COLLABORATION AND MORE-THAN-HUMAN INTERACTIONS IN CONSERVATION RESEARCH ABOUT NATIONAL HISTORIC WATERWAYS IN ONTARIO

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“ENOUGH OF
KINGDOMS!

Instead
let there be KINDOMS!

The fungal kindom. The floral
kindom. The faunal
kindom

where we hum the body’s every bone
in honor of the making &
the yet unmade

All of us kin. Co-creators
In conversation, McRedeye sez
with what shines

And with those divine
goddess rhizomes
rooted in the deeper dark

where life springs
full-blown from
the spark of matter”

Extract from **Kindom Canticle** by Art Goodtimes. 2021.
Kinship: Belonging In a World of Relations Volume 1 Planet, 134-135.

Reconnaissances

Pour Comète.

Merci aux eaux du canal Rideau et de la voie navigable Trent-Severn. Aux poissons, tortues, oiseaux, mammifères, reptiles, amphibiens, microorganismes, sédiments, plantes… qui habitent ces espaces, qui débordent de ces espaces, qui ont tant à nous apprendre. Avec respect pour le peuple Algonquin, gardien traditionnel du territoire non cédé où j'ai travaillé, et pour tous les peuples autochtones du Canada dont les connaissances et la musique m'inspirent.

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Abstract

Abstract Relationships between humans and the environment are messy and complex. This thesis makes sense of this complexity by using relational approaches to bridge social-ecological systems research with insights from the more-than-human social sciences and humanities. I focus on the case of environmental governance and conservation research in two of Ontario's National Historic Waterways: the Rideau Canal and the Trent-Severn Waterway. I analyze knowledge maps of factors that influence the environment of the waterways and the perception of relationships between humans and non-humans in the context of research. Through social-ecological network analysis, it was revealed different that groups conceptualize the Rideau Canal differently, but that all groups overemphasized social factors when identifying components that influence the environment. Knowledge maps, representing participants' mental models of the Rideau Canal, are used to generate narratives to inform policy and engagement strategies. Social-ecological network analysis was also used to make visible the different types of relationships between humans and non-humans in the context of conservation research. This unveiled a paradox of conservation. Attempts to produce evidence to conserve non-human populations and habitats are anchored in tense encounters, and sometimes procedures that are harmful for the individuals targeted by the research. I mobilize relational approaches and concepts from the social sciences to propose practical and theoretical insights and pathways for conservation research to become more-than-human. Such work necessitates the explicit recognition of the contributions of non-humans in research processes.

Keywords
Collaboration, friction, non-humans, relational sociology, social-ecological networks, Rideau Canal, Trent-Severn Waterway.

Résumé Les relations entre les humains et l'environnement sont complexes. Cette thèse donne un sens à cette complexité en utilisant des approches relationnelles pour faire le lien entre la recherche sur les systèmes socio-écologiques et les théories en sciences sociales et humaines qui vont par-delà l'humain. Je me concentre sur le cas de la gouvernance environnementale et de la recherche en conservation dans deux voies navigables historiques en Ontario : le canal Rideau et la voie navigable Trent-Severn. J'analyse des cartes de connaissances qui montrent des facteurs qui influencent l'environnement des voies navigables et la perception des relations entre les humains et les non-humains dans le contexte de la recherche. Des analyses de réseaux socio-écologiques ont révélé que les différents groupes conceptualisent différemment le canal Rideau, mais que tous les groupes surreprésentent les facteurs sociaux lorsqu'ils identifient les composantes qui influencent l'environnement. Les cartes de connaissances, qui représentent les modèles cognitifs qu'ont les participants sur le canal Rideau, sont utilisées pour générer des narratifs pour informer les politiques et les stratégies d'engagement. L'analyse des réseaux socio-écologiques a également été utilisée pour rendre visibles les différents types de relations entre les humains et les non-humains dans le contexte de la recherche en conservation. Cela a permis de dévoiler un paradoxe de la conservation. Les tentatives de produire des preuves pour conserver les populations et les habitats de non-humains sont ancrées dans des rencontres tendues, et parfois des procédures nuisibles qui sont pour les individus ciblés par la recherche. Je mobilise des approches relationnelles et des concepts issus des sciences sociales pour proposer des idées et des voies pratiques et théoriques pour que la recherche en conservation devienne plus qu'humaine. Un tel travail nécessite la reconnaissance explicite des contributions des non-humains aux processus de recherche.

Mots-clés
Collaboration, friction, non-humains, réseaux socio-écologiques, sociologie relationelle, Canal Rideau, Voie Navigable Trent-Severn.

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Introduction

This thesis looks at relationships between humans and non-humans in the context of conservation research about two National Historic Waterways in Ontario: the Rideau Canal and Trent-Severn Waterway. Building on momentum from a transdisciplinary, partnership research project investigating how to maintain and enhance ecosystem services in the waterways, the social science research presented in this thesis creates bridges between interdisciplinary social-ecological systems research and relational approaches in the social sciences and humanities. These frameworks are used to better understand people's perceptions of relations between humans and the environment around the waterways, and to identify pathways to support future management and research in the Rideau Canal, the Trent-Severn Waterway, and beyond.

Anchored in sociology, my research analyzes the ways in which collaboration in transdisciplinary research – both among humans, and between humans and non-humans – contributes to our understandings of human-environment relationships. To achieve this goal, this thesis operates at two levels. First, through conservation social science which used collaborative workshops to uncover people's views and knowledge about the Rideau Canal as a social-ecological system (SES), and network analysis to present these views as narratives that can be used to support management, policy, and engagement (Chapter 1). Second, I explored relationships within conservation research through a social-ecological network analysis of interactions between humans and non-humans that revealed both collaborative and frictional tensions (Chapter 2). Building on these empirical findings and following the literature, I finally propose practical and theoretical insights to recognize non-humans as actors and contributors in conservation research processes and to address tensions between humans and non-humans (Chapter 3). The chapters are complemented with connective tissues that take seriously the need to practice reflexivity. They provide additional context on how this thesis came to be.

This introduction first presents the broader context of contemporary human-environment relationships, including the role that science plays in these relationships. This is followed by an overview of the literature on two key concepts that shaped my work: social-ecological systems (SES) and collaboration. I then present the empirical case around which my thesis is built, Ontario's National Historic Waterways. I then unpack the boundaries of this thesis by exposing the research problem and questions. Following this, I explain the principles that guided my research, first theoretically and conceptually, and second methodologically. Finally, I briefly explain the process of this thesis and how it is structured.

Broader context

Humans and other inhabitants of the planet are facing complex, global environmental changes emerging from the domination of human social patterns (e.g., modes of production, ways of living) over ecological processes (Görg et al. 2017). These changes, including climate change, food insecurity, water scarcity, and drastic loss of biodiversity, are framed by environmental expertise as problems or social-ecological crises (Brand 2016; Görg et al. 2017; Lidskog et al. 2022). Calls for sustainability transitions which attempt to respond to these crises simultaneously depend on meaningful social transformation and continued reliance on, and trust in, established western expertise and knowledge about science and technology (Görg et al. 2017; Lidskog et al. 2022). Yet, the very framing of these changes as crises or problems is not neutral. It points to the hegemony of the natural sciences as part of the dominant discourse and regime which embodies a positivistic, objectivist, binary, colonial, controlling, capitalistic lens that shapes conceptualizations of social-ecological relationships and contributes to tensions and environmental destruction (Brand 2016; Clark 2019). Paradoxically, the very framings which have contributed to the emergence of environmental problems (e.g., the accumulation of data to better understand how we can manipulate the world and resources from the environment) are now being used to address these problems (e.g., the accumulation of data to better understand how we can control invasive species, protect native species, conserve biodiversity in working landscapes).

In this context, relational perspectives and ontologies that go beyond nature-culture dichotomies provide alternative understandings of human-environment relations which can be conceptualized as co-existing and mutually constituted (Brand 2016). Relational perspectives are often found in the social sciences and humanities, but some Indigenous people also have relational understandings of human-environment relationships, and part of the biological and conservation sciences build on ecological logics that emphasize relations between species and abiotic elements in ecosystems (Lejano 2019). The concept of the Anthropocene, which marks the scientific recognition that humans have impacted the planet's geology and functions (Waters et al. 2016), has also made it easier to acknowledge the co-construction of human processes with natural, environmental, and planetary processes (Lidskog et al. 2022). Humans both influence, and are influenced by, non-humans. Given these social-ecological understandings of environmental crises, the social sciences are increasingly valued and considered necessary to effectively facilitate sustainability transitions by providing reflexive, critical, and constructive expertise (Bennett et al. 2017; Berkes 2017; Lidskog et al. 2022). For example, the field of human dimensions of conservation and natural resource management is now well established, and the concept of social-ecological systems (SES) can be understood as a boundary object that connects work across the natural and social sciences (Hertz and Schlüter 2015; Partelow 2016; Bennett et al. 2017; Ford et al. 2021).

Furthermore, these realizations invite environmental researchers to adopt new meanings and practices, and to work toward transdisciplinary collaborations by crossing disciplinary but also professional and cultural boundaries (Perz 2019; Lidskog et al. 2022). Relationality also emphasizes expertise as a social process which is not only upheld objectively through the accumulation of knowledge and training, but rather which emerges through social networks that collectively recognize and sustain the credibility or status of a claim, skill, competence, or knowledge (Lidskog et al. 2022). This opens up expertise as a flexible process, and different types of knowledge including artistic, local, and Indigenous knowledges are now included in the environmental field (Lidskog et al. 2022). As such, environmental expertise builds on the natural sciences but also contributions from environmental humanities and social sciences (Bennett et al. 2017; Lisdkog et al. 2022), collaborative research processes that include local knowledge (Klenk et al. 2017; Mistry et al. 2021), community science that recognizes the ways in which non-scientists can contribute to scientific processes (Charles et al. 2020), and work with Indigenous communities and knowledges (Datta 2015). While exploring these avenues broadens the types of knowledges and expertise considered when working to address or solve environmental issues, these approaches also contribute to reframing human-environment relationships. For example, environmental humanities and arts such bio-art materially explore new configurations of relationships between humans and non-humans. In doing so, they raise new questions, rather than providing exact answers that can be immediately applied (Beaudoin 2021). This is valuable in that addressing social-ecological crises not only requires immediate action, but also thinking about what it would mean for humans to reconnect with nature (Ives et al. 2018). This can be brought into practice by identifying material leverage points in SESs (Ives et al. 2018) or by reframing the nature of our relationships with non-humans as intimate entanglements and relationships of kinship (Haraway 2016).

Within this broader context, the present thesis concerns itself with applied environmental research, and specifically conservation research defined as aiming to produce knowledge that can inform sustainable management in ways that simultaneously attempt to conserve biodiversity and improve the well-being of human communities (Kareiva and Marvier 2012; Cooke 2019). As a PhD student in sociology, I joined a research project aimed at better supporting management of two National Historic Waterways in Ontario. This project conceptualized the waterways as complex SESs in order to effectively improve management (e.g., Bergman et al. 2021) and acknowledged the need to include social scientists to improve environmental outcomes. The social science component of the project investigated the environmental governance systems of the waterways, as well as views about the state of the environment (e.g., Mistry et al. 2021; Beaudoin et al. in preparation a).

The readers are invited, as they make their way through the chapters, to keep in mind the broader context of social-ecological tensions and crises that currently underpin human-environment relations, the increasingly transdisciplinary nature of environmental research and especially applied research, and growing interest in and use of systemic, processual, and relational frameworks to frame such research.

Key concepts

In this section of the introduction, I locate myself conceptually by providing a literature review of two key concepts relevant to my work: the concept of social-ecological systems (SES), and the concept of collaboration.

Social-ecological systems

The concept of social-ecological systems (SES) does not have its origins in the field of sociology. The term "social-ecological systems" refers to systems composed of coupled societal and ecological subsystems which interact through bidirectional linkages at local and global scales (Gallopin 1991; Berkes and Folke 1998; Anderies 2002; Schoon and Van der Leeuw 2015). SES research is often inter- or transdisciplinary and mobilizes complex systems thinking, resilience theory, as well as a variety of methodologies like modelling, scenario-testing, and mixed methods to grasp some of the heterogeneous components and interactions of complex environmental situations. SESs can also be conceptualized as abstract system objects that are used to model real-world social-ecological interactions and phenomena (Glaser et al. 2012). Researchers in the field of SES recognize the need to better understand (1) our integrated relationship with the environment in which we live, (2) how to adapt to changes in both social and ecological systems and (3) how to generate and use knowledge about this relationship (Berkes and Folke 1998; Glaser et al. 2012; White et al. 2018; Perz 2019).

There are many strengths to the concept of SES. The concept favors a holistic understanding of the linkages between society and ecosystems by building on complex systems thinking (Berkes and Folkes 1998). SES also shares commonalities with the relational turn in the social sciences by moving away from positivistic and linear accounts of ecosystem dynamics toward increasingly relational and processual understandings of human-environment relationships (Davidson-Hunt and Berkes 2002; Mancilla García et al. 2020). Moreover, SES lends itself to the development of integrated models. While it remains a challenge to model complex, adaptive, self-organizing systems that are shaped by uncertain human actions and ecological states, various modelling approaches have been helpful: bioeconomics, management strategy evaluation, state and transition models, game-theoretic models, numerical simulations of complex systems, and network approaches (Schlüter et al. 2012).

In addition, SES is a versatile concept that can address multiple aspects of human-environment relationships. It is compatible with different sets of theoretical assumptions, methodological approaches, datasets, and frameworks (Binder et al. 2013; Hertz and Schlüter 2015). Thus, it can act as a boundary object (Glaser et al. 2012; Hertz and Schlüter 2015; Partelow 2016; White et al. 2018). Boundary objects serve two main functions: a social function to increase communication and cooperation among researchers, and a cognitive function to act as trading zones, providing a common language and set of concerns (Glaser et al. 2012). Furthermore, SES research generally recognizes the need to integrate multiple forms of knowledges, including local and traditional knowledge, to complement and supplement western scientific knowledge (Berkes and Folke 1998; White et al. 2018). Finally, SES provides us with pathways to rethink human-environment relationships. It acknowledges the need to shift our mental models and the ways in which science, research, and policy have conceptualized human-environment relationships (Folke 2006; Ostrom 2007).

However, SES is not a perfect concept. It features weaknesses, such as not appropriately accounting for some important aspects of human-environment relationships. Even though SES research acknowledges the need to include various forms of knowledge, Indigenous people and knowledges are still underrepresented in SES research. There are also mismatches between the knowledge of Indigenous people – which is generally holistic, experiential, and qualitative – and the scientific and institutional framings of SESs where decision-making draws on experimental and quantitative knowledge (Bowie 2013; McGregor 2012). These mismatches, as well as historical logics of colonization that permeate scientific research and the institutions who often have jurisdiction over SESs, can generate misunderstandings, feelings of irrelevance, and lower participation of Indigenous people in collaborative processes (Bowie 2013; McGregor 2012). Furthermore, epistemological pluralism, referring to equal consideration of the contributions of disciplines with different epistemologies, can be hard to operationalize in SES research (Miller et al. 2008). The lack of integration of different knowledges in this field often leads to over- or underemphasizing various aspects of human-environment relationships. For example, critical social sciences aren't often included in SES research which explains why the concept doesn't easily address power asymmetries (Thiel et al. 2015). The concept is also difficult to operationalize and formalize, resulting in most use of SES being analytical and theoretical rather than methodological (Cox 2014). This is partly related to the site-specific nature of SES research, the empirical diversity of coupled systems, the diversity of researchers operating in SES research, and difficulties in establishing clear boundaries to a given SES as we live in an increasingly global and connected world.

While it is not a panacea, we must remember that SES is first and foremost an interdisciplinary concept and field of research (Bennett et al. 2017). The real strength of SES as a concept lies not in generating purely ecological or sociological analyses, but in providing a way to generate complex and plural understandings of empirical social-ecological phenomena. In doing so, the concept acknowledges the potential of social sciences to help untangle complex systems; this is a step forward in a field that has traditionally failed to engage sociological research (Bennett et al. 2017; Lidskog et al. 2022). In my thesis, I have operationalized SESs as social-ecological networks to explore the methodological potential of the concept.

Collaboration

Collaboration is at the heart of the social fabric that makes up our living together. The word collaboration comes from the Latin *con-* (with), *laborare* (to work), and *-ation* (action): it means to work with someone (Neimanis 2012). This type of relationship is part of our daily personal lives as well as our professional and academic spheres of activity. Collaboration can occur in multiple ways, in various settings, between a plurality of individuals, and can be understood at the interpersonal, intra-organizational, and inter-organizational levels (Colbry et al. 2014). Sociology, political science, business administration, and psychology have studied various dimensions of collaboration including leadership, collective action, interorganizational behaviours, teamwork, and cooperation (Colbry 2014; Perz 2019). Some work specifically addresses the mechanisms of inter, multi, and transdisciplinary collaborations within and between the social and/or natural sciences (e.g., Frickel et al. 2016).

Precise definitions of collaborations generally refer to cooperative processes such as exchanging resources and formally or informally engaging in mutually beneficial – but not necessarily symmetrical – interactions (Thomson and Perry 2006). Some key dimensions of collaboration are related to structure (governance, administration), agency (individual and collective autonomy, interests), and social capital (mutuality, trust, reciprocity) (Thomson and Perry 2006; Thomson et al. 2009). In the context of transdisciplinary research, collaborative processes include planning grants and research projects, implementing, participating, and monitoring projects, and finally using the outcomes of projects (Jahn and Kell 2015). There can be different levels of collaborative relationships, for example mutual collaboration that involves co-creation, pooling which involves working independently until work is combined, and communication-focused interactions where people don’t rely on each other for producing outcomes (Matthews et al. 2012). Multiple mechanisms usually co-occur as part of collaborations (Newig et al. 2018).

Collaboration is discussed at length in the literature on environmental research and various approaches have been proposed including multidisciplinary research (Uiterkamp and Vlek 2007), boundary work (White et al. 2018), coproduction (Lemos et al. 2018; Cooke et al. 2021), action research (Mistry et al. 2021), living labs (Beaudoin et al. 2022b), and community science (Charles et al. 2020). Because environmental situations vary greatly, it is critical that knowledge be assessed by researchers with community partners to determine its relevance at the local level and to foster the development of effective practices (Sutherland et al. 2017). Collaborative processes thus help address power dynamics in environmental research and governance, as knowledge and power are tightly linked (Van der Molen

2018). Leadership and brokerage contribute to establishing effective and productive co-governance, for example by facilitating communication and linking groups that may not otherwise be linked (Bodin et al. 2006; Bodin and Crona 2011). Developing trust among researchers, managers, and communities through authentic conversations about the environment and lasting relationships facilitates collaboration and knowledge mobilization processes (Chapman et al. 2015; Nguyen et al. 2018). It's also been shown that researchers with extensive collaboration networks and who spend more time engaging the public have greater uptake of their findings (Nguyen et al. 2019).

As such, collaborative approaches are becoming increasingly popular in environmental research, governance, and policy development (Mancilla García et al. 2019) and there is an implicit assumption that collaboration, coproduction, and co-management always lead to positive or better outcomes than top-down approaches (Newig et al. 2018). This is in part because despite the challenges that it poses, collaboration makes possible things that would otherwise not be (Perz 2019). Collaboration in both research and practice is thus discussed normatively: "we 'want' collaboration because we think it is 'good.'" (Mancilla García et al., 2019: 1; Newig et al. 2018). However, while broad calls toward collaboration are sometimes seen as necessary, we need to recognize the challenges of this work if we want to mobilize it appropriately and in the right circumstances (Lemos et al. 2018; Perz 2019). Furthermore, tensions and awkwardness can be drivers of collaboration (Perz 2019; Mancilla García et al. 2019), but collaboration may not occur if there is too much friction.

This points to what has been termed by some as the collaboration paradox (Prentice et al. 2019): it is difficult to use theory to inform effective collaborative practices and governance because of paradoxical recommendations emerging from the growing literature about collaboration and collaborative processes. Furthermore, collaborations that lack diversity may not be sufficient to effectively address wicked problems (Prentice et al. 2019). These complexities, contingencies and paradoxes make the design of effective collaboration extremely complicated. Moreover, collaboration may not always result in improved outcomes. In fact, studies on the effectiveness of collaborative characteristics that are generally accepted as beneficial, like using a coordinator and goal specificity, yield inconclusive results (Scott 2015). Collaboration can also be costly and time-consuming, reproduce existing power asymmetries, lead to more conflict, or fail to address the environmental challenges at hand (Cinner et al. 2012; Boström et al. 2015; Bodin 2017; Perz 2019). If authority remains in the hands of a few, collaborative processes can be exclusionary, feed injustice, get stuck in bureaucratization, among other unhelpful social dynamics (Young 2020). It's also been found that in some cases, participation and collaboration can have negative effects on environmental outcomes (Newig et al. 2018).

In this context, collaboration seems like a trendy buzzword that helps researchers obtain funding and be relevant in academic, economic, and governmental 21st century landscapes (Neimanis 2012). However, gaps exist in terms of understanding the nuances of collaborations, how it is articulated in practice, and how to determine if collaboration really occurs. "[W]e as policy scholars and practitioners need to think more deeply about why we believe that collaborative groups are an effective tool for achieving public policy goals." (Scott 2015: 559). Moreover, from a social-ecological perspective, the biggest weakness of our current understandings of collaboration is that it is anthropocentric. While collaboration aims to include a broader diversity of human actors in various processes, questions have been raised about how to include ecological components and non-human actors in such processes and what role they could have. These questions have been raised in the arts and environmental humanities (Ambayec et al. 2021; Jevbrat 2009; Cypher 2017; Bastian et al. 2017).

Empirical case

In this section of the introduction, I locate my research empirically. I first provide an overview of the two waterways that are at the core of this thesis: the Rideau Canal (RC) and the Trent-Severn Waterway (TSW), two National Historic Waterways in Ontario. I also recount the story of a Strategic Partnership Grant (SPG) funded by the Natural Sciences and Engineering Research Council of Canada (NSERC) and how this grant has contributed to the shaping of my thesis.

Ontario's National Historic Waterways

Waterways have historically supported inland transportation, existing as alternatives to roads and railways, and built canals have extended our reach beyond that of natural rivers (Konings and Wiegmans 2016). Inland waterways also fulfill other functions unrelated to transportation: water management and water supply, tourism, recreation, ecological value, and cultural heritage (Konings and Wiegmans 2016). There are many challenges tied to the governance of inland waterways, such as mobilizing political will (Konings and Wiegmans 2016; Willems et al. 2018). Furthermore, institutions managing waterways often lack adaptability, for example they can fail to consider current and future challenges relating to aging infrastructure, lack of public funding, and increased climate pressures (Willems et al. 2018). Other challenges are tied to the management of social relations in the environmental governance of waterways, such as effectively including different knowledges, attending to power asymmetries that contribute to tensions around (in)justice, rights, and democracy, and securing the necessary resources and the right partners for collaborative governance and adaptive co-management to fulfill its transformative potential (Young 2020). Overall, waterway systems are complex webs governed by fragmented regimes made up of various species, technologies, levels of government, agencies, and community groups which behave, (inter)connect, and relate to each other in various ways. This is especially challenging because "the multiscale and boundary-spanning features of water do not, in general, adhere to human-defined political boundaries" (Mancilla García et al. 2019: 1). The ways in which waterways are governed can be improved through the recognition that waterways are coupled SES which must feature resiliency and adaptive capacity to deal with ongoing environmental changes and uncertainty (Berkes 2017). Achieving this recognition and building resilient, adaptive SES can be facilitated by collaboration – for example through co-financing arrangements, by involving of a wide array of actors, and by fostering social learning through networks and coproduction of knowledge (Berkes 2017; Willems et al. 2018; Mancilla García et al. 2019). However, this is no simple task and the relative success (e.g., improved social relations or improved ecological outcomes) of these efforts often vary as they depend on specific social-ecological contexts (Mancilla García et al. 2019). While managing waterways is inherently complex, we can specifically attend to the unique contexts of historic waterways which often span multiple jurisdictions and which are subject to multiple mandates, objectives, and competing priorities (Lin et al. 2020).

Canada has many inland waterways, including nine historic canals managed by Parks Canada (Charron et al. 1982; Parks Canada 2007). In Ontario, significant environmental and historical heritage can be found in the Sault Ste. Marie Canal, the Rideau Canal, and the Trent-Severn Waterway. This thesis is concerned with two canals in Southeastern Ontario that are linked to Lake Ontario: the Rideau Canal (RC) and the Trent-Severn Waterway (TSW) (Figure 0.1).

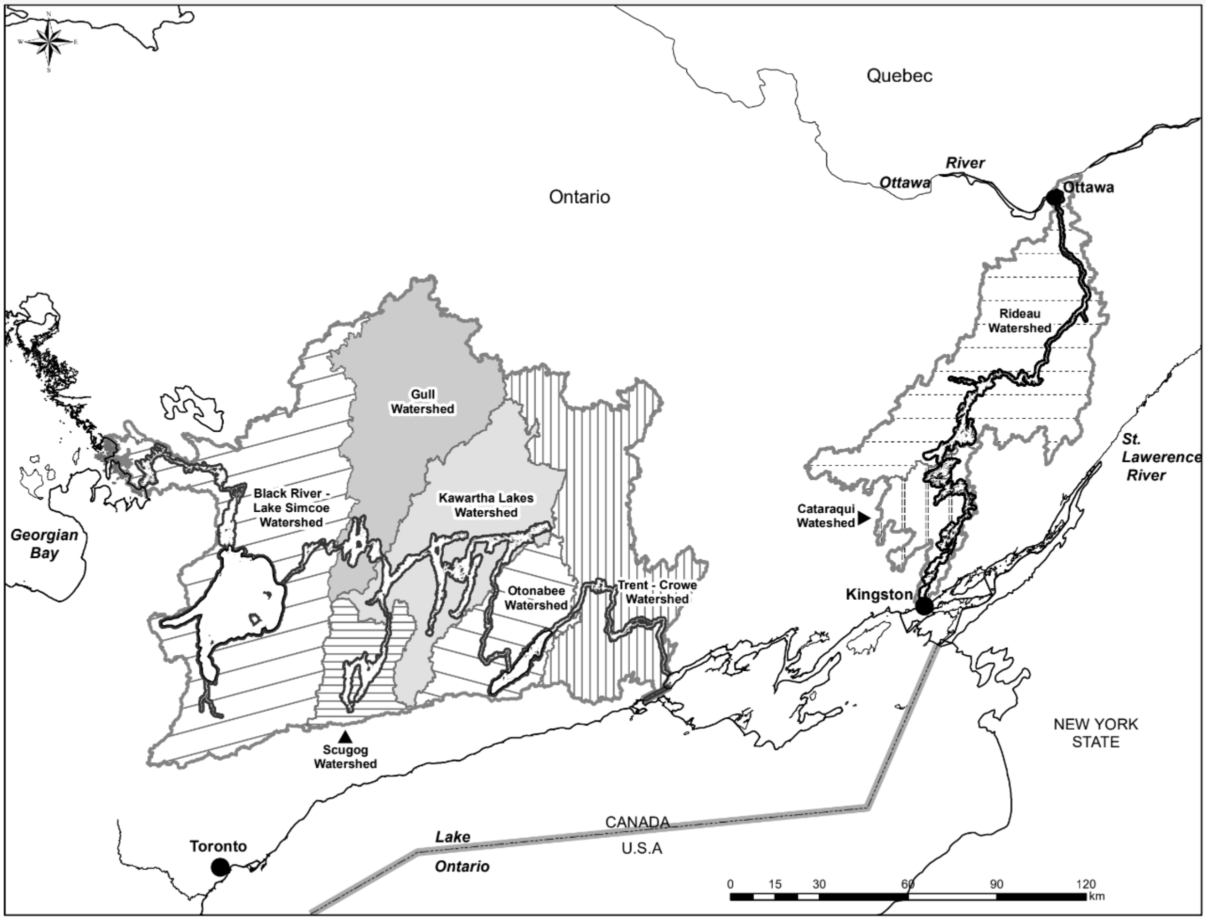

Figure 0.1. The Trent-Severn Waterway (left) and Rideau Canal (right). Map produced by the Ontario Waterways Unit at Parks Canada. Used with permission.

The RC's construction began in 1826 and the canal opened for navigation in 1832, effectively creating a navigable channel between the Ottawa River and Lake Ontario that bypasses the St Lawrence River (Table 0.1; Parks Canada 2005). The TSW's construction began in 1833 but was not complete until 1920 when it connected Lake Ontario through the Bay of Quinte with the Georgian Bay (Parks Canada 2000). These canals were intended to be safe military and commercial transport routes (Charron et al. 1982).

	Rideau Canal	*Trent-Severn Waterway*
Construction completed in	1832	1920
Designated as a National Historic Site in	1925	1929
Total length	202 kilometers	386 kilometers
Connected municipalities	Ottawa and Kingston	Trenton and Port-Severn
Connected water bodies	Ottawa River and Lake Ontario	Lake Ontario and Georgian Bay
Number of locks	47 masonry locks	37 conventional locks, 2 pairs of flight locks, 2 hydraulic lift locks
Number of dams	52 dams	125 dams
Other key engineering features		2 marine railways, 15 swing bridges
Areas often forgotten about	Tay Canal included in the Rideau Canal in 1831	Northern reservoir lake system in the Haliburton Highlands

Table 0.1. Overview of key features of the Rideau Canal and Trent-Severn Waterways. (Parks Canada 2000; Parks Canada 2005).

First managed as military systems under the British Ordnance in the 1800s, in 1936 the canals started being managed as transportation corridors by the federal Ministry of Transport and contributed to the development of Southeastern Ontario (Charron et al. 1982). Since 1972, they have been managed by the federal agency Parks Canada for their historic and aesthetic value, providing examples of early engineering technology in Canada (Figure 0.2), and as scenic corridors commonly used for leisure (Charron et al. 1982).

Figure 0.2. Peterborough Life Lock in the Trent-Severn Waterway. Photo by the author.

Parks Canada has jurisdiction over in-water and shoreline work relating to infrastructure, interpretation, and conservation (Parks Canada 2007). Other federal, provincial, and municipal authorities, including conservation authorities, also participate in the management of the waterways which are subject to a variety of legislative acts and policies (Charron et al. 1982). For example, at the federal level, the RC and TSW are subject to the *Parks Canada Agency Act*, the *Historical Canals Regulations*, the *Canadian Environmental Assessment Act*, the *Fisheries Act*, *the Species at Risk Act*, the *Canada Shipping Act*, the *Navigable Waters Protection Act*, the Historic Canals Policy, the Federal Wetlands Policy, and the Cultural Resource Management Policy (Parks Canada 2007). There are also other provincial, municipal, and watershed-level acts and policies that apply to these waterways. This makes for a jurisdictionally complex, and largely fragmented, governance context (Bergman et al. 2021).

Furthermore, the waterways themselves both fragment and connect the ecology around bodies of water pre-existing the canal. For example, in the RC, the Gananoque River and Cataraqui River watersheds were altered by the canal construction while the Rideau River watershed was less impacted; new connections were also created between the Rideau and Cataraqui watersheds (Bergman et al. 2021). While the landscapes within which the canals are located have pockets of natural forests and wetlands, they have been in large part transformed and used by humans for urban, agricultural, and recreational activities (Charron et al. 1982). Today, the RC and TSW are integrated to the many communities along the waterway as recreational spaces and economic drivers. There are many uses for the water such as navigation, recreation (e.g., angling, walking, swimming, skating), historical preservation, tourism, hydroelectric power, irrigation, and water supply, among others (Charron et al. 1982; Parks Canada 2007). There is even a location equipped with bolted anchors for outdoor rock climbing at the Kingston Mills Lock Station on the RC (Figure 0.3). Achieving balance across the various priorities of the diverse set of actors invested in these systems is a complex task.

Figure 0.3a. Sign to release Parks Canada from liability related to rock climbing at the Kingston Mills Lock Station (locks 46 to 49) on the Rideau Canal. Photo by the author.

Figure 0.3b. View of the waterway and bolted anchors for top-rope climbing at the Kingston Mills Lock Station (locks 46 to 49) on the Rideau Canal. Photo by the author.

While both waterways are concerned in this empirical case, the RC has been the primary focus of my research and of the researchers I worked with. Thus, I provide some additional context on the RC. It has multiple designations at the national and international level which are meant to recognize its unique historical, cultural, and natural heritage and its recreational value, and to conserve this value for future generations of Canadians. The RC became a Canadian National Historic Site in 1925 and a Canadian Heritage River in 2000 (Parks Canada 2005). Despite delays, it also became a UNESCO (United Nations Education, Scientific and Cultural Organization) World Heritage Site in 2007 for its historical role as military transportation route and for the continued operation and preservation of its infrastructure (UNESCO N.d.). The UNESCO World Heritage Site designation was obtained in large part due to work and pressure from a local community group, The Friends of the Rideau, which hoped the designation would benefit the site through improved protection and maintenance (Gfeller and Eisenberg 2015). This shows the potential of local initiatives to influence environmental governance, and to initiate globally significant change (e.g., the broadening of World Heritage concepts to include historic canals; Gfeller and Eisenberg 2015). It also highlights the importance of collaboration: once Parks Canada aligned with Friends of the Rideau, it was able to gather resources and expertise to support the ultimately successful nomination of the RC for a World Heritage Site designation (Gfeller and Eisenberg 2015). This is just one example of how collaboration has been a valuable and effective pathway to improve conservation outcomes in the context of the RC's environmental governance.

Overall, the RC is composed of a mix of built infrastructure, rivers, and lakes: the lock stations are historical sites, some reaches are barely developed and have clear waters (Figure 0.4), other reaches host farmland while some areas are heavily developed like Manotick, and the RC is heavily promoted for tourism in downtown Ottawa as the Ottawa locks are located near other destinations such as the Chateau Laurier and Parliament Hill (Stevens 2006). Over the years, some environmental research has been conducted on the RC studying the impacts of the canal's construction on water flow and eutrophication (Sonnenburg et al. 2009), fish populations and vegetation communities (Walker et al. 2010), movement patterns of the muskellunge (Gillis et al. 2010), contaminants in certain lakes (Stuyt et al. 2015), and the impacts of climate change on the skating season on the RC's skateway in Ottawa (Agrawal and Jahanandish 2019). Marketing research has also shown there is a need for more partnerships and long-term thinking when planning heritage tourism in the RC (Donohoe 2012). A knowledge gap was identified in terms of conceptualizing the RC as an SES in research to fully capture its complexity (Bergman et al. 2021).

Figure 0.4. People fishing on Upper Rideau Lake at the wooden deck of the Narrows Lock 35. Photo by the author.

The interlinkages between humans and their environment in the case of National Historic Waterways in Ontario emphasize the need for researchers to take integrated approaches that consider both social and ecological factors. The RC and TSW are complex landscapes that involve many actors: First Nations, federal, provincial and municipal partners (e.g., 13 counties and townships in the RC), conservation authorities (e.g., two conservation authorities in the RC), tourism agencies, environmental groups, lake and resident associations, groups with commercial and economic interests, fishermen, sportsmen, visitors, researchers… but also fish, turtles, microorganisms, insects, birds, aquatic and land-based vegetation, and the water itself, among others. Infrastructure and technologies such as homes, dams, locks, and boats also make up a significant portion of these SESs. Beyond the pressures caused by a plurality of actors who cohabit and collaborate in various – sometimes tense – ways, the RC and TSW also face other anthropogenic stressors. Concerns include urbanization and transportation, humans transporting invasive species that can exacerbate the loss of habitat and resources for native species, and extreme weather events (droughts and floods) that are linked to climate change. It is in this context that a team of researchers established a new working collaboration with Parks Canada.

The story of the NSERC SPG

In 2018, a team of ecologists, biologists, engineers, and social scientists from Carleton University, the University of Ottawa, and l'Université de Sherbrooke joined forces with Parks Canada and other government and community partners including conservation authorities, lake associations, and angling groups. A total of seven professors across universities and disciplines and two Parks Canada employees worked directly with each other and with research professionals (postdocs, lab managers), graduate students, and undergraduate students. This team carried out a multidisciplinary research project funded by a Strategic Partnership Grant (SPG) from the Natural Sciences and Engineering Research Council of Canada (NSERC). While some researchers on the team were new to the waterways, others have been studying or spending time in or near the RC and TSW for many years. The long-standing knowledge of residents, anglers, and lock staff among others helped newcomers gain a better understanding of these complex systems. Repeated attempts were made in the first two years of the grant to establish working relationships with Indigenous contacts provided by collaborators, and by identifying Indigenous communities nearest to the RC (e.g., Algonquins of Pikwakanagan, Kitigan Zibi Anshinabeg, Mohawks of the Bay of Quinte) and other formal groups (e.g., Algonquin Anishinabeg Nation Tribal Council, Algonquins of Ontario Consultation Office, Algonquins of Ontario, Metis Nation of Ontario, Institute of Indigenous Research and Studies at the University of Ottawa). These efforts unfortunately did not result in partnerships in the context of the grant.

The grant aimed to investigate the ecological integrity of the RC and TSW. I frame this grant as an applied research project (see page 10 of this introduction for a definition) as it tackled real-world problems by working with a range of partners that were directly concerned. The NSERC SPG specifically aimed to support management and maintain and enhance ecosystem services in the waterways. It was academically multidisciplinary, pulling from the work of natural and social scientists, but also transdisciplinary in practice as it involved decision-makers and community partners. Some concerns to be addressed by the grant related to multi-level governance of the waterways and overlapping jurisdictions, and the ecological impact of the waterways' infrastructure (e.g., locks, dams) on freshwater ecosystems through connection and fragmentation. It was proposed that an SES approach could serve as an appropriate framework to bring together experts from various disciplines.

Annual grant meetings served to coordinate partners and showcase various ongoing research projects. A summary paper was written by the team described the RC as an SES, showing some collaboration among those participating in the grant. Beyond this, some research projects took place in disciplinary silos, though these often involved collaboration with or the participation of community and government partners. Ecologists and biologists mainly led projects around the movement of various fish species in the RC (e.g., bass, muskellunge, invasive round gobies), genetic variations of different turtle and fish populations (e.g., painted turtles), indicators of water quality (e.g., zooplankton, algae), and ways of controlling invasive aquatic vegetation (e.g., Eurasian watermilfoil). One biologist also collaborated with an engineer to look at the interactions of fish movement and hydraulics in specific areas of the waterways. Social scientists analyzed views about governance of various actors involved in the system (e.g., researchers, government employees at various levels, business owners, locals and members of lake associations or stewardship groups). Most researchers worked in the RC as it is already an expansive and complex system that was local to the two main universities involved in the project. Few attended to the social-ecological dynamics of the TSW.

The grant provided three years of funding, but the project unfolded over four years, from 2018 to 2022. This year marks the final official year of the project – data collection is generally complete, analyses are ongoing or in their final stages, outcomes are starting to be published and submitted for publication. I was on boarded as a PhD student in 2018 to participate in the social science component of the grant. My thesis builds on work conducting conservation social science as part of this research project, and also goes beyond this work to pose questions about the very nature of applied conservation research. The theme of collaboration emerged in this project both as a result of the research (e.g., locals want to be involved in the management of the waterways through governance processes that are more transparent and inclusive; collaboration and coordination between those who are already involved in the governance such as various levels of government and other partners could be improved) and as a research practice (e.g., government and community partners collaborated with academics in the context of the research for planning workshops or to support angling efforts for data collection; collaborative writing has resulted in co-authored papers).

Thus, I pulled on the connecting of thread of collaboration that I saw as a social phenomenon that was key in applied, transdisciplinary conservation research. Simultaneously a practice, a method, and an expectation, it seemed to be often normatively discussed in the context of both environmental governance (e.g., "we need to collaborate to conserve the historical and natural heritage of the waterways") and environmental research (e.g., "we need to collaborate to do good research that can inform policy and management"). I myself operated within the space created by the NSERC SPG by collaborating with people who had long-standing knowledge in the system to identify key actors, by listening to people's stories about collaboration in the waterway through interviews (e.g., Mistry et al. 2021), by coordinating with locals interested in our work (e.g., Beaudoin et al. in preparation b, not included in this thesis), by hosting collaborative workshops with the social science team (e.g., Chapter 1 or Beaudoin et al. 2022a), and by writing about the value of collaboration for democratic environmental governance (Beaudoin et al. in preparation a, not included in this thesis). This led me to question how we could bring nuance to our understandings about collaboration in the context of applied, transdisciplinary conservation research involving a wide range of actors. Furthermore, I noticed that while people involved seemed the share the overarching goal of improving the conditions of and conservation of biodiversity in the waterways, discussions about collaboration were anthropocentric. Environmental actors were not usually discussed as active agents who participate as collaborators in this work, yet their presence was essential to the work. These observations guided my thesis, and the establishment of my research questions.

Boundaries: The research problem

In this section of the introduction, I unpack the boundaries of my thesis by explaining the unified sociological research problem that it tackles as well as the specific research questions that are answered in each chapter.

Problématique

By working directly in the grant, I found that the NSERC SPG created a space for actors to engage in dialogue but that there were many tensions around collaboration, both across humans and non-humans, in research about and governance of the RC and the TSW. The scope of this thesis thus focuses on collaboration across a diversity of actors in this case of applied conservation research, and more specifically in the production of knowledge about complex SES. The research problem addressed in this thesis thus relates to the fact that the ways in which we conceptualize and operationalize collaborations are complex: collaboration is complicated, hard to grasp and difficult to maintain. Additionally, SES invites us to attend to the coupled nature of social, ecological, and biophysical subsystems.

Multiplicity characterizes the very complex SESs that are organized and actualized – explicitly, implicitly, and for convenience – around the geographical spaces of the RC and the TSW. This leads to a complexity of possible collaborations that are constantly shaped and reshaped by anthropogenic forces – such as the research activities of different groups, various usages of the waterway (e.g., navigation, recreation, development), and decision-making at various levels of government – and ecological forces – such as fish movement, spread of invasive species (e.g., round gobies, zebra mussels), changes in water flow, and precipitation levels. Thus, this thesis thus takes seriously the claim that we live with the fish, turtles, zebra mussels, weeds, rocks, and nutrients of the RC waterway. It contributes social-ecological knowledge that both mobilizes collaboration as a method and also explores how we could expand our understandings of collaboration in the context of conservation research. It does so by using tools, methods, theories, and concepts from relational social and interdisciplinary sciences that are compatible with the ecological thinking that informs conservation research. The goal of this research is to better understand how collaboration can be used to further our understandings of the relationships between humans (e.g., the social) and environments (e.g., the ecological) in SES.

The main research question guiding this thesis is **How does collaboration between and across humans and non-humans inform our understandings about human-environment relationships in transdisciplinary conservation research?** The NSERC SPG served both (1) as a space to explore collaboration between humans using SES to frame the elicitation of mental models, and (2) as a case study to analyze more-than-human collaboration and interactions. In both instances, I conceptualized SESs as networks and paid attention to collaborative relationships. Using social-ecological network methods in two distinct ways allows me to attend to social-ecological dynamics in the waterway and to rethink collaboration so that it can extend beyond the human. In this research, both humans and non-humans were considered as beings that participate in networks. Thus, I mobilized the tools of social-ecological network analysis to explore how waterways could be understood as SESs, and to make visible the relationships between non-humans, researchers, decision-makers, and community members involved in the NSERC SPG. Collaboration was understood as practice, a method, and a type of relation, among many, which can exist between actors in SES. It was chosen as a key concept given its emerging importance in the empirical case and its overwhelming presence in the literature on transdisciplinary environmental, conservation, and SES research. This thesis thus has two distinct moments. First, it builds on research to actively contribute to conservation efforts and enhance management by analyzing views of a broad range of actors about social-ecological interconnections in the RC. Second, it explores the ways in which human interact with non-humans in the context of this research.

Research questions

The overarching question addressed in this thesis is explored through three sub questions which allowed me to operationalize my research. These also organize the structure of my thesis, which is composed of three research articles.

First, I explored the question *How can collaborative knowledge mapping and social-ecological networks be used to generate holistic understandings of waterways as complex SESs?* This allowed me to explore collaboration as a practice, a method that could be applied to coproduce knowledge in the context of conservation research – in this case, conservation social science – and to provide recommendations for policy. This question was empirically investigated in Chapter 1 through mapping activities in collaborative workshops and through social-ecological networks analysis.

Second, I started answering the question *How do people interact with non-humans in transdisciplinary conservation research?* in the context of the NSERC SPG. In doing so, I also explored questions such as *How do more-than-human collaborations unfold in social-ecological networks? Could or should we consider non-humans as research collaborators? How could we better acknowledge the frictions, tensions, and conflicts that are inherent to conservation research?* These questions were explored empirically through mixed methods, including qualitative interviews and partially articulated social-ecological network analysis, in Chapter 2.

Finally, I reflect on the ways in which networks and relational frameworks provide value to conservation research. Thus, I asked the question *What is the practical and theoretical value of relational approaches, and specifically networks approaches, to work toward more-than-human conservation research?* To answer this question in Chapter 3, I built on empirical findings from Chapter 2 as well as the networks and relational literature to propose ways to practically and theoretically work toward more-than-human conservation research.

