment interaction in the face of extreme uncertainty" (Chaffin et al., 2014, p. 56). Adaptive governance in complex adaptive systems should: provide necessary information, deal with conflict, induce rule compliance, provide infrastructure, and prepare for change (Dietz et al., 2003). Dietz et al. (2003) also proposed a set of necessary criteria for adaptive governance. The involvement of relevant parties, such as scientists, policymakers, and resource users in the analytic deliberation for rule development increases information movement and trust-building. Institutional nesting, which places authority at multiple levels, facilitates adaptive governance at each level and creates redundancies. A mix of institution types, such as markets, networks, and governments, can increase rule variety and subsequently compliance (Dietz et al., 2003).

Folke et al. (2005) frame adaptive governance as an expansion of the framework of ecosystem-based management to incorporate broader social aspects and a specific focus on governance for periods of rapid or turbulent change. Adaptive governance requires the linking of diverse actors at various levels in an effort to account for interconnected SES dynamics and uncertainties. Folke et al. (2005) presented four essential and interacting components of adaptive governance: knowledge generation of system dynamics, continuous learning through implementation, flexible and multilevel governance arrangements, and capacity for dealing with change. The criteria for successful adaptive governance also emphasizes collaboration, power-sharing, participation, social memory, and social networks (Folke et al., 2005).

Adaptive governance has been expanded and elaborated upon, both theoretically and empirically, since these two foundational publications (Armitage et al., 2008; Folke, 2006; Pahl-Wostl, 2009; Plummer et al., 2013). This expansion includes an in-depth discussion of the relationship between adaptive governance and the methods in which it is operationalized in practice (Chaffin et al., 2014). Adaptive management, one such method, emphasizes the necessity of considering environmental, economic, and social dimensions throughout the planning and implementation process, and constantly learning through experimentation and monitoring (Holling, 1978; Walters, 1986). While the operation of adaptive management requires institutions and environments that facilitate learning (Cosens et al., 2014; Cosens & Williams, 2012; Folke et al., 2005), the learning essential to adaptive management is also a necessary element of adaptive governance (Pahl-Wostl et al., 2007). Adaptive management, then, greatly benefits from flexible institutions with social connections to others with overlapping jurisdictions that facilitate learning (Folke et al., 2005). This component of overlapping but coordinated responsibility is further explored in both polycentric and collaborative governance.

2.3.3 Polycentric & Collaborative Governance

Problems in CAS are not confined to a particular governance level, and as such, governance that functions through monocentric, isolated entities provides a poor fit (Berkes, 2017). In contrast to monocentric institutions, polycentric systems are comprised of nested hierarchical units each with decision-making authority within a specific domain (Ostrom, 2010), where complete authority does not reside at any one level (Pahl-Wostl, 2009). Consequently, polycentric governance regimes are particularly affected by the nature and strengths of the institutions, organizations, and networks involved (Pahl-Wostl et al., 2012), and by the multi-level and cross-scale effects within nested governance systems (Duit & Galaz, 2008). Polycentric governance regimes are argued to be more adaptive and thereby less adversely affected or deteriorated by rapid change (Ostrom, 2005, 2010). Responding to non-linear interaction and cross-scale dynamics of CAS requires multi-level governance with actors linked both horizontally and vertically (Ostrom, 2005). Polycentricity can allow for a better match between the scale of the problem and the appropriate level of governance (Biggs et al., 2012; Ostrom, 2010).

Building on this emphasis of decentralization, collaborative governance arrangements, which draw upon local and scientific knowledge, can assist in addressing complex environmental problems (Armitage et al., 2012; van Tol Smit et al., 2015), as such arrangements are suggested to integrate various knowledge types, generate new knowledge through social learning, and efficiently spread knowledge through the network (Bodin, 2017). Collaborative governance was defined by Emerson, Nabatchi, & Balogh (2012, p. 2) as “the processes and structures of public policy decision making and management that engage people constructively across the boundaries of public agencies, levels of government, and/or the public, private and civic spheres to carry out a public purpose that could not otherwise be accomplished.” Collaborative governance for environmental issues often involves diverse stakeholders with heterogeneous knowledge bases and types (van Tol Smit et al., 2015), and the recognition of multiple sources and types of knowledge can help address problems associated with social-ecological uncertainty (Armitage et al., 2009). Collaborative governance arrangements also may facilitate the dense social networks that improve commons governance through facilitating social learning (Klasic & Lubell, 2020; Ostrom et al., 2002; Pahl-Wostl et al., 2012).

However, collaborative governance is also not necessarily the best configuration for all problems or contexts and has been criticized as being overly romanticized in literature as the end-all solution (Evers et al., 2016). Collaboration can be an ineffective endeavour for governance due to power imbalances and opposing interests or backgrounds (Bodin, 2017), and even when collaboration is not directly impeded by opposing goals, the arrangement may still not provide the necessary policy advancements. While collaborative governance arrangements can be highly effective in addressing complex environmental problems, characteristics of the proposed collaboration, actors, and problem should be considered before assuming it to be an applicable strategy, as the effectiveness of collaboration is influenced by the nature of social dynamics and social-ecological connectivity at various spatial and temporal levels (Bodin et al., 2016). Attempts to address complex SES challenges with a scalar mismatch between the governance system and targeted environmental issues may simply exacerbate problems (Bodin, 2017; Di Baldassarre et al., 2019).

Collaborative governance has been operationalized through co-management, which divides power and responsibility between government and local actors (Berkes et al., 1991). Co-management involves collaboration among and between actors of varying jurisdictional and institutional levels that can be described through horizontal and vertical connectivity (Pinkerton, 1994), and is a process of continuous problem-solving within these networks (Carlsson & Berkes, 2005). Co-management was merged with adaptive management to form adaptive co-management, and as such combines social connectivity with the experimental and experiential (Plummer et al., 2012). With a SES perspective that emphasizes the value of diverse knowledge types, adaptive co-management is a system of resource management, adapted for the context, involving heterogeneous organizations working across scalar levels, with a specific focus on social learning and institutional development (Armitage et al., 2009; Olsson et al., 2004).

The commonalities among adaptive and collaborative governance and adaptive co-management lie within the essential component of social connections among various governance actors and organizations that facilitates multi-level and cross-scale interactions as well as support learning capacity (Armitage et al., 2009; Berkes, 2017; Folke et al., 2005). The social networks that form essential components of these governance strategies facilitate the broad participation and experimentation across a multi-level governance structure (Bodin & Crona, 2009; Chaffin et al., 2014; Folke et al., 2005). As such, network structures of governance arrangements are of keen interest.

2.4 Networks in governance research

Characterizing social-ecological systems as complex adaptive systems provides a rationale to view governance as a network, as a CAS is comprised of independent parts that exchange energy, matter, and/or information (Costanza et al., 1993). The whole system can be viewed as a process as the dynamic relationships between parts influences overall characteristics (Duit & Galaz, 2008), and the relationships can be considered networks at nested scalar levels (Levin, 1999). A governance arrangement is embedded in the broader CAS and is also naturally a system of components (individuals, organizations, institutions) interacting in various ways, and as such lends itself to analysis via a network perspective.

Network analysis has been employed in different disciplines for various contexts over the last century (Borgatti et al., 2009; Freeman, 2004), ranging from small social networks (Padgett & Ansell, 1993) to vast internet networks (Java et al., 2007). The application of network science across both natural and social sciences has led to analysis of a broad variety of nodes and relations (Borgatti et al., 2009), and the development of underlying theory (e.g. Freeman 1978, Miller McPherson et al. 2001, Goodreau et al. 2009) and methods (e.g. Snijders et al. 2006, Wang et al. 2013). A social network refers to a set of social nodes connected through relations (J. Scott, Carrington, Marin, et al., 2015), and social network analysis provides a method to quantify the relations between nodes as well as the network structure (Borgatti et al., 2009).

A governance system comprised of different interacting components naturally lends itself to a network perspective. Natural resource governance, in particular, following the ideas of adaptive governance, adaptive co-management, and polycentric governance explained in the previous sections, is well suited to be explored through network analysis, as actors, rules, and resources interact in complex ways that impact outcomes (Bodin & Crona, 2009; Bodin & Prell, 2011; Janssen et al., 2006). Network analysis has been used to map knowledge and information flows (Barnes et al., 2019), communication and collaboration (Alexander et al., 2017; Baird et al., 2016; Bodin et al., 2020; Bodin, Nohrstedt, et al., 2019; Locatelli et al., 2020), policy connections (Hedlund et al., 2021; Metz et al., 2020), among other relations (Barnes et al., 2020; Bodin & Tengö, 2012). As network structure impacts overall behaviour and function (Valente, 2012), not all networks are suitable for pursuing a desired outcome (Bodin, 2017) and network characteristics of collaborative governance arrangements are of particular interest (Baird et al., 2019; Bodin et al., 2016). As such, specific network properties have been explored in-depth to better understand what properties may contribute to fruitful collaborative governance arrangements.

Network analysis provides a basis to quantify the structural network properties and investigate their subsequent impacts on the social processes being studied. Quantifying overall network characteristics can reveal general properties through descriptive statistics such as density, reciprocity, centralization, and cohesion, among others (Bodin & Crona, 2009).

Density is a metric calculated by the number of present ties divided by the number of possible ties (J. Scott & Carrington, 2011) (Table 2.1). High density has been suggested to improve the potential for collaboration (Olsson et al., 2004) and is a commonly included metric in the analysis of governance networks (Calliari et al., 2019; Ceddia et al., 2017; Chaffin et al., 2016; Fliervoet et al., 2016). However, density is difficult to compare between networks of different sizes (Anderson et al., 1999).

Whole network centralization is a metric calculated through the variability in centralities among nodes in the network in comparison to a perfectly centralized network of the same size (Freeman, 1978). High network centralization indicates a concentration of influence. Ideal network centralization for a governance network heavily depends on the context, with considerations for power imbalances (Morrison et al., 2019) and the phase of governance process very necessary (Bodin et al., 2006; Chaffin et al., 2016).

Table 2.1: Whole network properties

Network property	**Definition**
Density	The number of present ties divided by the number of possible ties (J. Scott & Carrington, 2011)
Centralization	Describes the extent cohesion is organized around focal nodes; the ratio of the actual sum of differences in node centrality scores to the maximum possible sum of differences (Freeman, 1978)

Furthermore, specific internal network structures can be analyzed to understand the active social forces impacting the network, as actors' choices of relationships in collaborative arrangements drive the emergent structure, which then impacts both individual and collective action (Berardo & Scholz, 2010). For example, Berardo & Scholz (2010) argue policy actors favour bridging capital and central coordination in early phases of network creation as extensive ties and centralization are beneficial for information sharing and addressing coordination problems. Such bridging network structures include open two paths and coordination through central actors (Table 2.2). However, this benefit diminishes for more complicated collaborative or complex problems that require trust and reciprocal bonding relationships (Berardo & Scholz, 2010).

Table 2.2: Sub-network properties

Network property	**Definition**
Bridging Structures	Open two paths and centrality that assist in coordination dilemmas (Berardo & Scholz, 2010)
Bonding Structures	Reciprocal relationships and transitive triads that assist in cooperation dilemmas (Berardo & Scholz, 2010)

Further research has been completed to better understand the contextual properties and forces that favour either bridging or bonding structures in collaborative governance networks. McAllister et al. (2017) investigated policy forums in Australia for the 2010 myrtle rust incursion and found there was more bonding capital at national scales, supporting their hypothesis that increased bonding would be necessary for settings where decisions need to be negotiated. They found no significant incidence of bridging capital at any level, not supporting the hypothesis bridging capital would support implementations on the ground. In contrast, Bodin et al. (2020) analyzed collaborative relationships in four UNESCO Man and Biosphere Reserves and proposed bridging structures would be prevalent and sufficient for all collaboration problems when overall network trust was high. Results displayed a tendency for bridging structures to support collaboration in systems with greater stability and by extension, perceived trust. This tendency coincided with the cases with highly active facilitators, although the authors suggest the contextual stability may provide a better explanation than the active facilitation in the prevalence of bridging structures.

Bonding structures of reciprocity and transitive triads are impactful in collaboration networks (Table 2.2). Triad transitivity refers to a structure of three links among three nodes, creating a closed triangle (Goodreau et al., 2009). It is commonly thought of as the tendency for actors to establish ties with friends of friends, although there are various rationales for the phenomenon (Bodin, Nohrstedt, et al., 2019). Transitive network structures have been proposed to be prevalent when risk perception is high (Berardo & Scholz, 2010). This risk, for example, could pertain to potential partner defection or uncertain benefits of a collaborative tie (Nohrstedt & Bodin, 2019). Transitive triads, also called network closure, can build trust and reputation and can be used to exert social pressure. A positive propensity for social network closure can be impactful on information sharing (Locatelli et al., 2020) and can contribute to measures of social-ecological fit (Barnes et al., 2019). The additional ties represented by bonding over bridging structures may also contribute to network redundancies that are beneficial in allowing a network to persist and reorganize (Alexander et al., 2017). Reciprocity refers to the tendency for a directed tie to be indicated by both nodes in a dyad. Reciprocal ties in part reflect stronger relationships (Prell et al., 2009). Some relationships, such as collaboration, are thought of as necessarily reciprocal relationships (Jasny et al., 2019). Understanding the evolution of collaborative governance arrangements requires particular attention to the relative balance between bridging and bonding structures, as such structures both reflect and impact levels of trust, conflict, and exchange (Robbins & Lubell, 2020).

Network context can be incorporated into the analysis through the inclusion of nodal attributes. Node attributes such as organizational type, spatial jurisdiction, or formal authority impact behaviour and consequently relationship choices (Bodin & Nohrstedt, 2016; Fischer & Jasny, 2017; Hedlund et al., 2021; Jasny et al., 2019). Homophily, the social process of actors disproportionally forming ties with like actors (McPherson et al., 2001), can heavily influence network structure (Barnes, Lynham, et al., 2016; McPherson et al., 2001). Sharing attributes can facilitate communicating complex information and mutual understanding (Prell et al., 2009), but can also lead to the development of distinct social groups, which can trap knowledge and behaviours in network communities (Crona & Bodin, 2011; McPherson et al., 2001).

Beyond mere homophily, organization type can impact the overall role of an organization within the broader governance landscape and subsequently choices of social ties. For instance, municipalities often hold unique roles in water governance networks as they can be components in top-down governmental structures but also engage in bottom-up collaborations (García et al., 2019). Said duality in roles may emerge in network structure through tie selection, and as such, specific inclusion of organizational attributes is important in network analysis to present additional insights. For example, the separation of government from non-governmental actors in the network analysis to understand the supposed shift from top-down government to governance for floodplain management revealed the respective importance of the latter (Fliervoet et al., 2016).

Within node attributes, the inclusion of jurisdictional or spatial levels can further reveal insights in multi-level governance networks (Guerrero, Mcallister, et al., 2015; Hamilton & Lubell, 2018; Hileman & Lubell, 2018). Hamilton and Lubell (2018) argued transaction costs of collaboration differed between institutional policy levels, with higher costs incurred at higher institutional and spatial levels. In investigating the Lake Victoria region climate change adaptation network, the authors found collaboration was significantly more prevalent when actors shared policy forums and significantly less prevalent at higher institutional and spatial levels. As such, actors were most likely to collaborate with mutual lower-level policy forum participation (Hamilton & Lubell, 2018). However, in a separate context, analysis of collaboration in the Whidbey Basin salmon restoration network displayed a much lower density of ties among local organizations than between either local and regional organizations or among regional organizations (Sayles & Baggio, 2017b). While context will heavily influence specific network structures in multi-level governance arrangements, the specific inclusion of scalar attributes can contribute to developing a better understanding of cross-scale collaboration patterns (Guerrero, Mcallister, et al., 2015).