Guiding principles 1: Theoretical framework

In this section of the introduction, I present the overarching theoretical framework and additional conceptual elements which guided my thesis work. More specifically, I explain how mental models and onto-epistemology contribute to my analysis of collaboration and human-environment relationships in the context of conservation research. I also provide an overview of approaches and new materialism from the social sciences and humanities that conceptualize non-humans as actors of the social world at the same level as humans. This is followed by my approach to relationality, and the relational framing of collaboration that I adopt in my thesis. Finally, I explain the ways in which networks allow me to operationalize this relational approach.

Mental models and onto-epistemology

Throughout my thesis, I use social-ecological networks to conceptualize people's views about human-environment relationships and in some cases their specific relationships with non-humans. Chapter 1 builds on a collaborative workshop technique to specifically elicit people's mental models of the RC as an SES. Mental models "are personal, internal representations of external reality that people use to interact with the world around them" (Jones et al. 2011: 1). Mental models provide information about complex systems given that they are dynamic cognitive models that represent people's knowledge structures (Gray et al. 2014). They include worldviews, cultures, and understandings of environmental systems (Clifford et al. 2022). However, as cognitive models, they are incomplete representations of reality that are constantly evolving and changing (Jones et al. 2011). They may also reveal gaps in terms of people's ability (or lack thereof) to conceptualize complex systems (Jones et al. 2011). In natural resource management, eliciting mental models can be used to explore convergences and divergences in people's views and understanding of complex SES, to aggregate or integrate differing views in shared models, to create collective representations of systems to use in decision-making, as a social learning process, to identify limitations and misconceptions in people's views, and to create shared pathways to conservation for example by providing problem-solving or communication strategies that are compatible with current understandings of a given system (Jones et al. 2011; Gray et al. 2014; Moon et al. 2019a). People's mental models can be elicited through various techniques including but not limited to collaborative conceptual modelling (Newel and Proust 2018), conceptual content cognitive mapping (Jones et al. 2011) and fuzzy cognitive mapping (Özesmi and Özesmi 2004; Papageorgiou and Kontogianni 2012; Gray et al. 2014). Mapping of mental models can be both qualitative and quantitative, their structures are often represented as networks of concepts or relations, and they can be analyzed with tools from network analysis or graph theory (Özesmi and Özesmi 2004; Jones et al. 2011; Gray et al. 2014; Moon et al. 2019a). Chapter 1 directly builds on this type of approach: I analyze social-ecological networks that represent aggregated social-ecological maps of the RC based on people's mental models of the diversity of factors that influence its environment (Beaudoin et al. 2022a).

Furthermore, given that mental models can be represented as networks of relations (Jones et al. 2011), elicitation of network data can be understood as eliciting or externalizing mental models or internal representations of a given set of relationships. These mental models reveal deeply ingrained assumptions and generalizations about how one operates, acts, and interacts with the world (Solem 2003). Mental models are not experiences, but rather constructs that emerge as we make sense of our experiences (Spector 2010). In fact, researchers and scholars rely heavily on mental models in their thinking and writing (Adams 2014). Mental models are understood as being influenced by disciplinary training and learning (Libarkin and Kurdziel 2006). The mental models of scholars include disciplinary knowledge about objects of study, relations between these objects, and discipline-specific dynamics (Adams 2014). This shows that eliciting ones' internal representation about a given set of relationship, as was done in Chapter 2 and 3, provides us with some information about one's ingrained assumptions and generalizations about these relationships.

Given that the assumptions of scholars are influenced by disciplinary training, asking conservation researchers about their interactions with non-humans as part of their work can reveal some of the underlying assumptions which frame these interactions. Disciplinary training among other things contributes to establishing ones' philosophical positions regarding ontology (the nature of reality and knowledge, our worldview, "the theory associated with what the world is or contains"; Solem 2003: 439) and epistemology (how we know the world, what we can know of the world, "the theory of knowledge"; Solem 2003: 440). Ontology and epistemology are understood as closely related, given that our worldviews and the ways in which we understand reality shape the ways in which we can learn from and generate knowledge about this reality (Solem 2003). Onto-epistemology is also understood as the foundation of scientific disciplines, with methods and methodology resting upon specific ontological and epistemological assumptions. In fact, "How a researcher thinks about reality (i.e., ontology, what exists that we can acquire knowledge about) and knowledge (i.e., epistemology, how we create knowledge) influences how they design and conduct their research" (Moon et al. 2019b: 296). In the field of conservation research, those with distinct disciplinary history but also other partners who may have differing scientific or professional training or cultural backgrounds may have distinct onto-epistemologies – distinct ways of conceptualizing, recognizing, engaging with, and learning about the environment and non-humans. For example, in the context of agrobiodiversity conservation, local farmers have differing ways of seeing and engaging with seeds and crops (e.g., describing traits that are relevant to one's preferences or culture, paying attention to growing behaviors, harvesting, and cooking qualities) compared to plant researchers (e.g., classifying through taxonomic categories, collecting data about set morphological features, using molecular methods to refine classifications) (Montenegro de Wit 2016).

While most conservation researchers assume ontological realism (e.g., there is a material reality independent of human thought), epistemological assumptions range from realism to construction (e.g., knowledge emerges from the non-human material entities that we study, or it is "constructed" by human perception of this reality) (Peterson et al. 2006). However, even among researchers attempting to engage in human dimensions and qualitative social sciences as part of their work in ecology and conservation, philosophical positions (e.g., ontology, epistemology, how this informs the choice of suitable methodology) are often absent, or not explicitly or appropriately addressed (Moon et al. 2016). As will be shown in Chapters 2 and 3, the interactions of conservation researchers with non-humans reveal some of the onto-epistemological assumptions of conservation research.

Including non-humans as actors

In the social sciences, early attempts to better understand relationships between society and ecology, or to integrate nature and culture, were made by Marx (historical materialism), Park (human ecology) and Bateson (ecological anthropology); other subdisciplines also study nature-culture relationships like human geography, ethnoecology, political ecology, and environmental history (Davidson-Hunt and Berkes 2002). There is also a growing literature that is termed more-than-human research that includes animal geographies, critical animal studies, ecofeminism, environmental humanities, human-animal studies, multi-species research, new materialism, queer ecologies, and science and technology studies, among others (Bastian et al. 2017). SES research also participates in attempts to bridge the divide between the social and the ecological, but at a fundamental level, this divide is still present in a concepts like SES. There is an inherent assumption that social/anthropogenic and ecological/environmental factors belong to separate realms that must be unified. This can be seen as a problem of ontology and language, as we may not have the words or concepts that truly reflect the coupled nature of the social and ecological in complex systems (Hertz and Schlüter 2015). Emerging in response to scientific resource management, SES plays an important role in the journey to rethink human-environment relationships. However, theoretical and empirical experimentation are still necessary to create an analytical lens that can grasp human-environment relationships in unified ways and that accounts for the capacities of non-humans.

Some approaches in the social sciences and humanities to more-than-human research provide flat ontologies which conceptualize relationships between humans and non-humans as being on the same level and which include expanded considerations of agency. Humans can be reintegrated at the same level as animate and inanimate nonhumans because the focus is no longer on defining objects. Rather it is on their emerging relationality. In this sense, one of the aims of new materialism "is to move beyond agency as a uniquely human, or even animal, characteristic." (Onishi 2014: 3) New materialism also goes beyond traditional dualisms of nature and culture. It is tied to relational perspectives that include concepts like ecologies, meshwork, knots, entanglements (Van der Tuin and Dolphijn 2010; Coole 2013).

These approaches "stress the continued becoming of organic and inorganic materialities in relations, milieus and processes that reactivate their potential for being and thus often exceed what has already taken place and become known" (Tiainen et al. 2015: 5). For example, in the context of collaboration, new materialism provides "a gentle reminder to pay attention and to cultivate our collaborations—human and more-than-human—with more care" (Neimanis 2021: 220). This approach allows a decentering from the human by focusing on emergence, vibrant matters, and relations which materialize in various milieus. Environmental and social components, known scientifically through theory and experimentation, can be seen through the lenses of new materialism as emerging forces whose forms unfold in relation to organic and inorganic surroundings. This onto-epistemology conceptualizes life and social processes as materially heterogenous and enmeshed communities: "To be one is always to become with many" (Haraway 2008: 4). This helps give non-humans a place and a voice in conservation research without falling into caricatural anthropomorphism. These efforts are not about attributing human capacities to non-humans, but rather about expanding the ways in which we understand capacity and agency so that it is more inclusive and not limited to humans. These understandings contribute to the analysis of relationships between humans and non-humans in Chapter 2, and the proposal in Chapter 3 for more-than-human conservation research which acknowledges the participation of non-humans in research about complex SES.

A relational approach

My relational approach has been greatly influenced by Ingold's work (2007, 2015) which links ecological embeddedness, skilled practice, perceptions, and the life of lines. Ingold's work conceptualizes ecology as the study of the life of lines which become enmeshed and create knots as they cross each other in time and space (Ingold 2007). Practices are seen as emerging from immersion in a space, from paying attention, and from time spent actively engaging with ones' surroundings, with other lines. His concept of the meshwork which refers "interwoven lines of growth and movement" (Ingold 2010: 3; Klenk 2018) opens up fields of interactions and allows us to retrace interconnections and trajectories which are not always visible with more rigid concepts and frameworks. In coherence with new materialism, this opposes nature-culture dualisms. While the concept of the meshwork opposes itself to network approaches (Ingold 2010; Klenk 2018), my relational approach is also inspired by actor-network theory which provides conceptual tools to include non-humans in research (Latour 2005). Actor-network theory includes humans as well as both animate and inanimate non-humans, acknowledging their capacity to act and contribute to shaping the assemblages which form the social (Latour 2005). Latour attempts to derive a scientific yet diplomatic approach to anthropology which aims to create an era of compassion among humans but also to include nonhumans in the discussion (Latour 2004). While science is efficient and has powerful capacities, it does not account for every experience of reality and can fail to account for relationality.

There has been a broad shift in the last three decades of sociological research toward relational thinking, which takes relations as a unit of analysis (Scott and Carrington 2011). Ingold and Latour, who have been influential in the development of my approach and to understanding relationships between humans and non-humans, can be positioned – albeit in quite distinct ways – as authors working within a relational paradigm. My thesis is also framed as operating within relational approaches: I focus on relations and attend to the patterns and quality of these relations (Scott and Carrington 2011). Opposing themselves to a long-standing tradition in the social sciences, relational approaches focus on relations rather than actors and their attributes (Scott and Carrington 2011). Relational approaches can draw on formal language (i.e., numbers, quantification, mathematics) to describe the structure of relations, but can also be informal. Ingold could be seen at the informal end of the spectrum with his open concept of the meshwork. Latour could be somewhere in between: while actor-network theory builds on the network metaphor and attends to actors that are connected through ties, it does not overly emphasize quantification. Social network analysis finds itself at the most formal end of the relational paradigm in the social sciences, as it quantifies relations and analyzes them through graph theoretic and statistical tools (Scott and Carrington 2011). Some authors also emphasize the need to complement formal relational approaches like social network analysis – which is good to identify complex patterns – with qualitative approaches that attend to the quality and history of relations as well as the contexts in which they unfold (Scott and Carrington 2011; Bodin and Prell 2011; Stein et al. 2011; Varda 2017; Giordano et al. 2017; Calliari et al. 2019).

Thus, I build on the relational framework to explore material realities and bodies, information, knowledge, and values that circulate in systems and influence the relations which connect people, places, and environments. Relational and processual approaches can also help us characterize, study, and understand SESs (Mancilla García et al. 2020). Relational manifestations are quite varied and can attend to a range of relations. For example, in the context of the RC and the TSW, there are intimate and activating bodily experiences of canoeing in the water, of grasping a fish at the end of a line. But there are also sterile inter-institutional policy networks which regulate the management of the waterways. In this context, the metaphor of networks allows us to see how actors align (or do not align) with each other, and how relations reinforce, constrain, and transform potential outcomes (Scott and Carrington 2011).

A relational understanding of collaboration and coproduction

Collaboration is both an object of sociological research and a practice constitutive of our activities as researchers; I conceptualize it in a relational way. Defined as working together, collaboration can be understood as both a practice (something that actors do) and a type of relationship (something that ties actors to each other). Having a relational conceptualization of collaboration allows me to move beyond humans to consider any being with which we engage as part of the NSERC SPG grant. By focusing on relations and how actors interconnect, I consider new conditions of possibility and expand the realm of potential answers to the question: *with whom do we collaborate?* Thus, I use collaborative practices as a relational research method to elicit and connect people's understanding of the RC as an SES, but I also mobilize relational thinking to grasp if and how relationships between humans and non-humans are experienced by conservation researchers as being – or having the potential to be – collaborative.

In this sense, relational understandings of collaboration are also tied to coproduction. There are two ways to conceptualize coproduction: (1) normatively, to refer to the choice of researchers and partners to coproduce knowledge in a way that involves different perspectives, and (2) descriptively, to attend to the power dynamics that shape the interactions between science, society, and nature (Lemos et al. 2018; Van der Molen 2018). In both cases, coproduction can be understood relationally: as a process resulting in the creation of knowledge that emerges from relationships between different actors, and as attending to the complex relations between actors in social, scientific, and ecological processes. In the context of environmental work and research, coproduction often refers to working with people embedded in SES who may hold valuable local, experiential, or Indigenous knowledge (Cooke et al. 2021). Furthermore, some of the best practices to apply when generating knowledge collaboratively in environmental research concern relations, for example the use of network thinking, leveraging boundary organizations and brokers, and ensuring that processes are cocreated (Lemos et al. 2018). The literature on the coproduction of knowledge and social order also encourages practitioners and researchers to be reflexive (Van der Molen 2018). Furthermore, more-than-human coproduction is also starting to be theorized in the humanities (Bastian et al. 2017). This makes it a relevant concept that contributes to relational understandings of collaboration.

Networks to operationalize my relational approach

In my research, networks are seen as metaphorical abstractions that help navigate the empirical complexities of interlinkages between humans and non-humans. They are used both (1) to build on collaborative processes and serve as a tool to aggregate knowledge maps about SES in efforts at coproduction, and (2) to operationalize my relational approach and relational understandings of collaboration. The networks I work with are seen as limited but useful tools that can help us understand some structural dimensions of relationships between social and ecological nodes. I do not conceptualize networks as exact reproductions of these relationships or of reality, but rather as conceptual and methodological tools and abstractions used to learn more about some aspects of these relationships.

My thesis mobilizes tools from social network analysis, including insights from research about collaborative networks, and tools from social-ecological network analysis to explore people's views about social-ecological systems and researcher perceptions about their interactions with non-humans. Beyond this formal approach, I also mobilize discussions with my peers in the NSERC SPG, as well as their stories and my own (limited) lived experiences in the waterways and as a graduate student in the project. In doing so, when thinking about the social and the ecological, I ask what does "it" do and how does "it" connect, rather than what "it" is. So, *what do social-ecological systems do? How are social and ecological actors connected to each other? What does the lived experience of these networks look like?* These questions emphasize a relational perspective, which I have addressed through a relational methodological framework.

Guiding principles 2: Methodological framework

In this section of the introduction, I present the relational methodology which guided my thesis work. More specifically, I provide an overview of the literature on social and social-ecological networks. Then I provide more information about the mixed methods rationale that is used to complement the network methodologies used in my thesis. This is followed by a clarification of the scope of my thesis.

Social network analysis

Social network analysis is specifically the study of social systems and networks. In this field of research, networks are mathematical models that represent social structure through datasets composed of dots (nodes) and lines (edges or ties) (Scott and Carrington 2011). Micro (e.g., individuals), meso (e.g., groups, organizations), and macro (e.g., nations) levels of sociality can be used as nodes representing various units of analyses (Scott and Carrington 2011; Kadushin 2012; Jones and Faas 2017; Varda 2017). The lines can represent a wide range of relationships and are known as arcs or edges (Scott and Carrington 2011). The notion of social network refers directly to the relationships that bind actors who interact repeatedly (Dall'Asta et al. 2012). Simply put, “a network is a set of relationships” (Kadushin 2012: 14), and more specifically, networks reveal new points of view on the complexities of the social world. Social networks can capture flows of information such as knowledge, values, trust, and norms (Dall'Asta et al. 2012). They can be used to help make visible informal relationships and the social conditions which foster or inhibit the emergence of collaboration (Cross et al. 2002; Dall'Asta et al. 2012; Calliari et al. 2019). This type of research often aims to support management and increase strategic collaboration across actors who are formally or informally connected (Cross et al. 2002). For example, social network analysis can be used as a strategic tool to develop adaptative policy by identifying central organizations in policy networks (Therrien et al. 2019). This ultimately results in favoring some relationships, to the detriment of others.

Specifically, in the context of environmental co-governance, social network analysis makes it possible to identify the web of relationships between various actors, to identify weaknesses in the network, and to propose concrete solutions to avoid working in silos (Calliari et al. 2019). Because the quality and quantity of relationships between actors have a direct impact on their ability to act on problems (Therrien et al. 2019), many researchers mobilize this approach to study complex environmental governance contexts (e.g., Bodin et al. 2006; Bodin and Crona 2009; Stein et al. 2011; Bodin and Crona 2011). Different social network measures can be used to understand some dimensions of relationships between actors in environmental governance. For example, density, reachability, betweenness, and centrality measures of a network can help us understand social memory, heterogeneity of actors, redundancy, learning, adaptive capacity, and trust (Bodin et al. 2006). Overall, “[i]t is clear […] that structure does make a difference” (Bodin and Crona 2009). Building on this knowledge of social network analysis, I also draw from social-ecological network analysis in my thesis.

Social-ecological networks

While social networks are limited to humans and traditionally exclude non-humans, one of the strengths of the network approach is that it is a common method used by the natural and social sciences: applied in both social and ecological contexts, it can thus be used to conduct integrative analyses and bridge theories (Bodin and Tengö 2012; Bodin et al. 2017; Barnes et al. 2019). Social-ecological network analysis is an emerging field of research. It acknowledges the interconnections between the social and ecological by effectively bridging methods and theories from social network analysis, insights from SES, and ecological networks research (Bodin and Tengö 2012; Bodin 2017; Bodin et al. 2017; Barnes et al. 2019). This subfield uses both human and ecological nodes to build networks. It provides tools for researchers to address problems of fit that manifest between ecological and social contexts and between humans who attempt to collaborate to tackle long-term problems (Bodin 2017). The level of social-ecological integration can vary in social-ecological networks which can be fully (a full set of social, ecological, and social-ecological ties are included in the network) or partially articulated (only ecological or social ties are included along with social-ecological ties in the network) (Sayles et al. 2019). Though social-ecological network analysis usually mobilizes quantitative tools from graph theory, a variety of other methods can be used with it including qualitative work, attributes analysis, and use of GIS data (Bodin and Crona 2009; Bodin and Prell 2011; Stein et al. 2011; Calliari et al. 2019).

Bodin (et al. 2017; et al. 2006, and Crona 2009; Mancilla García et al. 2019) acknowledges that in social-ecological network analysis, collaboration is both an object of research (e.g., collaboration in environmental governance) and a practice of research (e.g., inter- and transdisciplinary collaborations to generate social-ecological networks). This approach works toward the development of actionable interdisciplinary research where a network-centric framework along with SES can act as a boundary object that provides a common language and neutral grounds for researchers across disciplines to collaborate on interdisciplinary theories and methods (Bodin et al. 2017; Bodin 2017; Barnes et al. 2019). However, “many challenges remain to be solved” in the field of social-ecological networks (Bodin and Prell 2011: 371). Network analysis makes it difficult to understand cross-scale and cross-level linkages, networks of larger sizes, and the dynamics of social-ecological networks (Janssen et al. 2006; Cumming et al. 2010; Prager and Pfeifer 2015). Additionally, creating meta-frameworks that encompass all the spatial patterns, interacting species, and communities in a social-ecological network is difficult (Cumming et al. 2010) given that the collection of network data is labour intensive and involves spending a lot of time in the field (Prager and Pfeifer 2015).

Overall, social-ecological network analysis allows us to explore how humans are connected to each other, other species, abiotic elements of the environment, and technologies (Bodin 2017; Bodin and Tengö 2012). This makes it particularly useful to disentangle the interdependence of social and ecological systems and the complexities of collaborations which aim to tackle environmental issues. Furthermore, tools from social network analysis can be mobilized at various moments of research projects to strengthen our understandings of SESs, to identify leverage points, to nurture adaptive co-management, and to support the interdisciplinary and transdisciplinary collaborations that are inherent to SES research (Bodin and Tengö 2012; Cox 2014; Bodin 2017; White et al. 2018). In my thesis, I recognize the limits of network approaches and thus mobilize social-ecological networks both quantitatively and qualitatively, formally and informally, in combination with other qualitative methods.

Mixed methods and data triangulation

Mixed methods and multidisciplinary work are well suited for studying complex issues related to the environment (Amaratunga et al. 2002; Buijs 2009). They can facilitate the mobilization of research for applied purposes and help bridge the gaps between scientific (natural and social) knowledge and practice (Tashakkori and Teddlie 2010; Molina-Azorín and López-Gamero 2016). Qualitative and quantitative modes of analysis do not need to be opposed, in fact, they can be brought together to shed light on any research topic (Olsen 2004). Triangulation of different types of data, collected through various qualitative and quantitative methods, allows researchers to generate in-depth understandings of social phenomena (Olsen 2004; Denzin 2012). Thus, in my thesis I mobilize quantitative data (e.g., social-ecological networks) but also qualitative analyses (e.g., open-ended questions in interviews analyzed through thematic coding) to not only grasp the structure of relations, but also the quality of and context around the social-ecological relations in the waterways and the NSERC SPG. As the unfolding of complex social-ecological networks is influenced by things other than network structure (Mills et al. 2014), mixed methods allow me to capture the richness of interactions between and across humans and non-humans.

Scope

Networks of people engaged in conservation and complex SESs are often extensive and geographically dispersed – this makes it difficult, lengthy, and expensive to conduct a social network analysis on the entire network. Thus, the artificial boundary I adopt for this research is the research grant and I conducted this research with PIs and graduate students, as well as others involved with the grant. Samples were informed by people contributing to social science research or who were otherwise working on the grant. Unfortunately, it was difficult to establish contact with Indigenous people throughout the grant work (see page 24 of the case description); as a result, their absence is a limitation of this research. Acknowledging this limit, part of Chapter 2 explores the value of Indigenous knowledges to help rethink conservation research.

Some data was collected through collaborative workshops conducted in 2019 with the social science research team as part of the NSERC SPG work. Participants included a wide range of actors included in the research and governance of the waterways (e.g., community and environmental groups, economic interest groups, government representatives, academic researchers, and individuals concerned with water quality in the lower reach of the RC; Chapter 1). While a range of data was collected throughout these workshops (see Appendix 2 and Mistry et al. 2021), the data analyzed in this thesis is network data representing knowledge maps of the RC as an SES. Follow-up data collection for this thesis occurred in Winter 2021 under the form of mixed method interviews conducted with key members of the NSERC SPG. Both qualitative and network data were collected in these interviews. More details about the samples, exact methods, and data can be found in each chapter.

Process: The story of this thesis

In this section of the introduction, I talk about my process and build on the guiding principles (e.g., my theoretical and methodological framework) to explain how I address the outlined research problem and start answering my research questions. This is followed by the way in which my thesis comes together and an overview of how it is structured.

Answering questions

Social-ecological networks provide a relational method to operationalize the concept of SES. It conceptualizes the social-ecological world in a way that makes visible the articulations and manifestations of different relationships between social, ecological, and technical components. This network approach was supplemented by stories collected through interviews with members of the networks and my own lived experiences in research as well as in the RC waterway itself. With this work, I improve our understanding about the assumption that collaboration must be part of the process of research and management if we are to act collectively on social-ecological problems and conflicts. I both show the value of collaborative knowledge mapping in the context of SES research, but also reflect on ways in which we can expand our understanding of collaboration to include non-humans. This type of work makes it possible to provide more precise and nuanced recommendations that consider the complexities emerging from the diverse plurality of social-ecological actors involved.

As such, my thesis presents empirical accounts of people’s views about social-ecological relationships in the RC, and in conservation research about the RC and TSW. Furthermore, it provides recommendations for policy-makers to account for social-ecological dynamics in the RC, and perceptions of these dynamics (Chapter 1). It also provides practical and theoretical insights for conservation researchers and practitioners to acknowledge and think about their interactions with non-humans in the context of their work (Chapters 2 and 3).

In sum, the main argument of this thesis is that working together while using relational approaches (that can be operationalized through network frameworks) has value for conservation research. Relationality can be used to frame our methods (e.g., networks) and to productively include researchers from the social sciences and humanities in conservation research. Working together is seen as valuable both in terms of coproducing nuanced understandings of SES, but also in terms of working toward decolonization and having ethical, more-than-human conservation research practices. As mentioned earlier in this introduction, it is necessary for the social sciences and humanities to theoretically, conceptually, and methodologically be engaged with ecologists, biologists, conservationists, among others if we want to improve our ways of living and engaging with the environment and non-humans.

Putting it together

This is a thesis by articles. The conditions for submitting a thesis by articles to the School of Sociological and Anthropological Studies at the University of Ottawa have been met. My plan to write a thesis by articles was approved by my supervisor and the program coordinator, the thesis contains all the information found in a traditional thesis, and three articles have been written for publication in peer-reviewed journals (one has been published, two have been submitted; Appendix 1), I am the first author of all chapters, and not more than one article was written collaboratively.

Between each chapter are short pieces: connective tissues. These play the role of reflexive notes, as I take seriously the need to improve reflexive capacity in transdisciplinary conservation research. These reflexive notes also serve to connect the chapters to one another, building a narrative of how I encountered various concepts throughout my thesis work (e.g., systems, networks, ecologies), how I came to mobilize these concepts in my work, and how I position myself (e.g., ontology, epistemology, choice of methodology). These connective tissues are written like short stories, linking the chapter to one another in order to complete what could otherwise present as a fragmented set of articles. While this doesn't replace the narrative of a monograph, it seeks to provide the reader with more context and continuity as they read through this thesis.

Chapter 1 addresses the first sub question of my thesis, namely how we can use collaborative knowledge mapping and network analysis to better understand views of the RC as an SES, and how these views can be used to generate recommendations for policy-makers. Chapter 2 provides an empirical account of the interactions between humans and non-humans in conservation research, as reported by key members of the NSERC SPG. The presentation of empirical results is accompanied by a discussion about a paradox of conservation research unveiled by the work and the lack of explicit consideration for non-humans to be possible collaborators of conservation research. Finally, Chapter 3 builds on Chapter 2 to provide a set of six practical and four theoretical insights about the value of relationality, and specifically network frameworks, for conservation research to be more inclusive of non-humans. Overall, these chapters address the main question **How can collaborations between and across humans and non-humans inform our understandings about human-environment relationships in the context of transdisciplinary conservation research?** Practices of collaboration are conceptualized as both a method and a social phenomenon (e.g., a type of relationship) that can be combined with social-ecological networks to provide assessments of social-ecological dynamics in conservation research, both at the scale of the SES being studied, and at the scale of the teams conducting the research.

Connective tissue 1: Systems

The first chapter is tied to the concept of systems. I was working with the social science team of the NSERC SPG and we were approached by a community member. During our discussions, he proposed that we could host workshops with key actors in the RC to generate discussion and collect some data. Given previous conversations with the broader NSERC SPG about conceptualizing the RC as an SES, we thought it would be helpful to use a workshop strategy that built on systems thinking. Generally, systems refer to groups of elements, components, or subsystems that are tied to create a unified whole.

As a sociologist in training, with a background in relational anthropology, I found the concept of systems to be intriguing. Aspects of it seemed to inherently align with relational frameworks: it recognized that the ways in which actors or components are related matters, that the whole is more than the sum of the parts, that emergence – a topic that I'd recently explored in discussion with biophysicist Andrew Pelling (Beaudoin and Jaclin 2016) – could be accounted for through concepts like the "emergent properties" of systems. Systems thinking also reminded me of cybernetics. Coined by mathematician and philosopher Norbert Wiener, cybernetics refer to systems with feedback loops (Wiener 1985). The cybernetic paradigm unfolded across many disciplines and inspired analogies between organic living bodies and machines. In anthropology, it was Gregory Bateson who furthered this approach and I had been exposed to his work during my master's degree. Taking from cybernetics but also his training in biology, linguistics, and anthropology, Bateson postulates that "we are parts of a living world" (1979: 17). He proposed that life is a mass of interlocking processes that self-regulate and maintain constants through states of change (Bateson 1979:62). This understanding of relations and cybernetic systems was helpful to go beyond dualisms. To consider life, among other phenomena, as interlocking processes rather than discrete and static objects. I had embraced these relational assumptions by learning, in seminars and through my readings, that adopting dualisms (e.g., nature-culture, mind-body, subject-object, structure-agency) could be limiting, unhelpful, and create false dichotomies that didn't account for the complexity of the social world.

Thus, working with systems seemed to open up valuable pathways to explore and better understand human-environment relationships. It also seemed to be a concept that could bring together actors from different backgrounds, as my dive in the literature would later confirm (e.g., SES as a boundary object). With this in mind, the social science team decided to move forward with a system thinking workshop. While it is tricky and resource intensive to directly capture each component of systems to generate integrated system models, the systems literature also builds on the concept of mental models. In the context of systems research, models are generally abstract representations of a system. These representations are always limited and partial. As abstractions, they cannot account for the dense complexity and nuances of the empirical world, but they are a useful tool that we can learn from and that we can use to explore specific questions. Mental models specifically refer to internal, abstract representations that emerge as a person makes sense of the world around them. These mental models include our perceptions of different elements in the world, our past experiences, and concepts and knowledge that we've accumulated. Our mental models represent the understandings we've come to develop of patterns and of relationships between actors, components, and things. Our mental models are internal representations of systems which can be externalized to feed the development of more sophisticated models that can be analyzed quantitatively. After deliberation, including considering fuzzy cognitive methods that also draw from systems thinking, we settled on Collaborative Conceptual Modelling. This method seemed to provide multiple advantages: generating data about SESs by eliciting people's knowledge about the RC and providing opportunities for social learning.

However, taking this method into the field with different groups made me realize that systems thinking is difficult to operationalize and that the complexity it unveils brings on challenges (e.g., how do we manage data about complex systems when our methods generate large relational datasets? What do we do with this complexity? How can these mental models effectively inform management?). I quickly realized that we needed a method to manage the complexity that presented itself in our post-workshop dataset, but also in people's views and mental models, in the relationships between people, and in the relationships between humans and the environment more broadly. Being familiar with the social network analysis literature, and further uncovering through my comprehensive exams the use of network methods to analyze relational knowledge maps representing complex systems, I started viewing networks as an effective tool manage this complexity.

Despite the limits of SES and network approaches which I address throughout this thesis, Chapter 1 operates in a somewhat naïve acceptance of the assumptions that SES is a useful concept to frame our understanding of human-environment relationships. It also builds on the strengths of systems approaches and network methods without questioning them. It is a piece that performs conservation social science. It conducts research about people's views in the hopes of generating knowledge that can be applied in management and tests the value of systems and networks to achieve this goal. Later chapters build on this initial exploration of conservation social science to question the very basis of conservation research and include more critical angles.

Chapter 1
Collaborative knowledge mapping to inform environmental policy-making: The case of Canada's Rideau Canal National Historic Site

Journal

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Please note that the term "co-production" which was used in the published paper was changed to "coproduction" to align with the spelling used in the rest of this thesis. The order of references in parentheses has also been modified to match the format of this thesis. Supplementary material from this chapter can be found on the journal's website as MS Excel spreadsheets or in the appendices.

Abstract

The Rideau Canal National Historic Site is a complex social-ecological system that connects the Ottawa River and the St-Lawrence River in Eastern Ontario, Canada. As an interjurisdictional waterway, it presents interconnected social-ecological challenges. In this article, we analyze findings from five participatory workshops held with stakeholder groups in the Rideau Canal system. Participants in the workshops co-produced social-ecological relational maps that represent their knowledge and views about determinants of environmental health in the system. The maps were merged by the authors to create an aggregated, collective map grouping all factors that participants perceived as influencing the environmental health of the Rideau Canal. Our analysis focuses on two dimensions of these coproduction exercises. First, we use concepts and methods from social-ecological systems and social network analysis to analyze the content of the maps, examining convergences and divergences in stakeholder perceptions of the system and outlining insights into social-ecological linkages that might be relevant for decision- and policy-makers. Most factors cited were social, emphasizing the need for more careful integration of the social and ecological in our understanding of complex historic waterway systems. Second, we examine the value of our workshops, anchored in collaborative systems thinking and network analysis, as a method for eliciting highly variable local knowledge and experiences, and for summarizing these in a consumable form for decision- and policy-makers. We argue that this method facilitates inclusion of various knowledges and perspectives in decision- and policy-making processes and provides pathways to improve social-ecological resilience.

Keywords

Collaboration, knowledge mapping, network analysis, resilience, social-ecological systems, Rideau Canal

1. Introduction

Managing water resources that cross multiple jurisdictions is a major challenge. The existence of multiple governing bodies, as well as stakeholders and rightsholders with varying interests, can hinder effective policy processes and the development of social-ecological resilience. In addition, the uniqueness of freshwater ecosystems makes it difficult to establish universal best practices, emphasizing the need to tailor management and policy decisions to local contexts. Including the knowledge and perspectives of stakeholders and rightsholders in decision-making processes is recognized as a step toward addressing this challenge, although local knowledge should not be extracted but rather co-produced in reflexive and meaningful ways (Klenk et al. 2017). However, there are often many challenges in ensuring meaningful engagement.

This article addresses the need and attendant challenges of including local knowledge and perspectives in environmental decision- and policy-making spaces through coproduction in the case of the Rideau Canal National Historic Site (RC) in Ontario, Canada. The RC is a freshwater canal of significant ecological, historical, and cultural importance. Like many constructed waterways, the RC paradoxically presents barriers to conservation (e.g., ecological fragmentation, habitat loss, infrastructure footprint) while also providing opportunities for conservation and improved resilience (e.g., historical and natural conservation initiatives, effective management regimes, conservation-minded economic development) (Lin et al. 2020; Mistry 2020). The RC also has a range of stakeholders with varying perspectives and knowledge that could inform locally relevant environmental decisions and policies.

Knowledge coproduction is highly applicable to SESs, because relevant knowledge is held by people embedded in the social-ecological system (Cooke et al. 2021). Coproduction is "the collaborative process of bringing a plurality of knowledge sources and types together to address a defined problem and build an integrated or systems-oriented understanding of that problem" (Armitage et al. 2011: 996). While collaboration and coproduction are priorities for research funders, barriers such as lack of time and loss of control makes it hard to realize (Morris 2014), underlining the need to investigate methods for effective coproduction. Our approach to coproduction involved eliciting the perspectives and views of experts and non-experts through knowledge mapping activities, offering an efficient and practical way to improve resilience and inform policy and decision-making (Özesmi and Özesmi 2004; Papageorgiou and Kontogianni 2012; Gray et al. 2014). Resilience is understood as the ability of a system to respond to stressors while maintaining its functions (Berkes 2017). It relates to the importance of adaptive capacity in environmental governance, which can be explored through complex systems thinking that emphasizes the need for diversity, flexibility and strong relationships in management practices (Armitage and Plummer 2010).

We conducted five workshops with RC stakeholders to generate collaborative relational maps of the systemic forces that influence and interact with the environmental health of the RC. Our analysis focuses on two dimensions of these coproduction exercises. First, we examine convergences and divergences in stakeholder perceptions of the RC as a social-ecological system (SES), including analysis of a consolidated social-ecological network graph that combines the knowledge co-produced in the five workshops. Second, we discuss two ways in which collaborative systems thinking workshops and social-ecological network analysis is valuable: (1) for eliciting highly variable perspectives and knowledge and summarizing them in a consumable form for decision- and policy-makers and (2) for building resilience in the SES of the RC. Overall, our research highlights the importance of including a range of views to develop a holistic understanding of the RC system, while also recognizing the challenges of participatory governance and engagement. It also addresses the potential of collaborative systems thinking and network analysis to help bridge knowledge-action gaps in social-ecological research. Finally, it has implications for broadening environmental governance and policy by connecting and synthesizing multiple perspectives and knowledges, thus providing narratives and informed paths toward policy action.

2. Collaborative mapping of the Rideau Canal as a social-ecological system

2.1 The case

The RC is a designated UNESCO World Heritage Site, a Canadian Heritage River and a National Historic Site managed by Parks Canada, an agency of the federal government. Canal sections were built to connect pre-existing rivers and lakes, creating a new 200 km navigable pathway that connects the Ottawa River (City of Ottawa) and the St-Lawrence River (City of Kingston) in Eastern Ontario. The system encompasses two watersheds with several lakes and tributaries and passes through 13 counties and townships (Parks Canada 2017). Construction of the Canal was completed in 1832 (Charron et al. 1982) and its ongoing use has been shaped by – and contributes to shaping – the environmental health of surrounding ecosystems as well as associated social structures and processes.

Like other inland waterways, the management of the RC must balance multiple usages tied to water level management and water supply, tourism, recreation, conservation, and cultural heritage (Konings and Wiegmans 2016). Conflicting priorities about usage in the cross-jurisdictional context of the RC complicate governance. Additional challenges in the RC and other inland waterways relate to a lack of political will and funding, aging infrastructure, and lack of adaptability (Konings and Wiegmans 2016; Willems et al. 2018). There is also heterogeneity in social and ecological features across the various reaches of the Canal (e.g., inconsistent regulations across municipalities, multiple types of infrastructure, urban or forested shorelines). As a coupled SES, there are many tensions within the RC such as balancing conservation with recreation and development, as well as controlling the spread of invasive species without harming native species and species-at-risk (Charron et al. 1982; Poulin 2001; Bergman et al. 2021; Mistry et al. 2021). The social-ecological diversity within the system makes it difficult to generate empirical data and scientific knowledge that captures all of the complex dynamics of the waterway. This enhances the need to rely on local and expert knowledge and perspectives to generate integrated and nuanced understandings of the system that can support environmental management and policy-making.

Some research on the environment of the RC has been conducted (Sonnenburg et al. 2009; Walker et al. 2010; Gillis et al. 2010; Stuyt et al. 2015; Agrawal and Jahanandish 2019), but there is a lack of research integrating social and ecological components of the waterway to improve its management (for gaps and opportunities, see Bergman et al. 2021). From 2018 to 2021, researchers across the natural and social sciences from Carleton University, the University of Ottawa and l'Université de Sherbrooke conducted research in partnership with Parks Canada on National Historic Waterways in Eastern

Ontario. As part of this work, the authors facilitated workshops in which participants generated relational knowledge maps of factors influencing the environmental health of the RC. Participants, including residents, users, business owners, regulators, managers, and researchers, provided their perspective and knowledge (local, experiential, and scientific) on the RC.

2.2 Participatory production of knowledge with systems thinking

The literature on environmental management recognizes the importance of participatory approaches and collaboration to build resilience (Berkes 2017; Perz 2019), but participatory approaches have attendant challenges in building trust, engaging participants meaningfully, and dedicating enough time (Bell et al. 2013; Morris 2014; Metcalf et al. 2015; Black and McBean 2017). More specifically, while many methods for collaboration and meaningful engagement exist, few focus on coproduction of knowledge that accounts for system dynamics and resilience thinking (Newell and Proust 2012). While relational knowledge mapping and elicitation of mental models are effective methods for understanding complex ecological systems (Jones et al. 2011; Moon et al. 2019a), mapping exercises can be enhanced through participatory approaches (Gray et al. 2014). We analyze the outcomes of participatory workshops that used the Collaborative Conceptual Modelling (CCM) approach (Newell and Proust 2012, 2018) to map stakeholder knowledge and perspectives about the RC. This approach provides methods to articulate as well as mesh and extend the participants' individual mental models of a system through mapping and teamwork. It provides a practical way to develop shared understandings among participants from various professional, cultural, geographic, and disciplinary boundaries (Perz 2019) to support more inclusive decision- and policy-making processes. In fact, shared mental models are useful to create shared pathways to conservation (Moon et al. 2019a). The method also helps visualize the complexity of systems along with the challenges they pose for sustainability (Newell and Proust 2018).

Social-ecological systems (SES) is an interdisciplinary concept referring to dynamic, coupled systems in which societal actors and ecological units and subsystems interact through direct, indirect and bidirectional linkages (Glaser et al. 2012; McGinnis and Ostrom 2014; Schoon and Van der Leeuw 2015). Studying SESs supports improved adaptive capacity and encourages resilience thinking. For example, SESs can act as boundary objects providing a common framework to support effective coordination between actors with different disciplinary and professional backgrounds (Glaser et al. 2012; Hertz and Schlüter 2015). We use social-ecological network methods (Bodin and Tengö 2012) to analyze the relational maps and make recommendations for bridging knowledge-action gaps. This process brings together various actors and presents possible collaborations that build adaptive capacity, thus resilience. In doing so, we attend to power dynamics that shape interactions between science, society, and nature in the context of participatory approaches (Lemos et al. 2018; Van der Molen 2018).

3. Materials and methods

3.1 Participants

This research obtained approval from the University of Ottawa's Research Ethics Board. Five CCM workshops were held between March and December 2019 near the RC, in the Ontario communities of Smiths Falls and Battersea. Four of those workshops assembled different types of stakeholders (see Table 1.1) and aimed to gain insight about the environmental health of the RC as a whole. A fifth workshop was organized through action research to address concerns about water quality and was held with a mixed group from the Lower Cataraqui region of the RC (see Mistry et al. 2021).

Workshop	*Community and environmental groups*	*Economic interest groups*	*Academics*	*Government representatives*	*Water quality*
Participants	15	9	9	10	10
Pairs	7	4	4	5	5

Table 1.1. Number of participants and pairs of participants per workshop.

Purposeful sampling was used to identify "key informants in the field who can help in identifying information-rich cases" (Suri 2011: 66). As we aimed to capture a broad range of views, knowledge and perspectives about the RC, the team generated a large list of potential participants by searching online for non-governmental organizations, environmental groups, community groups, lake associations, businesses, and governmental groups, among others, related to the RC. Researchers and collaborators who have worked in the system for many years also helped identify relevant actors who have limited online presence but play an active role in the system. Academics were colleagues from the multidisciplinary research team described in Section 2.1. With the help of collaborators, we produced a tiered list of possible participants that prioritized key informants. We grouped participants for the workshop by stakeholder groups. Participants were invited according to the tiered lists until we recruited a maximum of 15 participants per workshop. Many efforts were made throughout the recruitment stage to engage with Algonquin and Mohawk communities near the RC by using contacts from collaborators and online searches, but these efforts were unsuccessful. A total of 52 individuals participated across the five workshops, with one individual attending both the community and water quality workshops.

During the last step of the knowledge mapping exercise in the workshop, participants were asked to work in pairs. The authors assigned the pairs by observing participants throughout the workshop and pairing people who, based on our knowledge of their affiliation, did not appear to have personal or professional relationships. One group of three was formed in workshops with an odd number of participants.

3.2 Workshops

The main question for the four stakeholder group workshops was “What can be done to maintain or improve the environmental health of land and water in the Rideau Canal?”, while the fifth workshop used the same question but substituted environmental health with water quality, due to the specific interest of that group as mentioned above. We organized the workshops around the CCM approach, which draws from systems dynamics and resilience thinking (Newell and Proust 2012, 2018). We adapted the CCM approach to include four activities that would allow us to identify dominant dynamics in the RC system, to identify leverage points and to develop new shared understandings (Newell and Proust 2012) within a three-hour workshop. The four workshop activities consisted of individual identification of factors which influence environmental health, the creation of a collective timeline detailing how these factors came to be, a knowledge mapping exercise, and a group discussion about leverage points to press for change (for more details on workshop activities, please refer to Supplementary Material 1/Appendix 2 in this thesis).

In this article, we focus on the knowledge mapping exercises. Building on previous activities as well as their knowledge and perspectives, participants individually identified the causal relationships among factors relating to the central factor “environmental health” or “water quality”. They were asked to add factors around the central factor on a piece of paper and to connect them with arrows showing the direction of influence, thus creating a systems map representing their mental models of the RC (Newell and Proust 2012; Moon et al. 2019a). Next, participants were paired and given a large piece of paper to merge the factors and relationships from their individual maps, thus co-producing knowledge maps and providing opportunities for social learning. One member of each pair described the content of the map to the rest of the group. This mapping exercise generated a total of 25 pair-level maps.

3.3 Analysis

We examine the convergences and divergences across stakeholder views in the maps and analyze a collective map of the RC that aggregates local and expert knowledge. Using MS Excel, we thematically coded the list of factors from the pair-level maps to get a standardized list of factors. Two of the authors reviewed the coding. We also classified factors as either social or ecological. Social nodes included primarily social processes, institutions, and activities such as management and regulations, recreational activities, economic activities, tourism, as well as technologies. Ecological nodes included primarily ecological processes such as biodiversity and species succession. Two of the authors reviewed this classification. Using these factor attributes, we classified relationships between factors in all maps as social ties (social node-to-social node), ecological ties (ecological node-to-ecological node) or social-ecological ties (social node-to-ecological node or vice versa).

We stored data from the maps in MS Excel as 25 unweighted, asymmetric adjacency matrices using binary coding; we coded the presence or absence of a relationship between factors as a 1 or 0. By merging adjacency matrices of pair-level maps from each workshop, we created aggregated workshop-level matrices. When merging these adjacency matrices, we summed the frequency at which participants cited each relationship between the factors to use as the weight of the relationship. We repeated this process with workshop-level matrices to create one aggregated matrix, a collective map.

We used the packages ‘sna’ (Butts 2019) and ‘igraph’ (Csardi and Nepusz 2006) in Rstudio, an integrated development environment for the programming language R (R Core Team 2017), to transform the adjacency matrices into networks and generate network measures. Graphs were generated in igraph using the default layout value which calls upon the Fruchterman-Reingold layout, a force-directed algorithm which determines layout according to the forces pulling nodes together and apart from each other (Csardi and Nepusz 2006). This analysis allowed us to describe and compare the structure of relationships between factors across maps (Özesmi and Özesmi 2004; Papageorgiou and Kontogianni 2012; Stakias et al. 2013; Gray et al. 2014; Giordanno et al. 2017; Moon et al. 2019a). To compare the structure of the maps across workshop groups, we ran one-way ANOVA tests with pair-level data. We also describe differences between workshop maps by using network graphs and measures. The collective map was analyzed through basic network measures and with the Louvain community detection which served to identify communities of factors by maximizing modularity (Smith et al. 2020). The clusters obtained from the Louvain community detection algorithm were used to identify interconnected nodes as distinct clusters of factors. These clusters led to key findings which we used to identify areas of action and create narratives that can be used in policy and decision-making.

4. Findings

4.1 Convergences and divergences in stakeholder views

The coproduction exercise in the workshops resulted in 25 pairs of participants, each creating 25 knowledge maps of the RC as a social-ecological system. The maps were converted into network graphs for analysis. A network is a set of relations between people, concepts or factors. In this case, the network maps represent people's perceptions of causal relationships (herein referred to as ties or edges) between factors that influence the environmental health of the RC (herein referred to as nodes). Network size refers to the number of nodes in a network, and network density refers to the proportion of actual ties in a network divided by the number of possible ties. A glossary of network analysis terminology is available in Supplementary Material 2 (Appendix 3 in this thesis).

Among the 25 pair-level networks (see Supplementary Material 3/Appendix 4 in this thesis), there was a near significant difference among workshop groups regarding the percentage of social and ecological nodes ($F (4, 20) = 2.664$, $p = 0.062$). There was also a significant difference among workshop groups regarding the number of ecological nodes ($F (4, 20) = 3.349$, $p = 0.30$). While most groups had similar proportions of social and ecological nodes at the pair-level, community and environmental groups had less ecological nodes in their maps. Inversely, the water quality pair-level maps included more ecological nodes.

We merged the 25 pair-level networks to create five workshop-level maps and identify convergences and divergences between groups (see Table 1.2, Figure 1.1a to 1.1e and Supplementary Material 4/Appendix 5 in this thesis). Workshop-level maps generally had a higher percentage of social nodes compared to ecological nodes. Most workshop-level maps also featured a higher proportion of relationships between social and ecological factors (social-ecological ties) compared to relationships between only social and only ecological nodes (social and ecological ties respectively). Ecological ties account for less than 26% of ties across all workshops. Community and environmental groups strongly emphasized social factors (80.77%) and social ties (55.93%) compared to other groups. The workshop-level map for academics was the most balanced in terms of tie type, closely followed by the water quality workshop which also had the most balanced proportion of nodes. Overall, participants cited social factors and relationships more frequently across all workshops, except the water quality workshop.

Network measure	*Community and environmental groups*	*Economic interest groups*	*Academics*	*Government representatives*	*Water quality*
Network size	52	38	38	36	46
Number of edges	177	120	92	167	244
Network density	0.07	0.09	0.07	0.13	0.12
Percentage of social nodes	80.77	71.05	65.79	63.89	52.17
Percentage of ecological nodes	19.23	28.95	34.21	36.11	47.83
Percentage of social ties	55.93	40.00	36.96	33.53	27.05
Percentage of ecological ties	10.73	10.83	26.09	20.36	26.74
Percentage of social-ecological ties	33.33	49.17	36.96	46.11	46.31
Edgewise reciprocity	0.66	0.47	0.11	0.48	0.41
Number of strong components	10	13	27	7	13
In degree centralization	0.31	0.33	0.29	0.60	0.49
Out degree centralization	0.23	0.13	0.18	0.39	0.49
Betweenness centralization	0.39	0.29	0.11	0.25	0.28
Eigen centralization	0.29	0.23	0.30	0.31	0.26

Table 1.2. Network measures at the workshop-level

To further compare workshop maps, we can use centrality scores that refer to the level of connectivity of individual nodes. More specifically, in and out degree centrality refers to the number of incoming and outgoing ties of a node. As expected, the central node “environmental health” and “water quality” had the highest combined in and out degree and betweenness centrality scores in their respective workshops. Some factors were cited in all workshop maps: invasive species, climate change, agriculture, boating, water quality, shoreline development and development pressures. Water quality was also a central factor in all workshops, and climate change was central for economic interest groups. Betweenness centrality scores also help identify nodes that act as bridges connecting otherwise disconnected nodes. Tourism and shoreline development were identified as bridging factors in four of the workshop-level maps, while boating, nutrient levels and water quality scores were identified as bridges in three of the workshop-level maps.

There was a significant difference across workshop groups regarding the number of strong components (which are subsets of mutually connected nodes) in pair-level network maps ($F (4, 20) = 3.765$, $p = 0.020$). Figure 1.1 shows network graphs and is accompanied by descriptions of relationships and network features for each workshop. We use network indicators from Table 1.2 such as edgewise reciprocity (which refers to the number of mutual ties in a network) and centralization scores (which provide insight about the level of overall connectivity of the entire network) to describe these structural network features.

Figure 1.1a to 1.1e present workshop-level graphs featuring the most central nodes, as determined by a combined rescaled in and out degree centrality score of 0.03 or more. We set a threshold of 0.03 to produce graphs that visually present the dominant nodes and relationships of each workshop map. The centrality score of a node determined node size in the graph, with the most frequently cited nodes having a bigger size. Orange represents social nodes and ties, and green represents ecological nodes and ties. Blue represents social-ecological ties. The width of lines corresponds to weight, that is the frequency at which relationships were cited by participants, while arrows represent the direction of ties.

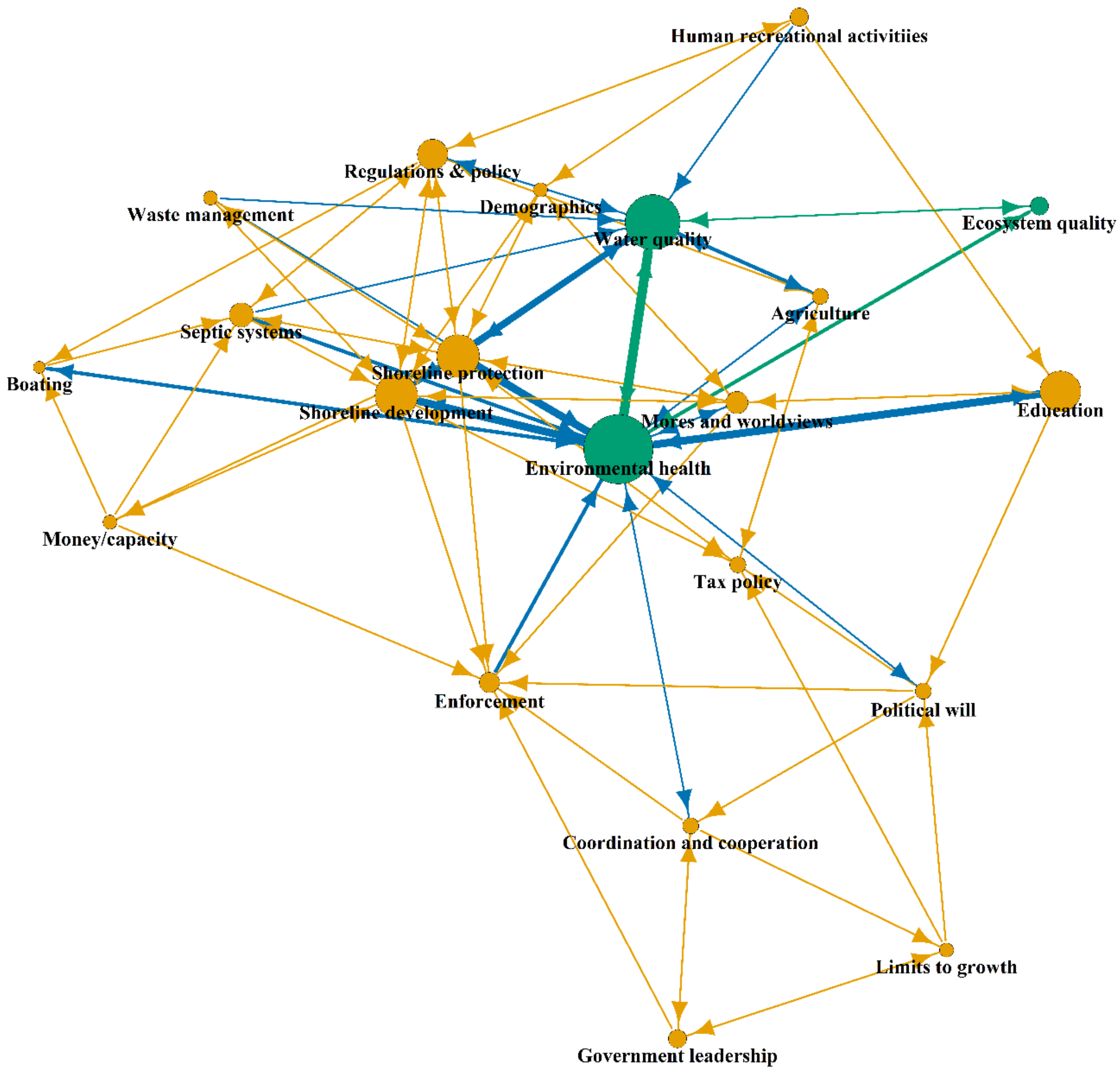

Figure 1.1a. Community and environmental groups workshop-level network graph.

The community and environmental groups cited more social nodes and those with the highest degree centrality were related to human infrastructure (shoreline protection, septic systems), but also values (education, mores and worldviews) and governmental activities (regulations and policy, enforcement, government leadership). Five out of seven pairs perceived the influence of water quality on environmental health, and two pairs saw this relationship as reciprocal. Pairs frequently cited shoreline protection, shoreline development and agriculture as related to water quality and environmental health, thus indirectly connecting these two central factors. Results also show that community groups had the highest edgewise reciprocity, which refers to the number of mutual ties in a network, thus indicating that community groups produced more mutually connected maps.

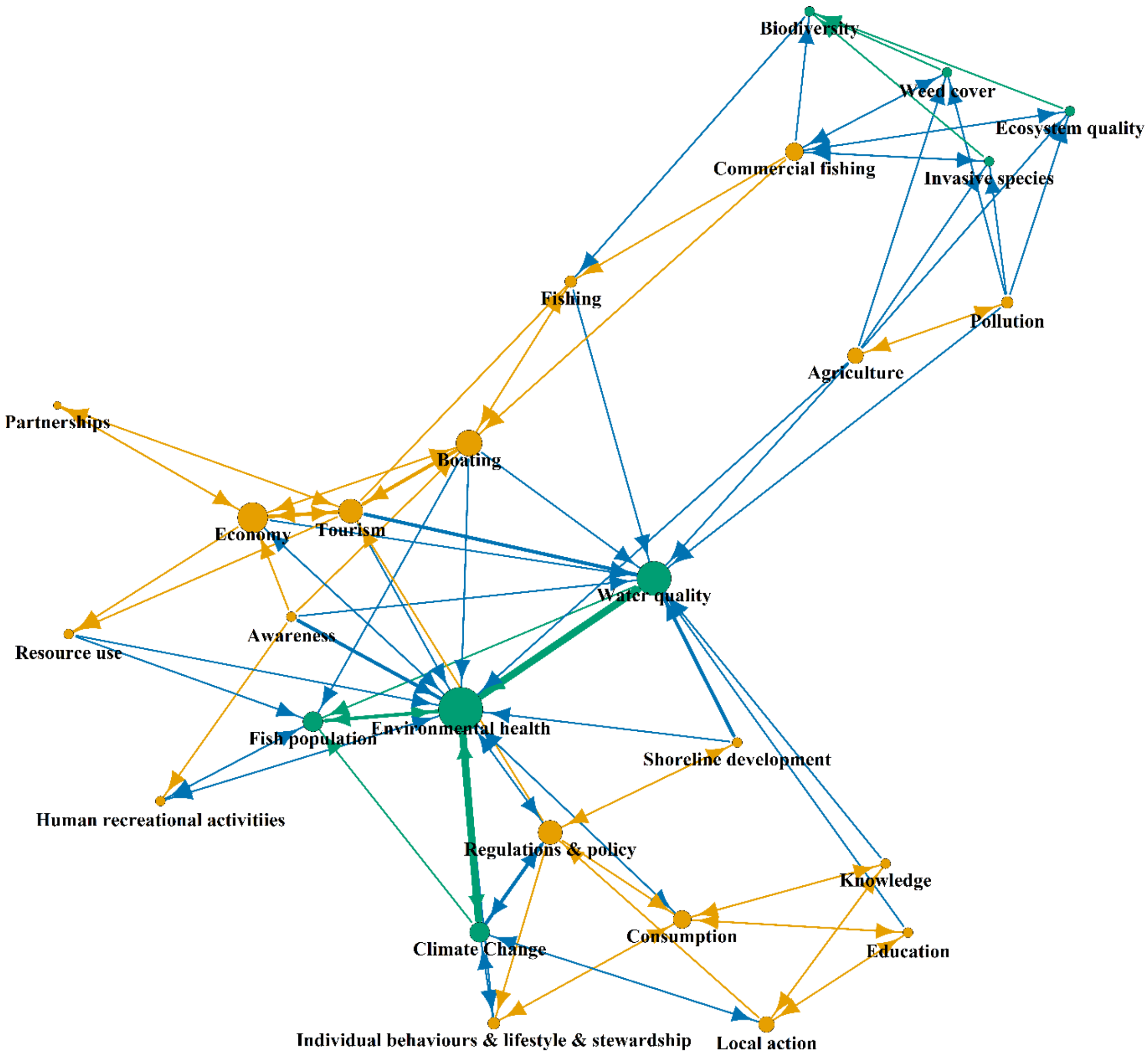

Figure 1.1b. Economic interest groups workshop-level network graph.

Economic interest groups had a more balanced view than community and environmental groups. Nodes with highest degree centrality related to human behaviour and decisions (boating, tourism, commercial fishing, agriculture, local action, regulations and policy), economic values (economy, consumption) and ecological factors (climate change, fish population). All pairs linked water quality and climate change to environmental health. Some also acknowledged the reciprocity of the relationship between climate change and policy. Although there are distinct clusters of social and ecological factors, there are many social-ecological ties, many which relate to economic activity.

Figure 1.1c. Academics workshop-level network graph.

Academics cited many ecological factors that had high degree centrality (invasive species, erosion, native species, algae, nutrient level, lotic/lentic system), but they also considered human behaviour (shoreline development, boating, enforcement, monitoring, political will). Most pairs mentioned the influence of boating on invasive species, and some linked fishing and fishing tournaments to boating. The influence of algae, invasive species and monitoring on environmental health was also identified. This network graph shows a relatively proportional view of social, ecological and social-ecological ties with some clustering. Overall, network indicators suggest that academics co-produced the most fragmented view of the RC with distinct clusters formed of connected factors (highest number of strong components, low number of edges, low score of density, low edgewise reciprocity, and lower centralization scores).

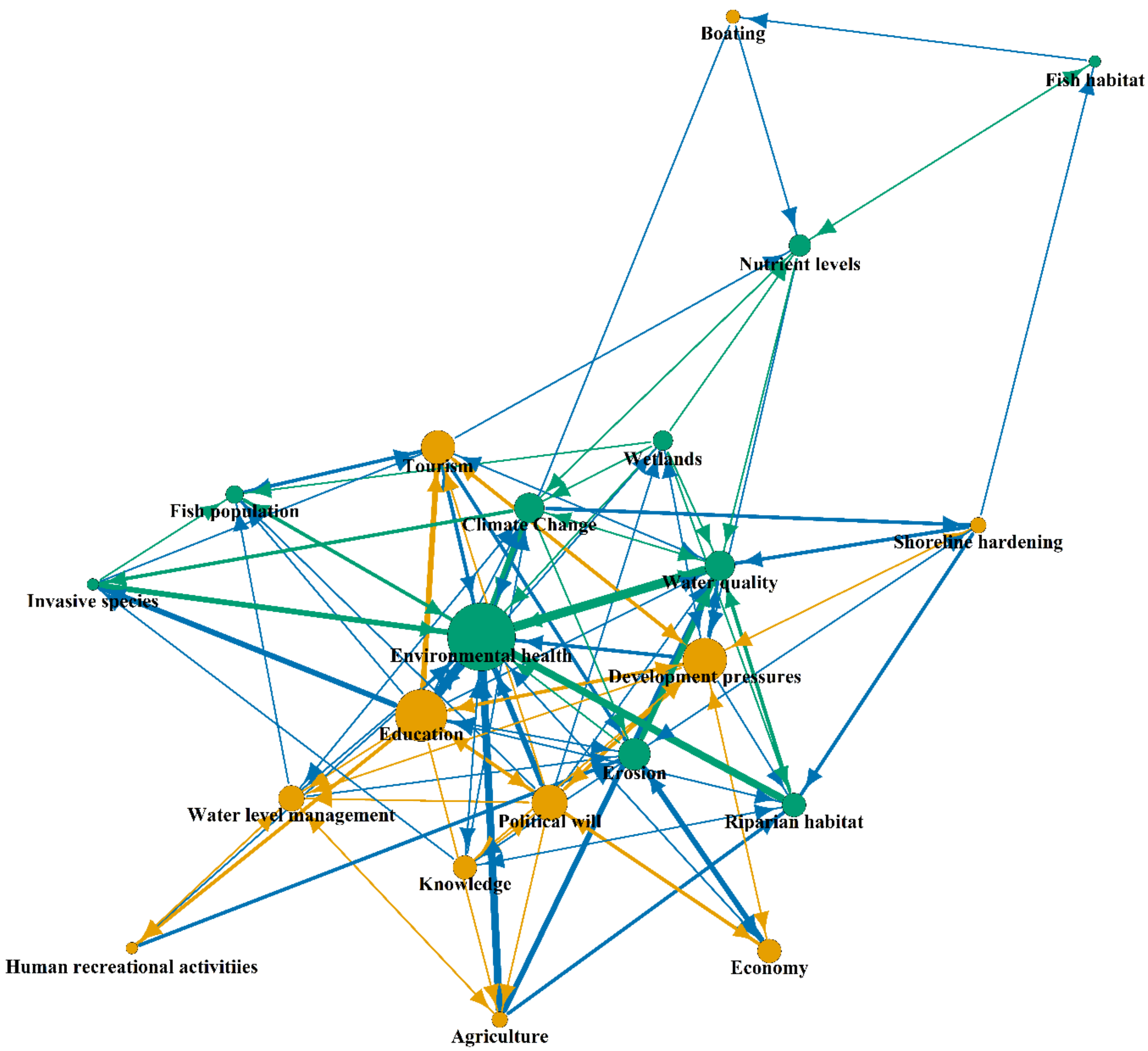

Figure 1.1d. Government representatives' workshop-level network graph.

Human actions and decisions (education, development pressures, political will, tourism, water level management) had the most ties in the government representative workshop, but some biophysical indicators were also central (erosion, climate change, water quality). All pairs linked education and water quality to environmental health. Agriculture, climate change and riparian habitat were also recognized by most pairs as influencing environmental health. A higher proportion of social-ecological ties in this network graph shows an integrated view of environmental health. Network indicators suggest that government representatives perceived dense connections among factors with the smallest number of separate clusters (highest network density and in degree centralization score, as well as the lowest number of strong components).

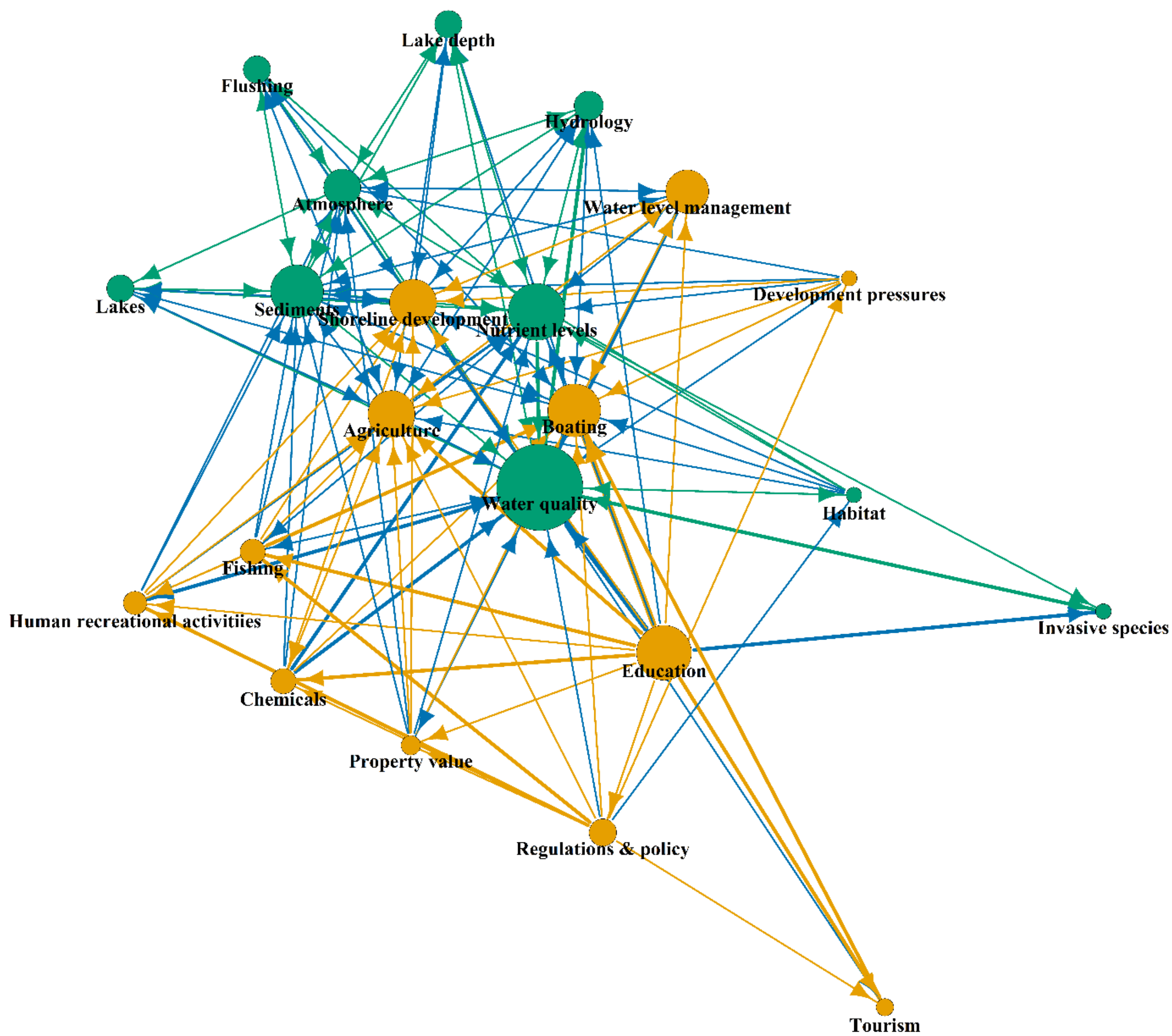

Figure 1.1e. Water quality workshop-level network graph.

Nodes with the most ties in the water quality workshop included both biophysical factors that directly relate to water quality (nutrient levels, sediments) and human behaviours that are perceived to influence these factors (education, boating, shoreline development, agriculture, water level management). Many pairs linked climate change and education to water quality, and education to boating. This network graph features many social-ecological ties where human actions influence biophysical indicators. However, social and ecological nodes are mostly located on opposite ends of the network, which indicates less direct connections. Overall, the water quality workshop-level map presents a densely connected map by featuring some of the highest in and out degree centralization scores and a high network density.

4.2 Collective-level map

The collective network was created by aggregating workshop-level maps, thus representing the knowledge and perspectives of all groups (see Supplementary Material 5/Appendix 6 in this thesis for the full map, tie list and node list). It has a lower network density than workshop-level maps due to ties being spread over a high number of nodes (see Table 1.3). The collective map is skewed toward social factors (70.54%) but is more balanced in terms of types of ties, with most ties connecting social and ecological factors (41.94% are social-ecological ties). Beyond environmental health and water quality, the most frequently mentioned factors include education, boating, climate change, invasive species, agriculture, shoreline development, tourism, and regulations and policy. The first four were cited in all five workshops. Overall, 26.79% (30) of factors were mentioned by four or more pairs of participants (out of 25), which indicates that around three quarters of factors were not frequently mentioned by participants.

Network measure	*Collective map*
Network size	112
Number of edges	689
Network density	0.06
Percentage of social nodes	70.54
Percentage of ecological nodes	29.46
Percentage of social ties	39.33
Percentage of ecological ties	18.72
Percentage of social-ecological ties	41.94

Table 1.3. Network measures for the collective map.

Factors that are well-connected in the map (high degree centrality) include education, shoreline development, boating, nutrient levels, water-level management, and erosion. Following environmental health and water quality, education, shoreline development, boating, nutrient levels, water-level management, erosion, tourism, and coordination and cooperation were the top bridging nodes in the collective-level map. Most pairs in all workshops cited water quality as influencing environmental health. Other more frequently cited relationships across workshops include the influence of shoreline development and agriculture on water quality, as well as the influence of boating, climate change, invasive species, and education on environmental health. As can be seen in the full map figure (Supplementary Material 5/Appendix 6 in this thesis), the network structure in the collective map is mostly formed by one cluster with some nodes being slightly less connected to the core of the network. The center of the cluster presents a mix of social-ecological ties, with social factors and ties at the periphery. Few ecological factors and ties are at the periphery, indicating that while they are more directly connected and better integrated in the network than social factors.

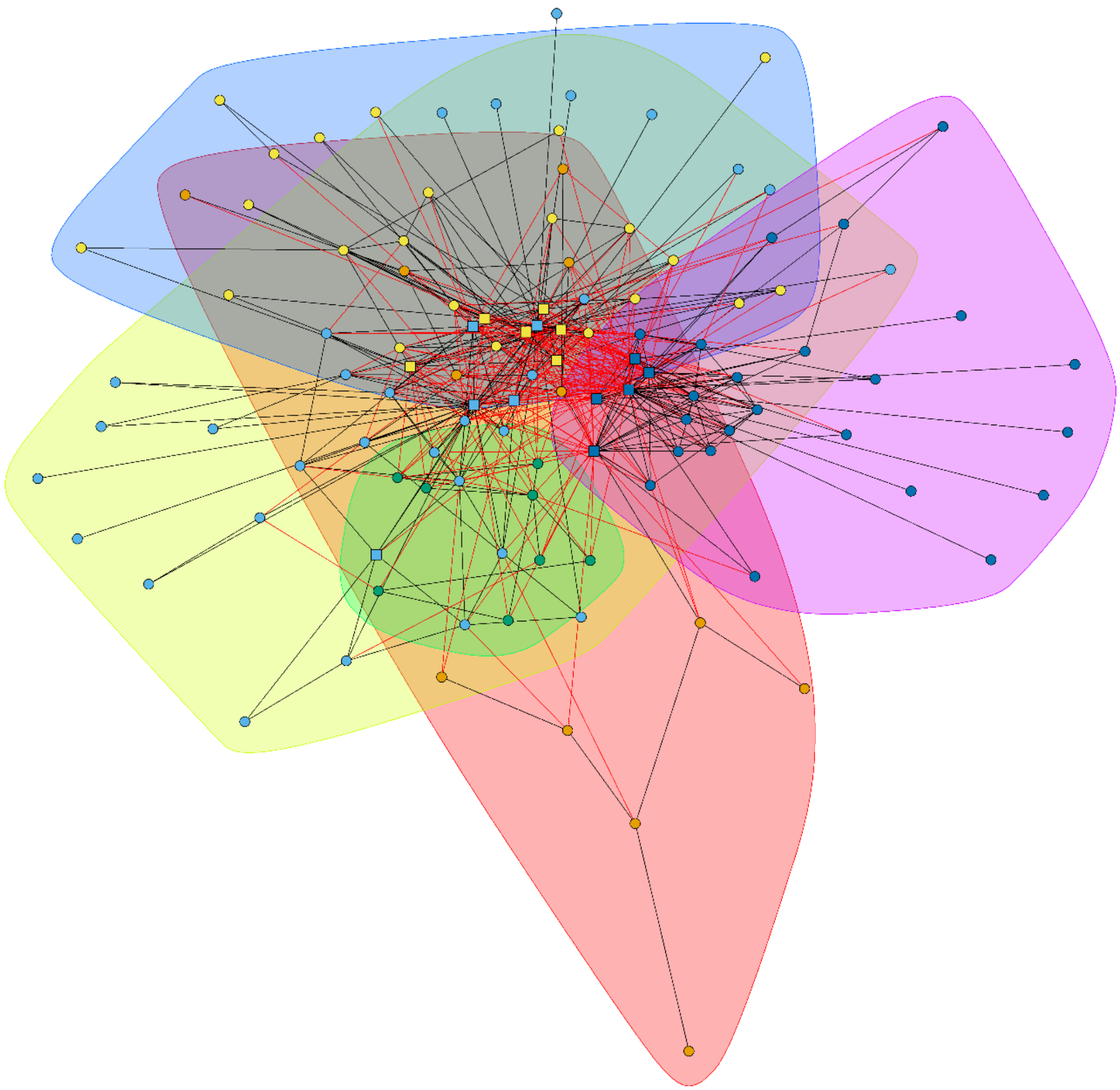

Figure 1.2. Collective-level network graph with results from the first round of Louvain community detection algorithm, which identified 5 main clusters (distinguished by color for visual convenience: blue, yellow, green, red, and pink).

Figure 1.2 presents results from the first round of the Louvain community detection algorithm which identified five main clusters. The Louvain community detection algorithm was applied again to the main clusters which had more than 20 nodes. This second iteration identified 13 clusters whose core findings are described in Table 1.4 (see Supplementary material 6/Appendix 7 in this thesis for individual graphs). These clusters encompass all nodes from the collective-level network, though only 31.35% of all ties are represented in the clusters. We can see that half of the clusters formed around social ties (six clusters), and only one formed around ecological ties. Six social-ecological clusters were also identified. Table 1.4 also describes some narratives that can be told from the core findings.

Cluster	*Classification*	*Narratives derived from the knowledge and perspectives found in the collective-level map*
1 Red	Social-ecological	Commercial fishing is perceived to impact turtle distribution, ecosystem quality and weed cover, and indirectly biodiversity. Jurisdictional quagmire is also seen as being influenced by the RC's construction (led by Colonel By in the 1830s), and influences land-use policy and phosphorous.
2.1 Yellow	Social	Coordination and cooperation acts as a bridge between multiple nodes and was frequently cited as influencing enforcement, monitoring and common vision. Broader social trends – such as placing limits on growth, making the environment a financial priority, and consumption – relate to individual behaviour and government actions like leadership and stewardship. Individual behaviours and enforcement are perceived to be especially influential.
2.2 Yellow	Mostly social	Education is central to this cluster and highlights related social factors such as actors related to education (e.g., Conservation Authorities, lake associations) and mechanisms that can influence education (political will and involvement, engagement, mores and worldviews, and awareness, which can be influenced by new technologies).
2.3 Yellow	Social-ecological	This cluster features environmental health. There are social ties between local action (like pesticide use), fish management, global actions, and regulations. Regulations act as a bridge, indicated by high betweenness centrality, between social actions and environmental health. Some biophysical indicators interact through ecological ties like native and invasive species, algae, and climate change. Climate change is seen as influencing and influenced by both environmental health and regulations.
3 Green	Social	This cluster centers around shoreline protection. It is tied to waste management and hospitality (which are both influenced by social media), and there are bidirectional relationships between shoreline protection and tax policy, septic systems, money and capacity, and demographics.
4.1 Blue	Social-ecological	Development pressures are influenced by knowledge, shoreline hardening and vegetation cover, while influencing municipalities and riparian habitats.
4.2 Blue	Mostly social	Boating influences boat launches and public access; it was frequently seen in a bidirectional relationship with fishing. Lock activities influence both boating and aquatic vegetation management, which would otherwise not be linked.
4.3 Blue	Social-ecological	Recreational activities mediate the relationship between aquatic ecosystems, fish populations and fish tournaments through reciprocal relationships. Fish populations are influenced by boating and fishing regulations as well as resource use and fish tournaments, which influence resource use, forming a feedback loop. Resource use mediates the relationship between rural infrastructure and development regulations.
4.4 Blue	Mostly social	Economy is seen as influencing and being influenced by tourism and erosion, and tourism also influences erosion. Partnerships are in

		bidirectional ties with economy and tourism. Community influences both tourism and cottages, with cottages influencing erosion.
5.1 Pink	Mostly ecological	Nutrient levels are influenced by property values (the only social node of this cluster) and biophysical factors like lake depth, sediments, atmosphere and lakes.
5.2 Pink	Social-ecological	Canal construction influences shallow zones in the waterway, which influence turbidity.
5.3 Pink	Social-ecological	Water quality is at the core of this cluster and is influenced by ecological factors like buffer zones, while influencing ecosystem productivity. It is also directly tied to many social factors like road salt, artificial lakes, water traffic, storm water management, pollution, agriculture and water-level management. This can inform recommendations such as focusing on dams and chemicals through water-level management and agriculture to directly and indirectly influence water quality.
5.4 Pink	Mostly social	Shoreline development influences municipal funds, and there is a bidirectional relationship between habitat and shoreline development, showcasing a social-ecological tension.

Table 1.4. Core findings among Louvain clusters presented as narratives. The color specified with the cluster number refers to the associated colored clusters in Figure 1.2.

5. Discussion

5.1 Insights for governance of the Rideau Canal

Working toward conservation and building social-ecological resilience requires an understanding of the complex dynamics that shape systems, as well as the diversity of perspectives and knowledge that people hold about these systems (Gray et al. 2012; Moon et al. 2019a; Furman et al. 2021). The findings show these diverse perspectives and knowledge and reveal that there are shared and divergent assumptions about environmental health in the RC (Moon et al. 2019a). The network maps are dynamic cognitive representations of reality based on life experience, perceptions, and worldviews, also known as mental models (Jones et al. 2011). Co-developing such mental models in natural resource management can help identify similarities and differences in actors' perceptions of environmental issues, integrate these different perspectives through social learning, and create collective representations of a given social-ecological system (Jones et al. 2011). These elements are essential for effective adaptive co-management because they build resilience by facilitating dialogue among stakeholders to collectively identify potential leverage points and form narratives to inform education and policy- and decision-making (Berkes 2017). This work is also novel in the context of the RC, thus providing the basis for future investigation of this dynamic waterway system.

A main finding is that social factors were overemphasized in the network maps. Most groups conceptualize the RC as an SES where more than half of the factors are social, which demonstrates that challenges to sustainability and environmental wicked problems "tend to be societal problems, rather than technical problems" (Berkes 2017: 7). Another significant finding is the different number of strong components between groups, which indicates that there are differences in the mental models of community groups, economic interest groups, academics, government representatives, and the water quality workshop participants when conceptualizing the RC as an SES. Differences between groups were expected since social and psychological factors such as environmental attitudes, socio-demographics, and environmental knowledge and concerns are known to influence perceptions of the environment and SES (Guo et al. 2018).

Community and environmental groups cited a higher proportion of social factors compared to other groups which could be attributed to higher levels of community involvement. Mental models are influenced by life experiences (Jones et al. 2011; Furman et al. 2021) and social interactions (Bustan 2016). For example, participation in the preservation of watersheds was tied to solidarity and attending to the interests of a group (Bustan 2016), supporting the insight that community groups perceive more social factors than other groups.

Although the academics and water quality workshops had the most fragmented workshop-level maps, they also had the most balanced view of the system in terms of social-ecological ties. The mental model of academics may be influenced by their training and the reductionist approach science takes to study the environment and empirical phenomena (Gallagher 2018). Academics are also generally more familiar with the concept of SES than other groups, and pre-existing knowledge of the concept is likely to have shaped their mental models of the RC as a system composed of distinct social and ecological components (for example, see Bergman et al. 2021). The fragmented representation demonstrates the utility of using SES as a boundary object in collaborative mapping exercises to foster interdisciplinary work and provide a holistic view of a complex SES (Hertz and Schlüter 2015). The fragmented view of the RC by academics may also be contextualized by the theory on the strength of weak ties, which refers to the idea that a person with many weak ties has greater access to a variety of novel, non-redundant information sources (Granovetter 1973; Aral 2016). Out of the participating groups, the academics are the least embedded from other actors and thus feature fewer weak connections within the RC system (e.g., they operate in thematic academic circles rather than RC-based community and management circles). As mentioned, they also present more homogenous views than other groups (e.g., scientific reductionism and prior understandings of SESs). This provides them with a less diverse pool of knowledge to draw from when generating mental representations of the RC, therefore presenting a simpler schema than the other groups, such as community groups who produced densely connected maps.

The water quality workshop demonstrates that focusing on a narrow topic with a mixed group of knowledgeable stakeholders may lead to more precise outcomes and balanced representations of social and ecological factors (Mistry et al. 2021). The mixed group also explains the fragmentation in the map as differences in environmental perceptions are expected between people who have different lived experiences and social characteristics (Jones et al. 2011; Guo et al. 2018; Moon et al. 2019a; Furman et al. 2021). While individual mental models and conceptual maps are only partial representations of a system, collaborative participatory mapping and the aggregation of shared mental models generated more complete representations of water quality in the Lower Cataraqui and the RC system (Jones et al. 2011; Gray et al. 2014).

The collective map allowed us to identify key factors and areas of action to maintain and enhance environmental health in the RC. Unsurprisingly, regulations and policy were frequently cited in the maps, revealing the reflexive potential of our method. Informing decision-making processes with the resulting narratives (see Table 1.4 for examples) about the possible roles of policy in the RC system creates space for nuanced discussions and structured decision-making when seeking to update, renew or rethink these policies (Moon et al. 2019a; Gregory et al. 2021). Our findings provide multiple pathways for consideration which aligns with the iterative dimension of adaptive management, thus building resilience in the RC system (Berkes 2017).

There was a strong consensus across all workshops on the influence of water quality on environmental health, indicating the need for action in this area. Other areas of action cited in all workshops were education, boating, climate change and invasive species, some of which are also the most connected factors in the map: education, shoreline development, boating, nutrient levels, water-level management and erosion. Many social factors (education, shoreline development, boating, water-level management, erosion, tourism, coordination and cooperation) play a bridging role connecting factors across the system, highlighting the role of human actions as potential leverage points (or problems) tied to biophysical indicators of environmental health like nutrient levels and erosion. Insights from network analysis and the relationships among factors can be used to prioritize action in the RC by identifying precise pathways of action.

This paragraph provides an example of how the map can be used to identify areas of action and pathways to support resilience. There was consensus across workshops about the need to consider education, it was also a central node and a bridge in the system. In alignment with the environmental education literature (Ardoin et al. 2020), it can thus serve as a leverage point to improve social-ecological resilience in the RC. The relationships in the collective map reveal specific realms of activities or behaviours that education should target like agriculture, boating, consumption, development, enforcement, fishing, recreational activities, landscaping, tourism, septic systems and water-level management. The collective map also reveals key actors of education in the system, Conservation Authorities and lake associations, who should be supported by decision- and policy-makers.

Our analysis of the collective map presents combined insights from expert and local knowledge as concise and precise narratives that can inform policy- and decision-makers (Table 1.4 and Supplementary material 6/Appendix 7 in this thesis for the respective maps). The network analysis also revealed consensus on the need for coordination and cooperation in the governance of the RC system. This mapping exercise provides a starting point for governmental collaborators who can use the results to highlight priority pathways for their respective jurisdictions and test mutually reinforcing solutions based on intersecting pathways (Newell and Proust 2012). Such an exercise is especially important to build resilience for the RC system considering it features jurisdictional quagmire (Mistry 2021, Bergman et al. 2021) which presents significant governance challenges that can impede adaptive co-management (Folke et al. 2005; Armitage et al. 2009).

5.2 Implications for decision- and policy-making

Research has shown that modelling and mapping of SESs in participatory approaches help to bridge disciplines and support decision-making (Anderies 2002; Özesmi and Özesmi 2004; Glaser et al. 2012; Rounsevell et al. 2012; Gray et al. 2012; Papageorgiou and Kontogianni 2012; Stakias, et al. 2013; Gray et al. 2014; White et al. 2018; Giordano et al. 2017). We used both quantitative thresholds (network measures) and qualitative information (the factors and the relationships between them) to provide evidence and derive narratives of system-wide interactions that can inform policies in the RC. Our research process provides a practical way for both local and scientific knowledge and perspectives to inform decision-making in a context where interconnections in large waterway systems are difficult to investigate empirically, particularly where there is limited empirical data on the SES (Bremer et al. 2020). This approach also provides a meaningful way to engage with key actors and foster social learning (Jones et al. 2011; Berkes 2017; Moon et al. 2019a Mistry et al. 2021).

The outcomes of these workshops underscore the need for careful thinking to effectively mobilize collaboration to improve environmental governance and research (Perz 2019). The mapping exercise in pairs and discussions on areas of action contribute to building shared understandings of multiple perspectives among participants and to developing holistic solutions (Mistry 2020). This method provides a way for researchers, governments, local groups and businesses, among others, to come together early on in engagement and consultation processes in order to understand how systems-thinking can be used to tackle complex problems, especially in the context of policy-making (Glaser et al. 2012). While the workshops enabled the authors and participants to strengthen their relationships with other disciplines, locals and government representatives in the RC, iterative approaches and ongoing relationship-building can improve the quality of outcomes over time (Young 2020).

This method is also a starting point to address power imbalances between local and expert knowledge by considering epistemological pluralism: each form of knowledge stems from different worldviews which are equal and valid (Miller et al. 2008). However, there are limits to this method of knowledge coproduction and the extent to which it addresses specific power imbalances as well as broader power dynamics. Our findings show that outcomes of this workshop remain anthropocentric as participants mentioned more social nodes. The workshops also had a limited number of participants who were selected by the authors, showing that collaborative processes remain limited by logistics (e.g., how many people can feasibly participate in each workshop) and relational power dynamics (e.g., who is given the opportunity to participate) (Young 2020). For example, Internet searches could only identify groups with enough capacity and resources to organize an online presence, and no more than 15 participants could attend each workshop. Though demographics were not recorded, the authors also acknowledge there was a skew toward men and an older population. Additionally, the authors are still working on building ties with Indigenous communities in the area surrounding the RC system so their perspectives could not be included. As such, this work represents the views of Canadian settlers. Future research must consider if and how formal systems thinking and relational approaches could be mobilized to rebuild conversations and relationships with Indigenous communities in the RC and other regions of the world.

Despite these limits, the workshop and network analyses have value in aggregating various stakeholder knowledge, framing it in ways that include both social and ecological factors, and providing findings that can serve as evidence to support policy and decisions, especially in the absence of empirical data. The aggregated, collective maps are tools that can help find points of agreement across participants and present combined knowledge in concise forms to governments. This can serve to articulate more nuanced and accurate narratives of social-ecological systems that are informed by those who know the system best with the goal of sustaining and maintaining SESs. This type of process advances collaborative governance efforts and builds resilience and adaptive capacity by developing relationships and co-producing knowledge representations of the system that otherwise would be fragmented and underutilized in management of the RC (Berkes 2017; Moon et al. 2019a).

While discussions are ongoing with government representatives on how they can integrate these tools in management of the RC, we present three suggestions. First, decision- and policy-makers could use findings from workshop-level maps (section 4.1) to identify similarities and differences in the knowledge, perspectives, and priorities of different groups. This can inform engagement and communication strategies for different actors who have distinct interests, priorities, and understandings of the RC system. In addition, decision and policy-makers could use the various network visualizations in the paper and supplementary materials (specifically Appendices 4 to 7 in this thesis) as a way to engage stakeholders, rightsholders and staff where there may be tensions or conflict and to initiate discussion about system-wide management of the RC. Second, decision and policy-makers could use the network statistics, for example the centrality scores of factors in the collective map, to identify collective priorities and areas of action. Key priorities and pathways to action can also be identified by looking for factors who score highly in different types of centrality scores (e.g., degree centrality which refers to direct connections and betweenness centrality which refers to bridging capacity). Finally, the key findings and narratives derived from the knowledge mapping exercise (Table 1.4) present consumable information to act on social-ecological tensions in the RC system. These narratives could be integrated in education initiatives, new policies and strategic planning.

This work has implications for policy as a means, not an end, to improve the collaborative nature of governance in complex systems. In fact, governments should pay more attention to different perceptions of the environment, coordination among multiple groups and entities that have different knowledge and perspectives, and demands for effective and meaningful participation to collectively improve the implementation of environmental policy and regulations in order to build resilience in both governance of the RC and within the SES itself (Young 2020; Liu 2021). Our findings and methods provide ways to meet these needs as they (1) co-produce local and expert knowledge in a way that includes both social and ecological factors and enhances social learning, (2) aggregate and present this knowledge in a consumable form for policy-makers, and (3) generate specific recommendations on various social-ecological issues. While more work remains to efficiently integrate participatory coproduction and knowledge mapping of mental models in decision-making about the RC, we offer many pathways forward for decision-makers in the RC and elsewhere to use these tools to work toward resilient social-ecological systems.