Furthermore, the inclusion of nodal attributes allows for further specific analysis into network roles. Relationships that join different actor types can facilitate connections across administrative levels (Hamilton et al., 2020), better coordinate emergency responses (Lind et al., 2008), and improve the diffusion of information (Levy & Lubell, 2018). This role of joining otherwise unconnected actors is known as brokerage, defined by Marsden as a process “by which intermediary actors [brokers] facilitate transactions between other actors lacking access to or trust in one another” (Marsden, 1982, p. 202). Gould and Fernandez (1989) classified five distinct brokerage chains based on categorical attributes of the three involved actors (see Section 3.4.1 for a description of all five chains). Chains where the broker and another actor share organizational type were classified as “insider” roles, and chains where the broker was the only representative of organizational type was an “outsider role” (Gould & Fernandez, 1989). Fernandez and Gould (1994) found both actor attributes and the brokerage chain classification impacted the benefits of brokerage. The effect of heterogenous brokerage is further impacted by the larger social context, as strong divides or a lack of trust between actor groups may reduce the productivity of brokers (Barnes, Kalberg, et al., 2016). Hamilton et al. (2020) pioneered a methodological update to assess heterogenous brokerage through exponential random graph models, and in analyzing two separate regional environmental governance collaboration networks found clear examples of brokerage chains connecting actors at different spatial levels, deemed as vertical brokerage chains. However, limited research on brokerage between actor groups (Hamilton et al., 2020) and how context impacts brokerage roles (Barnes, Kalberg, et al., 2016) calls for additional research into the role of brokerage in collaborative governance arrangements.

Specific application of network analysis within a SES framing emerged from both research on the existence and importance of social networks in resource management (Bodin & Crona, 2009; Hahn et al., 2006; Olsson et al., 2004) and specific calls for a better understanding of fully articulated social-ecological networks (Janssen et al., 2006; Norberg & Cummin, 2008). The specific inclusion of ecological considerations within social network analysis provides a quantitative method to advance understanding of social-ecological systems (Bodin, 2017; Bodin & Tengö, 2012). Inclusion of the ecological system in analysis through ecological relations connecting social nodes (e.g. Hamilton et al. 2019) or a separate ecological network (e.g. Guerrero et al. 2015a) provides a specific route to analyze the connections among and between social and ecological system components, a core feature of social-ecological systems. Social-ecological network (SEN) analysis has grown since Ekstrom and Young (2009) presented it as a network approach to address the problem of fit (Sayles et al., 2019). Social-ecological fit has been a prominent focus within SEN research (Sayles et al., 2019) and will be further described in the following section.

2.5 Social-Ecological Fit

SES research has repeatedly acknowledged the need for institutions to align with both social and ecological processes, and to take into account varying spatial and temporal levels (Folke, 2007; Lebel et al., 2013; Ostrom, 2010; Young, 2002). The extent to which this occurs falls under the problem of fit, sometimes referred to as institutional or social-ecological fit (Guerrero, Bodin, et al., 2015). Failure of institutions to fit the SES they govern may result in the degradation of ecosystem services; consequently, the identification of misfit may contribute to identifying critical gaps in governance (Ekstrom & Young, 2009).

The definition for fit provided in a 1998 International Human Dimensions Program of Global Environmental Change working paper presented the effectiveness of social institutions as a product of a fit with the social and biophysical landscape in which they operate (Folke et al., 2007). With the allusion to ecosystems and institutions as independent but connected CAS, fit was specified to include patterns and interactions across spatial and temporal levels (Folke et al., 2007).

Fit has been conceptualized, described, and measured in the literature in varying ways. The topic has been approached with focuses on institutions (Ekstrom & Young, 2009; Lebel et al., 2013; Ostrom, 1990), policy outcomes (Meek, 2013), collaborative governance (Becker, 2020; Bergsten et al., 2014; Guerrero, Bodin, et al., 2015; Sayles & Baggio, 2017b), and structural approaches (Bodin et al., 2014, 2016; Bodin & Tengö, 2012). Epstein et al. (2015) present three generalized categories of fit between institutions and their contexts: ecological, social, and social-ecological (SE) fit. Ecological fit addresses the spatial, temporal, and functional alignment between the institution and the environmental problem being addressed. Spatial misfit arises when the jurisdiction of the institution is too narrow or broad to adequately address the environmental problem. Temporal misfit arises when institutions cannot appropriately respond to rapidly changing environmental conditions or account for slow variables and thresholds. Functional fit refers to the cohesive governance of connected ecological systems. Social fit consists of considerations of institutions with respect to their jurisdiction and the values, beliefs, and participation of their stakeholders (Epstein et al., 2015). Such a perspective is based on polycentric governance (Ostrom, 2010), and emphasizes the heterogeneous needs of the stakeholders, social learning, and meaningful participation (Epstein et al., 2015). Both ecological and social fit need to be considered with the other measures as short-term attempts to increase ecological fit may result in long-term impacts on social fit and vice versa. SE fit refers to matching institutions to the broader SES through indicators of sustainability. SE fit seeks to maximize SES outcomes through specific institutional arrangements.

The literature on SE fit has two defining attributes. First, the fit of an institution must not be assumed but rather related to a measure of success, and second, as context greatly impacts potential success, contextual attributes must be specified (Epstein et al., 2015). Consequently, SE fit must be assessed for specific governance systems embedded in their context and not for theoretical arrangements.

The explicit framing of SES as complex adaptive systems provides the theoretical foundation to link governance to ecological resources together through a network perspective (Bodin et al., 2014; Bodin & Tengö, 2012; Guerrero, Bodin, et al., 2015). A social-ecological network perspective allows for the identification of interdependencies between social actors, which facilitates an analysis of the characteristics of any present collaborative governance arrangements (Bodin & Tengö, 2012), and should necessarily incorporate all relevant actors into the analysis (Ekstrom & Young, 2009). When a collaborative governance arrangement arises, the collaborative network needs to fit both the collective action problem and underlying environmental problem (Bergsten et al., 2019; Bodin, 2017); subsequently, SE fit refers to the alignment of the structure and nature of the governance network to the biophysical problem. SE fit uses a multi-level network approach, where both the collaborative governance arrangement and ecological system are described as separate but interconnected networks comprised of nodes and connections (Bodin, 2017; Bodin & Tengö, 2012).

Network-based SE fit can broadly be described through two dimensions of network characteristics: horizontal and vertical fit (Bodin, 2017; Bodin & Crona, 2009). Horizontal fit refers to the connections among nodes within layers, while vertical fit refers to connections between ecological and social layers and between levels in the collaborative network. Horizontal fit is based on the understanding that since collaboration can promote sustainable use of shared or interconnected resources, SE fit will increase if social connectivity is paired with ecological connectivity (Bergsten et al., 2014; Guerrero et al., 2013). Vertical fit describes direct connections between social and ecological components and between social components at different administrative levels (Alexander et al., 2017). The vertical connectivity of social nodes at varying administrative levels (e.g. local, regional, federal) improves alignment for multi-level ecological phenomena (Armitage et al., 2009; Guerrero et al., 2013).

There is an emerging use of SE network analysis for empirical assessments of fit (e.g. Alexander et al., 2017; Barnes et al., 2019; Bodin et al., 2014; S. Wang et al., 2019). For example, analysis of governance in the Heihe River Basin in China through a framework of horizontal and vertical ties demonstrated that increased alignment of social and ecological structures improved social-ecological management (S. Wang et al., 2019). Additionally, a comprehensive analysis of five coral reef fishing communities in Kenya associated social-ecological network closure with improved ecological conditions (Barnes et al., 2019).

Multi-level social-ecological networks can be further understood and analyzed through the investigation of small, internal network configurations (Bodin et al., 2016; Bodin & Tengö, 2012). These smaller configurations, known as building blocks or motifs, are specific connections among and between social and ecological nodes (Bodin & Tengö, 2012). Drawing upon decades of SES governance literature, specific motifs can be attributed to enhance or hinder fit. For example, in situations where two actors share a common resource, making decisions independent of the other can lead to ineffective management or overexploitation (Ostrom, 1990). Transformed into a motif, this common pool resource problem can be visualized as two nodes in the social network both connected to the same node in the ecological network (Figure 2.1) (Bodin et al., 2014). A connection between social nodes would facilitate reaching mutual agreements on resource use (Bodin et al., 2014).

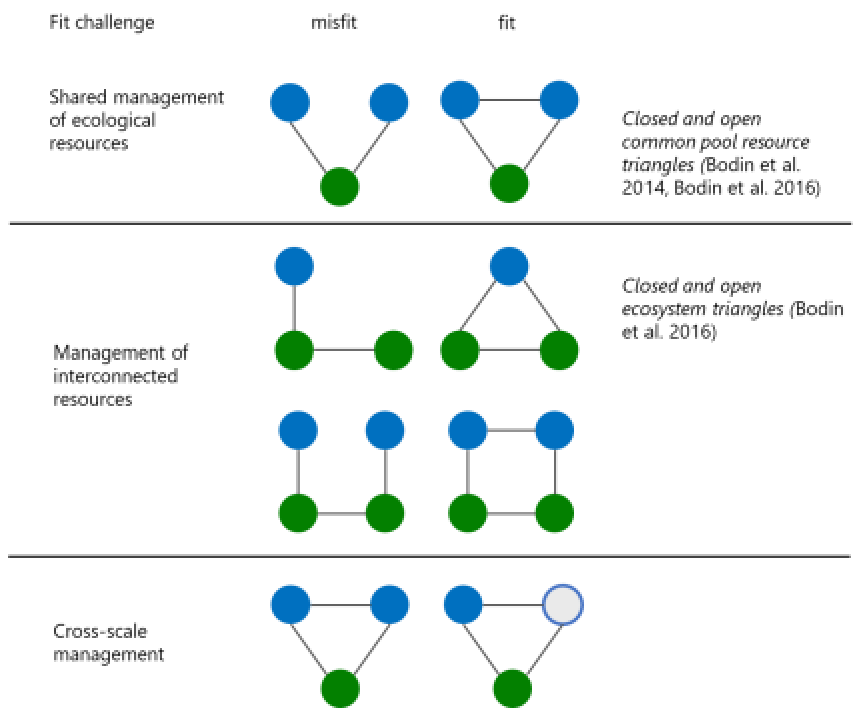


Figure 2.1: Motifs depicting social-ecological misfit and fit. Blue nodes indicate actors and green nodes indicate ecological components. The blue and gray circles indicate actors operating over different scales. Adapted from Guerrero, Bodin, et al. (2015)

Shared management of ecological resources presents one social-ecological fit challenge, and two additional challenges can be conceptualized through motifs: management of interconnected resources and cross-scale management (Guerrero, Bodin, et al., 2015). Social-ecological fit, stemming from the acknowledgment of ecosystems and institutions as connected CAS (Folke et al., 2007), recognizes the interconnected nature of ecological components (Ekstrom & Young, 2009; Galaz et al., 2008). As such, independent management of interconnected resources may lead to adverse effects that may escalate through feedbacks and threshold effects (Scheffer et al., 2001), as ecosystem changes are rarely confined to one component (Levin, 1998). Ties from the social actor to only one of two connected ecological nodes may perpetuate misuse, as any adverse effects on connected ecological components may not be recognized and can lead to severe biophysical changes (Bodin, 2017; Bodin et al., 2014). Ensuring connections to both ecological components closes the social-ecological loop and strengthens the feedback felt by the social node after use or management changes, as the social node can monitor changes in both ecological components (Alexander et al., 2017; Bodin et al., 2014). Coordinated management of interconnected components pertains to both spatially condensed ecological networks, such as trophic interaction in a coral reef (Barnes et al., 2019) or forest patches (Bodin et al., 2014; Bodin & Tengö, 2012), as well as geographically large networks, such as watersheds (Sayles & Baggio, 2017b; Widmer et al., 2019).

The last social-ecological fit challenge, cross-scale management, arises as management is often planned for discrete spatial areas yet biophysical systems operate simultaneously over continuous spatial levels (Guerrero, Bodin, et al., 2015). Scale mismatch occurs when management is applied at one level that does appropriately align with the problem (Cumming et al., 2006; Guerrero et al., 2013; Guerrero, Bodin, et al., 2015). Guerrero, Bodin, et al. (2015) and Guerrero, Mcallister, et al. (2015) operationalize cross-scale management within the specific definition of scale as spatial area; however, this concept can be applied in additional contexts as this mismatch can pertain to spatial, temporal, and functional scales (Cumming et al., 2006). As this research is operationalizing the definitions of scale and level presented by Cash et al. (2006), a congruent description of this challenge would be multi-level fit to maximize scale matching. Furthermore, the scale mismatch is not restricted to management, as modern governance, of both collaborative and top-down varieties, involves institutions operating over varied jurisdictional levels (Lubell, 2013). Social connections between these institutions or actors can contribute to scale match by facilitating coordinated decisions and implementation at multiple levels (Guerrero, Bodin, et al., 2015; McAllister et al., 2015; Sayles & Baggio, 2017b).

The presence and frequency of motifs can provide valuable information about relationships among and between ecological and social networks (Bodin et al., 2016; Guerrero, Bodin, et al., 2015). Advancements in social network analysis have allowed for analyzing multilevel social-ecological networks through considering the relative prevalence of specific motifs using multilevel exponential graph models (ERGMS) (P. Wang et al., 2013). The collected social-ecological networks can be understood as the dependent variable and the 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. As such, a positive and significant parameter for social-ecological network closure (Figure 1) would indicate a tendency for social connectivity when managing common-pool resources (Bodin et al., 2016; Guerrero, Bodin, et al., 2015).

However, there are limitations to solely using a network perspective to understand SE fit. Fit is heavily embedded in context and is thus heavily influenced by institutional attributes beyond connectivity (Epstein et al., 2015), such as institutional capacity (Lebel et al., 2013). For example, the distribution of responsibilities and capacities among nodes may impact governance effectiveness (Alexander et al., 2017). During the examination of social ties for social-ecological fit in marine reserve networks in Jamaica, a functional fit challenge hampered the application of new management strategies due to rigid and narrow mandates of involved government agencies. Overcoming such barriers would require a redistribution of mandates or extensive national coordination and collaboration (Alexander et al., 2017). As the capabilities of the collaborative governance arrangements, and subsequent governance outcomes, may be impacted by the formal responsibilities and capacities of the individual actors and institutions in the network, there is an additional need to consider the functional fit of the network (Alexander et al., 2017; Epstein et al., 2015).

2.6 Key Literature Gaps

Further research is needed to understand how specific network properties of collaborative governance arrangements can contribute to adaptive governance and SE fit in social-ecological complex adaptive systems (Bodin, 2017). Networks are inherent in governance regimes incorporating multiple organizations and institutions over various governance levels and have been specified as critical components of adaptive governance (Dietz et al., 2003; Folke, 2006; Folke et al., 2005). As network context, composition, and structure can impact governance outcomes, more empirical research is needed into specific structures within collaborative governance arrangements addressing sustainability challenges (Baudoin & Gittins, 2021; Berardo & Lubell, 2019; Bodin et al., 2020; Bodin & Crona, 2009; Guerrero et al., 2020). Specifically, more research is needed to examine in what contexts specific network structures, such as the previously described bridging and bonding structures, can contribute to addressing a collective action problem (Bodin et al., 2020). Network structures can impact information sharing, trust, and risk, and there is a need to better understand how additional factors will impact levels of trust and risk (Bodin et al., 2020), such as collaboration across subgroups (Robbins & Lubell, 2020).