6. Conclusion

The RC is a complex waterway that is difficult to manage. Conducting participatory workshops with various groups of stakeholders allowed us to capture local and expert perspectives and knowledge in a way that accounts for both social and ecological tensions. Systems thinking and network analysis methods allowed us to analyze the knowledge maps that represent the mental models of participants to aggregate various perspectives and mobilize various knowledges in a way that can inform policy, decisions and the overall governance of the RC. The collective map allowed us to identify priority areas of action through consensus across stakeholder groups, and areas where further deliberation may be required.

This tool has potential for representing social-ecological knowledge and paving the way for meaningful inclusion of various knowledges in decision- and policy-making processes through iteration. Conducting subsequent CCM workshops with increasingly refined questions and different groups of participants could bring clarity and precision to the priority pathways for action. As such, we suggest that future research using these methods include multiple instances of mapping and target specific concerns (e.g., the water quality workshop) where additional deliberation and knowledge could fill knowledge gaps on the interconnections between social and ecological components of complex systems. This research provides a practical method for decision- and policy-makers to integrate disciplinary and professional silos which can result in informed policy and management strategies that balance social and ecological priorities while simultaneously building adaptive capacity and resilience.

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Connective tissue 2: Networks

As a student in the NSERC SPG, I had multiple options for my PhD thesis. I ended up using some of the work emerging from this collaborative project (Chapter 1) while also building on this work to develop and answer my own research questions. Having previously conducted a laboratory ethnography to analyze the practices and gestures of artists and scientists in relation to non-humans, and more specifically in relation to *in vitro* cell culture (Beaudoin 2018), I started paying attention to the role of non-humans in the NSERC SPG, and to the ways in which non-humans were talked about. I began to wonder if my colleagues in the grant thought the non-humans concerned could be considered as collaborators, given the fact that most seemed to embrace the collaborative culture that emerged as the research progressed. Through the collaborative workshops and other interactions with the broader team, I had already identified collaboration as recurring theme, and a review of the literature unveiled that some research on the topic was conducted with social network analysis methods. I also noticed that in the arts and humanities, some authors explored collaboration with non-humans.

However, I wasn't sure if any of the relationships between humans and non-humans in conservation research were collaborative or not, and I wasn't sure how I could paint a clear picture of the range of relations and interactions between humans and non-humans in this context. While laboratory ethnographic methods had previously allowed me to directly experience such relationships – specifically providing me with opportunities to learn the practices of cell culture and conduct my own experiments – it was harder to see how the same methods could be applied in the NSERC SPG, as there was a significant number of researchers working with different non-humans. While I recognize that interactions with non-humans are complex and messy, I also felt that ethnographic methods lacked precision when it came to teasing out the complexity of such relationships. Despite the value of keeping things open-ended by working with metaphors such as meshworks and rhizomes, I found it challenging to operate within such fluid frameworks. Yet, I still wanted to emphasize the importance of relationships as I adopt a relational ontology that assumes that the world is co-constituted, that it is a product of the relations that tie humans and non-humans, animate and inanimate actors. This ontological assumption that the world is made of relations informs my epistemological positioning that we can know the world by attending to, making visible, and analyzing these relations.

Methodological choices must not only accurately address the research questions that are posed but must also align with ones' philosophical positioning. I was thus looking for a method that could help me see the relations between humans and non-humans in research, which I understand as key processes that make up the social world. This is also informed by my understanding of science and research as practices and social phenomena that can be studied with tools from the social sciences. In this context, using networks as a method to capture interactions between humans and non-humans came naturally. Networks can be used to precisely model different systems including SESs through a set of established methods, both humans and non-humans can be included in social-ecological networks, it is a tried-and-true method to capture different types of relationships and interactions including collaboration, and I had already started exploring network data management and analysis through Chapter 1.

However, during my comprehensive examination oral, those with experiences in the critical and ethnographic social sciences were somewhat skeptical of the concepts of systems and networks. They accepted that these approaches have some value, but also challenged me on its potential and its limits. Furthermore, I had been told by other professors in my department (sociology and anthropology) that network approaches were complex and technical, and that focusing on network methods could come at the expense of adequately answering research questions and at the expense of engagement with concepts and theories. Through these discussions, my readings, and my first exploration of network methods in Chapter 1, I decided to complement my use of networks with other methods. To ensure that I could capture the full richness of relationships between humans and non-humans, I decided to have a conversation with people about their relationships with non-humans before collecting network data. I also planned to do some participant observation by joining key members of the grant during fieldwork season on the RC, but I was unable to do so due to the COVID-19 pandemic. Fortunately, I was still able to conduct my interviews through video calls and experienced few pandemic-related delays.

The question I decided to investigate, my onto-epistemological position, and the decision to conduct mixed-method interviews led me to operate differently in Chapters 2 and 3 compared to Chapter 1. These chapters present work that no longer simply “performs” conservation social science with the goal of producing evidence that can be practically applied. Rather, it questions the very foundations of conservation research (including work from the natural and social sciences). Rather than focusing on an external view that conceptualizes the RC as an object, as an SES that must be better understood, I have oriented my methodological and analytical tools inwards, toward the very research processes that concern themselves with the RC. It is not only the RC itself that I conceptualize as a social-ecological network, but also research itself. While the use of networks can be limiting in some ways because it creates artificial boundaries within which representations of reality can be assembled, it is these artificial boundaries that make it possible to work with network data in meaningful ways.

Chapter 2
A paradox of conservation research: Collaboration and friction with non-humans

Journal

Article submitted to the journal *Social Science Information* in June 2022 (see Appendix 1).

The order of references in parentheses has been modified from the submitted manuscript to match the format of this thesis.

Abstract

Collaboration is often presented as an effective pathway to address environmental crises. Conservation research and practice is thus increasingly collaborative, as demonstrated by the variety of participatory approaches used to include diverse actors in research. However, current understandings of, and broad calls for, collaborations lack in nuance and remain anthropocentric. This paper explores the views of key actors in a transdisciplinary conservation research project about their relationships with non-humans. Using mixed method interviews, open questions were asked to explore how researchers along with government and community partners perceive their interactions with non-humans, and to discuss the potential for non-humans to be considered as collaborators. Social-ecological network analysis was used to quantitatively and graphically explore the different types of relationships reported by participants. This research uncovered a paradox of conservation research: while research is conducted with the aim of protecting and conserving the environment, the research process includes frictional relationships with non-humans. These can include violence and sacrifice, and non-humans are seldom considered as collaborators due to being perceived as objects rather than actors, and due to power dynamics between humans and non-humans in conservation research. We explore this paradox, as well as possibilities for non-human collaboration and pathways to challenge the onto-epistemology of conservation research.

Keywords

Conservation research, non-humans, non-human collaboration, social-ecological networks, transdisciplinarity

Introduction

In the face of current, multi-faceted environmental crises, collaboration is seen as one of the mechanisms that we must master to develop sustainable solutions and slow the anthropogenic destruction of the Earth's living systems (Bodin 2017). Simply put, collaboration means to work with someone (Neimanis 2012). It is seen as an essential tool to tackle wicked problems and social-ecological challenges that cannot be solved by working in disciplinary or professional silos (Glaser et al. 2012; White et al. 2018; Adams et al. 2018; Perz 2019). Collaboration in social-ecological systems (SES) takes place at the crossroads of ecological and social tensions. Mobilized to solve problems, it can also reinforce pre-existing conflicts or contribute to the emergence of new ones (Cinner et al. 2012; Bodin 2017; Perz 2019; Mancilla García et al. 2019). Thus, we can speak of a paradoxical collaborative turn, where collaboration is promoted as a necessity to solve problems even though some research has shown that collaboration is a complex and slow process that does not guarantee synergy (Vangen 2017). We need a better understanding of collaboration and social-ecological alignment to develop nuanced and more effective approaches to collaboration in research, governance, and management processes that concern SESs (Lemos et al. 2018; Wang et al. 2019).

The lens of SES attends to coupled social, ecological, and biophysical components and subsystems which have bidirectional linkages and interact at local and global scales (Gallopin 1991; Anderies 2002; Schoon and Van der Leeuw 2015). From this perspective, current understandings of collaboration are painfully anthropocentric. Work in social sciences and humanities that allow us to include non-humans in the social world can thus be of value to an SES approach, for example by bringing into question justice and nuanced representations of humans and non-humans (Lidskog et al. 2022). Considering relationships as well as notions of bodies and autonomy "offer[s] various entrances for rethinking, or invigorating, collaboration" in ways that include more than just humans (Neimanis 2012: 217). Haraway (2016)'s call for sympoiesis brings us to consider processes of making together with non-humans. New materialisms go beyond traditional dualisms of nature and culture to consider relational perspective such as ecology, systems, networks, meshwork, knots, and entanglements (Van der Tuin and Dolphijn 2010; Coole 2013). Actor-network theory (Latour 2005) also provides us with distinct relational tools to analyze interactions and relationships with non-humans. In this context, methods tied to social-ecological networks can serve as a bridge between the SES approach and relational social sciences that are inclusive of non-humans. Social-ecological networks draw from SES and the study of social and ecological networks (respectively developed in the social and natural sciences) to focus on the relations among and between humans and non-humans (Bodin et al. 2017).

Furthermore, science and expertise play a key role in shaping global and local responses to environmental crises through policies, funding, and programs (e.g., the Intergovernmental Panel on Climate Change (Pearce et al. 2018) and the Convention for Biodiversity (Robin 2011)). Thus, it is critical to analyze the view of scientists and to learn more about their relationships with non-humans in the context of research that informs responses to environmental crises. This paper presents an empirical case study analyzing relationships between human and non-humans in a transdisciplinary grant to conduct conservation research in two National Historic Waterways in Ontario, Canada. Mixed-method interviews were conducted with key members of this research grant. Collaboration and friction are understood as relations, among others, which can exist between and among humans and non-humans. Waterways and their surroundings are conceptualized as complex social-ecological-technical systems (McGinnis and Ostrom 2014) and analyzed in a descriptive, exploratory fashion as social-ecological networks.

The analysis uncovered a paradox in conservation research: while most of those involved in conservation research aim to improve the environmental conditions of the waterways, including the integrity of the habitat of many non-human species, the research process itself is fraught with tense relationships between humans and non-humans. Despite its aims to protect, preserve, and conserve, conservation research embodies a colonial framing and recreates power asymmetries where some humans have control over other humans, but also other species and ecosystem components. This paper presents empirical results about the types of relationships and perceptions researchers hold about the non-humans they work with. It also unpacks a paradox of conservation research, provides a non-anthropocentric understanding of collaboration and friction, and discusses conservation research as a social process whose onto-epistemology could be challenged. Future research should explore this paradox and new possible framings for conservation research in Canada and elsewhere. As environmental research and the accumulation of data has so far failed to successfully address pressing environmental crises, this research contributes knowledge about the social dynamics of transdisciplinary conservation research in the hopes of ultimately facilitating transformative change (Lidskog et al. 2022).

The case

Though we are undergoing a global loss of biodiversity, freshwater ecosystems are particularly at risk (Tickner et al. 2020). SESs allow the integration of conservation practice and research in communities, management, and governance in ways that value, conserve, and sustain the diversity of both life forms and livelihoods found in and around freshwater systems (Berkes 2021; Ortega-Rubio et al. 2021). Waterways are complex freshwater systems that often span multiple governmental jurisdictions, groups of experts, rightsholders, and stakeholders as well as species and micro-climates or ecosystems, and which face many anthropogenic stressors. The social-ecological challenges of managing such spaces in ways that align with conservation goals are evident in the case of the Rideau Canal (RC) and the Trent-Severn Waterway (TSW), two National Historic Sites located in Eastern Ontario (Canada) managed by Parks Canada (Bergman et al. 2021).

Researchers from three universities joined forces with Parks Canada and other community and government partners in a collaborative, transdisciplinary research project that crossed disciplinary and professional boundaries. Ecological, engineering, and social science research around the waterways was pursued during a 2018-2021 Strategic Partnership Grant (SPG) funded by the Natural Sciences and Engineering Research Council of Canada (NSERC). The NSERC SPG investigated the ecological integrity of the RC and the TSW as applied conservation research, which is defined as research aiming to generate knowledge accessible to end users (e.g., communities and governments) in order “to inform the conservation of biodiversity and sustainable management of natural resources” (Cooke 2019: 15).

As part of the team of social scientists conducting conservation social science research in the waterways (Bennett et al. 2017), I saw an opportunity to better understand relationships between and among the humans and non-humans involved in conservation research. The scope of this paper is thus an analysis of collaborative and frictional relationships across actors involved in the case of this NSERC SPG.

Methodology

Methodological framework

This exploratory paper reports on empirical research conducted to answer the question: *How do people interact with non-humans in transdisciplinary conservation research?* My methodology is informed by (1) SES (McGinnis and Ostrom 2014), (2) social networks (Scott and Carrington 2011; especially the use of social networks to study collaboration for example Cross et al. 2002; Dall'Asta et al. 2012; Calliari et al. 2019), (3) social-ecological networks (Bodin 2017), and (4) the inclusion of non-humans as actors of research (Latour 2005; Jepson et al. 2011) and potential collaborators (Jevbrat 2009; Ambayec et al. 2021). I take a case study approach and mobilize mixed methods that combines qualitative analysis with social-ecological network analysis to analyze different types of relationships between humans and non-humans. Mobilizing conversations and people's stories, as well as my own lived experiences in the waterways and the grant allows me to overcome the limits of quantification and to present a nuanced, relational analysis.

Network questions were the same across humans and non-humans in the network data collection tool to integrate social, ecological, and technical nodes in the same network level. This is distinct from how social-ecological networks are often used. Social-ecological networks either attend to complex environmental governance contexts without including ecological nodes (e.g., Marín and Berkes 2010; Stein et al. 2011; Parsram and McConney 2011; Bodin et al. 2006) or include distinct sets of ecological and social nodes as separate network levels that are connected through social-ecological ties (e.g., Bodin and Prell 2011; Rathwell and Peterson 2012; Sayles and Baggio 2017). The exploratory method featured in this paper aims to be more integrative and conceptualizes all actors as operating in unified processes rather than distinct networks.

Research design and sampling

Ethics approval was obtained from the Research Ethics Board at the University of Ottawa (S-09-20-5812). Qualitative and network data were collected through mixed methods interviews that first included open-ended question followed by a network data collection tool. Written consent was obtained by email prior to the interview, and verbally confirmed at the start of the interview conducted through video calls due to the COVID-19 pandemic. The waterways defined the geographical boundary of the network and the NSERC SPG served as a contextual boundary for the network (i.e., participants were asked to report their interactions and relationships with non-humans in the waterways as part of the NSERC SPG). The networks represent the views of participants on their relationship with non-humans. The scope of the data is thus a partially articulated social-ecological network (Rathwell and Peterson 2012; Sayles et al. 2019). It is restricted to outgoing relationships identified by participants, and relationships between non-humans (ecological, technical, and ecological-technical ties) were not collected nor included.

Sampling was conducted using public information found through online searches about professors, students, government partners, and community partners participating in the grant, and snowball sampling to include other relevant grant members that may not have been publicly named. Results in this paper are not generalizable. The interviews were conducted and audio-recorded between February and April 2021 with 26 key members of this research grant. Given my role in this research, I was one of the 26 participants, and answered all qualitative and network questions. Randomly generated pseudonyms are used in this article.

Qualitative analysis

Research demographics were collected during the interviews: occupation, affiliation, area of work/expertise, time spent working in the waterways, time spent working in the grant, role in the grant, and involvement in stages of the grant. This paper analyses three questions raised during the interviews: (1) “Did you interact with other species, such as fish, plants, turtles, etc. or the environment as part of your work in the grant? What was exchanged in your interactions with non-humans?”, (2) “In your opinion, could we consider non-humans as collaborators?”, and (3) “What is the value of lived experiences in the waterway (fieldwork or field visits) for your work in the grant?”. Interviews also included questions on human collaborations in the grant that are beyond the scope of this paper. Note-taking of each response and transcription of key elements was conducted by listening to the recordings. Inductive, thematic coding of this material in MS Excel identified emerging themes as well as convergences and divergences in views.

Quantitative analysis

Data about different types of relationships between humans and between humans and non-humans was collected through a network data collection tool hosted on SurveyMonkey. Participants were presented with a list of human nodes: key members of the grant (adapted from the participant list) and were given the opportunity to add up to 5 other people. To create non-human nodes, participants were asked to free list up to five species or elements for each of the following categories, with an option to include five additional species or elements at the end: fish, turtles, vegetation, insects and/or microorganisms, other living creatures, abiotic elements, infrastructure, and technologies. Research participants could skip any category with which they had no interactions. Questions asked about each node can be found in Appendix 8. The tool was designed to gather people's perspectives and participants were thus invited to select the type of relationship which most accurately described their experience of the relationship – as discussed in the open questions of the interview – rather than matching fix criteria for each type of relationship.

The data was extracted from SurveyMonkey into MS Excel, which was used to clean the data and generate edge lists of ties and their attributes: the frequency of interaction, the type of tie (social, social-ecological, social-technical), and the various relationships (Appendix 9). A node list (Appendix 9) was also created with attributes including node category (biologist, engineer, fish, etc.) and type of node (social, ecological, technical). This social-ecological network analysis focused on relationships between humans and non-humans thus humans that were not interviewed were excluded. The types of relationships (see Appendix 9) were recoded considering discussions during the interviews to generate 5 distinct relationship networks (see results). The data was imported into Rstudio version 1.4.1103, an integrated development environment for the programming language R (R Core Team 2017), to generate network statistics and to create network graphs using the packages 'sna' (Butts 2019) and 'igraph' (Csardi and Nepusz 2006).

Results

Participants

The 26 research participants were key members of the grant (Table 2.1), including senior (professors) and junior (graduate students) academics, research professionals (lab managers, postdoctoral fellows) as well as government and community partners.

Status in the NSERC SPG	*Number of participants*
Senior academic	7
Research professionals	2
Junior academics	9
Government partners	3
Community partners	4
Community partner with academic affiliation	1

Table 2.1. Number of participants, status in the NSERC SPG

Most participants were from two Ontario universities local to the waterways (respectively 11 and 7), with 2 affiliated to a Quebec university (some participants had two affiliations). There were 14 biologists with expertise in aquatic ecology, genetic ecology, fish biology, limnology, or conservation decision, 2 river engineers, and 3 social scientists with expertise in governance. One government participant was an ecosystem specialist affiliated to Parks Canada. Representatives of the two local Conservation Authorities, an aquatic biologist and a watershed planner, also participated. 3 community participants were associated with a group working to conserve muskellunge (Muskies Canada) with one also holding an academic affiliation, and 2 were representatives of different lake associations. Half of participants (13 – mostly junior academics) had only been involved with the waterways since the beginning of the grant (2018 or later), but others had been involved for at least 10 years (5, mostly government and community partners) or over 20 years (6, mostly community partners and senior academics). Most participants worked only on the RC (20).

Overview of relationships with non-humans

In the qualitative part of the interview, most senior academics and government partners reported having few interactions with non-humans as part of their conservation research and work due to necessary office work (e.g., writing grant proposals and papers, supervising students or staff, performing administrative tasks). Junior academics and community members reported having the most interactions with non-humans. Conversations about non-humans included “not just species, it’s also water and the land” (Emily).

In social networks, nodes represent people, concepts, organisations, or ecological elements while ties represent the relationships between those nodes. 26 humans, the participants, were included as nodes and they mentioned having ties to 99 distinct ecological nodes (defined as species and abiotic elements in the environment) and 67 technical nodes (defined as human-made infrastructure and technology), for a total of 192 human and non-human nodes (Table 2.2, Appendix 9). Biologists and ecologists were most represented among humans. Fish, vegetation, insects, and other living creatures were most represented among ecological nodes, and field technology was most represented among technical nodes.

Type	*Category*	*Examples*	*Nodes*		*Incoming ties*	
Human nodes	Biologists and ecologists	Academics, junior academics, government partners	15	7,8%	212	28%
	Social scientists	Academics, junior academics	3	1,6%	28	3,7%
	Engineers	Academics, junior academics	2	1,0%	62	8,2%
	Watershed planner	Government partner	1	0,5%	12	1,6%
	Muskies Canada	Community partner	3	1,6%	14	1,9%
	Lake association	Community partner	2	1,0%	17	2,2%
Ecological nodes	Fish	Largemouth bass, smallmouth bass, northern pike, muskellunge	13	6,8%	64	8,5%
	Turtles	Snapping turtles, painted turtles	6	3,1%	23	3,0%
	Vegetation	Eurasian watermilfoil, pondweed, lily pads, aquatic vegetation	16	8,3%	43	5,7%
	Algae	Algae (not specified), blue-green algae	7	3,6%	20	2,6%
	Insects	Mosquito, black fly, caddisfly, dragonfly	15	7,8%	28	3,7%
	Microorganisms	Zooplankton, benthic invertebrates	2	1,0%	6	0,8%
	Birds	Loon, osprey, other waterfowls	14	7,3%	20	2,6%
	Other living creatures	Zebra mussels, mammals (muskrat, otter), water snakes	16	8,3%	27	3,6%
	Abiotic elements	Water, water quality, sediments, nutrients, microplastics	10	5,2%	31	4,1%
Technical nodes	Infrastructure	Lock stations, dams, bridges	11	5,7%	39	5,2%
	Field technology	Boats, nets, fishing rods, sonar, YSI probes	37	19,3%	70	9,3%
	Computer technology	R programming language, ArcGIS, Nvivo	12	6,3%	15	2,0%
	Lab technology	Lab consumables, microscope, DNA sequencer	7	3,6%	25	3,3%

Table 2.2. Type and categories of nodes in the full network with examples and counts of nodes and incoming ties (the number of participants who mentioned having a relationship with nodes from each category).

The full network representing all ties between human and non-human nodes in the grant, as perceived by participants, was composed of 756 relationships (Figure 2.1, Appendix 9). These were classified as social (social-to-social node), social-ecological (social-to-ecological node) and social-technical (social-to- technical node) relationships. Nearly half of relationships were among humans participating in the grant (45.6%, 345), followed closely by social-ecological relationships (34.7%, 262) while social-technical relationships account for only 19.7% (149) of the network. Social nodes and ties are in the center of the network as we could obtain mutual ties between participants. Ecological and technical nodes closest to the center were most frequently mentioned, while those on the outer edges of the network graph were only mentioned by one participant.

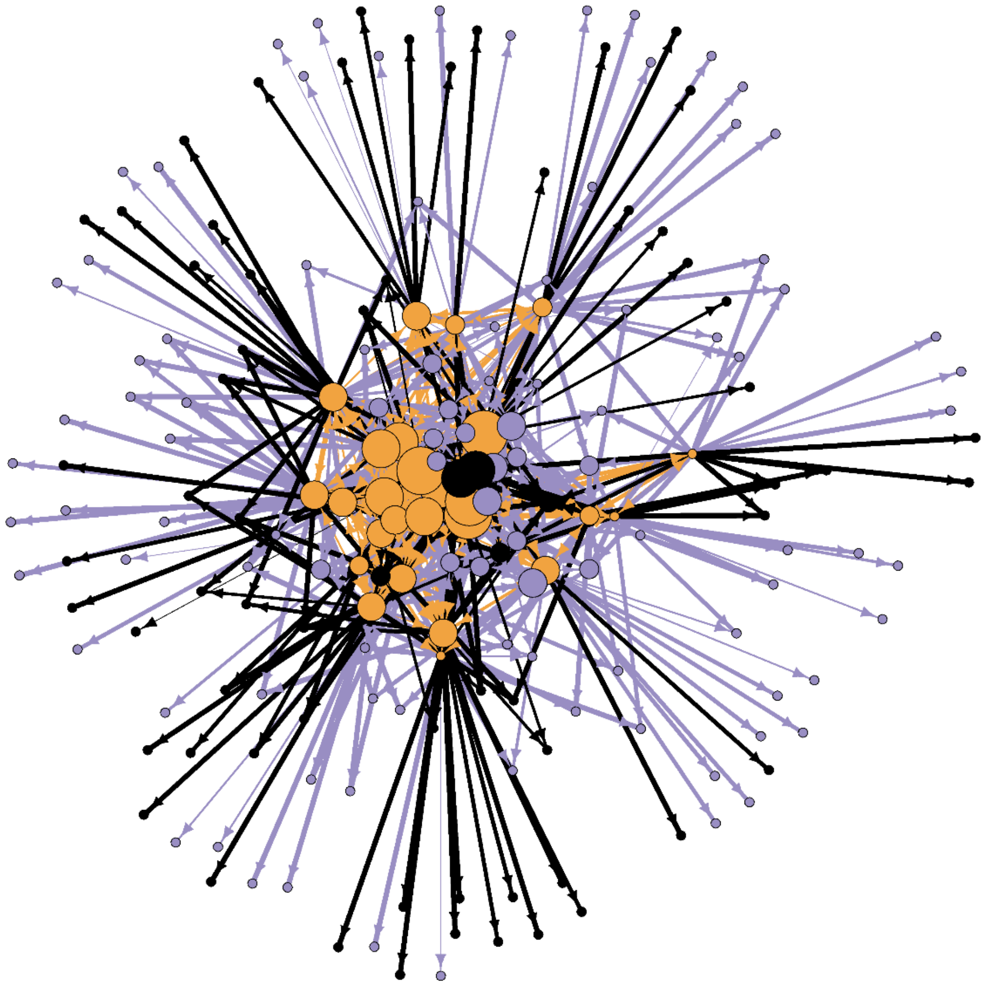

Figure 2.1. Full network graph with social (orange), social-ecological (purple), and social-technical (black) ties. Node size represents a scale based on in-degree centrality (number of participants who reported having a relationship to the given node). Tie width represents the frequency at which participants reported interacting with a given nodes. Arrows indicate the direction of the relationships.

Reduced network graphs were produced (Figure 2.2) by merging nodes per category (Table 2.2) and combining edges between nodes of the same categories. We see that the most frequent relationships in the NSERC grant were between biologists and fish, field technologies, and other biologists. Some non-humans were interacted with by many participants (fish, algae, insects, other living creatures, vegetation, infrastructure), while others were interacted with by fewer participants (microorganisms, lab technologies, birds).

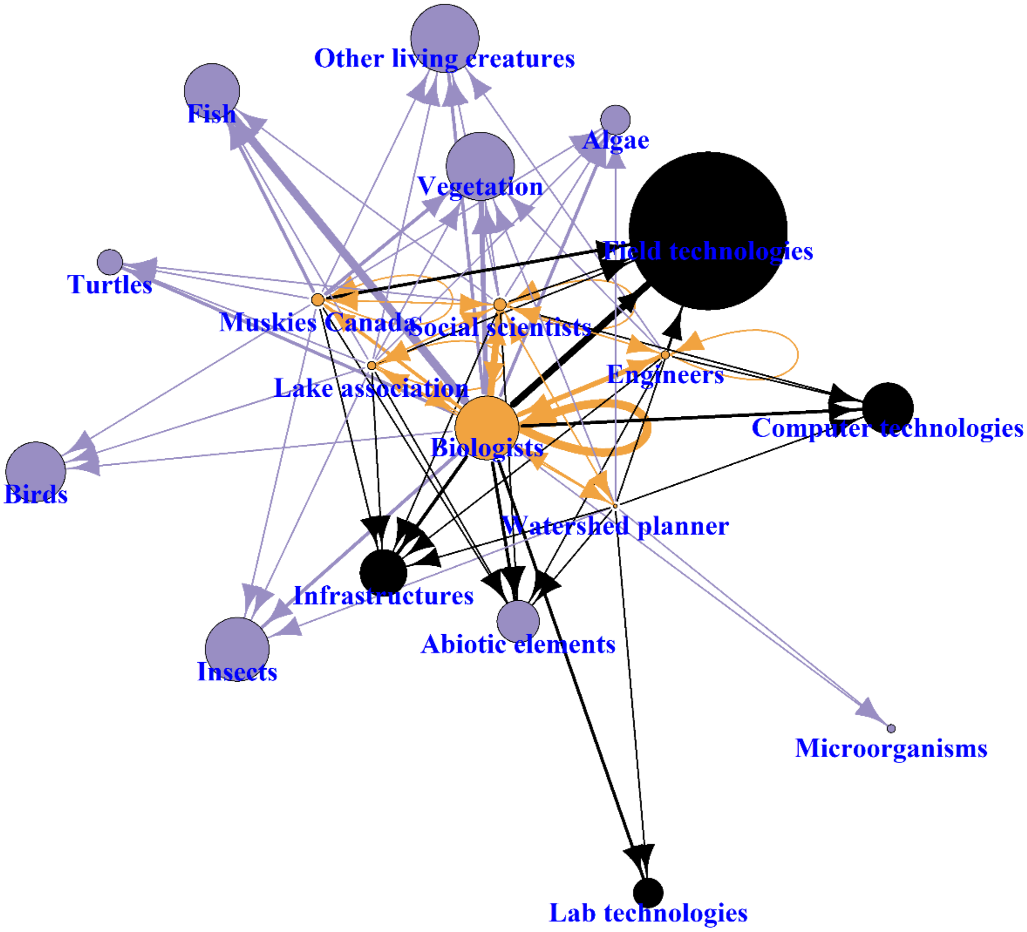

Figure 2.2. Reduced network graph of the full network representing social (orange), social-ecological (purple), and social-technical (black) relationships and nodes. Node size represents the number of nodes per category in the full network. Tie width represents a scale based on the total number of ties between each node categories in the full network. Arrows indicate the direction of the relationships. The meaning of colors, arrow, node size, and tie width are the same for figures 2.2 through 2.7, with equivalent data (total number of nodes and ties) for each network.

Five relationship networks were created based on the type of relationships reported by participants. These include (1) collaborative relationships, (2) relationships anchored in communication, monitoring, and supervision, (3) relationships anchored in data collection and analysis, (4) random and incidental encounters, and (5) frictional relationships anchored in tension or conflict (Table 2.3).

Network measure	*Full network*	*Collaboration network*	*Communication network*	*Data network*	*Random network*	*Friction network*
Network size	192	53	83	121	105	83
Human nodes	26	26	26	26	26	19
Ecological nodes	99	20	42	43	64	42
Technical nodes	67	7	15	52	15	22
Number of ties	756	253	278	278	222	107
Social ties	345	220	191	96	65	2
Social-ecological ties	262	25	70	87	112	79
Social-technical ties	149	8	17	95	45	26
Density	0,02	0,09	0,04	0,02	0,02	0,02
Edgewise reciprocity	0,39	0,58	0,36	0,11	0,06	0
In degree centralization	0,11	0,28	0,21	0,08	0,09	0,07
Out degree centralization	0,25	0,34	0,29	0,23	0,25	0,21
Weak components	1	1	1	1	1	2
Strong components	167	28	58	99	96	83

Table 2.3. Network measures for different relationship networks.

A basic comparison of network measures reveals that collaboration and communication networks were the densest and mostly featured social ties among participants (respectively 87% and 68.7%). While ecological nodes and ties were included in collaboration (37.7% nodes and 9.9% ties) and communication networks (50.6% nodes and 25.2% ties), very few technical nodes and social-technical ties were included (collaboration: 13.2% nodes and 3.2% ties; communication: 18.1% nodes and 6.1% ties). These networks also featured the highest in degree and out degree centralization scores, a network measure based respectively on the number of incoming and outgoing ties of each node, and the lowest number of strong components, showing these were the most mutually connected networks. This reflects sampling and data collection strategies which resulted in a partially articulated network with ties coming from participants toward other nodes only, not including ties between ecological and technical nodes. The data collection and analysis network featured the highest number of technical nodes (43%) and similar quantities of social (34.5%), social-ecological (31.3%), and social-technical ties (34.2%). The random and incidental encounters network mostly featured ecological nodes (61%) and social-ecological ties (50.5%). The frictional network featured very few social ties (1,9%), some social-technical ties (24.3%) but revealed that tension and conflict was mostly reported in interactions with ecological nodes (73.8%). This was also the only network to feature 2 weak components (i.e., 2 disconnected clusters of nodes). Table 2.4 reports the most interacted with non-human categories in each relationship network.

Collaboration network	*Communication network*	*Data network*	*Random network*	*Friction network*
-Fish (6) -Vegetation (5) -Algae (5) -Abiotic elements (4) -Infrastructure (3) -Field tech. (3)	-Fish (24) -Abiotic elements (13) -Vegetation (12) -Field tech. (10) -Insects (9) -Infrastructure (5) -Algae (5) -Turtles (4)	-Field tech. (47) -Fish (38) -Computer tech. (24) -Abiotic elements (16) -Lab tech. (15) -Infrastructure (9) -Algae (8) -Insects (7) -Vegetation (7) -Turtles (7)	-Infrastructure (30) -Fish (29) -Vegetation (20) -Birds (17) -Other living creatures (17) -Field tech. (15) -Turtles (11) -Insects (6) -Abiotic elements (6)	-Vegetation (16) -Insects (14) -Fish (13) -Field tech. (11) -Abiotic elements (10) -Algae (9) -Other living creatures (9)

Table 2.4. Most interacted with non-human node categories in the different networks, based on the number of incoming ties.

Collaborative relationships

The collaboration network (Figure 2.3) mostly featured relationships among humans, and only 10 participants reported having collaborative relationships with non-humans: 2 community partners, 1 government partner, and 7 academics. Some academics reported collaborative relationships with their target species (e.g., fish like largemouth bass and smallmouth bass) because of benefits for the species as foreseen outcomes of the research. For others, it was out of passion and desire to learn more about certain non-humans like algae. Water was the main abiotic element in the collaborative network, and it was seen as supporting the research but also the entire ecosystem and providing a space to connect with nature through activities like swimming and boating. One of the biologists playfully characterized all his relationships with ecological nodes as collaborative, echoing thoughts of another biologist who said that people sometimes thank turtles in conference presentations but not in a serious fashion. Some technical nodes were also included in the collaboration network, such as lock stations, bridges and boats which provide access to the waters.

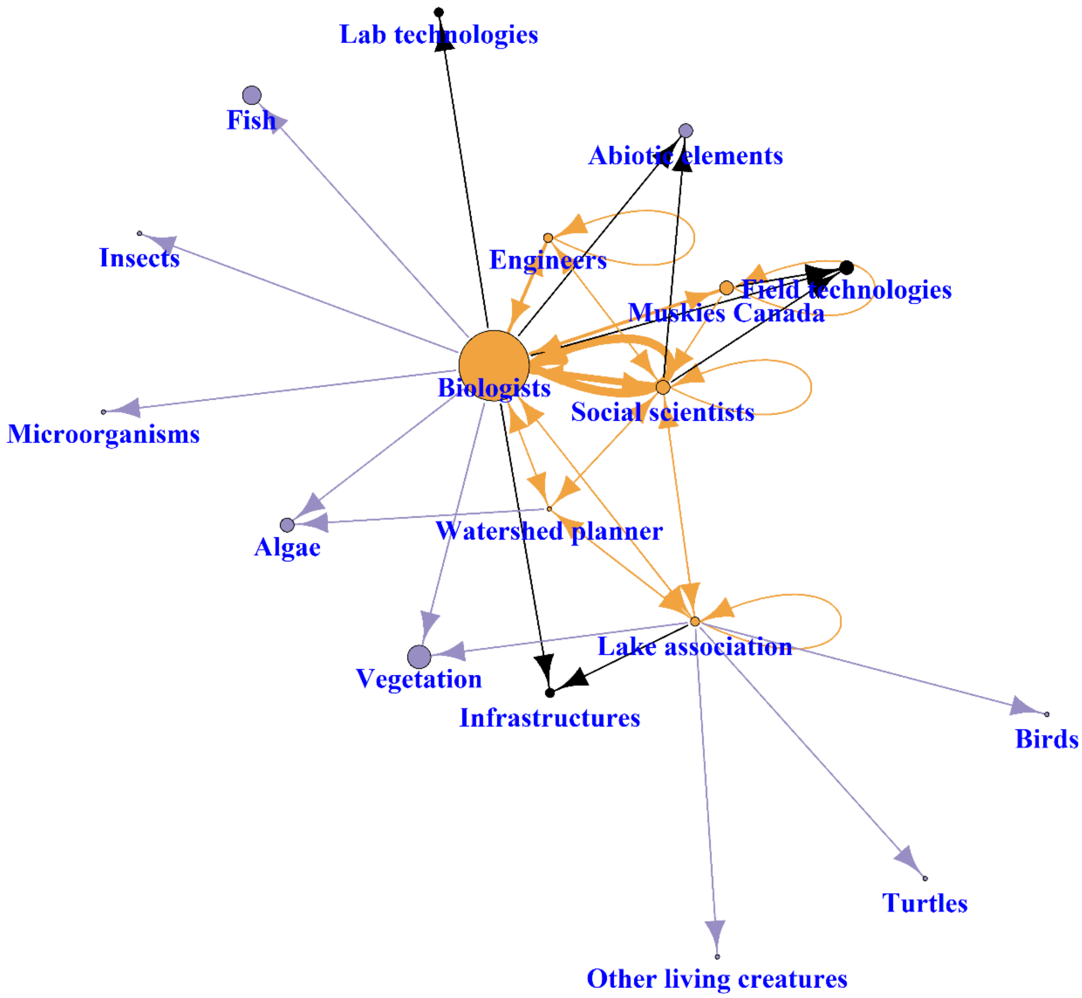

Figure 2.3. Collaborative network graph. Refer to Figure 2.2 legend (page 82).

When prompted, many (12) thought non-humans could not be considered collaborators. For many academics, non-humans were simply considered as objects of study. An engineer also spoke of agency: “It raises questions of what does it mean to be an active agent? You need agency to be an active collaborator. I’d like it if water could be a collaborator but I’m not sure” (Jake). A biologist also highlighted the lack of ability of non-humans to consent as collaborators in the research, and the fact that “it’s very human centric and arrogant to think it’s going to care [about my research]” (Andy). In fact, “They’re more victims than collaborators. They don’t have a voice. They can’t participate or modify the behaviors of human beings” (Ray). 11 participants recognized the need for more explicit acknowledgement of the role of non-humans in conservation work.

Conversely, 8 shared views that non-humans could be, or already were in their own way, collaborators of conservation work. Community partners (3) mentioned collaborative relationships with non-humans, for example through supportive action such as installing turtle nest protectors or during underwater photography sessions. Fish were also seen as “forced collaborators” in research that requires angling. One of the biologists believed that “the work itself doesn’t succeed in answering their questions if the species aren’t also able to play a part in that. I think that is a willingness to participate, an ability for them to answer these questions and provide insights even if we aren’t able to understand the answers right now” (Britney). She recognized that non-humans are not explicitly acknowledged by everyone who does conservation work, but that they play a key role in providing us with information and connecting people. However, consideration of non-humans as collaborators needs to be framed carefully: “As scientists, we have to try and not anthropomorphize the fish” (Maggie). For two social scientists, explicitly including non-humans in research was about challenging anthropocentrism and normative ways of thinking about non-humans as objects in western society and science. Including non-humans as collaborators was also seen as reflexive strategy to consider potential benefits and harms of the research for other species.

We can “recognize that even though in science these are the subjects or species that we use for experiments, they’re actually teachers and we’re learning from them, and collaborating with them, and we should have an equal relationship” (Emily). In fact, many (9) characterized their interactions with other species as learning experiences: “I see it as an honor. To me, we get to do these things, the animals themselves get to teach us about where they live, about their environment, about their situation, are they big enough, are they eating enough” (Britney). One participant thought reframing the role of non-humans as research collaborators could dissipate tension and establish bridges between different ways of knowing (i.e., natural sciences and Indigenous knowledges). But overall, less than half of participants considered that we could include non-humans as collaborators in conservation research.

Communication, monitoring, and supervision network

The communication, monitoring, and supervision network (Figure 2.4) was mostly composed of social ties, but 18 participants reported this type of relationship with non-humans: 3 community partners, 3 government partners and 12 academics. Communication and monitoring relationships with non-humans were often seen as one-way interactions with species (fish like muskellunge, northern pike, walleye, and bass; turtles like painted turtles and snapping turtles; aquatic vegetation like Eurasian watermilfoil; blue-green algae; benthic invertebrates) monitored by academics, government, and community members. Some of these are considered indicators of ecosystem health (e.g., benthic invertebrates) or habitat (e.g., aquatic vegetation as fish habitat). Abiotic elements such as water quality, nutrients, and sediments were also monitored by lake associations, the watershed planner, and some biologists. Telemetry research was mentioned as two-way communication with fish, as information is sent throughout the field season from tags inside fish to receptors in the waterway. Some infrastructure (locks and dams) as well as field technologies (water level gauges, remote control boat, and underwater cameras) were also included in this network, serving as intermediates between humans and the environment.

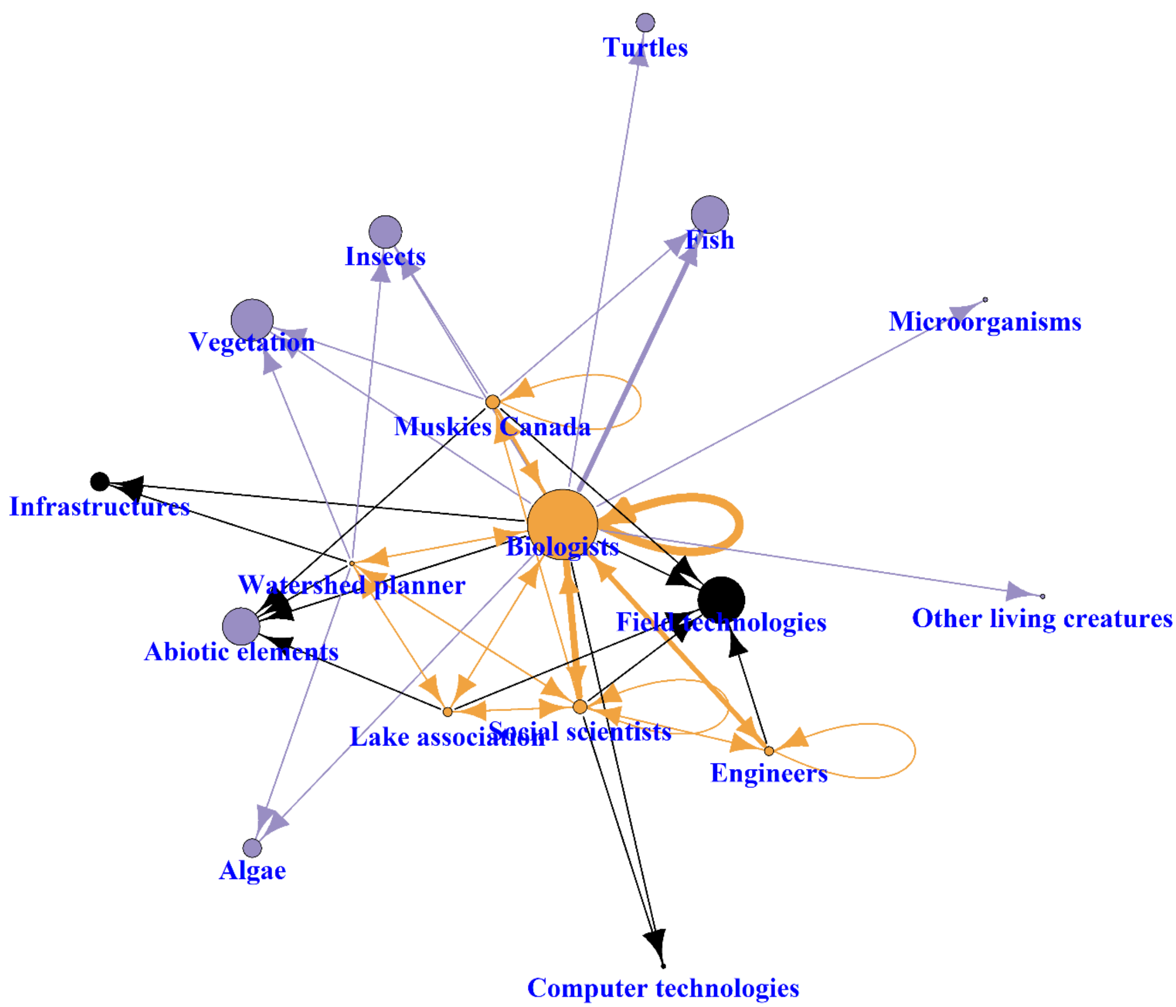

Figure 2.4. Communication, monitoring, and supervision network graph. Refer to Figure 2.2 legend (page 82).

Data collection and analysis

23 participants had interactions with non-humans anchored in data collection and analysis (Figure 2.5). The purpose of these interactions was to collect samples, measurements, telemetry data, and/or qualitative data to be processed through laboratory procedures, statistics, and modelling, among others. Most relationships in this network were reported by academics and members of Muskies Canada who

supported data collection in the context of the grant, and occurred with species targeted by research (e.g., fish, turtles, insects, microorganisms, vegetation, algae, or zebra mussels). Field, laboratory, and computer technologies all played a significant role in this network – with a high level of variation in field technologies (boats, nets, sonar, YSI probes, fishing rods, acoustic tags, canoes, among others). Only 7 members of the research team used lab technologies for their work (microscopes, lab consumables, DNA sequencer). Common computer technologies for data analysis included the R programming language, GIS software, and Nvivo.