Furthermore, as the relative involvement and relationship choices of different organization types at different scales will impact network structure (Fliervoet et al., 2016; Locatelli et al., 2020; Sayles & Baggio, 2017b), there is reason to investigate how organizational composition and scale may impact a transboundary flood planning network. Specifically, there is cause to investigate how non-governmental organizations are involved in flood planning networks and possible activity differences between government and non-government organizations (Fliervoet et al., 2016). Addressing this specific research gap will also contribute to the ongoing discussion of the specific role of government agencies in broader governance networks (Becker, 2020; Fliervoet et al., 2016; Kuehne et al., 2020; Serra-Llobet et al., 2016). Connections among organizations functioning at different governance levels are necessary to address scale mismatch (Cumming et al., 2006; Duit & Galaz, 2008); however, as the relative activity of organizations at different scales is heavily impacted by the context (Hamilton & Lubell, 2018; Sayles & Baggio, 2017b), there is reason to investigate how scale impacts collaboration in a transboundary watershed that is impacted by its broad geographic area and multiple jurisdictional levels (Plummer et al., 2016). Additionally, it is currently uncertain whether organizations pursue within level or cross-level ties for information sharing (Koontz, 2021). Further research is needed into how brokerage roles differ between groups in governance networks (Hamilton et al., 2020), and how those roles are shaped by network context (Barnes, Kalberg, et al., 2016), particularly as brokerage impacts knowledge flows (Levy & Lubell, 2018; Locatelli et al., 2020) and management priorities (Hamilton et al., 2020). As municipalities have been argued to hold unique roles in water governance broadly (García et al., 2019), and have critical functions in flood risk management specifically (Becker, 2021), it is important to inquire if municipalities hold a unique role in a regional flood planning network.

There is foremost a need for an increased understanding of social-ecological fit at regional scales (Bodin, 2017). Specifically, the use of SE network analysis for empirical assessment of SE fit is still an emerging research stream requiring additional contributions to begin to build a more comprehensive understanding of the relative occurrence of fit and misfit in governance networks (Bodin et al., 2016; Guerrero, Bodin, et al., 2015; Widmer et al., 2019). Additionally, a SE network has not yet been used to assess SE fit for flood planning at the basin scale. There is also potential to use qualitative analysis to understand how formal responsibilities and capacities of the individual actors and institutions in the network impact SE functional fit (Alexander et al., 2017; Epstein et al., 2015).

Chapter Three: Methods

3.1 Introduction

This study aligns best with a pragmatic approach, which recognizes that knowledge cannot be separated from human experiences (Morgan, 2017) and as such seeks to use the most appropriate method to address the research question (Yvonne Feilzer, 2010). Pragmatism can act as a guide for both qualitative and quantitative methods as the pragmatic approach prioritizes the cycle of developing a research design to address the research question (Morgan, 2017). This study employs a convergent parallel mixed methods research design (Creswell, 2009), specifically using a social-relational network perspective, which seeks to quantity relationships that objectively exist (Bailey, 2014).

This research is positioned within sustainability science and consequently recognizes social-ecological connectivity, and seeks to address a solution-oriented question with a transdisciplinary approach (Kates, 2011). To facilitate the transdisciplinary approach, this research was conducted within the formal memorandum of understanding between Brock University (ESRC) and World Wildlife Fund - Canada that is the Partnership for Freshwater Resilience. World Wildlife Fund - Canada provided a key informant to assist with this research.

3.2 Study Region

Since time immemorial the Wolastoqiyik (Maliseet) people have referred to this river as the Wolastoq, the “good and bountiful river” (St. John River Society, 2008). The watershed lies within the unsurrendered and unceded traditional lands of Wolastoqiyik (Maliseet). The Wolastoq/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) (Figure 3.1). 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 (Currie et al., 2020; Kidd et al., 2011), such that in 2013 the river was designated as a Canadian Heritage River (Plummer et al., 2016). With 400 years of colonial settlement history and environmental impacts, watershed health assessments have demonstrated the region is currently threatened by habitat loss, deforestation, water quality degradation, and climate change (Currie et al., 2020).

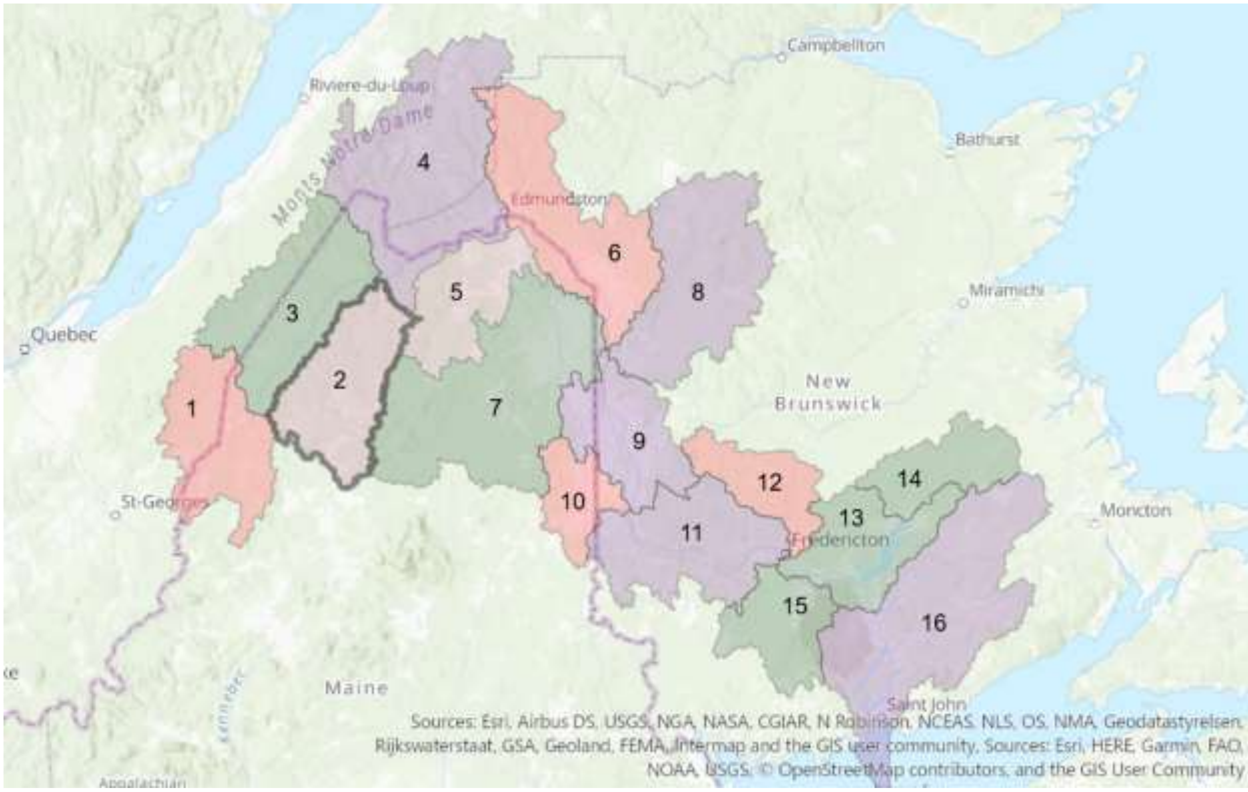


Figure 3.1: Map of the St. John River Basin divided into sub-sub basins (Government of Canada, 2020; USDA-NRCS, 2020). Numerical labels were assigned to provide respondents a mechanism to indicate flood planning locations.

The St. John River historically experiences two types of flooding: ice-jam flooding and open water flooding (St. John River Society, 2008). The breakup of winter ice cover in early spring may cause a first increase in water levels, and combined spring melt and precipitation may cause a second high water level further into the season, known as the spring freshet (St. John River Society, 2008; Woodhall-Melnik & Grogan, 2019). 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 & 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 & 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.

3.2.1 Flood planning in the region

Canadian provinces are constitutionally responsible for water legislation regarding water supply and resource management, including drinking water supply, environmental protection, and accountability (Hill et al., 2007). However, the distribution of responsibility purveying to water resources between provincial departments differs throughout the country. Concerning New Brunswick, multiple provincial agencies, intergovernmental agencies, and partnerships with federal agencies have key water-related roles and responsibilities (Department of Environment and Local Government 2018). Purview with regards to flooding, in particular, is distributed among provincial agencies (specifically the Department of Environment and Local Government and the Department of Justice and Public Safety), and among regional governments (Regional Service Commissions) and municipalities (Government of New Brunswick, 2014).

In the current Flood Risk Reduction Strategy, the province identified three primary objectives focused on the identification, inclusion, and mitigation of flood risk, with an emphasis on infrastructure (Government of New Brunswick, 2014). However, the 2020 Climate Change Action Plan Progress Report only identifies "continuing to update flood hazard maps" as a current provincial action item to address flooding concerns (Department of Environment and Local Government, 2020). There is ongoing work at regional and municipal levels to address flooding concerns, in part in partnership with the Federal Government, Provincial Government, and regional non-governmental organizations. For instance, the Federal National Disaster Mitigation Program provided partial funding for four flooding mitigation projects for the City of Fredericton and the City of Saint John in 2019 (Public Safety Canada, 2019). There is also ongoing engagement between municipalities and non-governmental organizations in compiling and operationalizing climate change adaptation plans, which largely include flood planning (Brogan et al., 2020; City of Fredericton, 2020).

3.3 Data Collection and Network Construction

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).

3.3.1 Establishing Network Boundaries

In this study, organizations were chosen as the node level (Baird et al., 2016; Fliervoet 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 & 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 Bain 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 (J. Scott, Carrington, Marin, 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 partner's 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 for large organizations (Fliervoet et al., 2016). The ecological network was restricted to the St. John River watershed.

<u>3.3.2 Network Gathering</u>

3.3.2.1 Network 1: Actors' collaboration network

A sociometric survey design was used to collect whole-network data (J. Scott, Carrington, & Marsden, 2015). The questionnaire was developed to collect descriptive information, network data, and qualitative data on impacts and barriers to collaboration. A pilot questionnaire was tested by two additional researchers, a key informant, and a fellow graduate student. Feedback was received and implemented into a final version in Qualtrics software (Appendix A). A questionnaire was distributed via email to the identified individuals with an introductory letter 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 with whom he had previous work repour by either phone or email. The student research made phone calls to the remaining English-speaking non-respondents.

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). Recognition is often a better method than recall in generating complete networks (Marsden, 1990). Respondents were first asked to select the organizations they communicate with for flood planning, and asked to consider exchanging information or advice, coordinating actions, or collaborating as criteria for selecting organizations. Selected organizations were then presented for recognition in the subsequent collaboration question.

Respondents were asked to select the organizations they collaborate with when making flood planning decisions, and to indicate this collaboration on a 4-option scale based on the frequency of interaction: *Rarely* (1-2 times per year), *Occasionally* (3-4 times per year), *Frequently* (6-12 times per year), or *Regularly* (2 or more times per month) (Alexander et al., 2017). 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, Nohrstedt, et al., 2019). Respondents were encouraged to consider all flood planning activities conducted since 2018 when answering.

Respondents were asked to indicate organization type as well as organization jurisdiction through either political or watershed boundaries. Additional information on flood planning activities was collected but lies outside of the scope of this research.

3.3.2.2 Network 2: Ecological network

The ecological network 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 & Baggio, 2017b; Widmer et al., 2019). The information for the ecological network is 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.

3.3.2.3 Network 3: Social-Ecological network

Respondents were asked to indicate from a labelled map (Figure 3.1) all of the sub-sub basins their organization conducts flood planning within (Guerrero, Bodin, et al., 2015). These responses were used to create the social-ecological network (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.

3.3.3 Network treatment

Participant responses on collaborative relationships were transformed from the indicated frequency (*Rarely, occasionally, etc.)* to a corresponding value of 1 to 4, where 1 corresponded to the least frequent and 4 to the most frequent. Responses were then dichotomized from valued indicators to binary indicators, including all reported collaborative strengths as a tie (Alexander et al., 2017). Responses from multiple individuals in the same organization were coalesced into a singular response using the maximum value reported (Baird et al., 2016). Matrixes were then symmetrized to create an undirected network using the minimum symmetry rule, meaning both organizations needed to report the collaborative tie for it to be included in the network. The matrix was restricted to only responding organizations. As such, the responses were transformed into a matrix where reciprocated collaboration of any strength was considered an undirected tie (Bodin et al., 2020; Fliervoet et al., 2016). Attributes were created for basin location, basin level (to indicate level within the geographic scale), organization type, and ties to non-respondents. The attribute for basin location was created from the responses indicating organizational sub-sub basins for flood planning. Sub-sub basins 1 to 6 are Upper Basin, 7 to 11 are Middle Basin, and 12 to16 are Lower Basin (Figure 3.1). Organizations that selected sub-sub basins from more than one of the three broader categories were classified as multi-basin. Basin level indicates if the organization function within a single basin or multiple basins.

3.3.4 Qualitative Data

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 and asked to select and then rank any of the challenges they have experienced. Respondents were lastly provided the opportunity to write any additional thoughts on flood panning they wanted to communicate to the researcher.

3.4 Analysis

Table 3.1 presents each research objective with the corresponding analytical method.

Table 3.1: Research objectives and corresponding analysis

Research Aim	Objective	Corresponding analysis
Research Aim Two	Objective One: To understand the centrality and transitivity in the collaboration network	Collaboration exponential random graph model (Section 3.4.2)
Research Aim Two	Objective Two: To analyze the impact of geographic scale and homophily on collaboration structures	Collaboration exponential random graph model (Section 3.4.2)
Research Aim Two	Objective Three: To assess the impact of geographic scale on brokerage in the network	Gould-Fernandez brokerage analysis (Section 3.4.1)
Research Aim Two	Objective Four: To assess if municipalities are brokers in the network	Gould-Fernandez brokerage analysis (Section 3.4.1)
Research Aim Three	Objective One: To analyze SE fit through a multilevel network approach	Multilevel exponential random graph model (Section 3.4.3)
Research Aim Three	Objective Two: To understand how collaboration contributes to functional fit or misfit	Qualitative analysis (Section 3.4.4)

3.4.1 Brokerage analysis

A Gould-Fernandez brokerage analysis computes brokerage counts for each of the distinct brokerage roles outlined by Gould and Fernandez (1989): coordinators, itinerant brokers, gatekeepers, representatives, and liaisons (Figure 3.2). Each brokerage chain is defined by the orientation of actors based on distinct actor subgroups. Coordinators join two nodes from their own subgroup. Itinerate brokers join two actors that belong to the same subgroup where the broker is of a different subgroup. Both gatekeepers and representatives join one actor from their own subgroup to an actor of a different subgroup, but differ in node orientation. For undirected networks, the counts for gatekeepers and representatives are the same. Liaison brokerage chains connect three actors from different actor subgroup (Gould & Fernandez, 1989).

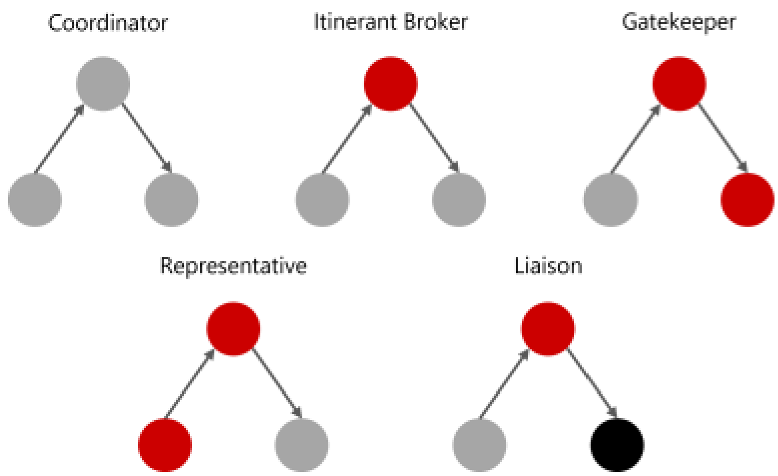


Figure 3.2: Gould-Fernandez brokerage chains. Adapted from Gould & Fernandez (1989).

A Gould-Fernandez brokerage analysis was performed in the SNA package (Butts, 2020) in R. The analysis provides global statistics and observed brokerage scores for all five roles for every node. Observed brokerage scores are compared to expected scores and variances from a null model of the same network size and density, with assumptions of normal distribution (Gould & Fernandez, 1989). Significance is determined through standardized scores and indicates brokerage activity substantially larger or smaller than expected in the null model, suggesting the presence of additional social forces. Two Gould-Fernandez analyses were performed; one used the categorical attributes of basin location, and the second used the attributes of government, municipalities, and other. Standardized scores were calculated for all five brokerage roles for each attribute category, and significance was determined, assuming a normal distribution with absolute standardized scores greater than 1.96 indicating significance (Gould & Fernandez, 1989).

3.4.2 Collaboration exponential random graph model

Exponential random graph models (ERGM) are a class of models that analyze overall network structure through smaller configurations within the network (Lusher et al., 2012). ERGMs analyze the empirical networks as the dependent variable, with the prevalence or absence of these smaller configurations, also called motifs, as the independent variables. Collected social networks can be understood as a product of locally occurring social processes, such as centralization or homophily, unobserved factors, and extraneous noise. Previous social network research and theory have associated many of the social processes and forces that impact network formation and structure with specific smaller configurations (Crona & Bodin, 2011; Goodreau et al., 2009; Lusher et al., 2012; Robins et al., 2007). ERGMs convey which motifs impact network structure, and this can then be used as a device to understand what social forces may affect the specific empirical network (e.g. homophily, centralization, closure). Node attributes can also be incorporated into the model to determine if they impart significant structural effects. As network characteristics such as centralization and homophily have been demonstrated to affect decision-making processes and subsequent outcomes (Bodin & Crona, 2009), understanding specific structures impactful in governance networks provides a method to better understand beneficial attributes for adaptive governance.

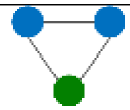
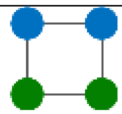
The occurrence of selected motifs in the network of interest are compared to the occurrence of those motifs in purposefully generated random networks. Each motif is given a parameter and standard error, as in a regression analysis. However, unlike a regression, ERGM accounts for observation dependencies implicit in networks. The parameter value indicates if a motif is over or under-expressed than expected in random graphs, and standard error determines significance. The occurrence, or lack thereof, of a motif can be used to understand if the underlying associated social mechanisms (e.g. homophily, centralization, closure) are enhanced or suppressed in the empirical network. Motifs need to be interpreted in relation to each other, as simpler motifs can be nested in higher-order configurations. For example, a two-star is contained within a triangle, and the inclusion of the lower-order motif leads to more precise interpretations for the higher-order motif (Snijders et al., 2006). ERGMs are typically fit using Markov Chain Monte Carlo (MCMC) Maximum Likelihood Estimation (Snijders et al., 2006). ERGMs are more robust to missing data from non-respondents than network descriptives (Robins et al., 2004). This is a particularly important characteristic for this analysis as the response rate was low.

ERGMs were fitted to the undirected collaboration network using MCMC simulation in *R v.* 4.0.5 in the *ergm* package (Hunter et al., 2020) and checked for goodness of fit and degeneracy (Appendix B). Models were developed in an explorative manner, to ensure all motifs necessary for answering the propositions were included while finding the model with the best fit (Bodin & Nohrstedt, 2016). To minimize convergence challenges, models were fit sequentially, adding in new terms only after the previous model converged (Alexander et al., 2018; Barnes et al., 2019). Initial models included baseline structural mechanisms and then were expanded to include nodal attributes.

3.4.3 Multilevel exponential random graph model

ERGMs have been expanded to model multilevel networks (P. Wang et al., 2013) and used to analyze fully articulated social-ecological networks (Barnes et al., 2020; Bodin et al., 2016; Guerrero, Bodin, et al., 2015; Pittman & Armitage, 2017; Widmer et al., 2019). The multilevel ERGM was fitted in MPNet to the observed social-ecological network (P. Wang et al., 2014) also following a sequential process, where beginning with baseline terms, additional terms were only added after the model converged. The ecological network and the social-ecological network were fixed to purposefully explore and understand the choices of collaborating organizations (Pittman & 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. A motif was determined to be significant when the parameter estimates were twice the standard error (Lusher et al., 2013). Motifs were chosen to capture the SE fit challenges of shared resource management and management of interconnected resources (Guerrero, Bodin, et al., 2015), given the fixed networks and a specific focus on how collaboration impacts fit (Table 3.2). The motif of the closed ecosystem triangle and its associated baseline encompassed by the second SE fit challenge, management of interconnected resources, was not included as it does not contain a collaborative tie (Figure 2.1). As the impact of scale was investigated more thoroughly in the ERGM, it was also not included in the multilevel model.

Table 3.2: 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 (Guerrero, Bodin, 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.

Blue nodes indicate organizations and green nodes indicate ecological components.

3.4.4 Qualitative analysis

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 (Alexander et al., 2017; Pittman & Armitage, 2017). 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 (Appendix C) 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.

3.5 Network limitations

Network analysis has inherent methodological limitations that need to be addressed in study design. The impact of these limitations can be mitigated or exacerbated by researcher choices. These considerations are particularly important although not consistently addressed when investigating collaborative governance (Guerrero et al., 2020). Considerations include setting network boundaries, definitions of ties, addressing missing data, and matrix creation procedures.

Failure to define, or appropriately define, network boundaries may decrease the validity of findings. Defining the boundaries of, as well as what classifies as a node, in a collaborative governance network can be challenging (Berardo et al., 2020; Cohen et al., 2012; Guerrero et al., 2020). As such, it has been recommended to consult individuals who are highly knowledgeable about the study region, the problem of interest, and the actors active in the problem (Berardo et al., 2020; Locatelli et al., 2020). A recent review of participant engagement in environmentally-focused social network analysis suggested engagement with participants throughout the research process improved the research and amplified the benefits of the outputs (Jasny et al., 2021).

Collaborative governance research, in particular, is impacted by the definition presented in data collection, as collaboration is multifaceted and comprised of various interactions, many of which impact others (Berardo et al., 2020). As such, the researcher's chosen definition will certainly impact the collaboration network collected, and may not reflect all relations and relation strengths. Dichotomizing valued ties into a binary network is a common network practice (Alexander et al., 2017; Berardo et al., 2020; Widmer et al., 2019); however, the choice of threshold for the dichotomization of ties may greatly impact network structure (Thomas & Blitzstein, 2011). Consequently, the definition of what constitutes a relationship, what strength of relationships are used, and if strengths are explicitly considered all impact analysis.

Lastly, missing data from non-responding actors within network boundaries can bias results (Kossinets, 2006; Smith & Moody, 2013), and there is a need to mitigate the amount and the effect of missing data in studying collaborative governance systems (Berardo et al., 2020). As there is an inherent likelihood of missing data resulting from survey methods, other sources to identify ties, such as text sources and policy partnership documents, are viable sources of collaborative ties in some contexts (Berardo et al., 2019, 2020; Hileman & Lubell, 2018). However, if a network is largely emerging informally, as it is in this research context, this method may not be suitable. Some analytical methods are more robust to missing data, for example, exponential random graph models (Robins et al., 2004). Researchers need to be warry of applying "analytical methods that are inadequate or sensitive to incomplete network data" (Guerrero et al., 2020, p. 7). The impact of missing data is connected to the choice of missing data treatment (Krause et al., 2020). This study chose deletion of non-responding actors to analyze a full sub-set of the network; however, both likelihood-based estimations and imputation methods may lead to less bias (Krause et al., 2020).

3.6 Study limitations & delimitations

This research used a transdisciplinary approach and incorporated elements of both the natural and social sciences, which leads to specific delimitations. Delimitations refer to choices made by the researcher to develop boundaries for the study (Mauch & Birch, 2003). In this case, boundaries were set to maintain the scope of the research within a maters thesis while ensuring sufficient rigour. This work was conducted for the completion of a master's degree program that follows a two-year timeline and the scope of the research was limited to ensure data collection and analysis occurred along certain timelines to meet degree requirements and the needs of the research partners. This research also only included a single round of data collection to meet necessary timelines; however, the incomplete network collected is a limitation of the study. The missing data was addressed through the deletion of non-responding nodes and the inclusion of an attribute of the sum of reported ties to non-respondents for each responding node. This additional attribute contributes to decreasing the bias in the partial network (Robins et al., 2004).

The researcher chose to investigate undirected social networks for collaboration and to only consider strong ties. The choice to use a strong symmetry rule removed unreciprocated ties from the network, although collaboration can be analyzed as a directed network (Jasny et al., 2019). Symmetrisation also removed the opportunity to analyze reciprocity in the network. While reciprocity was not found to be an issue in exploratory models, a previous study of a water management network in the region reported a lack of reciprocity (Baird et al., 2014). Additionally, the choice to consider an undirected collaboration network required to consider the ecological network as undirected in the multilevel ERGM. However, 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).

There are limitations of using organization-level interactions to understand a collaboration network, as it may miss important individual-level relationships and does not incorporate possibly impactful within organization relationships (Becker, 2021). Additionally, surveying a limited number of individuals from an organization may miss network ties, as not every individual will be knowledgeable about all collaborations.

Chapter Four: Findings

Chapter Four is presented by research aim and objective.

4.1 Research Aim One: Identify and describe flood planning network

Completed questionnaires were received from 58 individuals responding on behalf of 53 invited organizations (Table 4.1). Four organizations responded to the questionnaire invitation to indicate they were not within the network boundaries, reducing the number of possible responding organizations to 132. As such, the response rate for the network is 40%. Table 4.1 shows the composition of network actors and respective response rates. The majority of the actors are located within the province of New Brunswick. Municipal governments, non-government organizations, and watershed organizations responded in the highest numbers. Figure 4.1 shows the undirected collaboration network where only reciprocated ties were included. When only reciprocal ties were included, there are 9 isolates and the remaining 44 organizations comprise three components. The two fragments are comprised of organizations based in Maine and the reciprocal collaboration network does not include any organizations based within Québec. As the response rates for Maine and Québec were low, this research cannot comprehensively address collaboration across political jurisdictions within the watershed. As the largest portion of the watershed and questionnaire respondents are located within New Brunswick, the province will serve as the primary institutional backdrop for much of the discussion.

Table 4.1: Jurisdiction and organization categorization of responding organizations

	Municipal Government	Regional Government	Provincial Agency	Federal Agency	Indigenous Self- Government	Non- Governmental Organization	Watershed Organization	Research / University	Industry & other	Total	Total invited organizations	Response rate
Maine	4	0	0	1	0	0	0	0	0	5	16	31%
Québec	1	0	0	0	0	0	0	0	0	1	24	4%
New Brunswick	15	3	4	1	1	10	7	4	2	47	92	51%
Total	20	3	4	2	1	10	7	4	2	53	132	40%

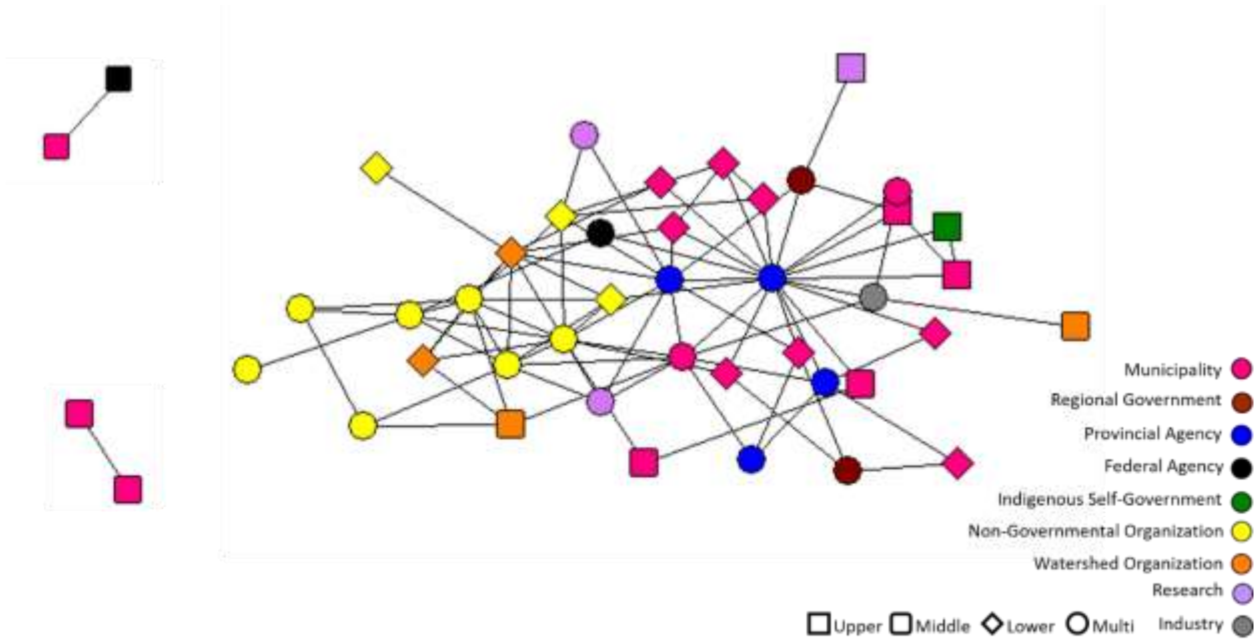


Figure 4.1: Undirected collaboration network (N=44) with isolates (N=9) removed from the diagram. Colour indicates organization type and shape indicates basin location. Density = 0.065

Flood management as a whole has been shown to cross management strategies (Dieperink et al., 2018) and policy sectors (Metz et al., 2020). In the St. John River Basin, flood planning is a multi-faceted issue with a variety of interconnected tasks (Baird et al., 2021). The network displays a range of organization types actively engage in flood planning and these organizations have varying legislated roles and responsibilities, as distribution of responsibility for flooding differs among the three main regions within the basin. Within Maine, responsibly for flooding falls to local communities, with legislated assistance from state and federal agencies (Maine Floodplain Management Program, 2010). Within Canada, responsibility for watersheds differs among provinces and territories. Responsibility to address flooding in New Brunswick falls among the provincial, regional, and municipal levels of government and is therefore separated by political boundaries. However, in Québec, flooding is the responsibility of watershed organizations (*Organismes de bassin versant*, OBV) over 40 distinct hydrographic areas (Leclerc & Grégoire, 2017), and as such is separated by hydrological boundaries. Funding for each OBV is provided by the provincial government, and the OBVs collectively participate in a collaborative federation, Regroupement des organismes de bassins versants du Québec, to share experiences and enhance achievements (Leclerc & Grégoire, 2017).

A lack of legislated authority to governmental or non-governmental bodies for purview over watersheds within New Brunswick has contributed to the ongoing involvement of small, environmentally focused non-governmental organizations in watershed issues. Ongoing work of these non-governmental organizations, self-described as both NGOs and watershed organizations from the collected network, is supported in part through provincial and federal funding (e.g. through the New Brunswick Environmental Trust Fund). Funding allotments are often provided for specific projects with specific time frames and can be subject to necessary alignment with broader overarching priority concerns or areas. The suspected impact of this inconsistent funding scheme will be elaborated on in subsequent sections.