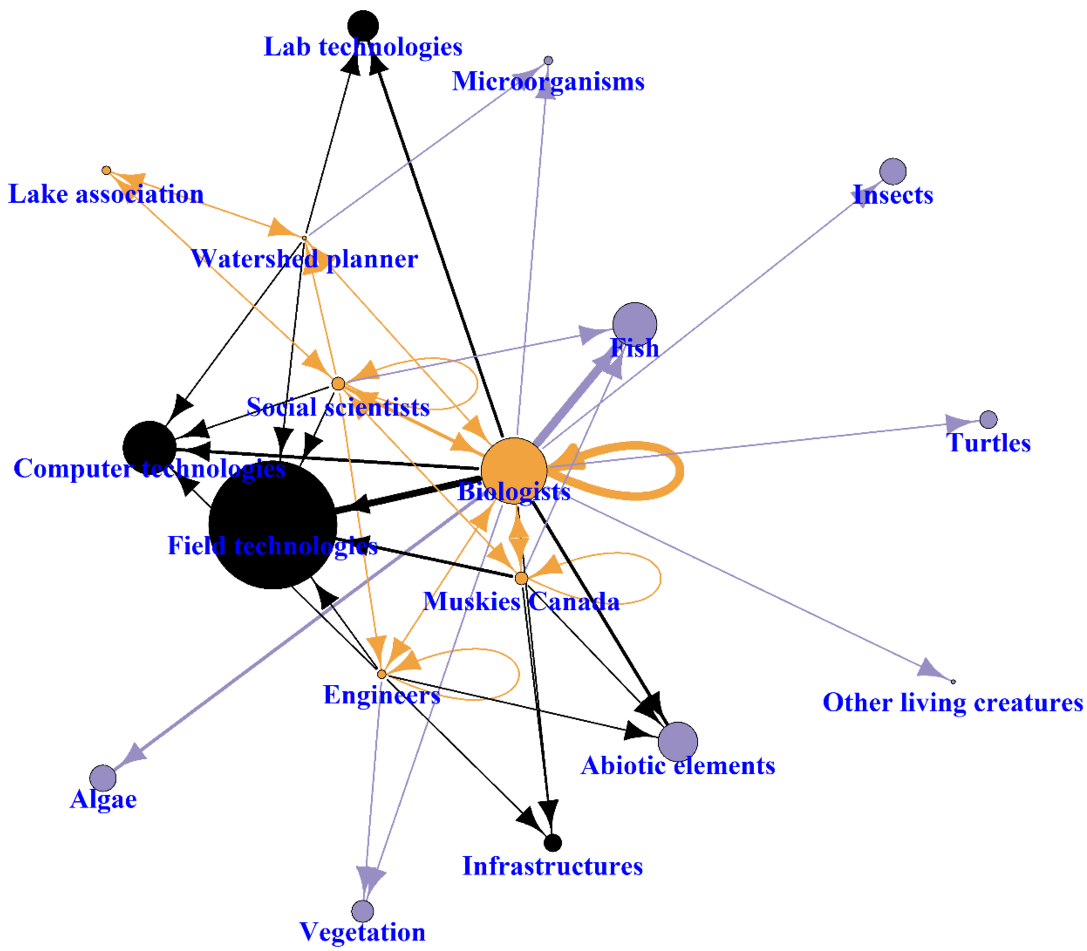

Figure 2.5. Data collection and analysis network graph. Refer to Figure 2.2 legend (page 82).

Random and incidental encounters

Most (24) participants reported having random or incidental encounters (Figure 2.6) with a wide range of species by simply spending time in the field as part of their work in the NSERC SPG; with only two of the senior academics not reporting these interactions. This occurred often with infrastructure (locks, dams, and bridges), as well as boats and water. Many random encounters with fish were attributed to bycatch. Aquatic vegetation, birds (osprey, waterfowls, bald eagles), other living creatures (water snakes, coyote, muskrat), and insects (mosquitoes, dragonflies) were also encountered incidentally when spending time on the waters and shorelines.

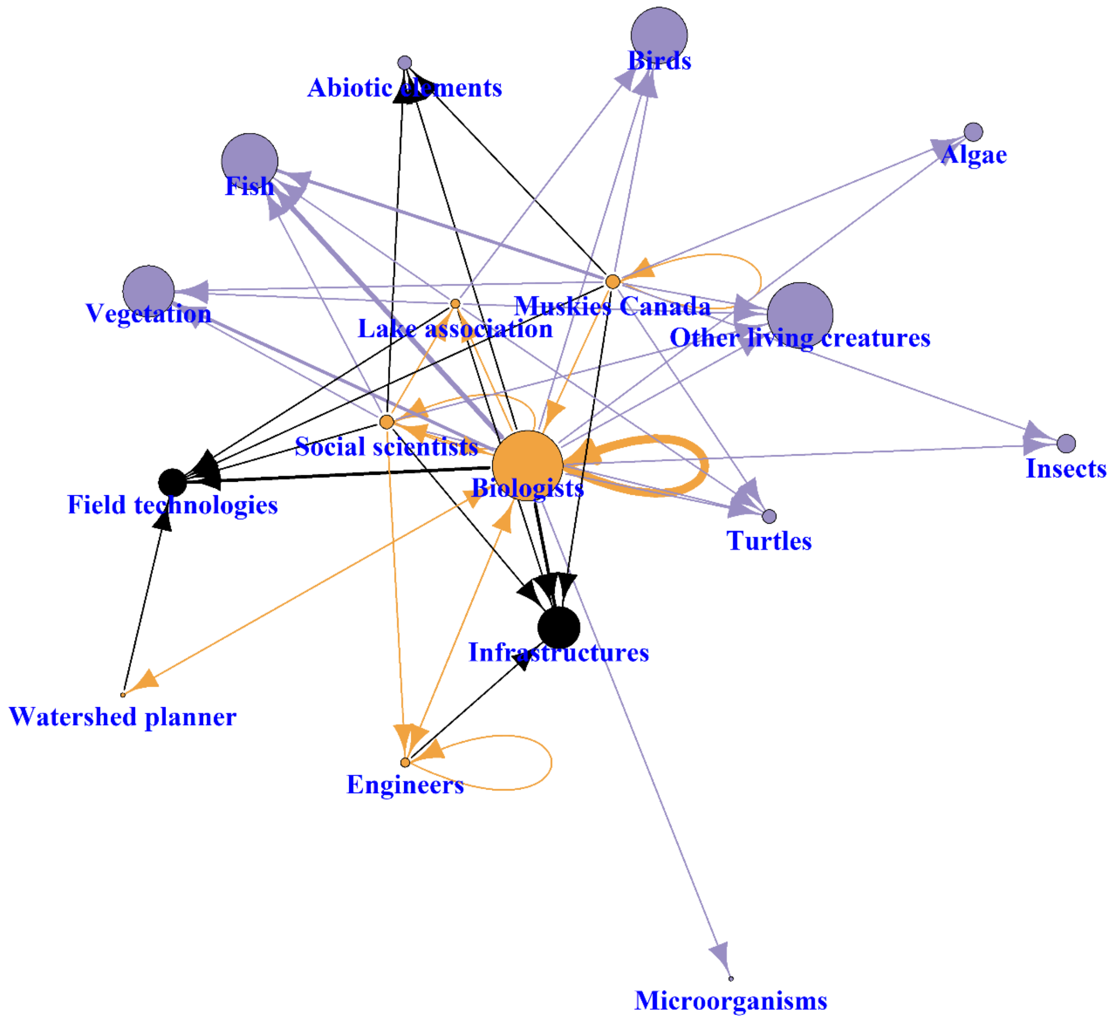

Figure 2.6. Random and incidental encounters network graph. Refer to Figure 2.2 legend (page 82).

Frictional relationships (tension and conflict)

Unlike the other networks, the friction network (Figure 2.7) featured very few social ties. In fact, only 2 of these were reported among participants, representing tensions between academics and one of the government partners due to bureaucratic challenges. Beyond social ties, 17 participants (all 5 community partners, 1 government representative, and 11 academics) reported having tense or conflictual relationships with non-humans. Some felt tension with different types of aquatic vegetation that would get in the way of their boats, nets, or fishing rods during fieldwork. Insects like mosquitoes, black and deer flies, and ticks also caused a nuisance and were included in this network. There was also tension felt during interactions with various technologies, such as infrastructure encountered during fieldwork, field and lab technologies that could malfunction, and data analysis software like the R programming language.

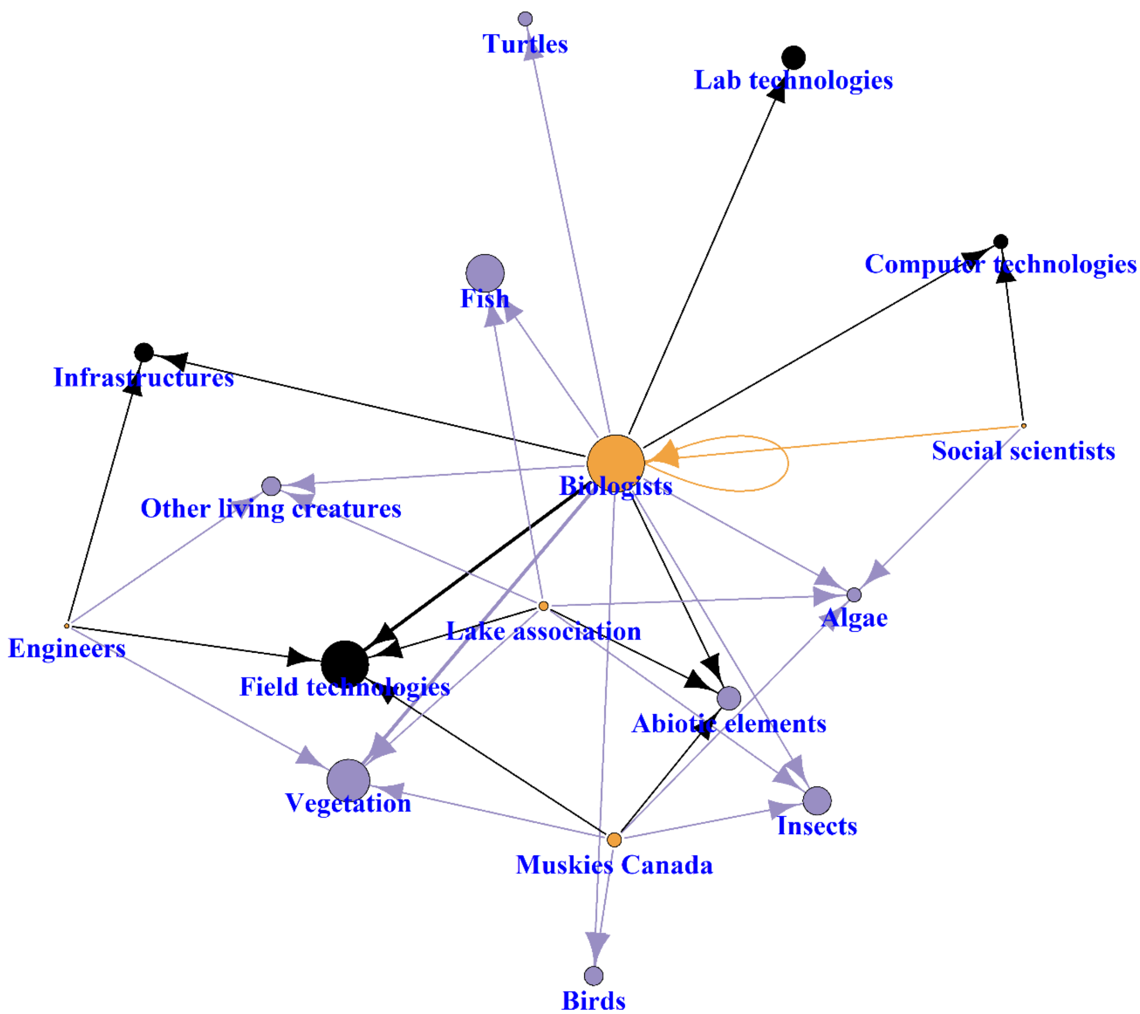

Figure 2.7. Frictional network (tension and conflict) graph. Refer to Figure 2.2 legend (page 82).

6 participants reported having negative emotions tied to their interactions with non-humans in the field. These were linked to the manipulation of fish and turtles that could be harmful (e.g., surgery to insert acoustic tags or collection of tissue samples), results indicating poor environmental conditions (e.g., poor water quality due to high numbers of algae, nutrients, sediments, or microplastics), or tensions tied to the presence of invasive species (Eurasian watermilfoil, round goby, zebra mussels). In fact, one of the projects had the goal of finding the most efficient way to control the presence of (i.e., destroy) invasive Eurasian watermilfoil. Some participants (6) went as far as to describe their interactions as causing damage or pain to other species, identifying non-humans included in the

research as victims of conservation work who are sacrificed: "Everything that I do for sure requires that sacrifice. So, in many ways they can be unsung heroes of research in that their death allows us to better understand the ecosystem" (Blake). Vegetation and microorganisms (zooplankton, benthic invertebrates, algae) were usually killed in laboratory or field procedures. Fish and turtle mortality were generally rare and accidental, yet manipulations could be harmful even with specimens being subsequently released.

This points to a paradox in conservation research, which was highlighted by many academics (9): while the interactions stemming from conservation research may be harmful to some non-humans, they are seen as necessary to derive benefits for the broader population and ecosystems. As one of the biologists reported:

> "I cannot catch a fish without causing stress, I cannot catch a fish without causing injury. So that individual is not better off for its interaction with me. That's something that I know and understand and accept as a researcher. There's always a bit of an imbalance that one can't take away. [… W]e might benefit that whole population including that individual. Or not. Maybe what we learn in a given lake won't actually be applied in that lake. It'll be applied in a different lake. And then the question is, is that of any material benefit to the bass that we interacted with initially?" (Matt)

There is thus a disconnect in affect and tone between the reality of fieldwork and intended outcomes of conservation research. Conservation research is perceived as providing long-term mutual benefits for humans (e.g., publications, improved conservation practices) and other species (e.g., improved habitat, less harmful interactions), even if immediate interactions are often tense. In fact, many (8) also spoke of harm minimization and consideration for the welfare of animals. Others (6) had interactions with the environment and non-humans that did not involve harm to individuals but had the explicit intention of conserving species, such as creating new habitat for fish spawning or loon nesting, protecting turtle nests, and monitoring. Those partaking in these actions were community partners and Conservation Authorities representatives rather than academics, pointing to the fact that conservation research embodies this paradox in a stronger way than other types of conservation work.

Ethics and other ways of knowing

In the qualitative questions, participants (9) reported experiencing positive emotions while interacting with non-humans in the field (e.g., excitement at the opportunity to interact with other species, enjoyment while collecting water samples, appreciation of random encounters). Some spoke about being involved in conservation due to feeling connected to nature and non-humans: "That's the reason I became a biologist, because I feel a commonality and kinship with all living things" (Andy). The need to value non-humans and consider them as kin rather than research objects was recognized by a minority, but more (7) brought up questions of ethics and respect. While ethics board ensure some harm minimization for animals, these requirements do not apply to all forms of life nor to abiotic elements involved in conservation work (e.g., plants, zooplanktons, algae, water). Thus, ethical responsibility falls on researchers to question the validity of their own work (e.g., are the costs worth the potential benefits).

This is tied to irreducible power dynamics between humans and non-humans in conservation work, as “nature doesn’t inherently love or hate science, but it wants to exist” (Andy). A sociologist also shared that humans, and specifically western societies, often attempt to bend nature to their needs rather than adapt to nature, which generates misalignment and “a general failure of society to organize itself in a way that is more consistent with natural systems” (Brad). This misalignment and other anthropogenic pressures generate tensions within human-environment relationships, causing nature – recognized as having agency – to respond with uncertainty, unpredictability, and crankiness.

Furthermore, a fifth of participants brought up tensions between western science and other ways of knowing (5), and the value of Indigenous knowledge for conservation work (4). In fact, natural science was described by one biologist as having traditions that are biased, classist, elitist, and colonial despite the common perception of scientific work as objective and unbiased that was shared by other participants. These traditions were seen as explaining why “I don’t think it [including non-humans as a collaborator in research] would be very widely accepted today, especially in the scientific community” (Blake). One government partner also mentioned learning more about Indigenous knowledge in recent years. She acknowledged that this work is slow, but it shows that different ways of knowing are increasingly being considered in conservation research and practice, both in academic and governmental institutions. One of the social scientists also emphasized the potential of Indigenous knowledge to be a starting point for considering other species in as research collaborators:

> What I’m hearing from Indigenous people and what they see as a relationship with the land is learning from it and observing it. And it’s something that we do in science, it’s just a different approach or framing. Natural science looks at the species in a very scientific methods way, so those steps are very intentional, each has a purpose, and it’s very technical. But in a different way of thinking, for example the Indigenous way of thinking, it’s based on just learning and making space for that connection and relationship to happen. (Emily)

Discussion

A paradox of conservation research

My results show that there is a paradox at the core of conservation research and practice: despite its intentions to protect and conserve, conservation research is fraught with tension, conflict, and sometimes violence that is not explicitly acknowledged and that is justified by the fact that the work is done with the intent to benefit other species and the environment. There is a disconnect between perceptions of doing good for the environment by putting in practice the foreseen outcomes of the research, and the violent reality which makes these outcomes possible. It also seems that this work generally benefits humans (e.g., collection of data, enjoyment of nature, training, obtaining a degree, publications), but not always non-humans (e.g., changes may not be brought to the area where conservation research took place, or data may not be useful in practice). Furthermore, the harm and sacrifices that are part of the work are not often explicitly acknowledged, and many conservation researchers viewed non-humans as simple objects of research. Yet, the network analysis revealed that relationships and interactions with non-humans are much more complex.

Building on actor-network theory, Cypher (2017) recognizes that anything that makes a difference in a system can be considered as a mediator, active participant, or actor of a process which enables outcomes to be produced (Latour 2005). Some collaborators, such as government funding, studios, pens, visual diaries, and computers, "have no idea we are connected, and yet they act on me here and now in the studio." (Cypher 2017: 124) This approach makes visible the diverse networks of influence that go into art or scientific production, both of which entail crafty practices whose outcomes would not be possible without direct and indirect interactions with non-humans (Beaudoin 2018). Indeed, we must follow the non-humans in our networks, adjust to their speed, attend to known frictions, and bend to their unexpected caprice (Cypher 2017). By understanding conservation research as a social process unfolding in social-ecological-technical networks, we can recognize that scientific publications, conference presentations, and policy recommendations are only made possible through interactions with non-human species, forms, materials, and technologies. We must work with the fish and turtles that present themselves in nets or at the end of fishing lines on a given day and adjust to technical difficulties. It is the very presence, absence, and actions of non-humans which enables conservation work: it creates the conditions of possibility for researchers and practitioners to explore, sample, probe, monitor, regulate, reflect, connect, write, act, protect, preserve, conserve.

Herein lies a paradox of conservation work. While conservation practices rely on the presence of non-humans, and while the work is conducted with the best of intention (e.g., to protect and conserve), conservation networks reproduce asymmetries and embody a frictional co-existence. This includes acts of violence and sacrifice, with non-humans generally left behind in the field rather than being fully acknowledged as actors of the research process. This paradox is most visible in the frictional relationships between non-humans and junior academics who conduct most of the fieldwork. Paradoxically, these frictions do not always benefit the environment – and seldom benefit the individual non-humans encountered in the field – but junior academics reported that spending in the field was an honor, that it was pleasurable, that it strengthened their connections to nature, and that it was helpful for their research. This paradox also extends to professors and decision-makers who reported spending more time in the office, and thus having less frequent interactions with non-humans overall. Though there are exceptions and some professors found ways to spend more time doing fieldwork or being in the environment on their personal time (e.g., by living on or visiting the waterways), there is a recurrent pattern that the higher people get in the hierarchy, the more they sacrifice spending time in the environments they are working so hard to conserve. This furthers the disconnect between humans and non-humans, making it harder for people with power to recognize the active contributions of non-humans in conservation research, and feeding into asymmetrical power relationships.

Non-human collaboration

There is a considerable literature in humanities and arts which includes non-humans as collaborators, for example in performance studies (Cull 2015; Ambayec et al. 2021) and musicology (Sewell 2009), among other art forms (Cypher 2017; Burke and Landau 2021). Bioart, and other art forms involving the active participation of non-humans, has contributed to non-anthropocentric discussions about bioethics, collaboration with non-humans, and the role of non-humans in science (Willet 2019; Beaudoin 2021; Gemtou 2021). Some artists even use network art to think about and conceptualize collaboration with non-humans in the context of art creation (Jevbrat 2009), showing the relevance of actor-network theory and social-ecological network analysis as tools to integrate non-humans as actors in social processes, and as possible collaborators despite frictional relationships.

Animal studies have also spent time looking at non-human collaboration through relational and post-anthropocentric conceptualizations of relationships between humans and non-humans. These approaches focus on making with (sympoiesis) rather than self-making (autopoiesis) (Haraway 2008, 2016). For example, Haraway's (2016) concept of kinship recognizes the mutuality and reciprocity of our relationships with non-humans. This approach considers dependencies between humans and non-humans, for example in the case of farm work where pigs actively contribute to practices of permaculture as collaborators (Emel et al. 2015). Some work in medical humanities also conceptualize companionship with non-humans and animal-assisted interventions as interspecies collaboration that promotes well-being (Kirk et al. 2019; Singleton 2021). This work generally invites us to revalue the contributions of non-humans in our interactions (Haraway 2016; Ambayec et al. 2021; Merritt 2021) in ways that allow us to consider non-human as collaborators. These insights could be applied to conservation research to reframe non-humans not as objects of study, but as kins – putting forth in the research process feelings of kinship experienced by some participants.

These radically inclusive ways of thinking about non-humans are emerging in the arts and humanities as the openness, creativity, and constant evolution of these fields facilitates the redefinition of boundaries (Jevbrat 2009). In contrast, western colonialism, positivism, and nature-culture dualism continue to shape the natural sciences. However, a significant amount of time is required to learn about detailed techniques or systems (e.g., physical, ecological, biological, or anatomical systems; laboratory or field practices) or fill the knowledge-action gap, leaving fewer opportunities to learn about and challenge underlying onto-epistemological assumptions. This, and the fear of anthropomorphizing non-humans by including them as collaborators, are barriers to applying a radically inclusive worldview in conservation research, and more broadly the natural sciences (Jevbrat 2009), as highlighted by a participant. Given strict standards of what constitutes a co-author or acceptable evidence, many assumptions need to be challenged for the natural sciences to start truly considering non-humans as scientific collaborators (Jevbrat 2009). For example, anxieties about anthropomorphism could be mitigated by rejecting assumptions of human exceptionalism and recognizing evidence about the wide range of emotional, cognitive, and symbolic capacities of non-humans that are often unacknowledged (Bastian et al. 2017). Despite these obstacles, some of these questions are being raised in interdisciplinary sustainability research (e.g., a research agenda raises the question, among others, of the role of non-human actors in living labs; Beaudoin et al. 2022b). However, research on collaboration with artificial intelligence showed that it is often considered as a subordinate rather than a collaborator or teammate (Sadeghian and Hassenzahl 2022), echoing results from my research both in terms of living and non-living non-humans which were not perceived as having the capacity to collaborate with humans. It shows we need more research on the role of technology and abiotic elements – rather than just living species – in collaboration and as possible collaborators.

A question of onto-epistemology

While there are many examples of interdisciplinary conservation research positively impacting resource management, policy, and practice (Cooke 2019), there are also limits to the "problem-solving" framing often taken up by conservation researchers. It bounds the spatiality and temporality of a given issue, thus failing to acknowledge its full complexity as well as questions of agency, justice, and representation (Lidksog et al. 2022). We can understand conservation research "not just as something that 'exists' but that is created and sustained" in positivistic institutional contexts that are often disconnected from biological and ecological realities (Montenegro de Wit 2016: 638; Clark 2019). This results in epistemological errors (e.g., the belief we can only progress by accumulating raw data that is quantified to generate and test predictions and hypotheses) that impact science, evidence-based management and policy, and ultimately can further disrupt ecosystems (Clark 2019). Furthermore, attempts at interdisciplinary research with disciplines that have differing onto-epistemologies often result in disciplinary capture or epistemological sovereignty, with the ecological or conservation sciences often being the dominant disciplines whose onto-epistemology is upheld and imposed (Miller et al. 2008; Brister 2016). Thus, we must first acknowledge that conservation research has been shaped by western onto-epistemology that traditionally embodies nature-culture dualisms, anthropocentrism, colonialism, and positivism. Then, we can reconsider how we understand the world (ontology), how we know it (epistemology), and how we ought to engage with it (ethics) to truly reframe our relationships with the planet and address environmental crises. This is important as "wicked problems tend to be societal problems, rather than technical problems" (Berkes 2017: 7), yet environmental expertise is still dominated by ecological, technical, and economic sciences (Lidksog et al. 2022).

The social sciences can provide reflexive, critical, and constructive tools to challenge the onto-epistemology of conservation work (Lidksog et al. 2022). For example, qualitative and quantitative work on mental models in conservation research and practice can reveal the assumptions people have about SESs, support the development of new SES models based in local knowledge, and establish shared conservation pathways anchored in mutual understandings (Moon et al. 2019a; Beaudoin et al. 2022a). Mental models can also be conceptualized as networks, giving weight to my method of using social-ecological networks to map people's perceptions of their interactions with non-humans. While there are limits to SESs and network approaches, namely that they are reductionist and can reproduce nature-culture dualisms, bringing in concepts and tools from the social sciences and humanities (e.g., mixed methodologies, qualitative analysis, actor-network theory, non-human collaborations, sympoiesis, kinship) can help mitigate these limits and enrich systemic approaches to include a range of views, values, and discussions about ethics and onto-epistemology. As such, we can refer to broader conceptualizations of collaboration from the arts that involve deliberate alterations of identity from composite subjectivities (Ambayec et al. 2021). In contrast, other fields often define collaboration so that there are "specific ontological entities who can collaborate while others cannot" (Ambayec et al. 2021: 1). What would it look like if we applied this performative conception of collaboration to conservation research? In the NSERC SPG, it makes visible the ways in which outcomes such as publications, evidence, and new policies are not simply the result of scientific processes conducted by researchers, but are rather a performance emerging from the contributions of bass, northern pike, painted turtles, zooplankton, aquatic vegetation, and algae, among others that have taken part in research about the waterways.

Furthermore, other ways of knowing exist such as traditional and Indigenous environmental conservation strategies from pre-colonial Africa (Mawere 2014) and Indigenous knowledge from elsewhere in the world such as India, North America, and Europe (Gadgil et al. 1993; Gadgil et al. 2021; Cai et al. 2022). However, western traditions of science have often excluded these ways of knowing the world (Kimmerer 2013) and reproduce colonial, asymmetrical, and extractive relationships with locals and Indigenous peoples (Cai et al. 2022). Beyond the impacts of colonialism on Indigenous relationships with nature (e.g., loss of land, loss of wisdom and knowledge), conservation research practices, discourses, and institutions often dismiss local and Indigenous ontologies and epistemologies as illegitimate, even though there are some convergences between scientific and Indigenous knowledges (e.g., use of common indicators for soil classification; Kolawole and Cooper 2022). This is also exemplified by the practice of prioritizing western taxonomies over traditional (local language) names of species in conservation efforts (Rubis 2020). Another form of recolonization is bringing Indigenous knowledge in western-centric frameworks, rather than fully engaging with worldviews of Indigenous groups such as developing a connection to place and paying attention to the complex webs of relationships between species (Bowie 2013; Rubis 2020). These colonial frictions in science, as well as local history, can make it difficult for conservation researchers to meaningfully include Indigenous peoples. For example, repeated attempts were made by researchers of the NSERC SPG to connect with Indigenous communities around the RC, but most attempts were unsuccessful. This is likely tied to the canal construction which disrupted and ultimately eroded traditional use of the region for travel, trade, hunting, and gathering (Bergman et al. 2021; Watson 2018). We cannot force reconciliation and collaboration as these processes take time, though we can make space to attempt to connect, understand why these attempts sometimes fail, and acknowledge the barriers posed by institutions (e.g., the length of a PhD program). Colonial tendencies in science also frame the ways in which other species, forms of life, and abiotic elements of the environment are conceptualized and engaged with (e.g., as objects and not actors), as highlighted by some participants. Thus, reconnecting with other species with whom relationships have been frictional will also take time.

Knowing the limits of conservation research in terms of including non-humans as actors of research and potential collaborators, there is a need to consider alternative onto-epistemologies and ways of knowing. Pathways to explore include relational social sciences and humanities that are more inclusive of non-humans, and Indigenous knowledges which embrace various ways of living and connecting with non-humans, as has been increasingly discussed in the literature and highlighted by participants in this research. More work needs to be done to bring together the pathways offered by these two fields to decolonize conservation research (Rosiek et al. 2020), as Indigenous knowledges are often anchored in or compatible with relational ontologies and approaches (Datta 2015; Muller et al. 2019; Paul et al. 2020). Reframing relationships with non-humans in conservation research as relationships of kinship (Haraway 2016; Van Horn et al. 2021) would be a good starting point for recognizing and addressing this paradox of conservation. Some Indigenous ways of knowing also explicitly frame plants as teachers with whom we collaborate to generate new understandings, or as collaborators to our diets (Kimmerer 2013; Dev 2018). While some of my participants spoke of some interactions as learning from other species, this view was not shared by all and was not explicitly represented in the knowledge and outcomes of the research. Moreover, two-eyed seeing – understood as learning to see the world through multiple ways of knowing that co-exist, with one eye to see with the strengths of Indigenous knowledge and ways of knowing and the other eye to see with the strengths of western scientific ways of knowing (Reid et al. 2021) – is also a helpful strategy to reframe the ways in which we conceptualize and practice conservation research.

Conclusion

This paper explored the views of researchers, government, and community partners about their interactions with non-humans in the context of transdisciplinary conservation research. Social-ecological networks were combined with qualitative discussions to unpack the range of views of actors involved in a case study, the 2018-2021 NSERC SPG to conduct conservation research in National Historic Waterways in Ontario, Canada. It was revealed that few considered their relationships with non-humans as collaborative, many found them anchored in data collection and analysis, and that non-humans were over-represented in the frictional network. This led to the articulation of a paradox of conservation research to conceptualize the fact that researchers aim to protect and conserve the environment yet end up in tense relationships that often include violence and sacrifice without being able to guarantee that these interactions will result in enhanced outcomes for individual non-humans or their population. This phenomenon was more common among conservation researchers than practitioners and community members whose actions generally build on pre-existing evidence and research to directly conserve a species or habitat (e.g., turtle nests protectors). Most participants also conceptualized non-humans as objects of research, though a minority made space for relational ways of thinking about the environment and want to engage with other ways of knowing. Challenging the onto-epistemology of conservation by embracing social science and humanities concepts (social-ecological networks, non-human actors and collaborators, kinship) and Indigenous knowledge has the potential to improve the transformative potential of conservation research and opens up possibilities to establish new social orders (Lidskog et al. 2022).

This research has relevance for researchers in both the social and natural sciences, as well as practitioners involved in environmental management and conservation who regularly engage with the environment and non-humans as part of their work in Canada and elsewhere in the world. It contributes to the advancement of theoretical knowledge by bringing nuance to broad calls for collaboration and taking up questions of how to include non-humans as actors of science, understood as a social process. It engages the more-than-human social science and humanities literature and connects it to the concepts of SES and social-ecological networks. This exploratory research also presents methodological innovations, bridging principles from actor-network theory with social-ecological network analysis to quantify collaborative and frictional relationships with humans and non-humans. Future research should reproduce this method, and also collect ties between non-humans to create possibilities to meaningfully conduct advanced networks statistical analysis (e.g., QAP procedures, ERGMs). This would also allow us to investigate the role of technology, which often seem to mediate relationships between humans and other species or abiotic elements of the environment. Finally, this research has social relevance as it generates data about the various non-humans involved in the RC and TSW waterways, and which are most researched to date (thus highlighting the need for more research about birds, mammals, and others in these systems).

This research is relevant for the RC and TSW, but also for conservation researchers and practitioners elsewhere in Canada and the world as it reveals dynamics that are at the core of conservation research. Future research should continue exploring the assumptions of conservation researchers about the environment they live in and the non-humans they work with. We could explicitly explore the role of distinct disciplinary onto-epistemologies in shaping interdisciplinary conservation research, knowledge and evidence, and impacts on community and government conservation practices. Work to decolonize conservation research by respectfully learning from Indigenous ways of knowing should also explore how to work in places – like the RC – where few relationships exist between Indigenous community, decision-makers, and local conservation researchers. Future research could also integrate the concepts of non-human collaborators and kins in initial conservation research design, and track the influence of these new concepts on conservation research process and outcomes.

Declaration of interest statement

I am author of this paper but also participated in the case (i.e., research project) that is analyzed in the paper. Some of the research participants were my colleagues and I knew most of the participants before conducting the interviews. I was also included as a research participant and provided answers to the interview questions.

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Connective tissue 3: Ecology

As shown in Chapter 2, discussions with other researchers and partners in the NSERC SPG allowed me to identify relationships between humans and non-humans. The results were bittersweet. A portion of individuals could see that non-humans can be collaborators or teachers in research, but many did not see this as a possibility. I expected that training in the sciences may result in such views but I wondered if spending time in the field would counterbalance this and create feelings of connection. Many did feel a connection to nature, but it did not always inform their research practices. Showcasing that positivistic training influences worldviews, at least one biologist felt that emotions about non-humans (positive or negative) would only serve to introduce bias in the scientific process. While other ecologists held more nuanced views, it was still difficult for them to envision non-humans as collaborators because they were seen as being subjected to human will in the context of research (as Francis said, “we act like god”). When I asked questions about how humans and non-humans interact in conservation research, I thought it would uncover hidden synergies that weren’t revealed in presentations at the annual grant meetings or in papers I had read. Instead, I often encountered perplexity: “I have an appreciation for their sacrifice, but I don't know how to turn it into a two-way relationship” (Francis).

This made me realize several things. As I had planned to do, I will need to get out in the field with ecologists and biologists in the future, as perhaps being present during these interactions could help me better understand tensions and perhaps pick up on unspoken or unnoticed synergies or opportunities. Beyond this, I realized that discussions about the inclusion of non-humans as actors, kin, or collaborators in the humanities and social sciences often remain abstract. Such discussions are tied to an ecology of words and ideas, but not always to an ecology of practices. When practices come into play, artists, practitioners, or Indigenous knowledge holders seem more concerned with the active participation of non-humans than scientists, as seen in Chapter 2. Thus, there is a need for more dialogue across disciplines concerned with non-humans and the environment, and there is a gap in methodological and practical innovations to operationalize the inclusion of non-humans in research and beyond.

For Chapter 3, I wanted to go beyond concepts and theories to think about practical advice for conservation researchers and social scientists to start implementing more-than-human conservation research. I provide a review of the network literature because I see it as a bridge, a productive pathway to strengthen dialogue between disciplines, and as having the potential to become a practical tool to facilitate the inclusion of non-humans. But it needs to be both: how we think and how we act must align. This is why the chapter also proposes theoretical insights for conservation research.

When thinking about the results in Chapter 2, the interactions in the field and labs that were described differed quite a bit from those I observed when working exclusively in laboratories with micro life forms (Beaudoin 2018). However, similar elements came into tension. For example, cells are bounded by a membrane which is porous, and laboratories themselves aim to be hermetic spaces of experimentation yet they are always leaking as humans and materials move in and out of those spaces (Beaudoin 2018). Membranes and boundaries also came into play for the NSERC SPG. The skin of fish was akin to porous membranes as researchers conducted surgery to insert tags that would provide data as the fish continued its movements in the waters. Researchers describing driving a boat in the canal rather than a pipette in a biosafety hood. The waterways are connected to other bodies of water and to land and thus are much less bounded than laboratories. Yet, the built portions of the canal act as boundaries that were artificially introduced in the water system, changing the course of watersheds and creating opportunities for navigation across lakes and rivers that were previously disconnected. Some research teams also captured samples of water, sediments, microorganisms, or tissue to bring back and process in a lab – showing back and forth movement between such spaces. In both waterway and laboratory research, humans must adapt to the temporalities of non-humans. It is much easier to access the waters and many of those who inhabit it in the summer, fieldwork especially using boats cannot occur if the weather conditions are unstable, and the manipulation of fish and turtles in the field needs to account for the sensibilities of organisms to be in or out of the water for set periods of time. In labs, work must occur at the right time to maintain the cells, tissues, or microorganisms that are targeted by studies. I also found growth and replication both in the biological and ecological systems being studied, and in the practices harnessed by humans to conduct these studies.

This short description embodies the ecological nature of conservation research itself. It is ecological in the sense that it studies the environment to better understand how different species and abiotic elements relate and interact with each other in specific biogeophysical systems. It is also ecological because it encompasses a set of practices, values, and languages that are in relation with each other and the environment (social ecology, human ecology). It is ecological because the actions of researchers are closely tied to their perceptions of the environment within which they work (ecological psychology). The idea of ecology has long been used as a metaphor in the social sciences, along with other biological metaphors (e.g., organisms, evolution). For conservation research to be inclusive of the social sciences and non-humans, it could also adopt this metaphorically ecological understanding of its own practices. What would change if conservation research was designed as a practice anchored in ecosystems co-constituted of relations between institutions, researchers, human and non-human partners?

Chapter 3
Practical and theoretical insights from relational sociology and environmental humanities for more-than-human conservation research

Journal

Article submitted to the journal *Nature and Culture* in June 2022 (see Appendix 1).

Please note that Beaudoin (submitted) refers to Chapter 2 of this thesis.

Abstract

More work should be done to integrate relational approaches across divides in transdisciplinary conservation research. I build on the literature and findings from a case study of research about Canadian waterways to explore practices, concepts, and theories anchored in relational sociology, networks, and environmental humanities for working toward more-than-human conservation research.

This is formulated as six practical and four theoretical insights which touch on the under-acknowledged fact that conservation research is itself ecological, on how social-ecological networks can be used as a tool for conservation research to include non-humans, and on how we must account for friction and potential collaborations between humans and non-humans. These insights also call for strengthening reflexive capacity. Relational and more-than-human approaches are mobilized in the hopes of improving the transformative potential of conservation research.

Keywords

Conservation, inclusion, networks, non-humans, practice, relationality, theory

Introduction

Traditional social and natural sciences have often used Cartesian, objectivist frameworks to study singular decontextualized objects, and even the study of systems has analyzed specific objects that can be measured (e.g., systemwide properties or features like resilience) (Lejano 2019). The relational turn in sociology opposes this focus on objects and static visions of a social world to study spaces between things and how the social world is composed of dynamic, unfolding relations (Emirbayer 1997; Lejano 2019). Such relational approaches are often used in environmental studies research seeking to better understand human-environment relationships (e.g., Putney 2013; Grauer 2020).

While relational approaches are often discussed in the context of social sciences and humanities, the natural sciences also have theories and concepts that focus on relations. For example, relational biology investigates the phenomenon of life by mathematically mapping structures and the organization of relations in natural systems (e.g., metabolic systems, ecosystems, and viral networks; Louie 2019). A relational systems framework that attempts to formally capture (i.e., quantify) complex, ecological interconnections has also been established for holistic analysis and modeling of living systems (Kineman and Wessman 2020). Ecological approaches in general also build on relational metaphors and concepts including ecosystems, food webs, and networks or flows of energy and matter, yet they often focus on a specific object like a particular species (Lejano 2019; Kineman and Wessman 2020).

Human dimensions in conservation and environmental management is now a well-established field that also embodies a relational understanding of humans that affect, and are affected by, the environment (Bennett et al. 2017). This research often mobilizes the concept of social-ecological systems (SES). While it is operationalized differently by various disciplines (Hertz and Schlüter 2015), it is generally relational in that it attends to interconnections between human and ecological components of systems (Ostrom 2007; Lejano 2019). However, many challenges remain in SES research (e.g., effectively integrating the social and ecological, integrating different knowledge systems). Building on relational and processual approaches is necessary to attend to these challenges (Mancilla García et al. 2020). Working to fill this gap, research in SES, sustainability, and environmental management is increasingly considering relationality, particularly in work that attends to Indigenous ways of knowing (Datta 2015; Lejano 2019; Muller et al. 2019; Paul et al. 2020).

In this article, I explore the value of relational approaches, and specifically network thinking which is mobilized in fields as varied as biology, physics, collaboration, and environmental governance (Borgatti et al. 2009; Scott and Carrington 2011). Networks can be "used to model and analyze practically any kind of system" (Bodin and Prell 2011: 11; Janssen et al. 2006). They generally represent structures through sets of dots and lines (Scott and Carrington 2011). In sociology, the dots (known as nodes) can represent social actors at different levels: individuals, groups, organizations, nations, or non-humans (Scott and Carrington 2011; Jones and Faas 2017; Varda 2017). The lines (known as edges or ties) are the relationships measured by researchers and can represent a wide range of relations such as collaboration, conflict, resource use, or academic citations, among others (Scott and Carrington 2011; Jones and Faas 2017). While there are limits to using networks as models or metaphors, these can be mitigated by considering the intentions of relationality to embrace rich descriptions of relationship networks that go beyond patterns and structural analysis (Lejano 2019). Furthermore, insights from the environmental humanities and new materialism are valuable to develop nuanced accounts of human-environment relationships.

While the environmental and conservation sciences are increasingly collaborative, seeking to include stakeholders and rightsholders in research processes to improve sustainability outcomes (Perz 2019), non-humans should also be included. They ought to be included not only because of the strong relationships that tie all beings on this planet (Reason 2005; Abram 2021), but also because they are at the core of environmental research and because the protection of their interests is a main driver of this research. Thus, I argue that relational sociology and environmental humanities more broadly, and particularly network methods and new materialism, can provide valuable insights for conservation research practice and theory. More specifically, networks and relational methods support the meaningful inclusion of non-humans as actors of transdisciplinary conservation research (Beaudoin submitted) and new materialism proposes pathways to consider more-than-human relationality. This article provides an overview of the literature on social and ecological networks and environmental humanities, followed by the mixed methods social-ecological networks approach I used to investigate relationships between humans and non-humans in a transdisciplinary conservation research project. I then present key empirical findings from this research. Finally, I propose a set of six practical and four theoretical insights to develop more-than-human conservation research. This article proposes conceptual, methodological, and collaborative innovations that favor the inclusion of a broader range of non-human actors. Achieving these goals involves reframing conservation research as a set of relational, networked knowledge-making and world-altering practices that depend on often intimate relationships with other species, technologies, the environment, and ecosystems. This reframing would fully acknowledge the contributions of non-humans to make conservation research more inclusive, and thus potentially increase its transformative potential.

Social and ecological networks

The network metaphor

Networks have a long-standing history in Western thinking. A history of its use shows that it was applied in the 1800s as a metaphor for anatomical structures (e.g., capillary networks), then to describe infrastructure including waterway networks in the 1940s, to finally be used in the computer (e.g., servers, Internet, neural networks) and social sciences (e.g., social network analysis) around the 1990s (Yung 2021). Use of networks can be mathematical, for example in social networks analysis described below, or anchored in conceptual metaphors (Scott and Carrington 2011; Jones and Faas 2017; Klenk 2018). It has been mobilized by anthropologists who concern themselves with connections between people, for example through the study of kinship networks (Knox et al. 2006) but also in relational sociology along with other metaphors (e.g., fields, ecology, circuits; Scott and Carrington 2011).

Used as a metaphor, networks are seen as abstractions or models rather than empirical objects or direct representations of reality. This enables discussions about relational embeddedness, that is the quality and richness of relations rather than only attending to their structure (Moran 2005). In sociology, actor-network theory calls upon the network metaphor to go beyond human-nature dichotomies and take seriously relationships between humans and non-humans (Latour 2005; Mützel 2009; Erickson 2012; Lejano et al. 2013). It allows researchers to include concepts, artefacts, technologies, and other species along with humans as actors who have agency in the social world, conceptualized as flat translation networks of co-existing mediators (Erickson 2012). This approach is usually interpretive and builds on qualitative data to tell stories, in contrast with social network analysis which builds on structural data. Yet there is a convergence of methods in relational sociology as actor-network research researchers increasingly mobilize network analysis algorithms and visualizations in their work (Mützel 2009).

Social network analysis

Social network analysis, a field developed mostly by sociologists, mobilizes networks to analyze the structure and patterns of social relations (Knox et al. 2006; Lejano 2019). It is considered a research paradigm with its own set of methods and measures, theories and concepts, and a body of empirical research (Scott and Carrington 2011). Social network analysis can be used in different ways to study a wide range of substantive topics such as social capital, digital social networks, organizational and collaborative networks, knowledge networks, among others (Scott and Carrington 2011). It is also used in the context of climate change adaptation and disaster research (Jones and Faas 2017; Varda, 2017; Giordano et al. 2017; Calliari et al. 2019; Therrien et al. 2019). Additionally, animal social networks research unveils social relationships among communities of non-humans – for example ants, birds, guppies, black bears, dolphins, elephants, and baboons – and found that some social abilities, relationships, and social structures are not exclusive to humans (Scott and Carrington 2011).