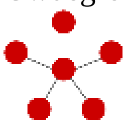
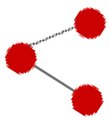
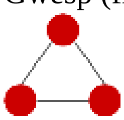
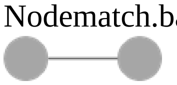
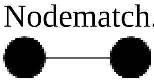
The network also displays limited ties connecting across political jurisdictions, although more ties likely exist than can be displayed in the collected network. Transboundary watersheds, in particular, may benefit from collaborative relationships across borders, as power imbalances, diverging national objectives, and limited opportunities to learn together may all hamper cohesive transboundary water governance (Armitage et al., 2015; Lebel et al., 2005; Plummer et al., 2016). The network would likely benefit from collaboration among the state and provinces within the St. John River Basin.

4.2 Research Aim Two: Analyze the network in reference to adaptive governance scholarship

4.2.1 Objective One: To understand the centrality and transitivity in the collaboration network

To address Research Aim Two, Objective One, the collaboration network was analyzed through an ERGM. Table 4.2 presents parameter estimates and standard errors from the converged ERGM (indicators of model goodness of fit are contained in Appendix B). Like many social networks, there is a strong negative coefficient for edges, meaning the network has a low density. There was no significant impact for isolates, centralization, or two actors to be connected to a common third actor. However, network closure, three actors all connected, was significant in the network. Ties to non-respondents was included as a nodal covariate to control for the bias in the partial network address due to the low response rate (Robins et al., 2004). The positive significant parameter indicates ties to non-respondents impact the tendency to form ties in the network.

Table 4.2: Collaboration ERGM parameter estimates

ERGM term		**Parameter Estimates (Std. Error)**
Edges 	Propensity to form ties	-4.5896 (0.518) ***
Isolates 	Propensity for isolates in the network	-0.2851 (1.235)
Gwdegree(fixed, 0.5) 	Propensity to form ties to actors with ties	-0.7871 (1.140)
Gwdsp(fixed, 0.5) 	Two actors ties to a common third actor	0.0095 (0.039)
Gwesp (fixed, 0.5) 	Three actors connected	0.5961 (0.206) **
Nodecov.respondents 	Effect of ties to non responding organizations	0.0598 (0.016) **
Nodefactor.basin	Single basin activity compared to the baseline of multi basin organizations	-0.0925 (0.157)
Nodematch.basin 	Homophily for basin level	0.2945 (0.253)
Nodefactor.gov	Government activity compared to the baseline of non government	-0.3301 (0.103) **
Nodematch.gov 	Homophily for organization type	1.3562 (0.271) ***

Alpha values were fixed at 0.5
Number in parentheses represent standard errors and (***)p < 0.001, (**)p < 0.01, (*)p <0.05, (.)p<0.1

As there is no meaningful impact of centralization on the network but a tendency for closure, there is some extent of bonding over bridging capital in the network. This tendency for bonding capital in this context aligns with Berardo 7 Scholz's (2010) risk-hypothesis for a high-risk cooperation dilemma, where complex collaboration problems require trust and reciprocal relationships. While research is ongoing to better understand specific components of high-risk dilemmas (Bodin et al., 2020), the risk has been postulated to stem from potential partner defection (Berardo & Scholz, 2010) and as well as questionable benefits of a collaborative relationship (Nohrstedt & Bodin, 2019).

The potential risk indicated by the tendency for network closure may be a product of network composition. As discussed to address Research Aim One, there is prominent activity of non-governmental organizations in the flood planning network alongside various levels of government. As such, many of the organizations conducting flood planning within this network are subject to uncertain funding cycles for the capital to engage in additional climate adaptation or collaborative projects. It may be reasonable to conclude there are likely questions of both if a collaborative tie will be worthwhile to address flood planning problems when collaborating among differing organization types, and if a collaborative relationship can be sustained long enough to do so.

The impact of resource availability and consistency has been documented affecting other collaborative arrangements for watershed governance. Koontz and Newig (2014) found access to resources, dedicated leaders, and local networks influenced differences in perceptions of the implementation and usefulness of collaborative planning activities, with available funding greatly impacting the ability to implement the collaborative plan. The San Francisco Bay Area's "bottom-up" approach to flood risk management, as discussed by Serra-Llobet et al. (2016), is comprised of regional networks involving local agencies and stakeholders. The stated limitations of this arrangement, however, are a lack of regulatory oversight to impose long-term plan updates and a lack of consistent and stable funding, both of which contribute to a short-term focus. This work, along with others, argues for a need for a balanced inclusion of a centralized authority to compliment a "bottom-up" governance approach (Guerrero, Bodin, et al., 2015; Huntjens et al., 2010, 2012; Pahl-Wostl, 2009; Serra-Llobet et al., 2016).

The variety of actor types involved in flood planning in the St. John River basin is indicative of the contemporary shift from government to governance (Armitage et al., 2012; Howlett et al., 2009; Lebel et al., 2006; Pahl-Wostl, 2009). While government is referring to the concept of top-down, state-centric hierarchical models of control, governance incorporates non-state actors, formal and informal institutions, and networks (Kooiman & Bavinck, 2005; Pahl-Wostl, 2009). Scholars have argued governance forms to sustainably address problems in complex adaptive social-ecological systems should incorporate and connect distinct groups beyond government, and the adaptive governance, collaborative governance, and adaptive co-management literature all place potential value in collaboration among diverse parties (Armitage et al., 2009; Dietz et al., 2003; Folke et al., 2005; Ostrom, 2005). The active participation of non-governmental actors in the collaborative flood planning network collected here demonstrates this shift.

However, governments continue to be integral within this shift to governance. Huntjens et al. (2010) argue large complex systems, like river basins, benefit from some degree of central authority to contribute to "facilitation of participatory processes, setting of standards, capacity building, conflict resolution, and cooperation across boundaries" (p. 276). Kuehne et al. (2020), in analyzing a freshwater assessment research network in the United States, noted government institutions may provide resource stability to build long-term bonding and bridging structures among diverse groups. As displayed by network composition, the active role of government in this network may hold the potential to be beneficial for collective flood planning efforts through contributing resource stability, although the investigation into contextually beneficial roles of government in collaborative governance is still an ongoing area of research (Fliervoet et al., 2016; Kuehne et al., 2020).

The role of government in collaborative governance, particularly with respect to a concentration of authority or resources, may impact network structure and dynamics. For example, Schneider et al. (2003) found networks supported by the federal National Estuary Program in the United States were denser, incorporated more diverse expertise, and increased participants' belief in the potential of the outputs to improve environmental conditions. Broader connectivity among organization types may lessen any governance silos, which even within the context of a broader governance network may impact information flows and collaboration (Crowder et al., 2006; Sayles & Baggio, 2017a).

The presence of bonding capital in the collected flood planning network suggests flood planning presents a high-risk dilemma. This network includes both government and non-governmental actors with various authority, resources, and organizational capacity. As previous research has demonstrated the impact of resource availability and consistency on collaborative governance (Koontz & Newig, 2014; Serra-Llobet et al., 2016), it is reasonable to postulate this discrepancy in organizational capacity contributes to network structure. As collaboration composition may influence environmental outcomes (Baudoin & Gittins, 2021), there is a need for further investigation into collaborative governance regimes specifically concerning who is involved and who is left out (Hall, 1999), and how institutional composition impacts the function and structure of collaborative systems (Berardo & Lubell, 2019).

4.2.2 Objective Two: To analyze the impact of geographic scale and homophily on collaboration structures

To address Objective Two to understand the impact of geographic scale and homophily on collaboration structures, terms for *nodefactor* (to capture activity) and *nodematch* (to capture homophily) were incorporated in the ERGM for broad level attributes for geographic scale and organization type (Table 4.2).

The geographic scale attribute consisted of a binary single basin or multi-basin categorization based on flood planning activities. As the St. John River Bain is often operationalized as three main basins (Kidd et al., 2011), flood planning activities within one of the Upper, Middle, or Lower Basins was categorized as single basin. If an organization reported flood planning activities for more than one of these basins they were categorized as multi-basin. This distinction between single and multi-basin organizations attempted to account for the varying spatial level of organizations (Alexander et al., 2017) while accounting for the nature of the transboundary watershed. The ERGM displayed no significant effect for activity or homophily based on geographic scale (Table 4.2). To capture homophily and activity for organizational type, organizations were assigned a categorization of government or non-government. Although seven distinct organization types were categorized for the network (Figure 4.1), the low number of respondents from some categories (Table 4.1) made including all seven categories impractical for modeling purposes. The categories were amalgamated into government and non-government following the primary network divide discussed by Fliervoet et al. (2016). The ERGM displayed government organizations engage in fewer ties than compared to non-government organizations and there is a strong tendency for homophily among both groups (Table 4.2).

The ERGM displayed no impact of geographic scale on sending ties, and this result differs from other's findings (Hamilton & Lubell, 2018; Hileman & Lubell, 2018; McAllister et al., 2017; Sayles & Baggio, 2017b). Sayles and Baggio (2017b) found notable lower than expected densities for ties among local actors and higher than expected densities for ties between either local and regional organizations or among regional organizations. Furthermore, Hileman and Lubell (2018), in analyzing multiple multi-level, regional water governance networks in Central America, found a positive significant effect for homophily for within geographic level and country attributes.

This absence of impact of geographic level on node activity or homophily, however, may reflect the study context. The categorization of the geographic level of an organization was based upon self-reported flood planning activities to account for the transboundary nature of the watershed. For example, a federal organization, which in a different context would be classified to operate over a broader geographic scale, only holds authority and conducts flood planning activities over a portion of the watershed and so was classified as a single-basin actor. In contrast, an actively engaged municipality that is situated within two of the sub-basins is classified as a multi-basin actor. As such, scale was not directly tied to jurisdictional role. The distinction between the two defined geographic levels was small and the multi-basin category contained seven of nine organization types. Furthermore, flooding is unequally distributed in the basin, with the Lower and Middle Basins experiencing greater effects and impacts than the Upper Basin. While fewer ties are connecting Upper Basin actors in the network, Lower Basin actors are comparatively more active. It is reasonable to postulate activity is more impacted by organization type and flooding impact than by geographic scale.

Understanding the impact of organization type on activity and homophily was operationalized through a binary government or non-government categorization. Non-governmental organizations were more active than the government counterpart, with a tendency for homophily among both groups (Table 4.2). A tendency for homophily is immensely common in social networks and has been seen along organizational divides in collaboration networks (Jasny et al., 2019; Locatelli et al., 2020). Locatelli et al. (2020) found a tendency for homophily among NGOs, private sector, and research actors in climate change adaptation and mitigation policy networks in Peru. Fliervoet et al. (2016) analyzed the network for collaborative floodplain maintenance in the Dutch Rhine delta based on a focus on either a flood or nature focus. While analyzed differently, the highest densities by group largely corresponded to within-group ties, where organizations were grouped based on organizational focus. The comparative lesser activity by government organizations in the collaboration network is in contrast to the flood protection network collected by Fliervoet et al. (2016), where government organizations were responsible for 75% of ties in the highest frequency networks.

Within the St. John River Basin, the levels of government hold the mandated authority and responsibility for flooding. Within New Brunswick, responsibility for emergency management, in particular, falls within the jurisdiction of the provincial government. The necessity for municipalities to interact with higher levels of government in this legislative context likely contributes to the evidence of government homophily in the network. The tendency for non-governmental organizations to be more active in the network may also stem from this distribution of responsibility. While government actors hold authority, non-governmental organizations may require collaboration to reach objectives (Warner & Van Buuren, 2009).

4.2.3 Objective Three: To assess the impact of geographic scale on brokerage in the network

Among the top ten brokers by total brokerage scores, there is a mix of organization types: provincial agencies, municipal governments, non-governmental organizations, and watershed organizations (Table 4.3). All of these organizations are either Multi-basin or Lower Basin actors.

When dividing organizations by basin location, there are significant coordinator, gatekeeper, representative, and liaison brokerage roles in the network (Table 4.4). When investigating group differences, the Upper Basin and multi-basin actors occupied significant brokerage roles. Upper Basin actors act as coordinators, connecting fellow Upper Basin actors. As only four Upper Basin organizations responded, even the presence of two coordinator brokerage chains is significantly high. Multi-basin organizations also function as coordinators, connecting fellow multi-basin actors, and have a significant total brokerage count, suggesting connections throughout the basin are likely impacted by the multi-basin actors. This brokerage analysis looked to further investigate the potential impact of geographic scale on the network, and in contrast to the activity measure in the ERGM, scale impacts brokerage role. While an Upper Basin actor is coordinating, multi-basin actors overall hold significant brokerage positions in the network. The relative importance of these brokers can also be seen through the list of top brokers by total scores, as eight of the ten are multi-basin actors (Table 4.3).

Table 4.3: Top 10 brokers by total brokerage scores

Organization	Basin	Total
New Brunswick Emergency Measures Organization	Multi	316
World Wildlife Fund - Canada	Multi	96
New Brunswick Climate Change Secretariat	Multi	68
City of Fredericton	Multi	54
Kennebecasis Watershed Restoration Committee	Lower	52
St. John River Society	Multi	46
Conservation Council of New Brunswick	Multi	34
ACAP Saint John	Lower	22
Nature NB	Multi	22
New Brunswick Department of Health	Multi	14

Table 4.4: Total brokerage counts by organizational location using Gould-Fernandez brokerage measures

	Coordinator	Itinerant broker	Gatekeeper	Representative	Liaison	Total
Upper	2*	0	1	1	0	4
Middle	0	6	2	2	4	14
Lower	26	34	29	29	2	120
Multi Basin	162*	98	172	172	86	690*
Total	190***	138	204**	204**	92*	828***

The p-values are represented as significance codes (*** p<0.001, ** p<0.01, * p<0.05)

Regional governance systems need to be able to "engage effectively at multiple scales" (Lebel et al., 2006, p. 19). Important aspects of a regional governance system are connections among actors within the same levels (horizontal ties) and between different levels (vertical ties) (Alexander et al., 2017; Armitage et al., 2009; Berkes, 2002; Hileman & Lubell, 2018; Ostrom, 2005). Connections across spatial levels are a necessary component of adaptive governance to cope with interconnected SES dynamics and uncertainties (Folke et al., 2005), and tangibly can contribute to the implementation of large-scale conservation initiatives (Guerrero, Mcallister, et al., 2015) and to social-ecological fit (Sayles & Baggio, 2017b).

While there was no impact of spatial scale on dyadic level effects in the ERGM, scale impacts brokerage activity as multi-basin organizations hold significant brokerage positions and therefore may impact knowledge flows (Levy & Lubell, 2018; Locatelli et al., 2020), as well as the communication of management priorities or implications (Hamilton et al., 2020). Ties among actors operating over different spatial levels also may be connecting different organization types. Relationships that connect different organization types provide a possible mechanism to combine different types of knowledge (e.g. expert, local, traditional ecological knowledge) and actively use each in different stages of the collaborative process (van Tol Smit et al., 2015). Brokers who are connecting different organization types may be in a position to greatly impact this movement and use of knowledge, as well as the relative emphasis on priorities or goals. Understanding differences in heterogeneous brokerage roles among different groups in a network may assist in devising interventions to facilitate greater connections among distinct groups (Hamilton et al., 2020). The development of interventions, however, would need to explicitly consider organizational constraints among distinct groups, such as resource availability and consistency, and formal responsibility. Furthermore, brokers connecting groups with distinct power imbalances may exist in a position to further perpetuate those imbalances in the pursuit of resources or management priority monopolization (T. A. Scott & Thomas, 2017).

4.2.4 Objective Four: To assess if municipalities are brokers in the network

When dividing organization type into government (regional, provincial and federal agencies, and Indigenous self-government), municipalities, and all non-government actors, there are significant coordinator and itinerant brokerage roles in the network (Table 4.5). Government actors occupy significant coordinator, itinerant, gatekeeper, and representative roles. The non-government actors and the municipalities do not occupy a significant brokerage role.

Table 4.5: Total brokerage counts by organizational subgroup using Gould-Fernandez brokerage measures

	Coordinator	Itinerant broker	Gatekeeper	Representative	Liaison	Total
Municipalities	2	34	7	7	46	96
Government	20*	160**	84*	84*	70	418**
Other	150	10	72	72	10	314
Total	172***	204**	163	163	126	828***

The p-values are represented as significance codes (*** $p<0.001$, ** $p<0.01$, * $p<0.05$)

To address Objective Four to assess if municipalities are brokers in the network, a brokerage analysis separated municipalities from other government bodies. The analysis found no unique role of municipalities as brokers, despite likely occupying a unique functional role in flood planning (Becker, 2021; García et al., 2019). The broader government category does occupy multiple significant brokerage roles. As coordinator brokers, the government actors are connecting to other government organizations. As itinerant brokers, the government actors are connecting to two organizations of a different categorization. While not explicitly contained within the analysis, the broader tendency for government homophily, as well as the regional context, would suggest the higher-level government organization are acting as itinerant brokers between two municipalities. In the role of gatekeeper or representative, which due to the undirected network are equivalent, the government broker is connecting another government organization to an organization of a different category. This prominent role of government actors as brokers is similar to the findings of Fliervoet et al. (2016) where government actors were prominent bridges in both the flooding and nature-focused networks.

4.3 Research Aim Three: Assess the collaborative governance arrangement for the principles of social-ecological fit to address the problem of flooding

4.3.1 Objective One: To analyze SE fit through a multi-level network approach

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 4.2 include both the baselines and the motifs of interest. As motifs are nested within each other, including baseline motifs in the model is essential for proper interpretation of higher-level motifs, as discussed in Section 3.4.2. Configuration A is significant and negative, as anticipated for a collaboration network as discussed in Section 4.2.1.

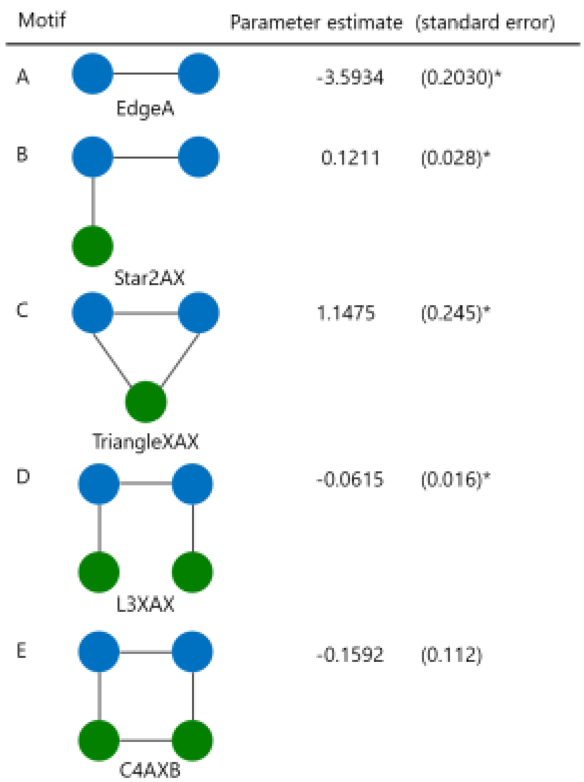


Figure 4.2: Multilevel exponential random graph model estimates. MPNet codes are provided for each motif. * indicates significant effect.

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 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.

Previous multilevel social-ecological network studies have found a positive and significant occurrence of the common-pool resource triangle (Barnes et al., 2019; Bodin et al., 2016; Guerrero, Bodin, et al., 2015; Pittman & Armitage, 2017; Widmer et al., 2019). Social-ecological closure through the common pool resource triangle has been associated with positive ecological conditions (Barnes et al., 2019). As acting independently with regard to a shared resource can lead to ineffective management or overexploitation (Ostrom, 1990), numerous network studies (e.g. Bodin et al., 2016; Guerrero et al., 2015) have further quantitatively demonstrated the utility of collaboration to enhance shared management.

Motif E corresponds to the second SE fit challenge of management of interconnected resources. Motif D is the baseline and 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. Motif E then provides insight into if this tendency is impacted when those different locations are connected. However, Motif E was non-significant meaning the closed square configuration occurred in the network within a range expected by chance.

While there is no significant parameter for the second SE fit challenge configuration, the baseline provides insight into the occurrence of this challenge in the St. John River Basin, as actors working in different sub-sub basins tend to not collaborate. A tendency to avoid collaboration with actors working in different areas may be desirable as it could reduce inefficient or ineffective ties (Guerrero, Bodin, et al., 2015). A negative parameter for Motif D paired with a positive, significant parameter for Motif E would indicate a specific tendency to only collaborate across different ecological nodes when the nodes are connected. However, as a positive parameter for Motif E was not found, a lack of collaboration across ecological nodes likely holds little SE fit benefit, as it 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 neighbours to govern for ecological connectivity (Bergsten et al., 2014; Bodin et al., 2016).

A direct comparison between the results from this inquiry in the St. John River Basin with those presented by Widmer et al. (2019) in investigating SE fit of collaborative governance in three regions within the Rhine River catchment area. The collaboration network for water quality management was comprised of a mixture of government agencies, non-governmental organizations, industry, and research bodies, and the social-ecological network was developed similarly. The first case presented, the Rhine at Basel, is also a transboundary context. Although the study used frequency counts instead of multilevel ERGM, the same baseline and test motifs were used to assess the management of interconnected resources through collaboration. The baseline was significant and positive in one of three cases and the closed square was significant in no cases, suggesting achieving collaboration connecting interconnected sub-catchments was particularly challenging (Widmer et al., 2019).

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 (Dieperink et al., 2018; Westerberg et al., 2017). 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). 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 (Becker, 2020; Galaz et al., 2008).

Management of interconnected resources through collaboration has presented a challenge across numerous SE fit studies (Bodin et al., 2016; Guerrero, Bodin, et al., 2015; Widmer et al., 2019) (see Pittman & Armitage (2017) for an exception). SE fit for multi-resource configurations is often harder to achieve than coordination or collaboration for a common pool resource (Guerrero, Bodin, et al., 2015; Pittman & Armitage, 2017; Widmer et al., 2019). Furthermore, collaboration for multi-resource configurations may be harder to achieve than singular responsibility for interconnected resources (the closed resource triangle; see Figure 2.1) (Bodin et al., 2016; Guerrero, Bodin, et al., 2015; Widmer et al., 2019). 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. As described in Section 4.1, organizations actively engaging in flood planning vary greatly in organization type, jurisdiction, authority, spatial level, access to resources, and there are evident collaborative divisions along a government versus non-government categorization. Multiple organizational and contextual attributes may intersect to decrease collaboration among organizations working in different sub-sub basins. While possible barriers to collaborating were discussed in reference to network properties, qualitative information was collected to explicitly address how collaboration may contribute to the functional fit of the network by understanding the benefits of and barriers to collaboration.

4.3.2 Objective Two: To understand how collaboration contributes to functional fit or misfit

The second objective sought to enrich the understanding of the dynamics within and functionality of collaboration in this setting to aid in assessing the SE fit of the governance arrangement. 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% (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 4.6. Knowledge was the most frequently mentioned effect of collaboration on flood planning, and technical resources and funding were the second and third frequent themes.

Table 4.6: Deductive code frequencies of responses to 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

Emerson et al. (2012) conceptualized the capacity for joint action to be the product of four necessary components: "procedural and institutional arrangements, leadership, knowledge, and resources" (p. 14). Respondents describing how collaboration has impacted flood planning ability frequently expressed the benefit of collaboration for increasing access to new information and enhancing understanding. 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*." Collaborative governance and management approaches frequently display the capacity to combine different types of knowledge (Feist et al., 2020; Plummer et al., 2012; van Tol Smit et al., 2015), coproduce knowledge (Armitage et al., 2012), and enhance knowledge exchange (Bodin & Crona, 2009; Kuehne et al., 2020; Olsson et al., 2007). A regional government respondent described:

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.

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. 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*." Lack of organizational capacity may decrease the fit of institutions in river basin governance (Lebel et al., 2013). For example, a lack of personnel or technical knowledge base may limit the ability to engage with stakeholders or engage in information gathering and sharing (Lebel et al., 2013).

Collaboration also provides organizations with access to authority to aid in 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. From both scholarly and applied perspectives, collaboration can provide authority to make decisions for and take action over a broader geographic region. 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*." Collaboration can provide a mechanism to better align the institutions with authority with the extent of the ecological process (Lee & Baggio, 2021).

While collaboration can provide access to additional resources, the end goal is collaborative action or implementation of governance decisions (Mattor et al., 2020). Multiple respondents suggested 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).

"*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, ie restoration efforts*" (NGO respondent).

Analysis of small and mid-sized local government organizations in the United States by Laurian & Crawford (2016) found organization capacity in mid-sized local government organizations was not correlated with environmental sustainability implementation, meaning smaller, lower capacity governments had similar implementation ability. However, "horizontal integration", describing partnerships with other government or public agencies was positively correlated with implementation (Laurian & Crawford, 2016). Collaboration can provide organizations with additional, perhaps necessary resources to expand internal capacities, although resources alone may be insufficient to further implementation. The intersection of benefits provided by collaborative relationships can contribute to functional fit, although those relationships are not without challenges.

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 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 (Figure 4.3). A list of common barriers was compiled from collaborative governance literature (Cohen et al., 2012; Guerrero, Bodin, et al., 2015; Hermansson, 2016).

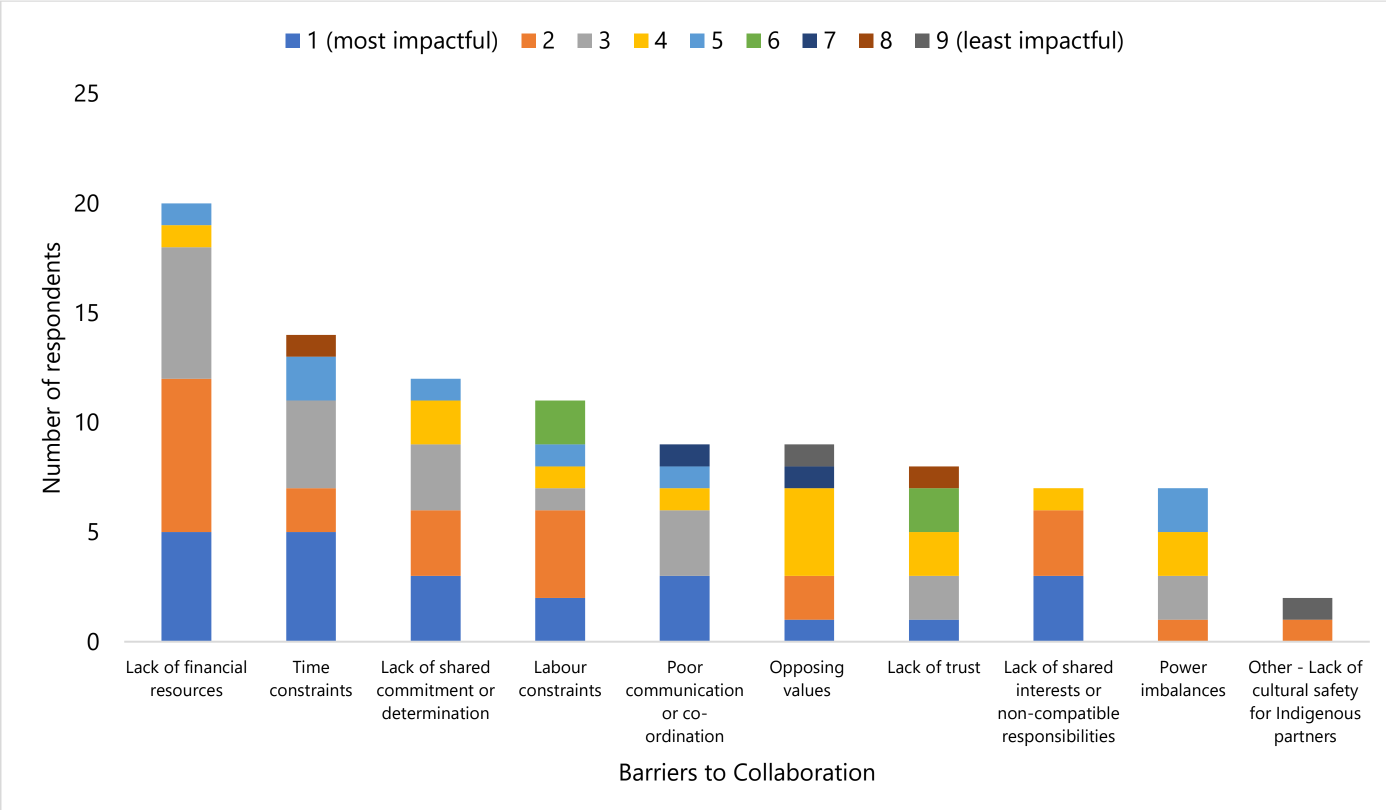


Figure 4.3: Selected and ranked barriers to collaboration. A rank of 1 indicates the most impactful barrier and a rank of 9 indicates the least impactful barrier.

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. These findings are directly in line with those of Cohen et al. (2012) who found a lack of finances and time restricted the development of relationships among organizations engaged in governance of coastal ecosystems in Solomon Islands. Furthermore, Guerrero, Bodin, et al. (2015) found financial, time, and labour constraints to be the most prominent perceived barriers to conservation implementation. A municipal respondent very directly conveyed this limitation: "*We have limited human, financial and or technical resources to effectively collaborate*". Furthermore, a watershed organization respondent described: "*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. As many organizations active in flood planning are subject to uncertain funding cycles as further described in Section 4.1, this is an unsurprising observation. However, 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 frequent barrier selected, and this observation may be partially explained by the numerous organization types with differing jurisdictions, authorities, and resources interacting. For example:

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)

While interaction and collaboration among various organization types and stakeholders are necessary components of adaptive governance (Dietz et al., 2003; Folke et al., 2005) and can contribute to SE fit (Epstein et al., 2015; Galaz et al., 2008), many contextual nuances must be considered before attempting to operationalize or improve an existing collaborative arrangement (Bodin, 2017). Opposing values, lack of trust, lack of shared interests, and non-compatible activities are barriers to collaboration that may be impactful when attempting to collaborate across jurisdiction or authority divides, a likely scenario in an environment shifting from government to governance. Specific contextual attributes, such as the respondent's identified lack of cultural safety for Indigenous partners, will further influence the collaborative relationships developed. Different institutional characteristics paired with different actor attributes will influence social processes and structures, in turn impacting ability to govern a complex adaptive social-ecological system (Galaz et al., 2008). All impact the extent of fit along an institutional scale to the biophysical landscape.

The qualitative analysis revealed many indications of functional misfit of the flood planning collaboration network in the St. John River Basin. Positively, collaboration was frequently described as enhancing knowledge transmission and understanding as well as enhancing implementation efforts. While collaboration was also cited as a means to increase access to resources, lack of financial resources was the most frequent barrier to collaboration. Nearly 30% of respondents indicated collaboration has not affected their ability to conduct flood planning and 53% indicated they experience barriers to collaboration, suggesting the current network dynamics could be improved to actively engage more organizations. There are challenges associated with limited capacity, government silos, conflicting priorities, inconsistent activity, and an absence of leadership. Many of these challenges contribute to explaining 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 (Huntjens et al., 2010, 2012; Kuehne et al., 2020; Schneider et al., 2003) and to support SE fit specifically (Bergsten et al., 2014; Guerrero, Bodin, et al., 2015).