As a formal method for relational approaches, social network analysis facilitates rigorous, quantitative empirical work that goes beyond traditional sociology. It displaces the focus from what individuals are (and what they're made of) to what they do (who/what they engage with and how). While traditional social network analysis is quantitative and anchored in graph theory and network statistics (Janssen et al., 2006), some researchers also use qualitative or mixed methods social network analysis (Stein et al. 2011; Lejano et al. 2013; Oancea et al. 2017; Varda 2017). While quantitative methods can test hypotheses, work with large datasets, and are especially useful in applied policy fields where numbers help convince decision makers, qualitative network data addresses the limits of quantitative work by allowing for rich descriptions of structural relations (Mützel 2009), and going beyond to account for people's stories and perspectives (Lejano 2019).

Ecological network analysis

Ecological networks, emerging from the biological sciences, are designed to capture the complex reality of ecosystem interactions between different species and are often based on observations in the field (Ings et al. 2009; Dormann et al. 2017; Delmas et al. 2019). While early perspectives in ecological networks were phenomenological, recent trends are mechanistic and structural in their robust quantitative analysis of interactions between individuals (Ings et al. 2009; Guimarães Jr. 2020).

Ecological networks are often used to study food webs (predator-prey relationships, trophic interactions), with recent empirical research often including only two species due to challenges in collecting data to build multi-trophic networks (Dormann et al. 2017). Just like social networks, ecological networks can be captured at various temporal, geographical, and organizational scales, and be based on the various interactions (e.g., competition, predation, parasite-host interactions, mutualism) between individual, species, trophic groups (Ings et al. 2009; Dormann et al. 2017; Guimarães Jr. 2020). This literature analyzes network patterns to better understand ecological and (co)evolutionary dynamics (Dormann et al. 2017; Guimarães Jr. 2020), but ecological networks have also been used in conservation to define and increase network resilience at various scales, and to explore pathways for multi-species conservation strategies (Isaac et al. 2018).

Social-ecological network analysis

Social-ecological network analysis is an interdisciplinary subfield which combines insights from social network analysis, ecological networks, and SES (Janssen et al. 2006; Bodin and Crona 2009; Cumming et al. 2010; Bodin and Prell 2011; Rathwell amd Peterson 2012; Bodin et al. 2017; Sayles and Baggio 2017; Bodin et al. 2019; Sayles et al. 2019). This approach acknowledges the interdependence of social and ecological components in environmental governance, resilience, and sustainable development (Janssen et al. 2006; Easdale et al. 2010; Bodin and Prell 2011). A wide range of social theories can feed social-ecological network analysis, such as common-pool resource management, adaptive co-management, boundary organizations, institutional fit, stakeholder selection, social influence, social capital, social learning, and social movements (Bodin et al. 2006; Bodin and Crona 2009; Bodin and Prell 2011; Bodin et al. 2016; Bodin et al. 2017). Research in this field mobilizes human and ecological nodes in the construction of their networks. Nodes can represent individuals, households, communities, local, regional, national, and international institutions as well as individual animals or groups of species, geographic locations, patches of vegetation, or bodies of water (Cumming et al. 2010; Bodin and Prell 2011; Rathwell and Peterson 2012; Bodin et al. 2016; Easdale et al. 2016; Sayles and Baggio 2017). SES and networks have also been used in participatory research to create shared mental models of a given system (Beaudoin et al. 2022a). Social-ecological network analysis is often formal, mobilizing quantitative methods to identify structural, social-ecological patterns. Social-ecological networks can be fully, partially, or non-articulated depending on the degree of social-ecological integration in the network data (Sayles et al. 2019).

Relationality in environmental humanities and new materialism

Beyond the value of network analyses and relational sociology for better understanding human-environment relationships, I also draw lessons from the field of environmental humanities which most commonly encompasses work from literature, history, philosophy, anthropology, and geography among other humanities (Foote and Cohen 2021; Garrard 2017). My efforts to establish more-than-human conservation research relate to cross-disciplinary work in the environmental humanities to address environmental issues by analyzing the social and cultural dimensions of human-environment relationships (Garrard 2017). While the field encompasses a wide breadth of theoretical inclinations and conceptual definitions, it converges around a desire to repair environmental harms, convictions that science and scholarship must revisit its core assumptions about non-humans and the environment, and belief that engagement and collaboration should include a wider range of actors (Foote and Cohen 2021). While this is ambitious, it aligns with the spirit of conservation as an applied field of research and practice which seeks to protect and conserve the environment. Both share a strong normative commitment and ethical positioning that the environment can and should be better protected from harm in the context of a human-dominated Anthropocene.

Within the environmental humanities, the subfield of new materialism sheds light on the ways way in which materiality and relations contribute to meaning-making processes that structure the social and natural worlds (Opperman 2021). Such an approach allows a decentering from the human, including considering agency as a more-than-human characteristic (Onishi 2014) and considering the unfolding relations between humans and non-humans, organic and inorganic surroundings (Haraway 2008). In this way, it also contributes to the non-human or more-than-human turn: a broad theoretical reorientation toward paying attention to and being concerned with non-human alterity (Opperman 2021). This work also encompasses a generally critical angle (e.g., critiques of power structures or language) that aligns with actor-network theory (among other work) and opposes dualisms to move toward a post-anthropocentric ethic (Opperman 2021; Van der Tuin and Dolphijn 2010; Coole 2013). It is this critical angle that allows us to expand upon the traditionally under-conceptualized agentic capacity of more-than-humans. Furthermore, the relational angle allows us not only to acknowledge the relations between humans and non-humans, in this case, in conservation research, but also the relations among ontology, epistemology, ethics and politics (Opperman 2021) which have shaped conservation research. To date, conservation research has been a generally anthropocentric practice that none-the-less seeks to conserve non-humans and the environment. Given their common goals, lessons from the field of environmental humanities and specifically new materialism can and should be considered by conservation researchers. The insights proposed in this paper thus build not only on relational sociology but also on the humanities, particularly to help us rethink and re-theorize the role of non-humans in research and conservation efforts.

Social-ecological networks approach

I conducted a case study of the interactions between humans and non-humans in a transdisciplinary conservation research project. The Natural Sciences and Engineering Research Council of Canada (NSERC) funded the 2018-2021 project through a Strategic Partnership Grant (SPG). It aimed to produce knowledge to enhance ecosystem services in two National Historic Waterways in Ontario, Canada. I carried out mixed method interviews with 26 key actors of the grant. There were qualitative questions about interactions, collaboration, and conflict with humans and non-humans in the research. To complement this rich qualitative data about interactions and relationships, partially articulated social-ecological networks were used (Sayles et al. 2019). This approach was inspired by the literature previously presented in this article: relational sociology, social-ecological network analysis, and environmental humanities.

This article presents findings from these mixed method interviews. Participants used a network data collection tool on SurveyMonkey to report the different human and non-human actors they interacted with, at what frequency, and through which type of relations (Appendix 8). The network data was extracted from SurveyMonkey into MS Excel to create edge lists that were imported into RStudio version 1.4.110, an integrated development environment for the programming language R (R Core Team 2017). I used the package 'igraph' (Csardi and Nepusz 2006) to create network graphs. Qualitatively, I report responses to the questions (1) "Do concepts like social-ecological systems play a role in collaborative research grants?", and (2) "What is the value of lived experiences in the waterway (fieldwork or field visits) for your work in the grant?". Notes were taken and key elements of responses were fully transcribed from the audio recordings into MS Excel. These were subsequently coded thematically to identify emerging themes and the range of views shared by participants.

Detailed accounts of the different types of relationships between humans and non-human actors in this case can be found in Beaudoin (submitted). This research also unveiled a paradox of conservation research: most researchers pursue conservation work out of love for the environment and to improve the well-being and habitat of different species populations, yet there are a lot of tensions with other species and non-humans in general that occur in conservation research social-ecological networks.

Empirical findings from a transdisciplinary research project

Key network findings

The full network reported by participants is composed of 283 nodes (117 humans, 99 ecological and 67 technical nodes) tied through 916 relationships (505 social, 262 social-ecological, and 149 social-technical ties) (Appendix 9). We can see that beyond the key members of the grant, social relationships in the grant involved multiple other people (Figure 3.1). Academics and their students were mainly at the center of the network, with interviewed community and government partners at the periphery of the main network cluster. Many of those included in the network, but not interviewed, are at the periphery and were only engaged by one participant, with some exceptions.

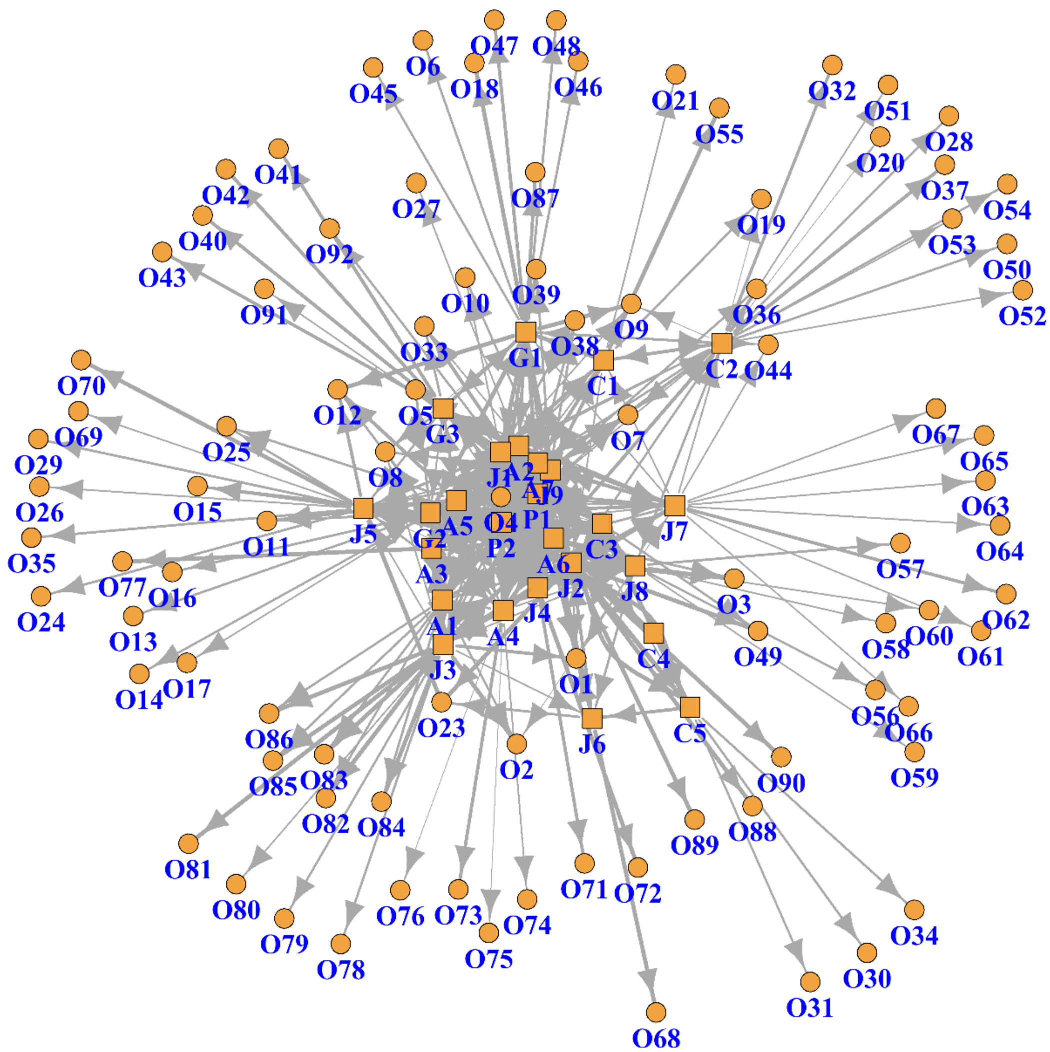

Figure 3.1. Social relationships within the grant. Yellow squares represent participants while yellow circles represent other humans cited by the research participants as people with whom they worked with in the context of the grant. Tie width was determined by the frequency at which participants

reported interacting with a given node. The arrows indicate the direction of the relationships. Labels represent codes given to nodes. Among participants, As are academic professors, Js are junior academics (masters and PhD students), Ps are research professionals (postdocs, lab managers), Cs are community partners, and Gs are government partners. Os represent others added in the network by participants.

Figure 3.2 provides an overview of the different ecological nodes (other species, abiotic elements of the environment) that participants interacted with. Fish and turtle are at the core of the network as they were often target species or incidentally encountered in the context of the grant. Different people also randomly encountered birds and mammals, among others. Academic professors often had less diverse encounters with other species and ecological elements compared to their students, research professionals, community partners, and most government partners who have more ties to ecological nodes. Ties are also generally thicker across Figure 3.2, compared to Figure 3.1 where most thick ties are in the core of the main cluster. This indicates that participants interacted more often with other species and the environment than with humans that were not key members of the grant.

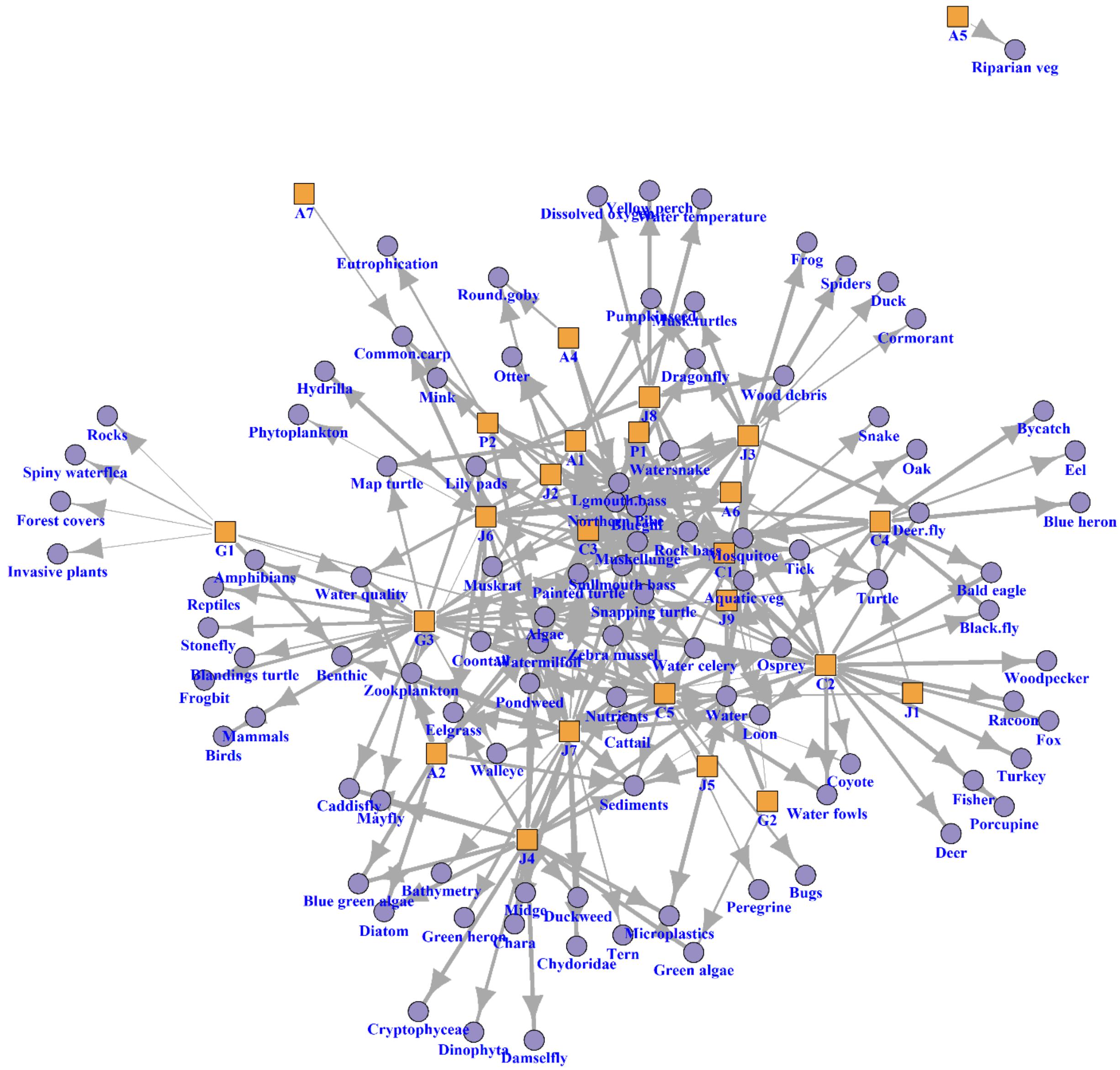

Figure 3.2. Social-ecological relationships within the grant. Yellow squares represent participants while purple circles represent other species or elements of the environment that participants interacted with in the context of the grant. Tie width was determined by the frequency at which participants reported interacting with a given node. The arrows indicate the direction of the relationships.

Figure 3.3 provides an overview of relationships with technical nodes (infrastructure, technologies) that were part of the grant. Clusters of technical nodes at the periphery of the network shows that many key members of the grant used distinct sets of technology or infrastructure as part of their work. However, a few elements overlapped and were cited by many including boats and canoes, lock stations, the programming language R, and Arc GIS among others.

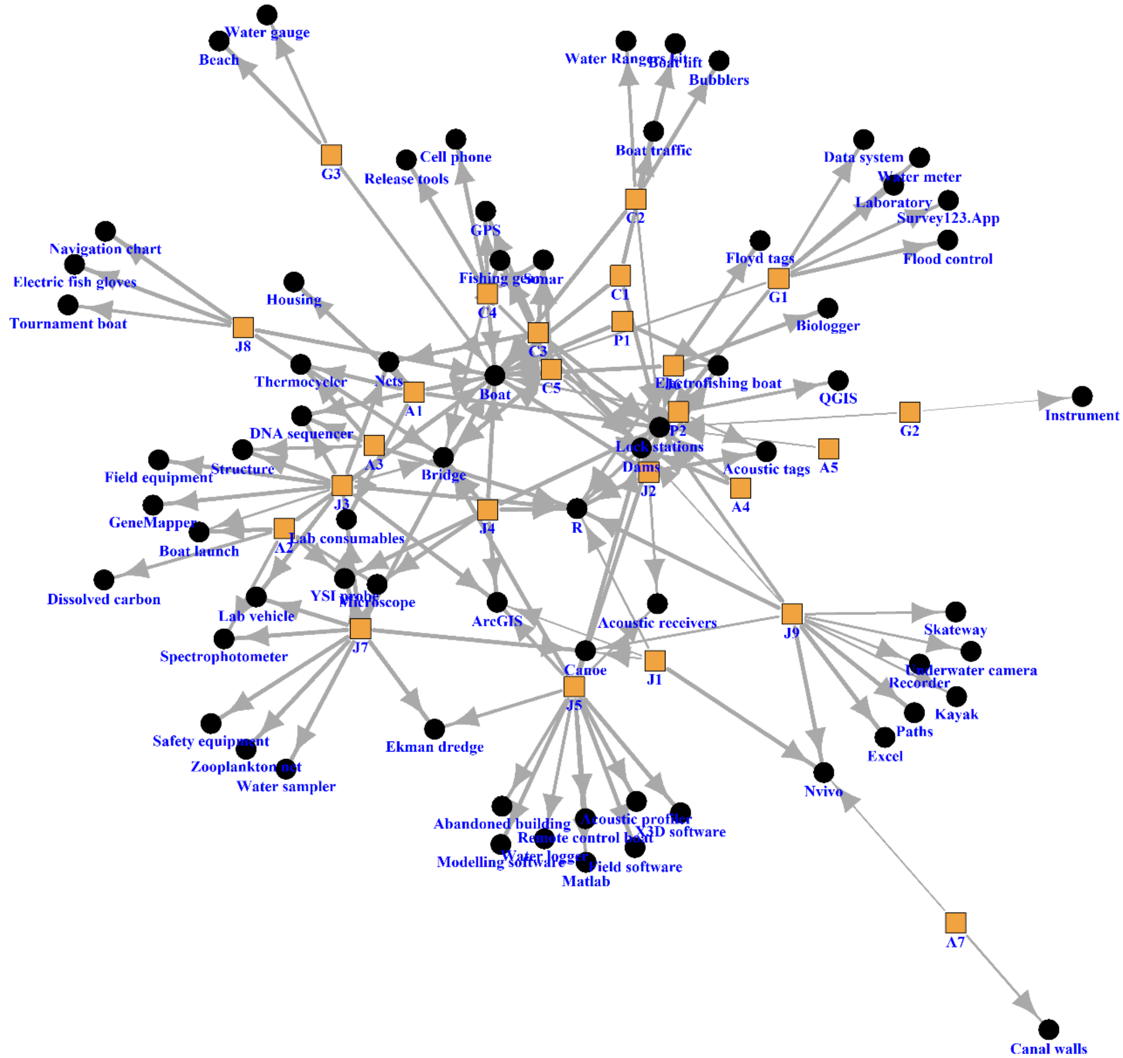

Figure 3.3. Social-technical relationships within the grant. Yellow squares represent participants while black circles represent technologies or infrastructure that participants interacted with in the context of the grant. Tie width was determined by the frequency at which participants reported interacting with a given node. The arrows indicate the direction of the relationships.

Looking at the full network data (edge list and node list, and reduced graph in Appendix 9) helps us identify dominant types of ties across the overall network. The most common interactions in this grant occurred among biologists, and between these researchers and fish. Many also interacted with algae, vegetation, and insects as part of the research project. While use of computer and field technologies was common, less used lab technologies and this was related to the non-humans they interacted with (e.g., those working with fish seldom used lab technologies in this project, but those working with turtles, zooplankton, and water samples did). Indigenous people, other federal organization, municipalities, and the public were only cited by biologists and ecologists. While there were no

Indigenous partners among key grant members, one biologist was able to engage in dialogue with an Indigenous eel specialist. People at Parks Canada (PC operations), Conservation Authorities and municipalities were also cited by many including engineers, sociologists and governance researchers, and lake association members. Findings in Beaudoin (submitted) unpack the different networks of relationships (e.g., collaboration, friction, communication) between humans and non-humans in this case.

Key qualitative findings

While some participants (9) were not very familiar with the concept of SES, others (7) perceived it as intuitive, valuable, and a possible bridge for multidisciplinary teams involving the natural and social sciences (e.g., to develop integrated approaches and conceptual agreements). In fact, the concept was seen as facilitating more effective conservation research overall: "As an ecologist, I think the most important first step is to realize how important social science issues relate to our objectives" (Francis). SES was also described by some as a necessary approach as "you can't divorce the human from the nature" (Phil). SES can also contribute to the development of new capacities in conservation research, for example a biology PhD student described having a social science chapter in her thesis despite not having a social science background. Moreover, SES informed my social-ecological network analysis which a participant recognized as valuable to create "an inventory of all the data that we collected [so] we can see what variables we have, what is being used where, and what options we have" (Abby). As such, the concept of social-ecological network can bring support when conceptualizing grant proposals, research questions, and collaborative publications, but it can also build relational understandings in conservation research. One of the main tensions reported around the use of SES was that it can be difficult to put in practice: "This is very interdisciplinary and it's social-ecological. But it's how you do it, right? Because language and words are cool [b]ut the actual application or practicality of it is a whole different issue that a lot of people don't really think about" (Emily).

Beyond SES, many (14) reported being nature lovers who love spending time in the field and have a strong relationship with nature. While spending time there strengthens that connection, many (12) also shared that it results in positive emotions and a sense of meaning. Some (8) also spend time in or around the waterways beyond research, for example doing recreational activities (angling, paddling, snorkeling, wildlife photography, observations as naturalists) which inform their viewpoint as researchers. Interestingly, practices tied to these recreational activities can both overlap and differ from conservation research practices. For example, angling can be practiced for fun or to catch fish for research. Someone also shared how interactions with fish during underwater photography was much less invasive than capturing and performing surgery to insert tags inside fish for telemetry research:

> Sometimes you will get in a situation where you're interacting with a fish underwater. And you can tell that they're aware of you but they're willing to just let you be around. And maybe they react to your body movement for a bit, and they just keep going about doing their thing which could be spawning or looking for food. […] I had experiences with spawning fish that are initially like 'What the hell is this thing' but if you stay still long enough, they are eventually just like 'It doesn't look like it's going to come attack me' and they just keep going about their business. At that point, that kind of interaction to me is almost like we're collaborating. He or she is letting me take my camera and it's moving around doing its thing in front of the camera. I'm taking pictures or just watching it, gathering information while it's going around doing its business. [I]n collaboration there's an exchange of information and perhaps that exchange of information for the fish is a recognition that this large thing is not going to hurt it. (Phil)

Nearly half of participants (10) also thought that having lived experiences in the SES they study is helpful to generate ideas, to better understand methods, and to gain a better understanding of the system, including its social-ecological dynamics. Some outliers (3) studying sociology and human dimensions did not think that spending time in the field was necessary for conservation research, as you can talk to those who have relationships with nature and gain insight from their views, relationships, or expertise.

Practical insights for conservation research

1. *Social-ecological network analysis facilitates transdisciplinary collaboration*

Social-ecological network analysis can facilitate transdisciplinary collaboration. As specified by a participant, social-ecological network assessments can serve as inventories of species, ecosystem components, variables, but also equipment, gear, software, and other methods used for data collection and data analysis in specific projects. Thus, it could be used as a tool to identify ties, or potential ties, between humans and non-humans in ways that can be leveraged to enable transdisciplinary collaboration. For example, someone joining a grant or lab could look at the social-ecological networks of ongoing projects to identify possible collaborators by looking in the network to see which research, government, and community partners are working on similar species, variables, or with similar methods. As an inventory of social-ecological relationships in research, these networks could also be used to leverage data that has already been collected, thus limiting fieldwork that can have harmful impacts. Social-ecological networks can also facilitate transdisciplinary collaboration and serve as a boundary object given that SES is interdisciplinary, and the network framework is common to many disciplines (Hertz and Schlüter 2015). It also provides methodological avenues for transdisciplinary teams to practically operationalize SES as networks, a gap identified by participants in relation to the use of SES in conservation research.

2. *Social-ecological network analysis reveals how non-humans are involved in conservation research*

An effective entry point for conservation research to include non-humans is to identify relationships with non-humans through networks. Social-ecological networks, by making visible different relationships between humans and non-humans, can support the inclusion of non-humans as actors of conservation research (Beaudoin submitted). It is a tool that stimulates reflection, as many researchers had never explicitly thought about their own relationships with non-humans in the context of their work (Beaudoin submitted). Resulting networks can be used to explicitly value what is exchanged between humans and non-humans in conservation research (e.g., knowledge, information, teaching moments, emotions). Additionally, insights from social-ecological networks can help improve social-ecological alignment in SESs and in conservation research itself, thus improving the effectiveness of its outcomes (Bodin et al. 2014; Sayles et al. 2019).

Survey tools to build partially articulated social-ecological network, such as the one I used, could be easily integrated in research processes. Furthermore, social-ecological networks can also be generated more informally – for example through drawing networks, listing relationships, or in participatory network creation workshops – to create fully articulated networks based on experience and expertise rather than systematic data collection. These informal strategies also create opportunities to explore rich descriptions of relationships, rather than only their patterns or structure (Lejano 2019). Conservation researchers could thus track their research networks through social-ecological network assessments to explicitly account for their relationships with other species and abiotic elements of the environment, and to acknowledge their contributions in the research processes.

3. *Social-ecological networks of conservation research also include technology and infrastructure*

When reframing conservation research to include non-humans, it is easy to think of other species targeted by the research such as fish, turtles, among others. Social-ecological networks, along with SES, also invite us to consider broader system dynamics and how other species interact with each other and humans outside of research. However, we should also attend to the ways in which technology and infrastructure are networked to other actors and mediate relationships between humans and other species and ecosystem components. This is acknowledged in the concept of social-ecological-technical systems (McGinnis and Ostrom 2014). It also aligns with actor-network theory that can include humans as well as both animate and inanimate non-humans as co-contributors that shape and participate in the social world (Latour 2005). This should be a priority as human infrastructure is often found in SESs targeted by conservation research and efforts: roads or bridges provide access, dams and canals reshape watersheds, houses and other forms of development can provide shelter for humans, impeded access to field sites, or impact ecosystem dynamics. Additionally, technology plays a large role in conservation research (e.g., to access field sites, to collect and analyze data). Including both technologies and infrastructure in social-ecological networks of conservation research is thus as important as including other species.

4. More-than-human conservation research thinks outside the box and explores methodological pluralism

As recognized by most participants, spending time in the field and experiencing direct relationships with non-humans is valuable. It contributes to building meaningful connections and tacit, experiential knowledge about the environment. Overall, methodological pluralism such as using mixed methods is a valuable avenue for conducting meaningful more-than-human conservation research. Quantitative network methods can test hypotheses, make sense of large datasets, and provide numbers that are useful for decision-makers; this can be complemented by other methods that explore stories, experiential knowledge, or multimedia materials. A truly relational approach can mobilize networks but must also attend to "the relationships themselves that constitute each link" (Lejano 2019: 6), as I attempt to do. Including qualitative, participatory, and creative methods in conservation research can thus help showcase evolution, flux, and movement in relationships between humans and non-humans, as working from networks alone makes it difficult to capture change (Bodin et al. 2006; Scott and Carrington 2011). Methodological pluralism and experimentation with qualitative and experiential methods also align with critiques of environmental humanities about traditional research methods and offer pathways to account for more-than-human interests in research and conservation work. Furthermore, mobilizing these strategies builds interdisciplinary capacity in conservation research (e.g., the biologist who included a social science chapter in her thesis) and could also create opportunities for senior academics and social scientists who often spend less time in the field to connect with the environment and non-humans that they study.

In terms of multimedia work, these types of connections can reframe interactions with non-humans as seen in the underwater photography sessions reported by a participant. Conservation research could benefit from explicitly building on anthropology's expertise in ethnographic films and strategies to generate data across multiple media (Collins and Durington 2014). While I have seen ecology labs use videos to engage the public on social media, multimedia accounts of encounters with fish, turtles, and other non-humans could also be considered in reflexive processes and as creative modes of production and engagement with the environment. While we cannot use direct observations or lived experiences as data or evidence to quantify ecological phenomena (Beaudoin submitted), we can, however, use them to extend and reframe what we consider to be useful data and evidence for conservation research (e.g., Bennett 2016). Mobilizing this strategy, I created an online, interactive map presenting images, sounds, and videos to contextualize different dimensions of conservation social science in the grant[1].

5. *More-than-human conservation research explicitly acknowledges the contributions of non-humans*

We can ask "Why do we acknowledge only our textual sources but not the ground we walk, the ever-changing skies, mountains and rivers, rocks and trees, the houses we inhabit and the tools we use, not to mention the innumerable companions, both nonhuman animals and fellow humans, with which and with whom we share our lives?" (Ingold 2011: xii). Non-humans such as fish, water, and perhaps data analysis software could be included in acknowledgement sections of articles, student theses, in conference presentations, or in public engagement opportunities. This relates to exploring different possibilities for explicitly including non-humans as contributors to the research and possible collaborators. While some researchers were open to the idea of including other species as co-authors in grant applications or publications, others believed this would be inappropriate because they do not contribute to the writing process, lack the ability to provide consent, and are often positioned as victims in conservation research (Beaudoin submitted). The practice of acknowledgement could thus be an in-between measure to increase explicit recognition of the participation of non-humans in the research, similarly to the practice of land acknowledgement. While there are limits to this approach (e.g., we can recognize traditional, unceded territory but often this is not accompanied by decolonization efforts or meaningful change; Asher et al. 2018), it is a first step in recognizing colonialism and creates space to challenge asymmetrical power dynamics. Similarly, while acknowledging the land, water, and other species that participate in conservation research is not sufficient, it recognizes the need to – and creates space for – challenging the assumptions of conservation research about non-humans. These acknowledgements could also bring attention to the range of different power dynamics unfolding between humans and non-humans, with some perceived as victims and others as collaborators.

[1] Please see https://chbeaudoin.wixsite.com/envsocialscience/transspecies-collaboration.

6. More-than-human conservation research is reflexive

Findings from my research align with the increasingly recognized need for improved reflexivity in conservation science (Montana et al. 2020; Beck et al. 2021; Boyce et al. 2022). Reflexivity invites reflection on personal values, positionality, and colonial, disciplinary and personal history (Beck et al. 2021; Boyce et al. 2022). Reflexivity acknowledges that our relationships with our research topics often pre-exist our research and spillover. While reflexive practices create space to challenge pre-existing assumptions about non-humans, asking if and how non-humans could be research collaborators is also a pathway to initiate reflexive thinking. Cultivating a practice of reflexivity involves asking questions at the individual, interpersonal and collective level, in this context about dynamics between humans and non-humans (Table 3.1).

Topic	*Reflexive questions tied to non-humans*
Questioning personal values	What are my personal values about other species? What type of relationships have I had with different species? How is this different than my values about and relationships with technology and infrastructure? How does this influence my research?
Questioning contextual assumptions	How have other species been treated in the system I am studying (e.g., exploitation, resource extraction, stewardship, respect)? Has this changed over time? How does this influence my research?
Questioning disciplinary assumptions	What normative assumptions about other species exist in the research fields that I work in? Where do these assumptions come from? What can we learn from deconstructing some of these concepts (e.g., biodiversity, invasive species)?
Questioning research actions	How do the interactions I have with non-humans in my research or work differ from interactions I have with non-humans in my personal life (e.g., doing recreational activities)? What, if anything, needs to change about these interactions with non-humans? Why? How?
Considering new possibilities	What can I learn from social-ecological network assessments about the contributions of non-humans to my research? What would change if considered non-humans as actors or collaborators of my work?
Considering ethics of research	Is my research worth it? Do the potential benefits or improved conservation outcomes outweigh the potential harms to local communities, rightsholders, fish, turtles, zooplankton, algae, vegetation, among others, that may be sacrificed in my research?
Considering other ways of knowing	What can I learn from people who have different values, worldviews, and ways of knowing in relation to non-humans (Boyce et al. 2022)? How can I better engage these other ways of knowing?

Table 3.1. Questions to develop a reflexive practice in more-than-human conservation research

Theoretical insights for conservation research

1. *Conservation research is an ecological, relational, and networked practice that already includes non-human actors*

Relational approaches provide a framework for conservation researchers and practitioners to reflect on relations between humans and non-humans. In fact, relational sociology and social networks are compatible with concepts from the ecological and biological sciences – such as ecological approaches, ecological networks, and social-ecological systems – that focus on relationships and interconnections between different species and life forms, abiotic elements, human actors, and infrastructure (Lejano 2019; Mancilla García et al. 2020). However, these relational understandings are generally turned outwards, with researchers often conceptualizing ecosystem dynamics, non-humans, and governance as objects of study that provide data (Beaudoin submitted). Yet, we can build on the relational and ecological understandings that ecologists and conservationists apply to the environment and use them to conceptualize their own research practices through an ecological lens, and to recognize the centrality of non-humans in the research process (Bastian et al. 2017). Thus, conservation research itself can be theorized as a social-ecological system or a network where researchers and non-humans are tied through collaborative, communicative, tense, and random encounters (Beaudoin submitted). While social studies of science and science and technology studies have long understood science as a networked practice where non-humans play significant roles (e.g., Latour and Woolgar 1986), conservation research could address its frictional relationships with non-humans if it considered this insight.

Networks provide a flexible method that aligns with relational approaches but are also limited because data collection is resource intensive, networks do not capture dynamics, and different sampling strategies produce different network structures (Bodin et al. 2006; Scott and Carrington 2011; Bodin and Prell 2011; Therrien et al. 2019). There is also a lack of concepts and theories anchored in network thinking (Borgatti et al. 2009; Scott and Carrington 2011; Sayles et al. 2019). The large focus on methods leads to concerns that network approaches reduce social life to dots connected through lines, and that networks do not inherently include broader context (Erickson 2012). Thus, some authors move beyond networks toward more fluid relational approaches (Klenk 2018). For example, meshworks conceptualize dynamic trajectories of individuals and knowledge entangled in lines of becoming (Ingold 2011, 2017; Klenk 2018). More-than-human conservation research could thus benefit not only from networks thinking but also from metaphorical pluralism, since the applicability, range, and relevance of every relational metaphor is limited (Keulartz 2007).

2. *Agency and new materialist ontologies are heuristics to include non-humans as actors of conservation research*

We can ask what concepts or theories are necessary to seriously consider non-humans as social actors. Agency is a conceptual layer used in the social sciences which accounts for actors who are “doing something, that is, making some difference to a state of affairs” (Latour 2005: 52). As long as something leaves a trace, produces a transformation, and leaves an account of its action it can be considered to have agency (Latour 2005). Agency is a key tool in sociology and actor-network theory, but also in environmental humanities and new materialism. The latter conceptualizes agency as going beyond human bodies and action, and rather emerging from “how relational networks or assemblages of animate and inanimate affect and are affected” (Fox and Alldred 2015: 399). Yet, agency isn’t often mobilized in ecological and conservation research, and components of ecosystems are seldom conceptualized as individuals or collectives that act consciously (Davidson 2010). When agency is mobilized, it is often in a restricted sense (e.g., agent-based modelling of SES; Schlüter et al. 2014). Thus, there is a mismatch in how social and ecological actors and networks are conceptualized by the natural and social sciences and humanities. While ecosystems and social-ecological research accounts for structure through systems thinking and network analysis, mobilizing agency as a heuristic for conservation research could be productive. Moving beyond a dualistic debate, structure and agency can be understood as co-occurring and we can thus consider how the structure and networks of relations facilitate or hinder, but do not fully determine, potential actions and influences of different actors (Scott and Carrington 2011). This could help find distinct and shared agential and social capacities across social-ecological divides (Bastian et al. 2017), as has been done in my research where the same questions were asked about human and non-human actors for network data collection. Overall, broadened conceptualizations of agencies (Cypher 2017) that apply to more-than-human bodies are an important heuristic that could be mobilized in conservation research to include non-human actors.

3. *On friction, collaboration, and coproduction with non-humans*

The critical anglers of environmental humanities can shed light on conservation research and work, which can be interpreted as colonial practices anchored in control. Legislative controls limit local practices and traditions, access to protected areas is restricted, spread of invasive species needs to be controlled, enemy species biologically control pests (McGregor 1995; Shields et al. 2019). The concepts of invasive and native species can also be deconstructed as xenophobic metaphors (Keulartz 2007). These examples point to the anthropocentric, colonial, and positivistic onto-epistemology of conservation (Montenegro de Wit 2016; Clark 2019). I argue that this onto-epistemology frames research practices, and ultimately feeds the asymmetrical power dynamics reported between humans and non-humans in conservation research, such as manipulations that involve harm or sacrifice of target species (Beaudoin submitted). In this context, viewing fish and turtles among others as collaborators is simply incompatible with the onto-epistemological assumptions established in this field.

However, some biologists recognize that non-humans just want to be, to exist (Beaudoin submitted). Thus, we could reframe relationships with non-humans in conservation to go beyond control and objectification. Relational sociology and new materialism can contribute to reframing these relationships as a co-existence while explicitly accounting for tensions, frictions, but also potential collaborations. Even so, including non-humans as collaborators in conservation research raises difficult questions: "How do we conduct scientific or artistic research in collaboration with someone whose experiences, sensations, and knowledge is difficult or impossible to understand? Can one collaborate with someone whose intention and agenda is not known?" (Jevbrat 2009: 2-3). Broader perspectives on agency discussed previously allow us to address some of these challenges as we can consider the role of non-humans with nuance, as actors embedded in dynamic webs of relationships whose presence, absence, and actions transform and make a difference in conservation research. As collaborative practices in environmental research already cross disciplinary, cultural, and national boundaries (Perz 2019), conservation researchers in the natural and social sciences should reflect on how collaboration could cross boundaries between species, and between animate and inanimate actors.

Coproduction is a helpful conceptual tool to achieve this goal. It can be understood (1) in participatory research as a collaborative, participatory method for researchers and partners (e.g., Indigenous, local community, government) to coproduce knowledge in a way that involves different perspectives and voices, and (2) in science and technology studies to describe the power dynamics that shape the production of shared worlds and the interactions between science, society, and nature (Bastian et al. 2017; Lemos et al. 2018; Van der Molen 2018). It has been argued that extending coproduction, collaboration, and participatory frameworks to include non-humans would produce better understandings of social-ecological dynamics, including those unfolding in research processes (Bastian 2013). In fact, humans are members of the broader planetary ecosystem and biotic communities, and we must attend to the well-being of all individual creatures, species, and ecosystems (Reason 2005; Abram 2021), but the exclusion of non-humans is common and unacknowledged (Bastian et al. 2017). Emerging from environmental humanities, more-than-human coproduction is a profoundly relational endeavour that acknowledges the intimate entanglements of being, becoming, and making with others (Renold and Ivinson 2022). While methodological experimentations to actively engage non-humans in coproduction and participatory research are spearheaded by the humanities and social sciences (e.g., more than human research, human-animal studies, new materialism, multi-species research, ecofeminism, science and technology studies), the biological sciences need to be engaged and involved in these experimentations (Bastian et al. 2017). Building on this recognized need to develop new methods to include non-humans in research (Bastian et al. 2017) and given the use of network analysis to support effective collaboration and coproduction (Poocharoen and Ting 2015), my approach to social-ecological network analysis should be further investigated as a means of supporting more-than-human coproduction in conservation research. While the identification of non-human actors was one of my results, future research should build on these network findings to include non-humans at the outset of conservation research projects (Bastian et al. 2017).

4. On the welfare of non-humans and harm reduction in conservation research

The notion of welfare in conservation research and practice is complex given dynamics of predation and competition in ecosystems and the perceived need to eradicate invasive species for the sake of native or endangered species (Sekar and Shiller 2020). While conservation research often includes manipulations, capture, tissue sampling, behavioral experiments, surgery, among other practices which can be harmful, researchers do their best to minimize harm (Beaudoin submitted). However, there are shortfalls in conservation research and practice in terms of ensuring the welfare of animals in the wild (Beausoleil et al. 2018; Hampton and Hyndman 2019; Sekar and Shiller 2020). For example, conservation should not only consider fitness (physical state), but also the dynamic between fitness and feeling (mental state) (Beausoleil et al. 2018). In addition, a wide variety of species has been shown to experience physical and emotional pain, engage in relationships, and perform complex cognitive tasks making animal welfare ethically relevant (Sekar and Shiller 2020). The welfare literature also relates to a paradox of conservation research (Beaudoin submitted): the well-being of individual specimens is not always fully considered (e.g., feelings and not just fitness), harms and negative welfare impacts could be further minimized, it is still unclear how potential harms and potential benefits can be evaluated and balanced yet this generally determines if ethics approval is granted, and the full complexity of welfare impacts may not be captured by current indicators (e.g., impacts of relocation or non-lethal manipulations) (Beausoleil et al. 2018; Sekar and Shiller 2020). Furthermore, many human activities impact animal welfare (e.g., development, farming, recreational hunting, control of invasive species), yet researchers and conservation practitioners rely on surrounding communities for funding and to ensure that best conservation practices are followed as widely as possible. Thus, animal welfare is not always a priority as it can threaten relationships and weaken trust with partners that are essential for conservation research and work to occur in a first place (Hampton and Hyndman 2019; Sekar and Shiller 2020). This makes for a complex landscape in which to operate.

Considering insights from relational sociology and new materialism also highlights the fact that welfare research generally does not include non-animal life forms. This is evident in the presence human and animal ethics boards in universities, and the absence of ethics boards to approve work with plants, cell cultures, algae, and microorganisms among others as mentioned by participants (Beaudoin submitted). There is also no conceptualization or consideration of the welfare of inanimate non-humans, such as water and soil. While some conservation work attends to the welfare of fish involved in telemetry research (Cooke et al. 2013), I further suggest that we could harness relational approaches and new materialism to extend concerns of welfare beyond animals to other life forms and elements of the environment. Explicit consideration of frictional relationships with non-humans does not necessarily imply the elimination or reduction of research practices (Hampton and Hyndman 2019), but it offers opportunities to reframe, rethink, and refine conservation practices, as well as opportunities to reinterpret evidence gathered using traditional scientific methods (Abram 2021). Social-ecological network analysis and other relational approaches described throughout this article can help conservation research think about how it could be a better collaborator for the non-humans that it involves in conservation research.

Conclusion

As shown throughout this article, network metaphors and relational approaches hold value for conservation research. Use of networks is shared across disciplines and fields of research; it can thus serve as a common framework for conservation research to be inclusive of non-humans. Working toward relational conservation research is also a step toward including insights from the social sciences and humanities, which is deemed necessary to facilitate environmental sustainability transitions and achieve transformative, social-ecological change (Lidskog et al. 2022). In this article, I built on network theory, relational sociology, environmental humanities, and findings from the social-ecological network analysis of a transdisciplinary conservation research grant to present six practical and four theoretical insights for conservation research.