Chapter Five: Conclusion

5.1 Introduction

Current environmental changes are causing catastrophic damage to communities (Davenport et al., 2021; D. Wang et al., 2021), and efforts to govern need to be based on a social-ecological systems understanding. Adaptive governance systems that incorporate diverse actors over different geographic and jurisdictional levels, provide opportunities to develop knowledge, and have the capacity to deal with change may provide a mechanism to address current environmental challenges (Armitage et al., 2009; Dietz et al., 2003; Folke et al., 2005). Flooding, one example of a pressing environmental concern, requires to be governed cohesively at the watershed scale (Niemczynowicz, 1999). Collaborative governance arrangements present a possible governance scheme to better govern social-ecological systems than top-down governance alone.

The purpose of this research was to advance understanding of collaborative governance as it relates to social-ecological complex adaptive systems, specifically through a network perspective to examine how network properties relate to adaptive governance and social-ecological fit. Network structure impacts overall behaviour and function (Valente, 2012); consequently, not all networks are suitable for pursuing a desired outcome (Bodin, 2017). Specific relational patterns within collaborative governance networks can reveal both benefits and shortcomings of the network.

Research Aim One sought to identify and describe the flood planning network. The collected and compiled network of reciprocal collaboration among 53 responding organizations revealed a combination of both government agencies and non-governmental organizations with active roles in the network.

Research Aim Two sought to analyze the network in reference to adaptive governance scholarship. The exponential random graph model of the collaboration network displayed a positive tendency for closure and non-significant parameters for centralization, indicating the presence of bonding over bridging capital. The network exhibited homophily along a government versus non-government categorization and government organizations displayed decreased activity in comparison to non-government organizations. Scale had no impact on homophily or activity. Geographic scale impacted the network only through the relative brokerage activity of multi-basin actors. The Gould-Fernandez brokerage analysis displayed municipalities occupied no significant brokerage role in the network, but the remaining government organizations occupied multiple significant brokerage roles.

Research Aim Three assessed if the collaborative governance arrangement displayed the principles of social-ecological fit to address the problem of flooding. SE fit was assessed through a multilevel exponential random graph model and the results displayed limited SE fit of the collaboration network to flooding at the basin scale. The multilevel exponential random graph model displayed a significant positive parameter for the common pool triangle motif demonstrating organizations tend to collaborate with others in their sub-sub basin. Collaboration in the St. John River Basin may be assisting in SE fit. However, collaboration among organizations working in different sub-sub basins was significantly negative, which impedes ability to cohesively govern the basin. Qualitative responses were coded and displayed collaboration impacts flood planning through providing knowledge, technical resources, and funding. Respondents identified lack of financial resources, time constraints, and a lack of shared commitment or determination to be impactful barriers to collaboration.

5.2 Contributions

This research presents a series of specific properties of the collaborative governance arrangement in the St. John River Basin that contribute to broadening understanding of collaborative governance as it relates to social-ecological complex adaptive systems. The collaborative flood planning network in the St. John River Basin displayed structural tendencies indicating the presence of bonding capital and limited SE fit.

The presence of bonding capital in the network may indicate flood planning presents a high-risk cooperation dilemma due to possible partner defection (Berardo & Scholz, 2010) or questionable benefits of collaborative relationships (Nohrstedt & Bodin, 2019). Both potential explanations can be partially attributed to the organizational and institutional composition of the network. Organizations engaged in flood planning in this context hold various roles, authorities, jurisdictions and are subject to different resource availability and consistency. Access to consistent funding has been shown to impact implementation efforts (Koontz & Newig, 2014) and the ability to maintain a long-term focus (Serra-Llobet et al., 2016). Qualitative responses indicated lack of resources presented a barrier to collaboration. Specifically, respondents referenced the negative impact of relying on external funding sources and limitations of insufficient organizational capacity to engage in collaboration. This research suggests discrepancies in resource availability and consistency among organizations in the network influenced network structure by decreasing the potential for organizations to build or maintain ties, and increasing the perceived risk of collaboration, as seen in the tendency for network closure. As such, environments with resource limitations may lead to the use of bonding structures to address collective action problems. Qualitative responses conveyed collaboration increased access to knowledge, technical resources, and funding. Consequently, the network is contributing to functional adaptive governance for flood planning in the region by encouraging the dispersion of knowledge and resources that may allow for improved decision-making and subsequent action. The network also contains both horizontal and vertical ties, essential within collaborative regimes to facilitate appropriate scale matching (Armitage et al., 2009; Berkes, 2002; Ostrom, 2005; Scheffran, 2012).

However, several weaknesses in the network suggest the current governance structure would be insufficient to encourage further transition into an adaptive governance approach for flood governance. Adaptive governance requires horizontal and vertical ties connecting actors over a broad region to account for system interconnectedness and improve regional decision making (Guerrero, Bodin, et al., 2015; Sayles & Baggio, 2017b). This network lacks strong ties connecting across jurisdictions as well as strong vertical ties connecting across spatial levels.

Additional investigations have shown challenges in progressions towards adaptive governance for flooding (Becker, 2020; Fournier et al., 2016). Becker (2020) investigated the institutional fit of municipalities to flood risk governance in the Höje Å catchment area, Sweden, and found connections between municipalities were often brokered by individuals representing other organizations. Network analysis focusing on relationships among individuals in municipal administration demonstrated limited connections among the three municipal administrations included, indicating flood planning was largely conducted in isolation. Additionally, a central actor in the network is, "a voluntary association without decision-making power and little influence over the three municipal administrations" (Becker, 2020, p. 286). Additional work displayed municipalities were highly dependent on external actors and limited horizontal ties existed to upstream communities (Becker, 2018).

In the St. John River Basin flood planning collaboration network, as in the network collected by Becker (2020), non-governmental organizations with no legislated authority and limited or uncertain resources occupy important brokerage roles in the network. The collected network here also displays a lack of connections throughout the watershed, as demonstrated by the negative and significant parameter for the multilevel motif indicating collaboration among actors in different sub-sub basins. Qualitative reports of municipalities lacking the capacity to engage in collaboration further demonstrate a degree of isolated flood planning. Taken in conjunction, these results do not suggest a resilient network governance approach to flood planning.

The reliance of this network on non-governmental organizations presents a challenge for future shifts towards adaptive governance, as previously discussed inconsistent funding mechanisms may result in fragile ties. For example, the loss of essential staff, a lack of funding to maintain projects, or a shift in strategic plan direction could result in lost relationships. The prominent brokerage role of a few non-governmental organizations in this network creates weakness, as a loss in capacity in any one organization may remove the brokerage links connecting other organizations. An extent of redundancy is critical for when an impactful individual leaves an organization in the network (Alexander et al., 2017).

There is potential in this context for higher-level government agencies to provide said necessary redundancy. Brokerage analysis on categorizations along a government versus non-government divide displayed higher-level government agencies were frequent brokers in the network. However, qualitative responses cast doubt on the functional success of government agencies acting as brokers, as numerous respondents criticized the current hierarchical government functionality in addressing flood planning cohesively.

The current collaborative network in the St. John River Basin, while demonstrating functional benefits, also has implications on the region's ability to address flooding as a social-ecological complex adaptive system. Governance for CAS requires the ability to cope with uncertainties, react at appropriate scales, and continually build understanding (Dietz et al., 2003; Duit & Galaz, 2008). Suitable governance regimes should include layered institutions, social networks, and learning capacity (Chaffin et al., 2014; Dietz et al., 2003). The current network structure decreases the potential to govern flooding as a CAS, as an absence of high-level leadership and coordination decreases the collective capacity to continually build understanding. For example, isolated municipalities may not share knowledge with nearby communities. A perpetual short-term focus due to resource limitations reduces the ability for long-term monitoring and evaluation. The absence of high-level leadership in this network greatly reduces collective ability to generate an ongoing understanding of system complexities at the watershed scale.

The analysis of the multilevel SE network demonstrated limited SE fit of the collaboration network to flooding at the basin scale and has contributed an additional example of a multilevel SE fit study at the regional scale. This is the first instance a multilevel network approach has been used to assess SE fit to flooding at the basin scale. The multilevel exponential random graph model displayed collaboration in the St. John River Basin may be assisting in SE fit for flood planning. However, collaboration among organizations working in different sub-sub basins was significantly negative, which impedes the ability to cohesively govern the basin as flooding demands attention to the basin as a whole (Niemczynowicz, 1999). The multiple barriers to collaboration indicated by respondents likely combine and interact to shape these relational patterns (Cohen et al., 2012).

This research as it was conducted within the Partnership for Freshwater Resilience has provided a social network analysis for the organizations within the St. John River Basin and was communicated back to participants through a webinar and infographic.

5.3 Recommendations

This research taken in totality contributes to the ongoing discussion of the role of top-down governance within collaborative arrangements. That is to question: what is the role of multilevel network governance in this context? Both Bergsten et al. (2014) and Guerrero, Bodin, 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, Bodin, et al., 2015). Pittman and Armitage (2017) suggest more work is required to understand how network governance forms in the contexts where "hierarchies are the dominant mode", such as in the research presented here. More research is required to understand: 1. In what contexts do collaborative networks emerge with hierarchies?; 2. how can hierarchies and networks modes exist?; and 3. in what contexts would that be optimal?

More specifically, understanding group differences in brokerage roles embedded in context is a developing area of research (Barnes, Kalberg, et al., 2016; Hamilton et al., 2020). For regional environmental governance regimes, especially those containing portions of top-down government structures, brokers may occupy critical positions to actively promote or possibly suppress the prioritization of diverse knowledge types, perspectives, and goals in the collaborative process (Hamilton et al., 2020; T. A. Scott & Thomas, 2017; van Tol Smit et al., 2015). With suggestions to progress towards more decentralized and adaptive governance arrangements for addressing sustainability challenges only increasing, understanding the relative roles of common organization types may be influential in better developing equitable collaborative systems.

This research presents an opportunity to replicate a similar study in additional watersheds to understand the broader characteristics of flood planning governance in Canada. As the division of authority over water resources and over watershed management specifically varies among provinces and territories, network characteristics are also likely to differ. Additional research would contribute to understanding which network attributes are case-specific and which broadly affect flood governance in Canada. While investigating each case can provide contextually grounded recommendations, understanding the larger patterns can contribute to informing higher-level system changes. Future studies could furthermore address some of the delimitations and limitations presented in Chapter Three to collect and analyze more comprehensive networks. For example, the use of a directed collaboration network in a multilevel ERGM would then allow for the specific analysis of upstream-downstream dynamics, a future area of research in itself.

Lastly, this research can provide recommendations for applied practice within the St. John River Basin. Broad recommendations can be made to encourage increased connections among municipalities, enhanced collaboration across the basins and jurisdictional divides, and maintenance of long-term timelines such that planning does not stop post-flooding events. However, these recommendations would benefit from additional highly contextual analysis to provide clear next steps to address the governance challenges identified in the network analysis.

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Appendices

Appendix A: Questionnaire instrument

Informed Consent

Title: Flood Planning in the St. John River Basin
Date: August 8, 2020

Principal Investigator:
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INVITATION
You are invited to participate in a study that involves research. The objective of this study is to understand how those in the St. John River Basin communicate and make decisions regarding flood planning.

WHAT'S INVOLVED?
You will participate in the survey, which is expected to take approximately 20 minutes and will focus on questions related to the people and organizations/agencies you communicate with regarding flooding as well as your social activities in relation to decision making in the St. John River system. Follow-up interviews may take place to clarify responses if needed.

POTENTIAL BENEFITS AND RISKS
The results of this project will be compiled and available as a report made available through the Environmental Sustainability Research Centre at Brock University (Ontario) and will also be published in a scholarly journal. This research will help us to better understand how decisions are made and the communication structure around flooding in the St. John River Basin. We hope that the results of this work will lead to actions to improve communication and governance of flooding, and thus your participation may have benefits to you and others in the basin over time.

Although individual names will not be used, there is a potential risk that identities might be discernible. Results will be presented using a generic title (such as "landowner" or "NGO member").

CONFIDENTIALITY
Your name will not appear in any report resulting from this project. With your permission, confidential quotations may be used. The information we collect from you in this study (your responses) will be kept on a password-protected computer/secure server. Data and records created by this project are the property of the principal investigator and the research team, and individual responses may only be accessed by the research team. If you choose to withdraw your participation in this study at any time, any material related to your responses or involvement in the study will be destroyed.

VOLUNTARY PARTICIPATION
Participation in this study is voluntary. If you wish, you may decline to answer any questions or participate in any component of the study. Further, you may decide to withdraw from this study at any time. Should you choose to withdraw from the study, your data will be destroyed.

PUBLICATION OF RESULTS
Results of this project will be presented as a report and journal article, and may be used to direct future research studies in the St. John River Basin. Results may also be presented at conferences. A copy of the report summarising the results will be available from the researchers Dr. Julia Baird or Dr. Ryan Plummer via telephone and email.

CONTACT INFORMATION AND ETHICS CLEARANCE
If you have any questions about this study or require further information, please contact the Principal Investigator using the contact information provided above. This project has been reviewed and received ethics clearance through the Research Ethics Board at Brock University (# 19-200). If you have any comments or concerns about your rights as a research participant, please contact the Research Ethics Office at (905) 688-5550 Ext. 3035, reb@brocku.ca.

Thank you for your assistance in this project.

CONSENT FORM

I have checked the box below to indicate that I voluntarily agree to participate in this study described above. I have made this decision based on the information I have read in the Information-Consent Letter. I have had the opportunity to receive any additional details I wanted about the study and understand that I may ask questions in the future. I understand that the responses I provide may be used for future, related research. I understand that I may withdraw this consent at any time.

- o I consent to the terms above
- o I do not consent to the terms above

Introduction

Thank you for your willingness to participate in this survey. The purpose of these questions is to understand with whom your organization collaborates with when making decisions and conducting activities related to flood planning in the St. John River Basin.

We are interested in flood planning for future Spring freshets because of the immense damage caused by the 2018 and 2019 floods. Flood planning includes both preventative and precautionary measures to address risks of future flooding. While flooding events are immediately followed by a response and then a recovery phase, these questions want to understand flood planning outside of times of crisis. Example activities may include infrastructure projects, community outreach & education, climate change adaptation planning, or flood mapping.

We are specifically interested in communication and collaboration regarding flood planning. Collaboration here refers to the regular professional sharing of human, financial and or technical resources, engaging in joint activities, and organizing joint activities.

Part One: About You

Your Name: ________________________________

Your Email: ________________________________

Your Occupation: ____________________________

Company / Organization / Agency and department if relevant: _________________________

Organization type:

Indigenous self-government / Federal Agency / Municipal Government / Non-Governmental Organization / Regional Government / Provincial Agency / Watershed Organization / Other (please specify)

Which boundary better describe your organization's jurisdictions:

Political boundaries

Watershed boundaries

(if political, directed to below)

Please Select your organization's jurisdiction:

Maine:	Québec:	New Brunswick:
Municipality (City, Town or Township)	*Municipality (City, Town or Township)*	*Municipality (City, Town or Township)*
County	*County Regional Municipality*	*Rural Community*
State	*Provincial*	*Local Service District*
Federal	*Federal*	*Regional Service Commission*
Other (please specify)	*First Nations*	*Unincorporated Area*
	Other (please specify)	*Provincial*
		Federal
		First Nations
		Other (please specify)

(If watershed, directed here)

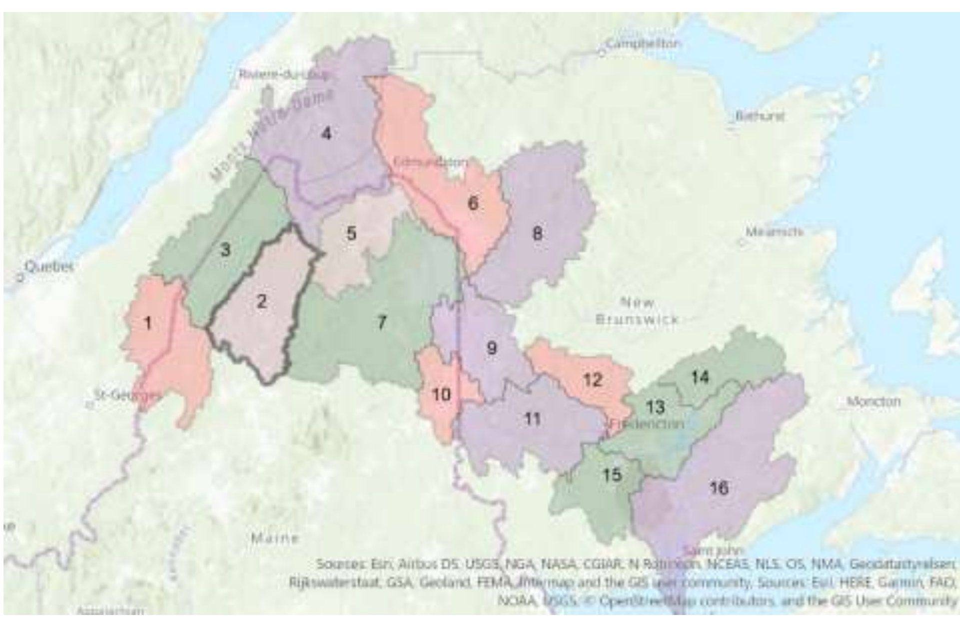
What watershed boundaries define your organization's jurisdiction? Please be as descriptive as possible ____

PLEASE RESPOND TO THE REMAINDER OF THE QUESTIONS FROM THE PERSPECTIVE OF YOUR COMPANY / ORGANIZATION / AGENCY
Part Two: Flood Planning Activities

For what part of the watershed does your affiliated organization conduct flood planning?

Please consider flood planning activities since 2018.

From the map below, select the region(s) your affiliated organization conducts flood planning.



Do you engage in any of the following flood planning activities? Check all that apply.

Data collection	**Assessments & Plans**	**Planning process**	**Projects**	**Communication**	**Other**
Floodplain mapping	Vulnerability assessments	Identifying problems & goals	Updating aging grey infrastructure	Communication with the public for emergencies and education	Please specify
Flood modeling & projections	Natural asset assessments	Develop a working group with stakeholders (collaborate with others)	Building flood prevention infrastructure	Internal communication and training for emergency preparedness	Please specify
Understanding watercourse flows and levels	Mitigation studies	Developing bylaws & regulations	Installing green infrastructure solutions	Coordinate and communicate with partner organizations	Please specify
Obtaining and sharing data with the provincial government and others (e.g. watershed organizations)	Risk assessments	Monitoring & evaluation	Habitat restoration & rehabilitation		
	Develop natural asset management plans	Identifying and finding needed skill sets to implement plans			
		Learning from others to improve plans ("social learning")			

Part Three: Networks

With whom do you **communicate** with about flood planning? This can include exchanging information or advice, coordinating actions, or collaborating. Check all that apply.

Full list divided into sub lists by type with check boxes

With whom do you collaborate when making flood planning decisions? Please consider flood planning activities conducted since 2018. If you do not collaborate with a listed organization, you may leave the row blank.

Collaboration includes the regular professional sharing of human, financial and or technical resources, engaging in joint activities, and organizing joint activities

Organizations	How often? *Rarely* (1-2 times per year) *Occasionally* (3-4 times per year) *Frequently* (6-12 times per year) *Regularly* (2 or more times per month)
[populated from the selected organizations in the communication question]	

Part Four: Successes and Challenges

How effective do you think you and your nearest collaborators (those who worked directly with you) were in addressing these different tasks?

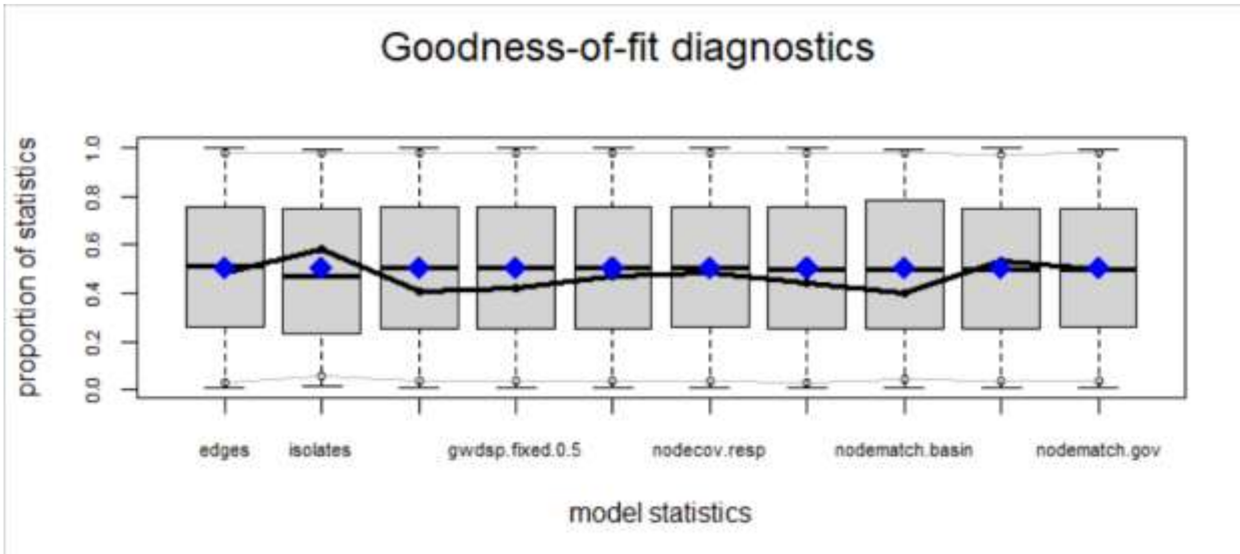
[task list populates from selected activities in the previous section]	*Not at all effective* *Somewhat effective* *Effective* *Very effective* *I don't know*

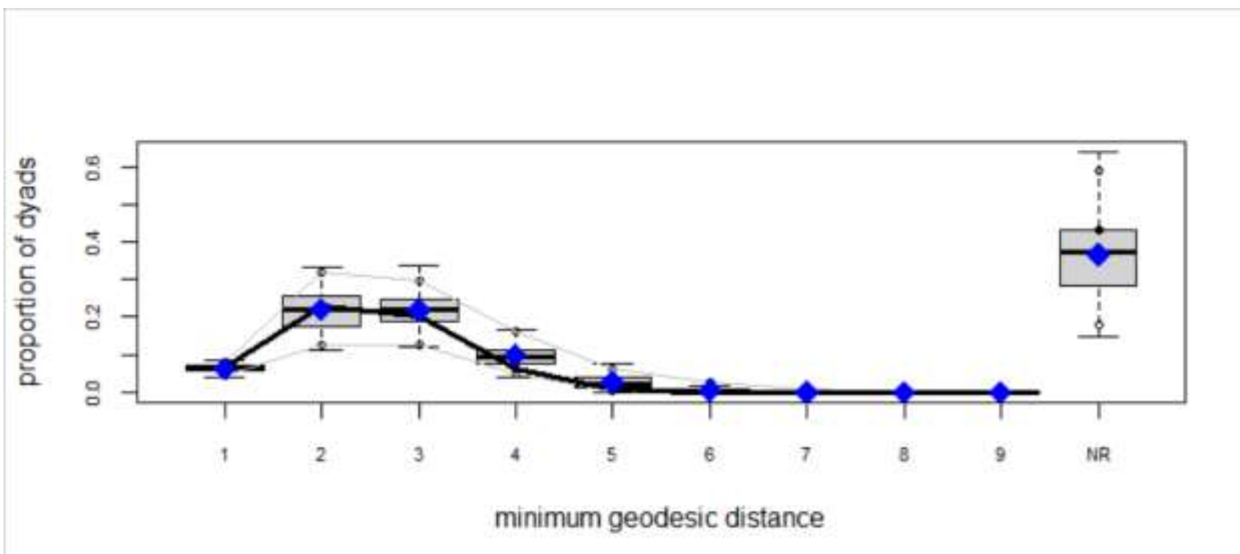
How effective do you think your flood planning efforts have been in general?	*Not at all effective* *Somewhat effective* *Effective* *Very effective* *I don't know* *Not applicable (e.g., if the process is not yet complete, or there has not been enough time passed to assess)*

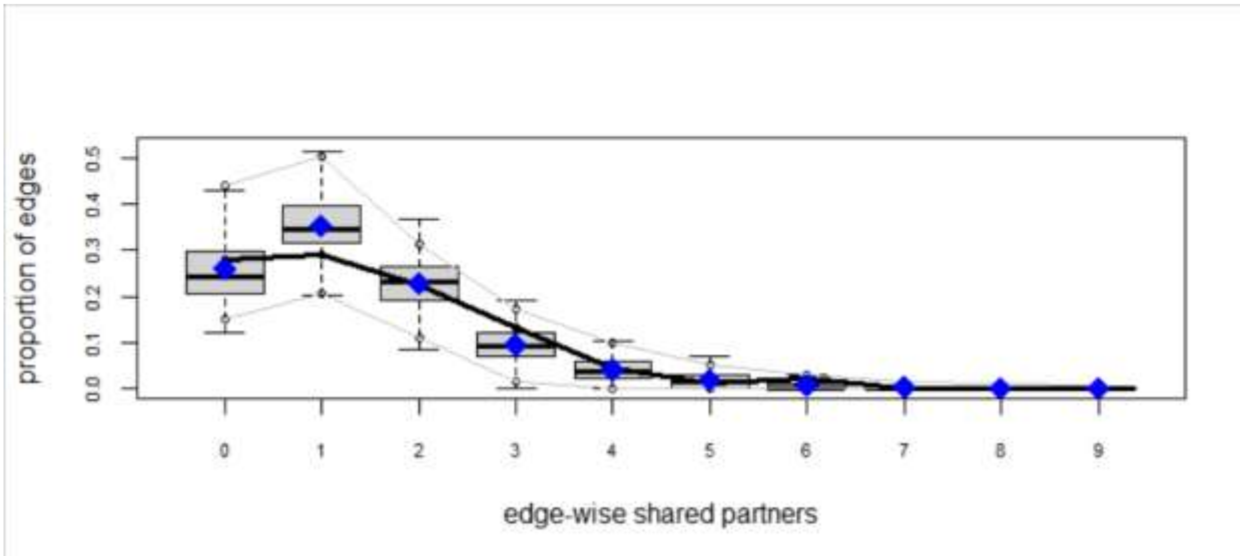
Collaboration includes the sharing of human, financial and or technical resources, engaging in joint activities, and organizing joint activities.

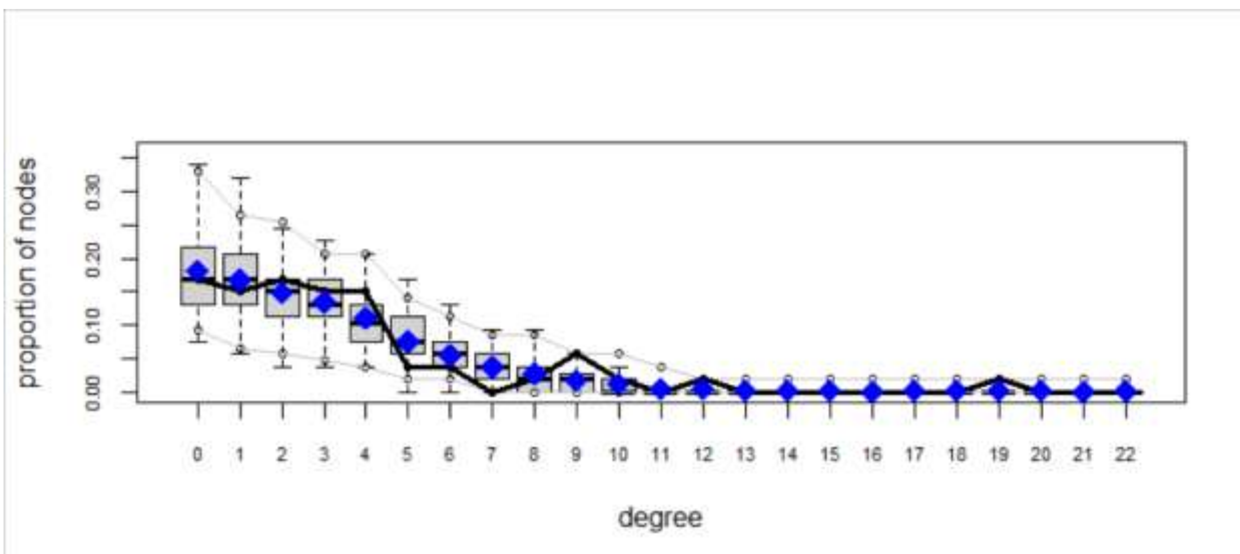
Does collaboration affect your ability to conduct flood planning?	*Yes* *No*	
If yes, how does collaboration affect your ability to conduct flood planning?	Open	
Have there been challenges collaborating with others?	*Yes* *No*	
If yes, which of the following statements reflect the challenges you have experienced? Select all that apply and then rank from most impactful (at the top) to least impactful (at the bottom).	*Lack of shared interests or non-compatible responsibilities* *Lack of shared commitment or determination* *Poor communication or co-ordination* *Lack of financial resources* *Time constraints* *Labour constraints* *Power imbalances* *Opposing values* *Lack of trust* *Other (Please Specify)*	
Would more collaboration be helpful to you for flood planning?	*Yes* *No*	
(if Yes) Whom would you want to collaborate with? Why? In the Who box, you can refer to specific organizations and/or types of organizations.	Who: (*open*)	Why: *(open)*
Do you have any other comments concerning collaboration for flood planning?	*Open*	

Appendix B: Exponential random graph model goodness of fit






proportion of edges
0.0
0.1
0.2
0.3
0.4
0.5
0 1 2 3 4 5 6 7 8 9
edge-wise shared partners


proportion of nodes
0.00
0.10
0.20
0.30
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
degree

Appendix C: Codebook for affects of collaboration

Code	**Description**
Knowledge	"Shared knowledge generation enhances understanding of what is known and not known" "Enhanced transmission or conductivity of knowledge increases performance" "Social learning leads to shared theory of action, strengthens shared understanding and commitment to shared goals" (Emerson and Gerlak 2014 p. 772)
Technical resources	Useful resources to collaborative governance include technical support (Emerson et al. 2012, Emerson and Gerlak 2014, Scott and Ulibarri 2019).
Funding	Local governments' capacity to implement depends on fiscal health (Honadle 2001) that is the "municipality's ability adequately to fund its pro- grammes and services, as well as having the means and flexibility to support its more innovative priorities" (Krause 2012 p. 2404). Budget support is instrumental to successful collaboration (Lubell et al. 2009).
Implementation	"Collaborative processes are intended to achieve improved environmental outcomes through better management of the resource and the implementation of collaboratively identified project goals, resulting in an overall improvement of resource conditions" (Mattor et al., 2020, p. 486)
Authority	"How the groups of organizations will govern and manage together in the CGR [collaborative governance regime] and integrate with external decision-making authorities" (Emerson et al. 2012)
Employee time & training	Local governments' capacity to implement depends on staff capabilities (Honadle 2001), and "there must be enough employees to perform the tasks expected of them and they must be adequately skilled" (Krause 2012 p. 2404).
Leadership	Collaborative governance provides multiple opportunities and forms of leadership (Emerson et al. 2012), and "multiple leaders are drawn on and cultivated to represent diverse organizations and perspectives" (Emerson and Gerlak 2014 p. 772). "Leadership is crucial for setting and maintaining clear ground rules, building trust, facilitating dialogue, and exploring mutual gains." (Ansell and Gash 2007)