In terms of practice, social-ecological networks can effectively support transdisciplinary collaboration and provide tools that reveal how non-humans, including other species but also technologies and infrastructure, are actors of conservation research. Networks can also be used to set the stage for including non-humans in conservation research, in combination with other methods that acknowledge and strengthen meaningful connections with non-humans. More-than-human conservation research also opens up possibilities for new relational practices, such as including non-humans in acknowledgements or as co-authors and developing reflexive capacity. Theoretically, social-ecological networks and relational approaches can frame conservation research as an ecological, networked practice. The concept of agency, mobilized both in relational sociology and new materialism, is also a useful heuristic to reflect on the ways in which non-humans are involved in conservation research. In turn, these broadened conceptualizations of research and non-humans make it possible to consider more-than-human coproduction as well as to inform the conservation and animal welfare literature and expand its concerns for a variety of non-humans.

Networks and relations are effective entry points for discussions between researchers in the natural and social sciences and humanities. While networks can be used in a variety of ways to satisfy various research needs (e.g., to collect data, as a metaphor, as a tool to support collaboration), they are not a panacea. They simply provide snapshots of a constantly changing world. Still, in a world where conservation efforts and management are increasingly evidence-based (e.g., Cooke et al. 2017), networks are valuable in that they can be used to generate relational evidence that appeals to practitioners and decision-makers. They can also be used in combination with insights from environmental humanities and new materialism to ensure that context, meaning, and flux are accounted for when including non-humans as actors. The practical and theoretical insights presented in this article are valuable for conservation researchers across disciplines. While I contribute to growing discussions of relationality in the conservation and network sciences, social scientists and humanities researchers – including those working in social network analysis, more-than-human research, and science and technology studies among others – could also benefit from this analysis of conservation research as a social process. This work can also benefit the communities and governments working with conservation researchers by explicitly unpacking how non-humans contribute to conservation research. Future research should continue building bridges between Indigenous knowledges and relational approaches in the social sciences and humanities (Datta 2015; Lejano 2019; Muller et al. 2019; Paul et al. 2020) to decolonize conservation research in ways that make space to respectfully acknowledge the more-than-human.

Declaration of interest statement

I was a contributor to the case study (i.e., I participated in the research project described in the case study) that is analyzed in the article. Thus, I participated in my own research as a participant and provided answers to all interview questions. I also knew most of the participants and some were my colleagues.

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Connective tissue 4: Attuned inquiry

In this final reflexive note, I want to take the opportunity to formulate an ethical commitment. If we take seriously the ecological character of conservation research, we acknowledge that researchers shape, and are shaped by, their relationships with humans and non-humans in the field, in labs, in institutions. Reflexivity is a strategy to deal with the fact that we can never be purely objective when conducting research: the choices we make are influenced in part by our ontological and epistemological assumptions, by our methodological choices, but also by our personal lives and the things that connect us to our area of research. Our ethics also contribute to the positions we end up taking in knowledge production processes (Subramani 2019). Moreover, some theoretical inclinations are inherently tied to certain ethical positions or moral arguments. For example, applied fields like conservation research among others often embody the idea that public funds and other resources that support research should be used to give back to the ecosystems, public, communities, or governments that fund the research, or which could otherwise benefit from its results. Another example can be found in social scientists and humanities researchers working with critical theories who acknowledge injustice and inequity while challenging the structures that maintain power asymmetries. Relational approaches regarding the environment and non-humans, by focusing on relationship, acknowledge that humans co-exist with a broader set of beings and highlight the need for mutuality or kinship. Building on this connection between ontology, epistemology, and ethics, I propose an ethic of attuned inquiry. While this can be seen as bias which introduces subjectivity in research, reflexivity invites us to explicitly acknowledge our biases (as we all have them) to account for the embodied and situated nature of knowledge production (Subramani 2019).

As a researcher involved in knowledge-making processes that attend to the environment and non-humans, I find it is my duty to table ethical considerations that apply across disciplinary, professional, and species boundaries. While I started reflecting on the need to make an ethical commitment since working with cells in labs during my master’s research, its formulation has evolved over time, and I currently define this commitment as attuned inquiry. This commitment is a political and ethical stance which informs my conceptualizations of, and practices of becoming with, non-humans in research and other aspects of life. By adopting ethics of attuned inquiry, conservation research and practice could be reframed as a practice of conversations. In fact, attuned inquiry moves away from logics of control which have historically shaped the field of conservation toward logics of attunement, of educating ourselves to pay attention, of developing new modes of attention, of politeness and diplomacy, and of respectful curiosity.

This idea is in part inspired by the parliament of things and diplomatic anthropology, and the desire to create an era of compassion among humans that also includes non-humans (Latour 1997, 2004; Stengers 2011). The idea of diplomacy implies presenting oneself politely to the world: with this politeness there must be patience along with persistence. With this stance, Latour (2004) is hoping anthropology may be hopeful and contribute to future negotiations of peace among all beings. Similarly, Stengers asks us to think about the "polite questions that one creature may address to another creature" (2011: 518). Being polite is essential given that other actors can only react or try to answer our questions through what they perceive, understand, or imagine of our intentions (Despret 2010). This can apply to our attempts to include non-humans more explicitly as actors of knowledge production processes, but also in working with various actors some of which are more privileged or vulnerable than others. For Despret (2010), the idea of politeness is linked to good manners and the idea of asking good questions to keep our interlocutor interested. Attuned inquiry recognizes that both humans and non-humans are deserving of such good manners. It also recognizes that we need to pay attention to ensure we are asking the right questions, as asking good questions helps enrich the world (Haraway 2015).

Attunement can be considered as the development of a sensitivity to recognize cues from the environment, as a capacity to respond to these cues, and as paying attention to the differences that we encounter (Ingold 2015; Klenk 2018). Attuned inquirers practice and develop the skills of being attentive and responsive to others and their experiences (Klenk 2018). This can be done in the context of transdisciplinary research (Klenk 2018) but also in other life processes. Concepts of collaboration, diplomacy, good manners, and politeness come back to an epistemological commitment of conducting research by educating our attention (Ingold 2013). This is akin to wild ethics, not considered to be a set of rules or principles for right conduct but which “has more to do with a simple humility toward others – an attentive openness not just toward other persons but also toward the inexhaustible otherness of the manifold beings that compose this earthly world” (Abram 2021: 50).

Such attunement can be acknowledged and enacted – as Chapter 3 proposed – through coproduction which can include a broader variety of human and non-human actors not only in data collection processes, but also in the establishment of research questions, research design, and analysis. This is seen as essential because research methodologies not only respond to research or applied problems, they also influence the ways in which those problems are constructed (Renold and Ivinson

2022). More-than-human coproduction is thus a research practice that speaks to an ethical commitment of engaging with the non-humans with whom we are entangled, and of learning from other ways of knowing such as the more-than-human relational ontologies emphasized by some Indigenous knowledge holders and scholars (Renold and Ivinson 2022). Experiments in more-than-human coproduction have included training exercises and interactions between service dogs and dogs in training, interactions with bees through hive inspection and habitat maintenance, collecting materials in the woods to connect with underrepresented plants in forests, and swimming and boating at a rivers' mouth where fresh and saltwater blend to connect with the elements (Bastian et al. 2017). This type of more-than-human coproduction can help us reframe our cognitive frameworks, or mental models. For example, it was shown that some of these more-than-human experiments shifted the views of a beekeeper from a logic of control in beekeeping (e.g., efficacy of the method, convenience for the beekeeper, following strict timeframe) toward what we could call a logic of attunement (e.g., being mindful, having interventions that align with the natural behaviors of bees, asking if the intervention takes into account the bees' needs) (Bastian et al. 2017). Reframing conservation research and work – including practices of collecting data and intervening in the environment – as attuned inquiry makes space for more-than-human coproduction. It allows us to pay attention to the welfare of fish, turtles, but also insects, plants, and water. In doing so it challenges human exceptionalism and speciesism (valuing some species more than others or more than abiotic elements). This can be uncomfortable and can lead to cognitive estrangement as we need to step out of established ways of doing and knowing (e.g., how can we interview turtles, how does informed consent and anonymity apply to working with water), but such awkwardness can be explored productively (Bastian et al. 2017).

Conceptualizing research as attuned inquiry is also helpful to move beyond normative expectations of collaboration. This was key for this thesis, as I uncovered more and more tensions and frictions between humans and non-humans as my research progressed. Earlier, this thesis referred to literature about how collaboration and participation are not without issues (e.g., not every human or non-human may be interested in participation, it is not the best course of action for every situation, it can reinforce power asymmetries, it does not always result in better outcomes, it can be tokenistic). An attuned inquiry that pays careful attention to the different types of relationships unfolding between actors can adjust its approach and adopt or modify collaborative practices if and when necessary. An attuned inquiry would also be mindful about when it is time to back off – either temporarily or permanently – if a line of inquiry is seen as causing more harm than benefits. Beyond friction, attunement also makes space for neutrality. For quietness. For the lack of relationships. And for slow paces, slow relationships which take time to fully emerge. Attuned inquiry allows us to pay attention to relations, but also to what happens (or doesn't happen) in the gaps between those relations. This could be a productive avenue for future conservation research: how, if at all, does silence manifest itself in relationships between humans and non-humans in the context of conservation research and practice? How is it understood, perceived, experienced? What is its role? This could help make visible some key dynamics that are not always acknowledged – especially in the context of waterways where life bubbles under water, often quiet and unseen from the surface unless one is directly engaging with it (e.g., in conservation research, through snorkeling, angling, capturing, sampling, or monitoring).

In this context, attuned inquiry is two-fold. First, it is an ethical commitment anchored in paying attention to all actors involved, whether human or not, and to our relations with them in order to acknowledge their contributions as active participants of world-making processes. Second, attuned inquiry is also a form of ontological and epistemological engagement that consists of asking good questions, of asking them with modesty and restraint to be able to listen carefully to the answer, and of reacting to these answers (or lack thereof) by accounting for them in our research design, methods, and communications. This attention is crucial for conservation research to become a more-than-human practice for it is only when "we acknowledge the myriad presences around us not as objects but as subjects in their own right – as open-ended beings with their own inherent spontaneity and active agency – then we swiftly become aware of the relationships that we sustain with those beings." (Abram 2021: 50).

This last connective tissue presented my ethical and political stance. I acknowledge that there is a wide range of views among conservation researchers who are generally working to conserve and protect the environment, some of whom are already attuned to the sensibilities and capacities of non-humans. Thus, this connective tissue is an invitation for conservation researchers and practitioners to continue paying attention, to keep an open mind, to openly discuss and reflect on the roles of non-humans in research, and to develop new ways of paying attention. It is my hope that this kind of openness and attunement could not only provide us with better understandings of the frictions that contribute to a paradox in conservation research, but it could also contribute to reframing this research and changing the nature of power dynamics in research interactions. Attuned inquiry is an invitation to be curious and caring, in solidarity with others on this planet.

Conclusion

This thesis has demonstrated how collaboration and social-ecological networks are valuable to better understand human-environment relationships. It contributes to ongoing discussions in the literature that galvanizes the use of social sciences in conservation research and work about social-ecological systems (SES) (Moon et al. 2019b; Lidskog et al. 2022). In this thesis, I have mobilized strategies from sociology (e.g., social networks and reflexivity) and theories from the humanities (e.g., more-than-human relationality and new materialism) to contribute to, and analyze, the field of conservation research. Thus, my work contributes to both the natural and social sciences, to both practice and theory about what it means to conduct social-ecological research, and to including a diversity of both humans and non-humans in research.

In a broader context of tense relationships between humans and the environment – as demonstrated through climate change, biodiversity loss, and water scarcity among others – my work makes visible relational pathways to improve our relationship with nature. As interdisciplinary environmental research has shown, evidence and data can help us make informed conservation decisions (Cooke et al. 2017) and speaking with people who are directly concerned and who have different types of knowledge can help us better understand the systems that we hope to preserve, maintain, protect, conserve (Cooke et al. 2021). Beyond these strategies, I have demonstrated in my thesis that we should also explore the ways in which we conceptualize our relationships with the environment through mental models (e.g., our internal representations of the world) and our interactions with non-humans as part of this research. Our philosophical assumptions (e.g., onto-epistemological assumptions about what we think the world is and how we think we can know it) can frame the ways in which we view the relationships we have with non-humans and the environment, which is especially important to consider in the context of research that is concerned with the environment.

In this conclusion, I present some of the key results from this thesis, come back to the key argument underpinning this work, present its sociological and empirical relevance, address its limitations, and propose avenues for future research. I end by tying back to attuned inquiry (Connective tissue 4, page 125) and presenting a view of conservation as conversations.

Key results

In this section of the conclusion, I briefly review the key results of each chapter.

Chapter 1

Chapter 1 presented results of a network analysis of social-ecological maps generated by a wide range of actors with knowledge of the RC. Workshops were organized by group (e.g., community groups, economic interest groups, government representatives, academics) as we could not host all relevant actors in a single workshop due to logistics. This grouping ended up being key in the analysis. The maps were aggregated at the workshop (or group) and collective-level in order to show the convergences and divergences in views of the RC as an SES. It showed that there were some divergences in the ways in which groups conceptualized the RC as an SES (e.g., community groups perceived more social factors, academics perceived the system as more fragmented, the water quality workshop generated a well-balanced map). The collective map also revealed that overall, participants identified more social than ecological factors as influencing the RC's environmental health. As mentioned in the introduction, one of the challenges with the concept of SES is that it can reify social-ecological divides rather than generate truly holistic representations of systems. The collective map showcases an example of this through over-representation of social factors. Yet, we were still able to use people's mental models of the RC productively. For example, the workshops that brought people from various backgrounds around a specific concern (water quality concerns in the Lower Cataraqui region of the RC) produced outcomes that could be more useful in an applied setting (e.g., Mistry et al. 2021) as it can form new relationships among people who share concerns, can help obtain shared understanding, and produces more nuanced and holistic visions of the problem than group-specific workshops focused on broader issues (e.g., environmental health in the RC as a whole).

Furthermore, the collective map representing aggregated knowledge could be used by decision-makers in the context of applied natural resource management and conservation work. It not only accounts for expert knowledge (e.g., scientists from academia and government participated in the workshops) but also for local knowledge. It can be used to set priorities in the waterways (e.g., which factors were most often cited in the maps, which factors act as bridges between other factors), and to identify pathways for decision-making by looking at how specific factors are connected in the maps. For example, the discussion showcased education but concerns about invasive species could also be explored by looking at how other factors directly and indirectly connect to it. Using community identification network methods also allowed us to identify cluster of factors that we used to generate narratives. These narratives represent recent, collective understandings of the system and could thus be used as evidence to inform decision-making and policy, especially when empirical data about the system as a whole is lacking. Even though these maps are not perfect representations of the RC as an SES, these narratives can also help inform communication, engagement, education, and stewardship strategies to ensure that they align with current understandings of key actors in the system. For example, best practices could be explained, and decisions could be justified, in ways that align with current understandings, thus maximizing support from people in the system.

Chapter 2

Chapter 2 presented results from a mixed methods analysis of interactions between humans and non-humans in the context of conservation research in Ontario's National Historic Waterways. It combined social-ecological networks with thematic analysis of qualitative data to produce nuanced understanding of the range of views held by key members of the grant about their interactions with non-humans. Key results from this analysis show that collaborative relationships were seen by most as occurring between humans and few cited having collaborative relationships with non-humans, data collection networks included many technologies, informal encounters were often with other species encountered in the field, and few participants reported having tense relationships with other key members of the grant while many tensions and frictional relationships were reported with non-humans. These tensions often revolved around the manipulation of target species that could be harmful or certain elements of the environment getting in the way of fieldwork (e.g., aquatic vegetation getting caught in the boat), and some challenges arose from the use of technologies (e.g., failing technologies, frustrations during data analysis). These results indicate that the there is a paradox at the core of conservation research: conservation researchers aim to protect and conserve the environment, but their methods to achieve these goals can be harmful for the very environment and individuals that they are trying to protect. This is seen as necessary harm in the context of work that can ultimately protect broader populations of fish and/or ecosystem habitat. However, this conservation research has guaranteed benefits for humans (e.g., training, publications) while benefits are not guaranteed for the non-humans that are involved, and sometimes harmed or sacrificed. Furthermore, most conservation researchers did not think we could consider non-humans as collaborators.

Many responses either embodied the power dynamics between humans and non-humans that is at the core of the paradox (e.g., non-humans were not viewed as not collaborators but simply as objects of study), or they recognized these power dynamics (e.g., non-humans are not collaborators because they are victims of the research and cannot consent to take part in the collaboration). Some were open to considering the contributions of non-humans as teachers and collaborators, and others felt a kinship with the environment, but these views were only expressed by a small number of researchers who didn't necessarily integrate these views and values in their methods. Thus, the current framings of conservation research, and more specifically their onto-epistemological assumptions, can be seen as incompatible with other onto-epistemologies and ways of knowing which open the door to acknowledging the participation of non-humans in research and other processes. The arts and humanities, as well as some forms of Indigenous knowledge, were discussed as holding different assumptions that consider non-humans as actors and active collaborators or teachers.

Chapter 3

In Chapter 3, I built on the empirical results from Chapter 2 as well as the literature on relational and network frameworks in the social sciences and humanities to propose six practical and four theoretical insights for conservation research. This chapter argues that relational understandings from the social sciences and humanities can be compatible with the ecological and biological sciences – which themselves mobilize relational metaphors. I built on these shared understandings to propose both concrete (i.e., practical) and abstract (i.e., theoretical and conceptual) pathways to explore for conservation research to become more-than-human in the short- and long-term. Social-ecological networks were presented as a tool that can facilitate transdisciplinary research in order to work collaboratively toward these goals. Doing so rests upon developing explicit understandings of the roles of non-humans in the research, for example through social-ecological network assessments, and by working to include not only other species but also technologies and infrastructure. Conservation research could also adopt new practices. First, methodological pluralism and capitalizing on qualitative, experiential, and multimedia data and methodologies is a productive pathway that ecologists and biologists should continue exploring by working with social scientists to include broader types of evidence and data in conservation research. New practices around explicitly acknowledging non-humans and their contributions (e.g., in grant applications, publications, presentations) could also be adopted. Finally, conservation research needs to build reflexive capacity in general, but also specifically regarding relationships with non-humans.

Theoretical and conceptual insights for conservation research included the need to understand the relational and ecological nature of conservation research itself. It is not only the complex SESs that are being studied that embody social-ecological dynamics, but also the practice of research. This insight stems from the sociology of science and science and technology studies and it aligns with the need for more reflexive capacity in conservation research. It is imperative that we acknowledge how research itself influences ecosystem dynamics, and how reframing our understandings of research is a necessary step to forming more harmonious relationships with non-humans and the environment. Other concepts were presented as having the potential to support such a reframing, including the concepts of agency and more-than-human coproduction. Finally, relational and network approaches were identified as a pathway to rethink animal and conservation welfare in expanded ways (e.g., other forms of life and not just animals could be included in the welfare literature). This could help researchers move beyond concerns with welfare to ask how to become better collaborators or kins when conducting research with non-humans.

Key argument

In this thesis, I have demonstrated how we can use relational social-ecological approaches to collaboratively works toward conservation goals. This demonstration was done in two parts, first by showing the value of coproducing SES knowledge maps for policy. Second, by highlighting a paradox of conservation research in the relationships between humans and non-humans, and by identifying pathways to get out of it. These two approaches demonstrate the overall value of relational approaches and draw from the full spectrum of relational approaches. This spectrum includes both informal (e.g., Ingold’s meshworks, flat ontologies in new materialism) and formal (e.g., social networks) approaches or frameworks. Informal frameworks generally attend to the quality of relations while acknowledging their nuances, dynamism, and complexity that is not always directly graspable, and formal approaches attempt to grasp these relations through mathematical or other formal means. While the latter inevitably reduces relations to structural patterns (e.g., networks composed of assemblages of lines between dots), there are also limits to informal approaches (e.g., the meshwork is a flexible concept that makes space for nuance, process, and fluidity but it can make it hard to be precise when analyzing social phenomena or formulating research questions). Mixed methodologies that draw on both quantitative and qualitative data allowed me to attend to relations both formally and informally, thus counterbalancing quantitative reductionism while allowing me to formulate a careful and precise analysis.

As I've shown throughout my chapters, we can simultaneously draw from different parts of the spectrum of relationality to generate better understandings of SESs. In Chapter 1, social-ecological networks were used to show divergences and convergences in the structure of people's mental models, but also to generate qualitative narratives about interconnections in the RC that can be used for policy. In Chapter 2, partially articulated social-ecological networks were treated quantitatively and graphically, but the interpretation of the relationships represented in these networks were completed with people's stories and perceptions that emerged in open-ended discussions during mixed method interviews. Finally, Chapter 3 showed a range of strategies, building on network analysis but also the use of networks as metaphors, other relational metaphors (e.g., ecology), and on the relational interpretation of other concepts (e.g., agency, coproduction) for conservation research to become more inclusive of more-than-humans.

In this thesis, collaboration – a method and practice but also a type of tie among people and actors – was conceptualized relationally. Such a relational understanding helped me identify opportunities to generate enhanced understandings of SES, for example through coproduction of knowledge and collaborative workshop activities that facilitated social learning (e.g., people were paired in the workshops and asked to merge their knowledge maps of the RC). The focus on relations also helped me attend to more-than-human collaboration, by looking at the different types of ties with non-humans as perceived by conservation researchers as part of their work. Such a relational approach made visible a paradox of conservation research. Beyond enabling relational analysis, social-ecological networks could also be used as a tool to fulfill collaborative potential more effectively in conservation research (e.g., aligning potential collaborators) and to explicitly include non-humans at the outset of research projects.

While social science can either be done for conservation (e.g., applied research) or on conservation (e.g., studying conservation work and research as a social phenomenon), such a dichotomous representation of the possible contributions of social science is limiting (Bennett et al. 2017). Thus, one of the key messages I also want to share with this thesis is that we can simultaneously work toward conservation while also questioning the meaning of this work and its foundations. Doing so is necessary for the field to grow and to effectively include insights from a wide range of social sciences and humanities (Bennett et al. 2017). As policy and interdisciplinary environmental research increasingly call for inputs from the social sciences (Lidskog et al. 2022), this must be done carefully. It is not sufficient for the social sciences to simply provide advice and input for policy- and decision-makers and natural scientists; doing so could even be dangerous if it helped to implement technical solutions that could hinder broader social transformations (Lidskog et al. 2022). One of the strengths of the social sciences lies in their ability to critically analyze potential outcomes of proposed solutions and to question and go beyond problem-solving frameworks (Lidskog et al. 2022; Clark 2019). If we want to continue growing and forming better relationships with the environment and non-humans, as much as is realistically possible, we must not only draw from the social sciences to effect immediate changes in behavior and support the practical application of technical solutions. While dialogue across disciplines and theories is growing, it is imperative to keep this momentum going and to ensure that a wide range of theories and methods in the social sciences are acknowledged and able to contribute to conservation research – including relational approaches, as I have opted to do in this thesis.

Key contributions

In this section of the conclusion, I present the key contributions of this thesis both in terms of sociological impact (given that sociology is my discipline of training), but also in terms of empirical relevance and practical implications.

Sociological impact of the thesis

While the conservation social sciences – field in which I position myself – generally aim to contribute to conservation efforts (e.g., improve conservation practice, policies, or outcomes), it can also contribute to advancing knowledge in the social sciences themselves (Bennett et al. 2017). Thus, my thesis not only contributes to the interdisciplinary field of conservation research and to management of the RC and TSW, but it also has sociological impacts.

Relational analysis

First, my thesis contributes to further developing and exploring the value of relational approaches in the social sciences. It does so in multiple ways. It creates bridges between key concepts of interdisciplinary conservation research (e.g., SES) and humanities theories like new materialism through the framework of relationality. Within the social sciences, it also builds on relationality as a common framework to engage in dialogue than spans the full relational spectrum, from new materialism, flat ontologies, to actor-network theory, social-ecological network analysis, and graph theory. Thus, I work with concepts that can be boundary objects between researchers within the social sciences and humanities, as well as between the natural and social sciences. Overall, my thesis also contributes a relational understanding of collaboration in the sciences and in conservation initiatives, explores collaborative methods (e.g., collaborative workshops that enable coproduction of knowledge maps), and it brings nuance to broad calls for collaboration in the literature by considering non-humans as potential collaborators all the while acknowledging tension in research relationships between humans and non-humans.

My thesis also contributes to the development of network methods in sociology by exploring how social network analysis can concretely build on insights from actor-network theory to include non-humans. In doing so, it also explores how the inclusion of non-humans anchored in sociological and more-than-human research concepts and theories aligns – and diverges from – the social-ecological network literature, for example by including non-humans on the same level as humans rather than in distinct subnetworks. It also shows how social-ecological networks can be used in a sociology of science context, not just to explore the governance of SESs but to conceptualize research itself as an ecological, networked practice composed of social-ecological dynamics.

In terms of relational analysis, my thesis also explores the value of mental models in a conservation social science context. While mental models have been increasingly used in environmental research, especially in systems thinking and SES research using network tools to analyze externalized mental models in support of conservation and natural resource management, it is not as frequently used in the discipline of sociology. Thus, my thesis contributes to discussions about how sociology could work with the concept of mental models, which emerges from pragmatist philosophy and has been discussed cross-disciplinarily in fields such communication, psychology and cognitive studies, economics, and organizational studies (Lindstedt 2018).

Sociology of science

Second, my thesis contributes to sociology of science by providing an analysis of the views of conservation researchers on their own interactions with non-humans. It aligns with science and technology studies that often question the hegemony of western, dichotomous ways of knowing and affirming expertise. These fields not only break down dualisms between nature and culture, science and other ways of knowing, but also between humans and non-humans. As the discussion in Chapter 2 highlights, the arts are especially helpful to question assumptions and expand the roles that we see as possible for non-humans to have in research processes. While I engage more directly with new materialism, insights and authors from this field also overlap with ecofeminism (e.g., Haraway 2008, 2016) thus my thesis can contribute to discussions in these fields. While I work with network analysis which is sometimes seen as conflicting with new materialism and other informal relational strategies, I value the insights about more-than-human research emerging from these fields. These insights allowed me to better understand research and knowledge-making processes, while also showing how network strategies can be a useful strategy to operationalize discussions tied to insights from more-than-human research.

Human-environment relationships

Third, my thesis contributes to our understanding of human-environment relations both via analysis of people's views of waterways as an SES and via analysis of conservation researchers' views of their relationships with non-humans in this SES. Given the recognition that epistemological errors, such as assumptions of humans as beings that are separate from nature, have resulted in destructive and harmful practices for the environment, there is much talk about rethinking human-environment relationships (Clark 2019). In Chapter 1, I explore how the framework of SES and knowledge mapping make visible social-ecological interconnections to further the discussions about humans-environment relationships. Beyond this, Chapter 3 explores both practical and theoretical avenues for rethinking human-environment relations in the context of research.

To me, this is essential because conservation and environmental research generate evidence and recommendations for policy, decision-making, and other conservation actions. However, if the research producing this evidence and these recommendations is based upon colonial or positivist assumptions, then the evidence and recommendations will also embody these assumptions. Thus, challenging the assumptions held by researchers is essential, but it requires both short (e.g., use networks, practice reflexivity, acknowledge non-humans contributions in publications) and long-term strategies (e.g., can conservation research acknowledge the agency of non-humans, what could more-than-human coproduction look like in the context of conservation research, what innovations could be developed in the welfare literature to acknowledge not just animals but also other life forms and even abiotic elements of the environment). While no single thesis or paper can fully rethink human-environment relationships to ensure more sustainability, respect, and mutual benefits, my thesis contributes to ongoing discussions on how to achieve such a rethinking.

Transdisciplinarity

Finally, my thesis contributes to how sociology can align itself with other disciplines to conduct conservation research, and with other professions to contribute to conservation. While my work is quite applied in that it seeks to identify pathways to support more effective policy and research (Chapters 1 and 3 especially), I show the value of key sociological concepts such as agency, power, and social networks and how they can be used in local and regional conservation research and work (Bennett et al. 2017). In contrast with other social sciences like anthropology and human geography, sociology has only recently started being considered in conservation and sustainability research (Bennett et al. 2017). Thus, my thesis is a significant contribution to building on these recent conversations between sociology and interdisciplinary environmental research. Furthermore, by mobilizing boundary concepts (e.g., networks, SES), I show how sociology can engage in productive cross-disciplinary dialogue.

Finally, my thesis also shows how we can practice reflexivity in transdisciplinary conservation research. More specifically, the connective tissues provide examples of how to put our research into context and acknowledge the situations that influence how we produce knowledge. My connective tissues thus acknowledge my history (e.g., discussion of a past research project) and philosophical assumptions, and how these elements feed into my methodological and conceptual decisions.

Empirical and practical relevance

Beyond its sociological impact, my thesis also has empirical and practical relevance. Empirically, I have generated data that features local and scientific knowledge about the RC as an SES. This can be used to inform policy, engagement, and communication strategies. Chapter 1 is also an example of how collaboration could be used in applied research, but also in other conservation contexts. Furthermore, the workshop strategy was summarized in a report, created by the social science team in collaboration with a community member who helped us organize the workshops, for others to possibly conduct their own knowledge mapping workshops (Mistry et al. 2020). As such, this project also has social relevance as the data and methods featured in this thesis can support future research but also the participation of locals in co-governance and management in the RC and TSW, and beyond.

This research also contributes empirical evidence about a paradox found in conservation research and shows that this paradox is stronger in conservation research than among community members and government representatives who work toward conservation through actions that directly support non-humans in the environment. This is an important empirical insight. Furthermore, the social-ecological networks featured in Chapter 2 show different types of relationships between humans and non-humans, providing us with empirical evidence about collaboration and tension in conservation research, as well explicitly acknowledging the overwhelming presence of technologies in such work. Practically, I proposed pathways to challenge the assumptions of conservation research about non-humans in Chapter 3 – these pathways and insights can benefit conservation researchers but also practitioners and community stewards who work with or use evidence from the conservation research field.

Generally, the social sciences can contribute empirically and practically to conservation in many ways. For example, it can describe phenomena, diagnose or evaluate success and failure in conservation, disrupt existing power asymmetries, engage reflexively with the assumptions underlying conservation actions, generate innovations (e.g., news ways of thinking, new planning strategies), and finally the social sciences can be instrumental for conservation (e.g., to support governance, design better conservation models, obtain support for conservation initiatives, ensure ecological outcomes, develop equitable processes) (Bennett et al. 2017). In this sense, my thesis is disruptive, reflexive, generative, and instrumental. It is disruptive in that it includes a diverse set of actors in knowledge coproduction (Chapter 1) and also explores how we could include non-humans as actors, and possibly collaborators, of conservation research (Chapters 2 and 3). Thus, it addresses power asymmetries across disciplinary and professional boundaries (recognizing the value of social and natural science knowledge, recognizing the value of local and institutional knowledge and not just academic expertise), but it also makes visible the power asymmetries between humans and non-humans in conservation research itself. My thesis is reflexive in that it explores social-ecological narratives anchored in local knowledge to establish management priorities as well as challenging current framings of conservation research. The connective tissues also show how reflexivity can be applied to ones' own work. Finally, it is generative and instrumental in that it provides tools and strategies (e.g., knowledge maps representing mental models, network analysis) but also outcomes (narratives and pathways) to support governance and inclusive, equitable processes for conservation and natural resource management in the RC and TSW.

Limitations and future research

There are a number of limitations tied to this thesis. Some of these are tied to specific concepts, to the overarching theoretical and methodological frameworks, or to specifics of the different chapters. While providing an overview of some limitations of my thesis, I also propose how future research could address these limitations. This overview of limitations is non-exhaustive, but it aims to acknowledge the biggest drawbacks of my research.

Concepts and methods

First, we must acknowledge the limits of the concept of SES. Though the concept can help sociologists include ecological concerns in their research, it is not the most useful concept for sociology in its current form. It has a limited definition of the social world which can fail to address core dimensions of sociological investigation like power, discourse, and class (Thiel et al. 2015; Bennett et al. 2017). Furthermore, despite attempts to mobilize other relational approaches to counter the social-ecological divide that is inherent to the concept of SES, this thesis reifies this divide in some ways. Chapter 1 specifically classified nodes as social or ecological and while Chapters 2 and 3 also include technical nodes, these are still strict classifications that consider humans as distinct from other types of nodes. Future research could conduct network analyses that aren't based on such classification and could create node classifications around the functions of nodes in the network, structural equivalence, community clusters, or other network analyses (Scott and Carrington 2011). Furthermore, future research could also propose new definitions for the concept of SES. I argue that the concept remains useful because of its ability to act as a boundary object across disciplinary and professional boundaries, and that perhaps we should keep using this terminology which is now well-established, and which has credibility in various fields. Yet the concept likely needs to be redefined as it is now commonly use in ways that go beyond systems research, and to integrate social and ecological actors or components more effectively.

There are also limits associated with using networks as an operationalization of the relational framework. My goal was to highlight the fact that relational frameworks across disciplines and theories share commonalities on which we can build to develop more-than-human conservation research, for example by showing that the humanities, social sciences, and ecological sciences all use relational networks even if it is in distinct ways. However, future research could explore with more depth the similarities and distinctions, and the (in)compatibilities between social network analysis and other relational frameworks in the social sciences, like actor-network theory and Ingold's meshwork. There are also limits inherent to formal approaches like networks. For example, data collection is lengthy and showing the evolution of network relationships usually requires taking multiple measures, which can be costly in terms of resources. Furthermore, for this thesis I worked in a constrained amount of time bounded by the length of the NSERC SPG and my own PhD funding. Thus, I was only able to include one measure of the social-ecological network of the NSERC SPG and I couldn't see if these networks changed over the course of the project. Future research could thus include social-ecological network assessments at the outset of conservation research projects rather than only as an outcome of research. This would allow for the explicit design of more-than-human conservation research and would also allow for collecting multiple instances of data throughout the project to track the evolution of social-ecological research networks.

Another limitation of the network approach used in Chapters 2 and 3 is that the data collected only allowed me to build partially articulated social-ecological networks (Sayles et al. 2019). This is limiting even if it can be a valuable trade off that still helps address questions focused on better understanding relationships (Sayles et al. 2019). Fully articulated social-ecological networks could be established by collaborating with ecologists or biologists who are collecting data that could be used to create networks. For example, in the context of the NSERC SPG, I could have explored the potential for telemetry data showing fish movement, or genetic data identifying turtle populations, to create networks – with ties based on visits to the same locations or genetic closeness. Such efforts should be explored in future research.

There are also limits tied to mixed methods frameworks. While these are generally seen as valuable and allow to collect empirical data that is complementary, with qualitative data to contextualize quantitative analysis, having to handle different sets of data and multiple layers of analysis can make it harder to explore each set of data in depth. While I had training mostly in ethnographic and qualitative methodologies, I had a limited amount of time to learn network methodologies. Given the fact I also engaged in thematic analysis of open interview questions and given the fact that I was mostly dealing with partially articulated networks, I made the decision not to conduct advanced network statistics (e.g., exponential random graph modelling). Future research could look at applying these methods to my data or similar types of research to further compare and explore the structural differences and commonalities of various relationships in social-ecological networks of conservation research.

Other limits of my research include the challenge of trying to bridge disciplines through the relational framework. While the focus on relations does establish some basic compatibility and overarching commonalities to various approaches in the humanities, social sciences and natural sciences, there is still a need to address onto-epistemological differences some of which may be incommensurable. While I started addressing these questions in my thesis, especially in Chapters 2 and 3 by unpacking the onto-epistemology of conservation research and how this could be challenged by new materialism, relational frameworks, and indigenous knowledges, doing this work is a significant task and my thesis has not fully resolved these questions. More work is required in this area. For example, future research could survey researchers not only in a specific project but across universities, disciplines, professions (e.g., include government and community partners), and cultures (e.g., in Canada include local Indigenous peoples, immigrant communities) to try and identify underlying ontological and epistemological assumptions, how these are related, how these inform various research and action strategies in conservation, and if they are tied to different ethical attitudes regarding non-humans. Case studies on specific projects could also focus on learning more about onto-epistemological differences as well as provide opportunities to develop individual and collective reflexive capacity. Tied to this, there are limits to using mental models in research as they are incomplete representations of reality and may contain errors. However, careful use of mental models in research is still valuable for conservation (Moon et al. 2019a). Furthermore, the exploration of the value of mental models in Chapter 1 was fairly brief and could be further investigated in the context of sociology and conservation social sciences.

Sampling

Finally, as in any research, there are limitations tied to the sampling strategies and the pool of participants of the different research activities. In Chapter 1, the list of potential participants was establishing by looking for groups and individuals explicitly working on or around the RC online, by asking for contacts from our collaborators at Parks Canada, and by having the list vetted by other researchers who have been working in the RC for years. However, some people in the list were simply not available to join the workshops at the time at which they were scheduled. These people were later interviewed when possible, but they did not participate in the knowledge mapping exercise. Furthermore, people who do not have a visible presence or working collaborations in the RC were not included. This is a frequent challenge in social science research: how to do you reach people who do not want to be seen or involved, or who are not interested in the topic you are studying (e.g., conservation in the RC) even though their input would be valuable? Furthermore, we couldn't establish solid contacts which Indigenous peoples and communities to whom we reached out, thus Chapter 1 mostly represents the views of settlers. As mentioned in Chapter 1, the participants of the workshops were also skewed toward older white men, thus revealing the mental models of a particular subset of people who are involved with the RC: those who are privileged enough to have time to volunteer in community groups or to participate in the workshops. Future research should explore methods that are compatible with the schedules, resources, and worldviews of other groups (e.g., youth, women, immigrant populations, Indigenous communities concerned with the RC).

In Chapters 2 and 3, empirical data was based on mixed method interviews with key members of the grant. The list of potential participants was built from online searches to identify people working in the grant and snowball sampling to identify others who may not have been publicly named. Having knowledge of the grant as a PhD student conducting social science work for the project, I was able to validate that the core contributors of the grant were included, and the response rate was extremely high (81.25%, 26/32 including myself). However, my validation was skewed by the fact that I worked with the social science team and not as closely with other teams. Furthermore, the network data collection revealed that key grant members worked with community partners and some government partners that didn't overlap and who didn't attend annual grant meetings, thus they were not included as key grant members and were not interviewed (see Figure 3.1). It is also of note that key members of the NSERC SPG didn't represent every discipline that works in conservation research, including no Indigenous scholars. Furthermore, since the team had very few Indigenous partners (only one biologist was working with one Indigenous partner, who was not identified as a key grant member at the time of the interviews), their views about relationships with non-humans were not included even though participants talked about these views, and colleagues of mine both in the natural and social sciences thought that their insights could be useful to explore relationships with non-humans. While it is a limit, this sampling does reveal that despite efforts, not every conservation research project is able to develop partnerships with Indigenous peoples, especially in projects where researchers and governmental partners have few existing ties with local Indigenous communities, and in areas like the RC which features a history of colonial tensions. Yet, it would have been interesting to compare Indigenous views to non-Indigenous views in the context of non-human relationships in research projects, and thus future research could apply the same method to a range of research projects featuring different partnerships and different ways of knowing. This could also help us explore if, and how, network methods are compatible with other ways of knowing. Efforts at reconciliation and decolonization need to continue both within conservation research contexts and beyond.

Other future considerations

Beyond the future research identified above in relation to the limitations of my thesis, there are other avenues that should be considered. Some of these have already started to be explored in the literature, but more work is required.

There could be more work done with mental models and collaborative workshops focused on specific social-ecological issues (e.g., water quality as was done for one workshop – other topics that could be specifically addressed include invasive species with different workshops to focus on specific species, private development in some areas where it is becoming problematic, and conflicts between different user groups). There could also be more statistical work done with mental models and combining insights from the psychological and cognitive sciences with conservation social science and research more broadly. Relational perspectives could be helpful to explore if and how relationships between actors influence their mental models and to evaluate the social learning value of collaborative workshops where people are instructed to merge their mental models as was done in Chapter 1.

Building on the topic of workshops and mental models, workshops could be developed for conservation researchers and practitioners that include explicit training on mental models, ontology, epistemology, justifying methodological choices, ethics, reflexivity, and other key social science concepts. These workshops could be valuable by (1) providing a training opportunity for everyone to learn about how concepts and insights from the social sciences can help improve social-ecological and human dimensions research, (2) by providing opportunities to evaluate knowledge about these topics and skill levels in using these concepts before and after the workshop, and if learning about these concepts influences conservation research processes and outcomes, and (3) by creating opportunities for networking and co-creation. Such workshops could help establish trading zones that can be both used to generate data for analysis (i.e., to conduct research) and to strengthen conservation research practices (e.g., by building capacity and skills, by creating new ties in networks). Furthermore, scientific expertise whether from the natural or social sciences, even if it is critical and reflexive, cannot in and of itself generate the necessary social transformations for 21st century western society to develop a sustainable relationship with the planet (Lidskog et al. 2022). Other forms of knowledge and actions are necessary, as shown in the conservation research networks by the involvement of community groups, government representatives, and most importantly non-humans. The workshops would thus need to be inclusive of not just researchers, but of the whole range of actors who are involved, and who could be involved, in conservation efforts.

Finally, my thesis highlights that work to conceptualize more-than-human coproduction needs to be expanded. This concept is still exploratory but has the potential to be operationalized through methodological innovations. Having been involved in some research on living labs (Beaudoin et al. 2022b), which is a collaborative innovation approach usually involving co-creation, I believe there is some potential to explore and operationalize more-than-human coproduction in such contexts which also makes space for testing new practices.

Furthermore, work about non-humans is generally difficult to grasp even when we are working with individual actors (or individual nodes as in networks). For example, networks generally include individuals or clearly defined groups such as fish or turtles, and could include other individual elements like rocks. A bounded body of water can also be relatively easy to conceptualize, but water always leaks as bodies of water are not hermetically bounded. As streams, rivers, and waterways inherently connect different bodies of water, and these connections vary in intensity, it can be harder to operationalize this type of connection through networks. Thus, we can think of the actors within the waterways to form networks, but what about the waterways themselves? And what about forests, fields, wetlands? This is a challenge of scale. While current understandings of coproduction with more-than-humans often speak of specific species, for example working with pigs as collaborators of permaculture (Emel et al. 2015), could we think about conceptualizing ecosystems (or SESs) themselves as actors or potential collaborators? What would agency look like if we were to speak at the scale of landscapes, waterscapes, or climate? These are questions that will be essential to tackle in the context of more-than-human conservation, especially as the Convention for Biodiversity plans to conserve 30% of the planet by 2030. Such goals show a desire to work at larger scales, and to consider the dynamics between humans and non-humans at these scales. We can also use reflexive capacity to question the desire and perceived need to work at this scale, where this need comes from, and what it means in the context of the conservation research.

Conservation as conversations

> **Living as part of the whole starts from the essential insight that we are already participants**: we are part of the cosmos, always in relation with each other and the more than human world, glorious yet temporary centers of awareness and action in an interconnected whole. Yet, in other ways, the idea of living as part of the whole is aspirational, even utopian in that it offers a vision of humanity far from our present state. **As David Abram puts it "we no longer live in convivial relationship with the more-than-human-world, and that in itself is precarious"** (1996, p. ix). In this view, the purpose of education and inquiry becomes to heal the wounds brought about by the dualism in which we have been marinated.
>
> Living as part of the whole is not a regression from the objective consciousness of Enlightenment thought to an earlier and more primitive "participation mystique" or "original participation" (Barfield, 1957) in which human beings are mythically embedded in their world with no differentiation of consciousness. Rather it reaches forward, toward an emergent quality of participation which is self-aware, reflexive, in which human experience is highly autonomous and differentiated, and yet recognizes it is embedded in its world. The human mind is neither undifferentiated nor embedded, but arises in the evolution of the cosmos, is an expression of the being of the cosmos, is the cosmos rendered self-aware, the perspectives we bring enable us to directly participate in the self-disclosure of the world (Ferrer, 2002).
>
> **The point, very simply, is that we are part of it all, and the moral and practical issue for all humans is to learn to live in a way that does justice to this participation**.
>
> (Reason 2005: 39-40, emphasis is mine)

Building on Connective tissue 4 that precedes the conclusion, I want to conclude this thesis by calling for conservation research to be seen as a practice of conversations. I have talked throughout this thesis, especially in Chapters 2 and 3, about needing to rethink conservation research – including its philosophical assumptions, concepts, and methods – in order to innovate and develop more-than-human conservation research. While I proposed practical and theoretical insights and pathways to do this work, a simple way to summarize these insights is that conservation research could be seen as a relational practice, a conversation. Given that humans are part of the whole (Reason 2005), of the unbounded meshwork (Ingold 2010) of life and matter that connects beings and actors on this planet, conversations in conservation should go beyond dialogue between humans to include dialogue with non-humans. I joked at the beginning of this PhD that I wanted to interview fish and turtles. I did not quite achieve this goal in my thesis, partially because I was unable, due to the COVID-19 pandemic, to meet with ecologists in the field to explore this option while they worked with fish and turtles. However, I established a conversation with the RC. Working on the NSERC SPG for my thesis was a privilege in that it gave me time to pay attention, to become attuned to the vitality of the waters, to ask the RC questions and carefully listen for its answers, to meet others who could teach me about its history and their own relationships with this space. I used an underwater camera to film some images of fish hiding in the rocks in shallow waters near the Hogs Back lock station. I captured images of vibrant green algae, gently floating below the water. I walked along the canal walls while travelling across the City of Ottawa for my personal affairs. I went skating and canoeing with friends around Dow's Lake and the downtown Ottawa canal area. I visited the locks at the Ottawa River, Jones Falls, Narrows, Kingston Mills. I took pictures of the flowers, the infrastructure, and the humans inhabiting these spaces (see https://chbeaudoin.wixsite.com/envsocialscience/interactive-map). I spoke to lock staff and learned from their practical knowledge. I rode in a voyageur canoe with my colleague and others whom I had just met at Rideau Paddlefest off the land at Lower Beach Park in Smiths Falls, onto the Rideau River that's part of the RC. I met with Parks Canada at their offices next to the Peterborough lift lock and the Smiths Falls combined locks. I formed relationships with community members when we met in cafes near the waterway for interviews. I learned from ecologists, biologists, engineers, planners, scientists from universities and government agencies during meetings at Carleton University, conference calls, and other meetings held online due to the COVID-19 pandemic.

Seeing conservation as a practice of conversations is not just a matter of research. It is also a matter of how we live and how we engage in relationships with the environment in our personal lives. Conservation goes beyond theory toward practice: we must walk the talk. In doing so, we must reflect on how we can confront institutions, how we can confront the traditional ways of doing research when we need to do research a certain way to even be included by these institutions, and how we can create opportunities for those with less power to confront these institutions and still be included. This includes not only considering how power dynamics affect students, people of color, Indigenous people, people with mental health issues, the LGBT+ community, but also non-humans. I keep asking myself, how could we seriously consider non-humans if we aren't willing to give them a seat at the table. Some may say – as my research has shown – that it's not possible to give them a seat at the table. They may say that it would be impractical to have aquariums for each species placed on chairs around a table given the fact that they can't write a text or contribute to research budgets. But perhaps, the question isn't about how to create space for them at our table and how to force them into our conversations. Rather, the question could be about where we can place the table so that the fish, turtles, waters, rocks, students, Indigenous communities, and others can comfortably find their own seats and feel able to initiate and guide conversations.

In closing, I was recently inspired by Dr. Zoe Todd's keynote talk at the Environmental Studies Association of Canada this year (May 2022). She talked about researching freshwater fish futures in the context of social transitions. She talked about the colonial history of western science and academic institutions in Canada, about the whiteness of the conservation research field – which I admit was also over-represented in the NSERC SPG research team. She talked about the status quo within academic fields and institutions which reproduces power asymmetries, both among humans and with non-humans. She talked about the possibility of considering fish as scientists who themselves have their own epistemology and methods of operating in and learning about the world. So when we write a paper, could we ask what it would look like if instead we didn't write at all and created films or multimedia maps to present the results? Can we try to find a way to interview fish and turtles, to make research a two-way conversation? Can we try to improve the ways in which all types of partners contribute to research design and not only those who are privileged enough to have the time and resources to seek out researchers? And if current methods don't allow for it, if research institutions and our colleagues don't take it seriously, maybe it just means that we are going in the right direction, and that we need to continue putting our efforts into pushing forward while pushing back on existing assumptions. It will be hard, but that doesn't mean it shouldn't be tackled and shouldn't be done. Transformations are hard, tense, and embody friction. If we truly want to do things differently, if we want to work toward a sustainability transition, we need to develop more convivial ways of living with the environment. This is not just an academic or a research process, it's the process of a lifetime, the process of a collectivity, and it requires commitment to try and contribute to productive change. So that my young niece and nephews have a real shot at developing their own relationships with the RC, and the fish, and the turtles, and the aquatic vegetation that call the RC their home.

I've been privileged to work with conservation scientists and social scientists who are aware of these tensions, who are actively working on these issues. Who confront institutions and try to do things differently, whether it be through community science, building on the enthusiasm of locals who approach us, by questioning the role of and new modalities of data, or by creating sounds, images, and films that touch us in deep ways. I hope that this thesis, too, contributes productively to these conversations.

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Appendices

Appendix 1. Proof of articles submitted for publication.

Chapter 1: Article published at Environmental Science & Policy.

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Outline

Figures (2)

ELSEVIER

Environmental Science & Policy
Volume 128, February 2022, Pages 299-309

Collaborative knowledge mapping to inform environmental policy-making: The case of Canada's Rideau Canal National Historic Site

Christine Beaudoin [a], Isha Mistry [b], Nathan Young [a, b]

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Highlights

- Collaborative knowledge mapping elicits a range of knowledge and perspectives.
- Our method aggregates views of the Rideau Canal as a social-ecological system.

Chapter 2: Article submitted to Social Science Information in June 2022.

Re: Submission of a research article

Nature + Culture <[redacted]>
Sun 2022-06-19 4:00 PM
To: Christine Beaudoin [redacted]
Cc: Jana Schoppe <[redacted]
Attention : courriel externe | external email
Dear Christine Beaudoin,

Your manuscript entitled "The value of social-ecological networks and relational metaphors: Practical and theoretical insights for more-than-human conservation research" has been successfully submitted to Nature + Culture. Upon receipt of new submissions, the Editors consider the paper's appropriateness for N+C. We have begun this process with your paper and notify you in the near future whether the paper has been sent for the full review process.

Thank you for considering Nature + Culture as a possible outlet for your work.

All best,
Jana Schoppe, Managing Editor

Chapter 3: Article submitted to Nature and Culture in June 2022.

Social Science Information SSI-22-0075

Social Science Information <[redacted]>
Sat 2022-06-18 3:13 PM
To: Christine Beaudoin <[redacted]>
Attention : courriel externe | external email

18-Jun-2022

Dear Miss Beaudoin:

Your manuscript entitled "A paradox of conservation research: Collaboration and friction with non-humans" has been successfully submitted online and is presently being given full consideration for publication in Social Science Information.

Your manuscript ID is SSI-[redacted].

You have listed the following individuals as authors of this manuscript:
Beaudoin, Christine

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Sincerely,
Thomas Coppey
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Appendix 2. Collaborative Conceptual Modelling workshop methodology

Chapter 1. Supplementary material 1: Collaborative Conceptual Modelling workshop methodology

Collaborative Conceptual Modelling (CCM) mobilizes systems thinking in order for participants to articulate and blend their mental models through mapping activities (Newell and Proust 2012). The CCM approach includes multiples activities that aim to produce a collaborative and iterative understanding of a problem and identify the key variables related to the problem. These activities support social learning but also the identification of leverage points and possible actions for the future.

The overarching questions for the workshops were: “What can be done to maintain or improve environmental health in the Rideau Canal?” and “What can be done to maintain or improve water quality of the Lower Cataraqui region of the Rideau Canal?”.

Four activities from the CCM approach (Newell and Proust 2012) were selected for the workshops:

1. “What are the challenges?
    - Individually listing the top five factors that influence and are influenced by the environmental health of the Rideau Canal or water quality in the Lower Cataraqui.
2. “What are the stories?”
    - Creating a collective timeline to identify how these factors came to be.
3. “Can I see how you think?”
    - Identifying the relationships among factors through mapping.
4. “What are the leverage points?”
    - Discussing leverage points for effecting change.

Logistics before the workshop included: identifying the time and location for the workshops, identifying potential participants and extending invitations, confirming the list of participants and sending out preparatory material to participants. The preparatory material consisted of the agenda, the workshop discussion questions, a PDF of the workshop presentation. To prepare for the timeline activity, participants were also asked to bring an event, piece of information or study that impacted the environmental health of the Rideau Canal or the water quality of the Lower Cataraqui.

Logistics at the workshop included having media equipment to display the PowerPoint presentation (a laptop and projector), having blank papers for the listing activity, creating a large horizontal timeline with pieces of flipchart paper and having sticky notes to add events, having blank papers for the individual mapping and providing a flipchart paper for groups to merge their maps, as well as having a flipchart paper to record leverage points discussed in the last activity. Materials include blank paper, flipchart paper, markers, tape, pens, sticky notes and the media equipment. At least two of the authors (CB and IM) were present at all workshops to lead and facilitate the activities. In some cases, the third author (NY) was also present as a facilitator.

The workshop started out with an overview of the research project as well as the purpose and objectives of the workshop. We provided a brief explanation of systems thinking and the CCM approach and also explained how we conceptualized the Rideau Canal as a social-ecological system. After presenting the agenda and overarching questions, we started the first activity. Our working question for this activity was “What factors enhance or diminish the environmental health of the Rideau Canal?” or

“What factors enhance or diminish the water quality of the Lower Cataraqui reach of the Rideau Canal?”. Participants had 10 minutes to create a list of 5 factors. They were asked to be as specific as possible and ensure that the factors are variables that can vary up and down. 10 minutes were allocated for sharing the factors among the group.

The working question for the second activity was “How did these factors come to be?”. One workshop facilitator went around the table asking participants to provide an event or piece of information to add to the timeline while another facilitator took note of the events and arranged them in chronological order on the flipchart timeline. After going around the table, participants were given the opportunity to provide more elements for the timeline. Around 10 minutes were allocated for this activity, which was followed by a 10-minute break. Sticky notes and markers were left out during the break so that participants could add more elements to the timeline.

After the break, the facilitators presented the third activity and working question to participants: “What are the relationships among the factors?”. The facilitators provided an example of the mapping as well as guiding points for participants. This activity was separated in three parts. First, participants had around 15 minutes to create an individual map with “Environmental health” or “Water quality” as a central factor placed in the middle of their sheet of paper. They were asked to add around 10 factors on their paper and to connect them with arrows showing the direction of influence. Second, participants were asked to merge their individual maps in groups of two or three, and to include around 20 factors in their maps. They had 30 minutes to complete this activity. Finally, 15 minutes were allocated for each group to share the content of their maps.

The final activity centered around the working question “What can be done to improve the environmental health of land and water in the Rideau Canal?” or “What can be done to improve the water quality of the Lower Cataraqui Region of the Rideau Canal?”. The goal of this discussion was to identify leverage points in the system. Facilitators returned to the main question and asked participants to identify the types of intervention that would contribute to positive environmental outcomes.

Our team has unpacked workshop results from the water quality workshop along with interview data from people in the Lower Cataraqui region of the Rideau Canal in a new publication (see Mistry et al. 2021). Additionally, we have created a report to provide more information to groups who may want to host their own CCM workshops (see Mistry et al. 2020).

Appendix 3. Network analysis glossary

Chapter 1. Supplementary material 2: Network analysis glossary

This supplementary material provides a glossary of network terminology that is used in the paper. The documentation for the sna package in R (Butts 2019) provides more information about how each measure is conceptualized in the programming language.

Node: A node or vertex in a network refers to the points which can be connected.

Tie: A tie or edge in a network refers to the link between two nodes.

Network size: Number of nodes or vertices in a network.

Network density: Proportion of actual ties in the network divided by the number of possible ties in a network. See function *gden* in Butts 2019.

Dyad: A dyad is a pair of nodes in a network. Each dyad can be null (no tie between *v1* and *v2*), mutual (reciprocal tie between *v1* and *v2*) or asymmetric (non-reciprocal tie coming from *v1* to *v2* or from *v2* to *v1*). See function *dyad.census* in Butts 2019.

Triad: A triad in a network is a group of 3 nodes.

Dyadic reciprocity: Refers to the proportion of mutual or symmetric dyads in a network. See function *grecip* in Butts 2019.

Edgewise reciprocity: Refers to the proportion of connections or ties that are mutual or reciprocated in a network. See function *grecip* in Butts 2019.

Network components: Components are maximal subsets of mutually connected vertices in a network. The connected parameter can be characterized by different strengths to identify several types of components. See functions *components* and *component.dist* in Butts 2019.

> **Strong component:** In strong components, connectedness exists if there is a directed path between *v1* and *v2* as well as a directed path between *v2* and *v1*.
>
> **Weak component:** In weak components, connectedness exists if there is a semi-path from v1 to v2 (that is, a path in a symmetric graph).

Centrality and centralization: Centrality is a node-level measures while centralization is a graph-level measure. These provide insight on the the position of nodes in a network as well as the structure of the network. See functions and *centralization* in Butts 2019.

> **Degree centrality:** Score refers to the number of ties that a node has. In directed networks, we distinguish incoming and outgoing ties through in and out degree centrality. This measure helps identify the degree of connection of a node or network. See function *degree* in Butts 2019.
>
> **Betweenness centrality:** Score represents the shortest-path betweenness of a node. It refers to the extent to which a node lies on the shortest path between other nodes, thus allowing us to identify individual nodes that act as bridges and the intensity of bridging in a network. See function *betweenness* in Butts 2019.

Eigenvector centrality: Score represents that values of the first eigenvector of the graph where the centrality of each actor is proportional to the centrality of connected nodes. Thus, it takes into account the connectedness of multiple nodes, thus giving a sense of influence throughout the network and not just on directly connected nodes. See function *evcent* in Butts 2019.

Structural equivalence: Structural equivalence refers to the extent at which nodes are connected to the same other nodes in the network. See function *sedist* in Butts 2019.

Regular equivalence: Regular equivalence refers to the extent to which they play similar structural roles in the network, that is, if they are connected to similar types of nodes. See function *redist* in Butts 2019.

Quadratic Assignment Procedure (QAP) hypothesis tests: Linear regressions that are adapted for network data test hypotheses through the QAP procedure. This test controls for the underlying network structure. See functions *qaptest* in Butts 2019.

Louvain community detection algorithm: This function finds community structures through the modularity measures with a hierarchical approach. See function *cluster_louvain* in Csardi and Nepusz 2006.

Appendix 4. Pair-level network graphs and data

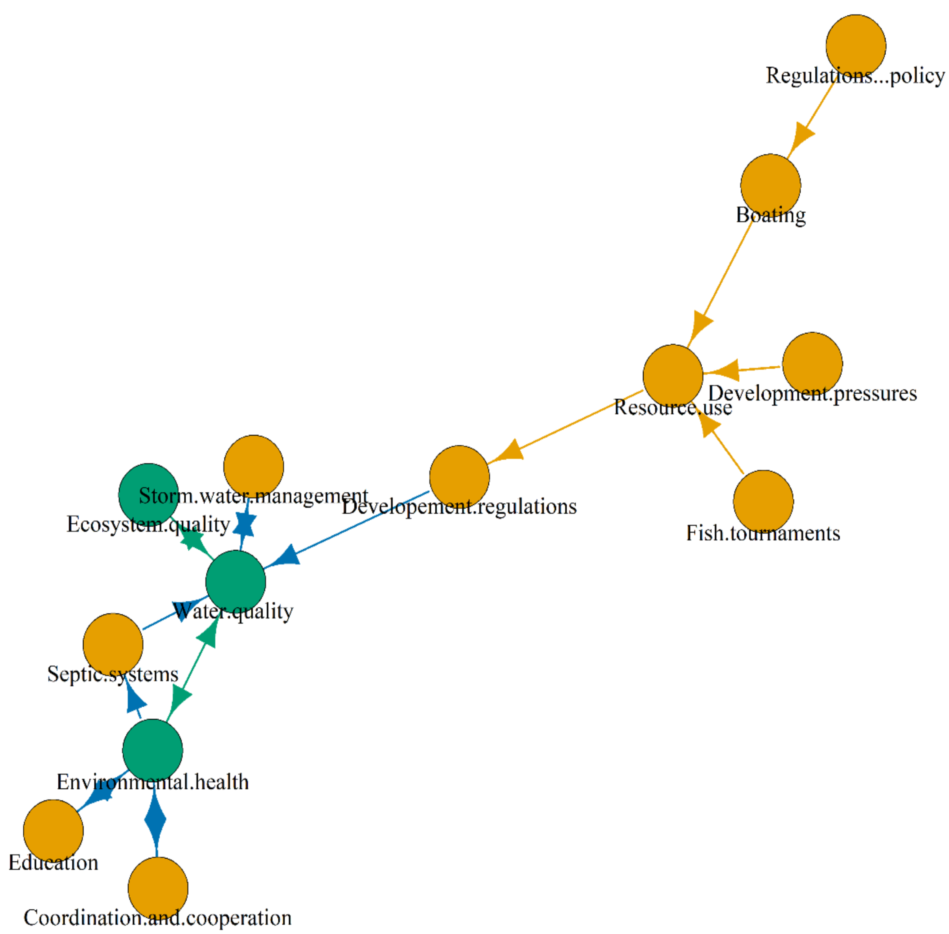
Chapter 1. Supplementary material 3: Pair-level network graphs and data

Legend that applies to all network graphs in this appendix

Orange nodes: Social nodes **Green nodes:** Ecological nodes
Orange ties: Social ties **Green ties:** Ecological ties **Blue ties:** Social-ecological ties

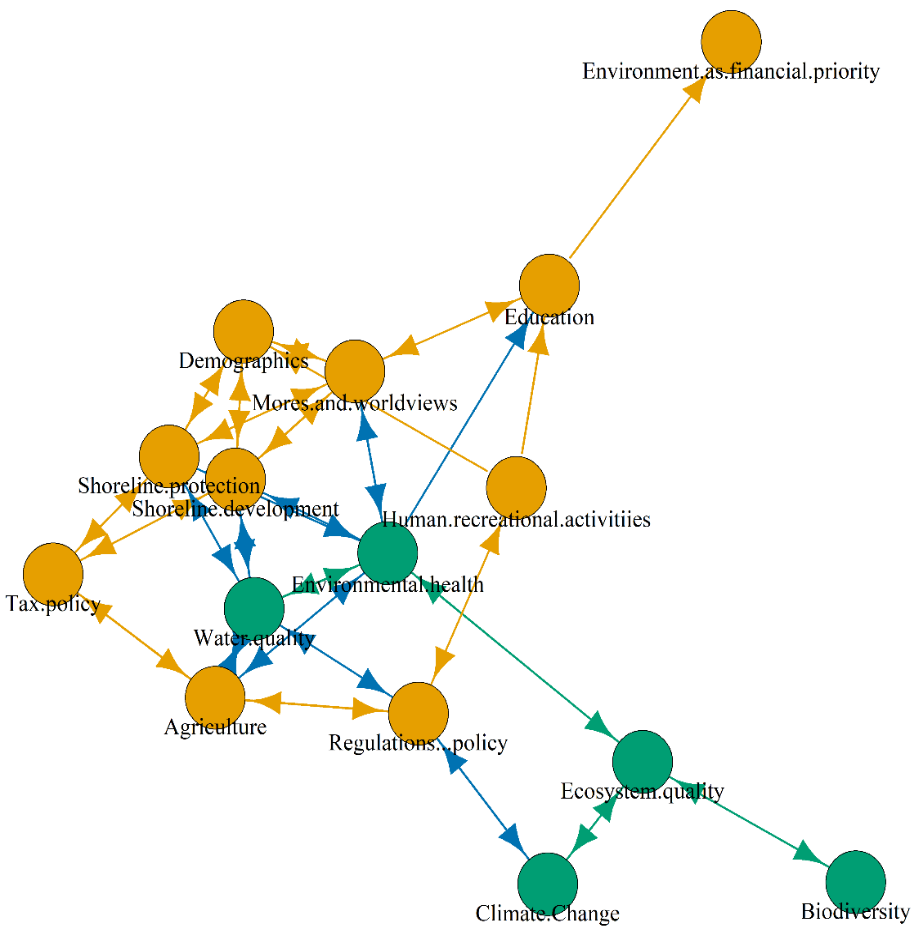
Pair-level networks for the community and environmental groups

Pair 1: Community and environmental groups

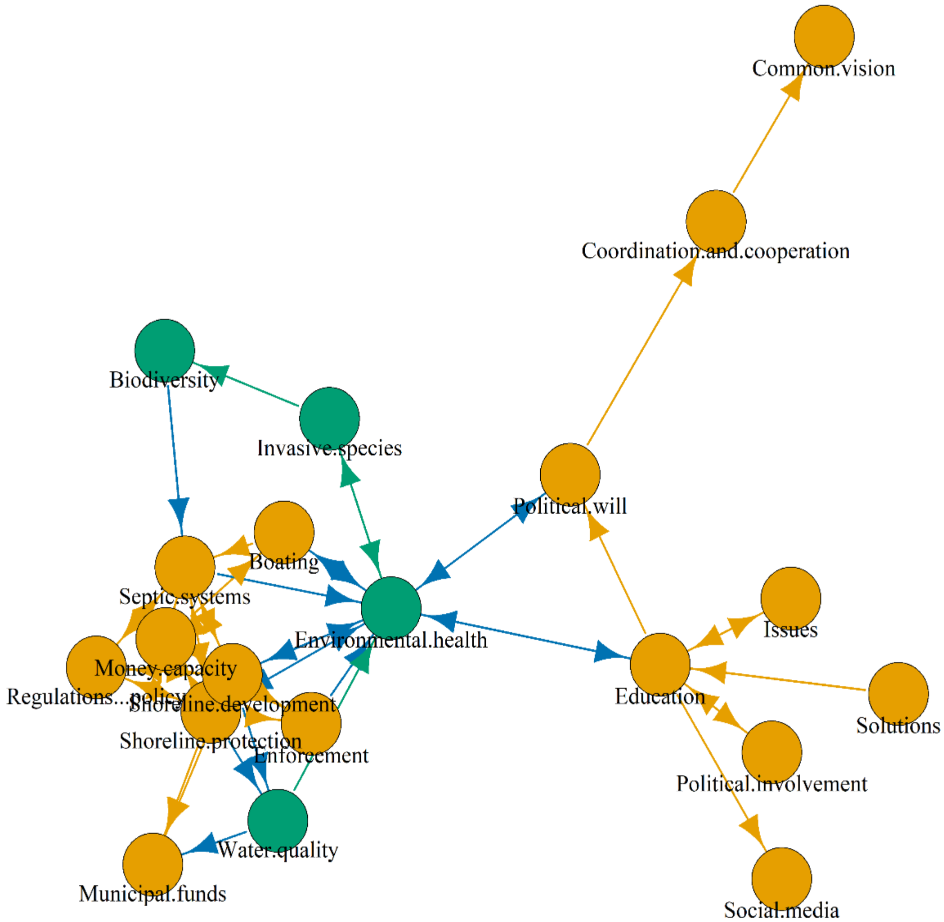


Pair 2, Community and environmental groups

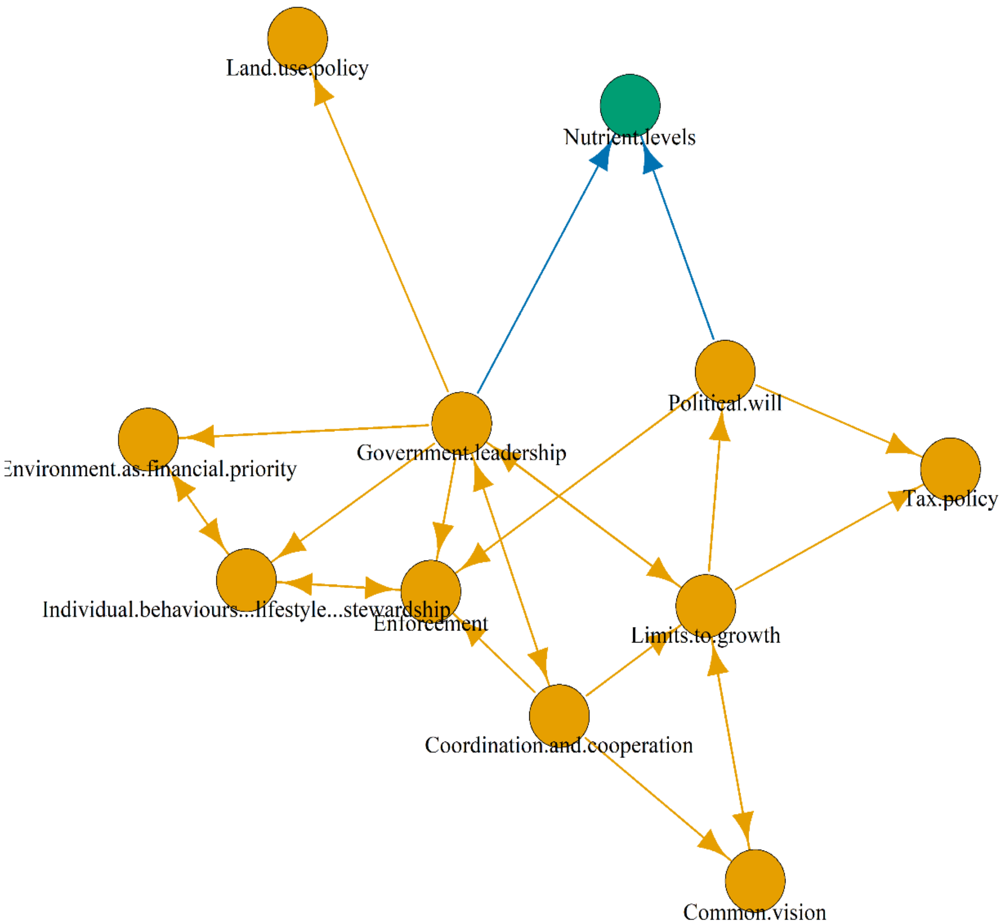
Pair 3, Community and environmental groups



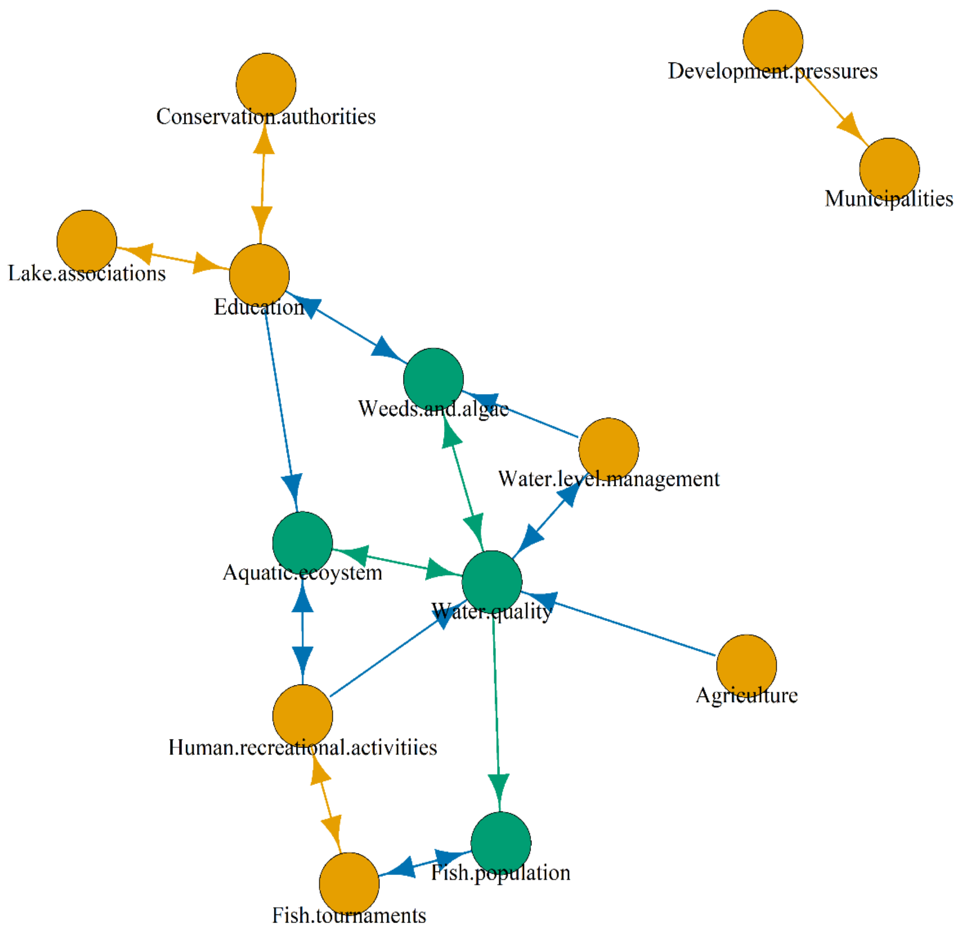
Pair 4, Community and environmental groups



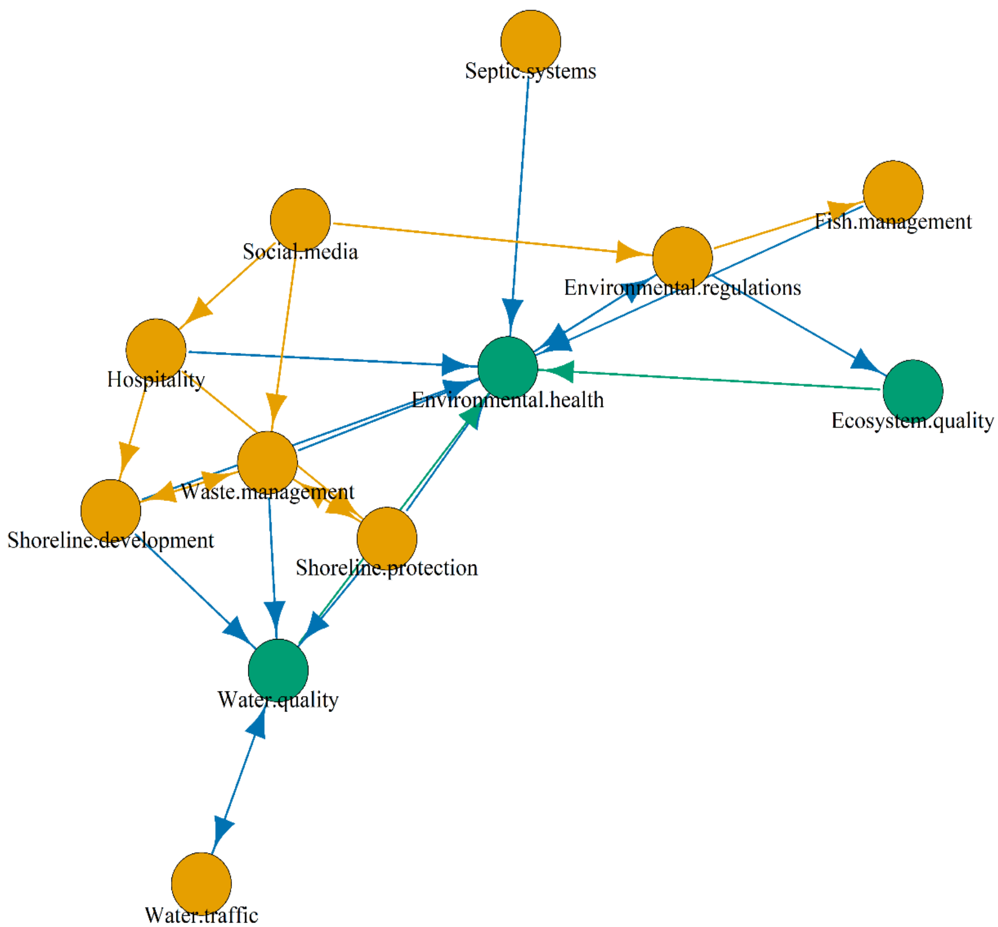
Pair 5, Community and environmental groups



Pair 6, Community and environmental groups

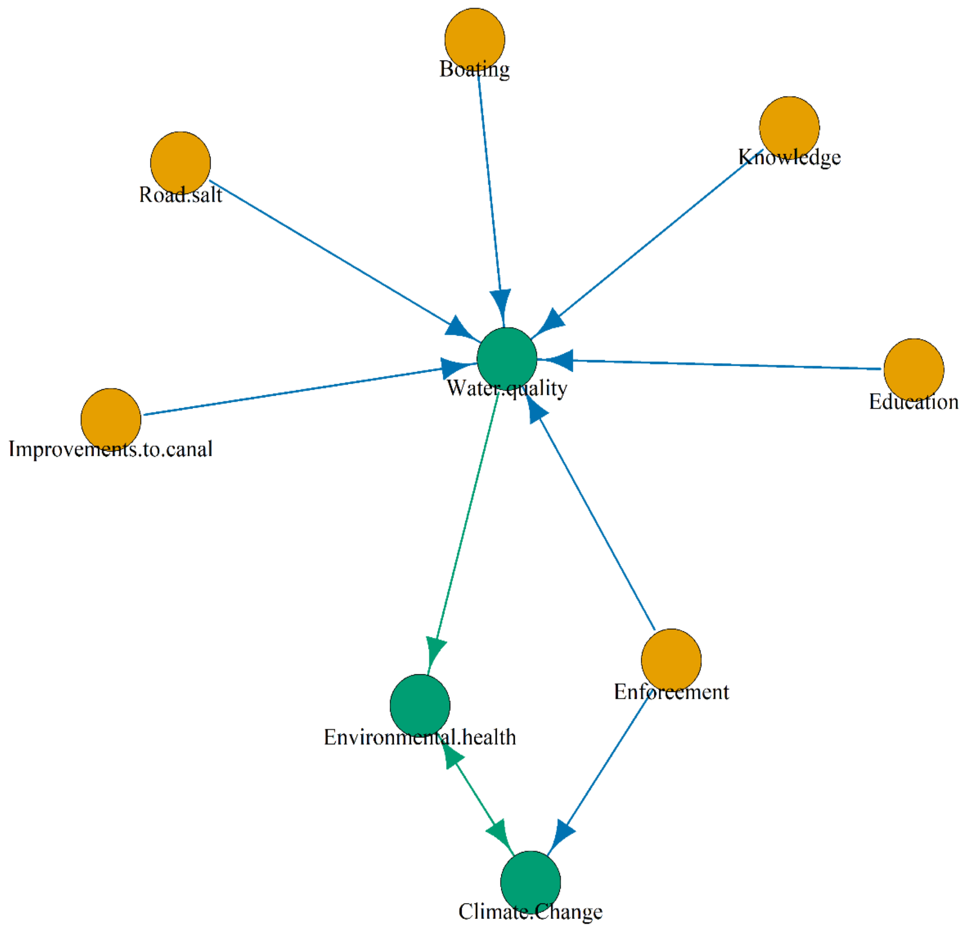


Pair 7, Community and environmental groups

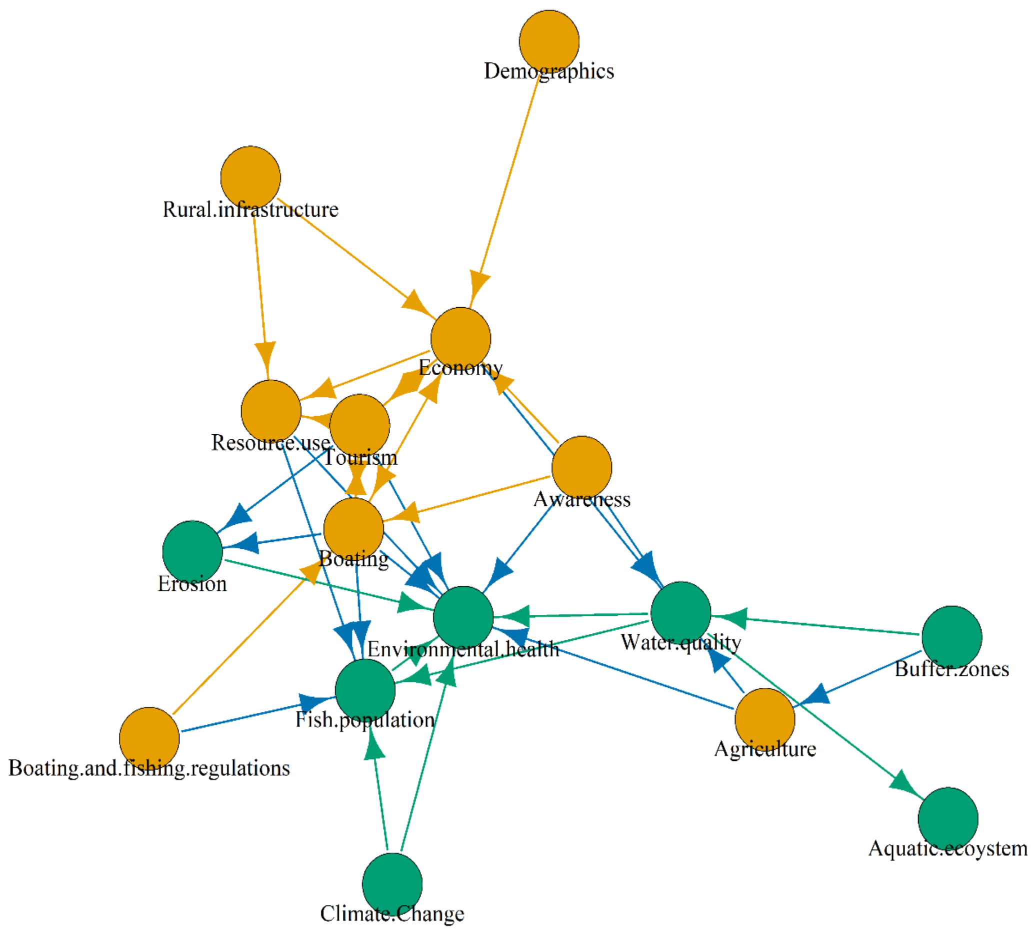


Pair-level networks for economic interest groups

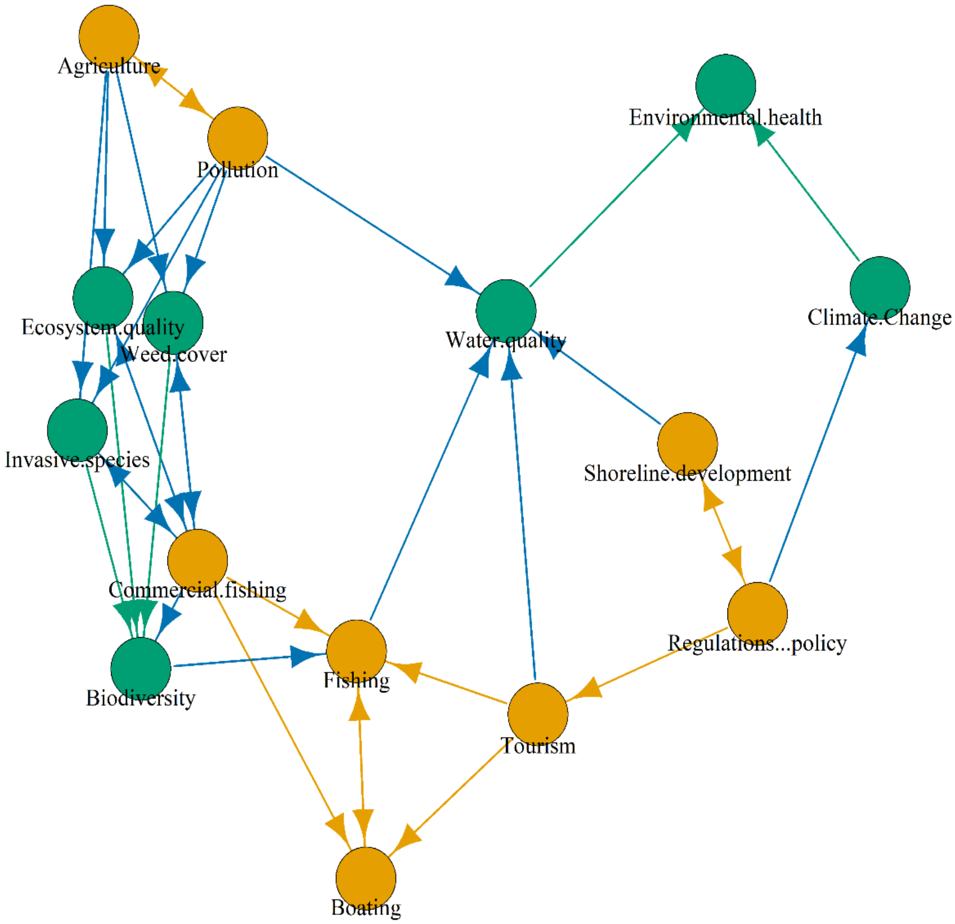
Pair 1, Economic interest groups



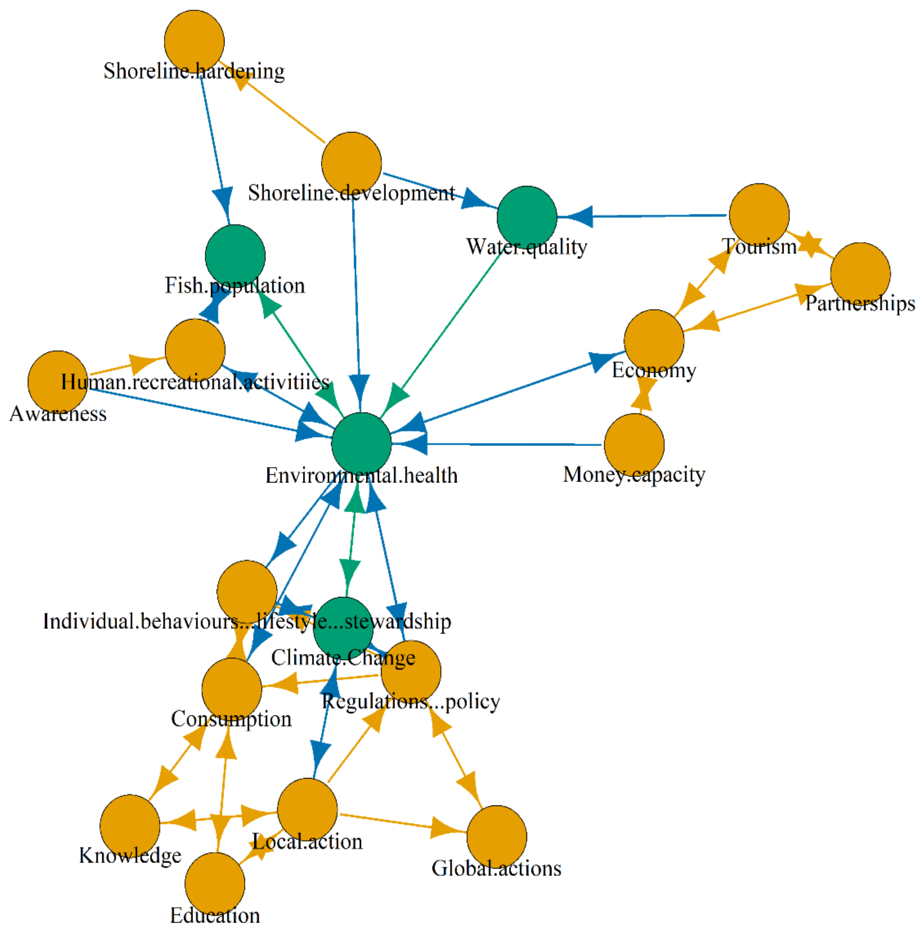
Pair 2, Economic interest groups



Pair 3, Economic interest groups

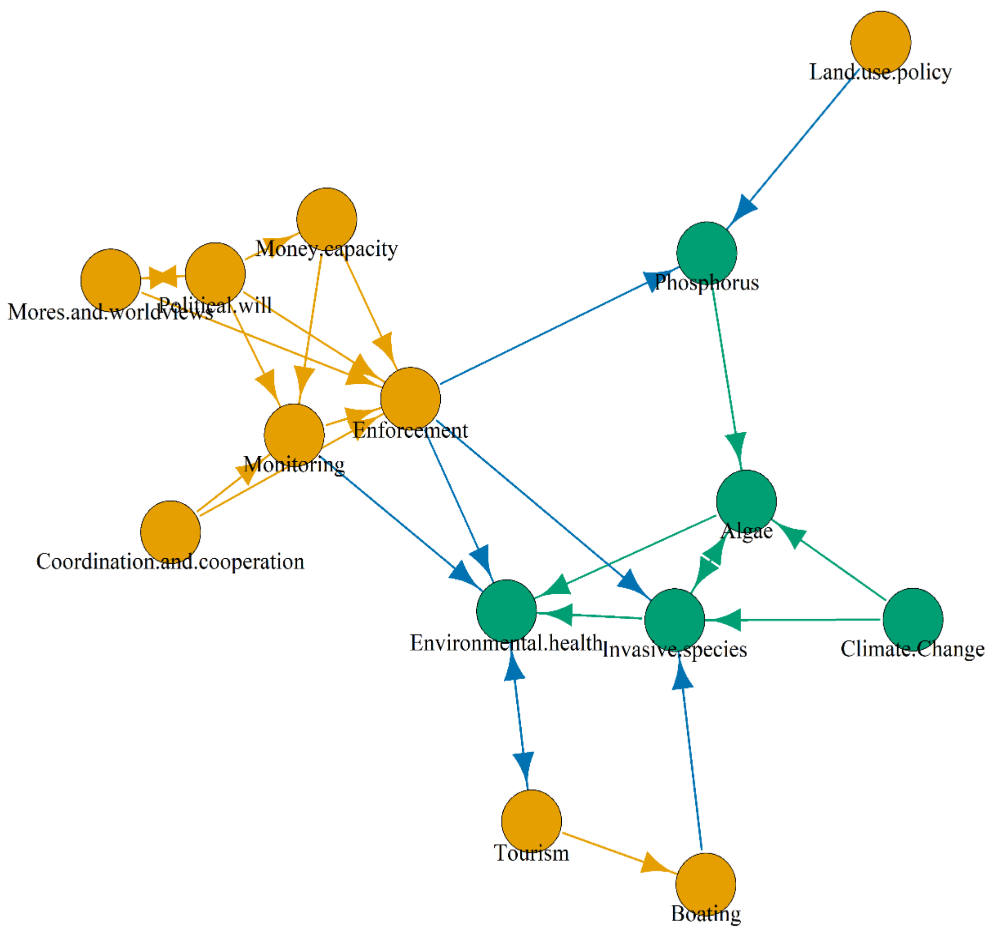


Pair 4, Economic interest groups

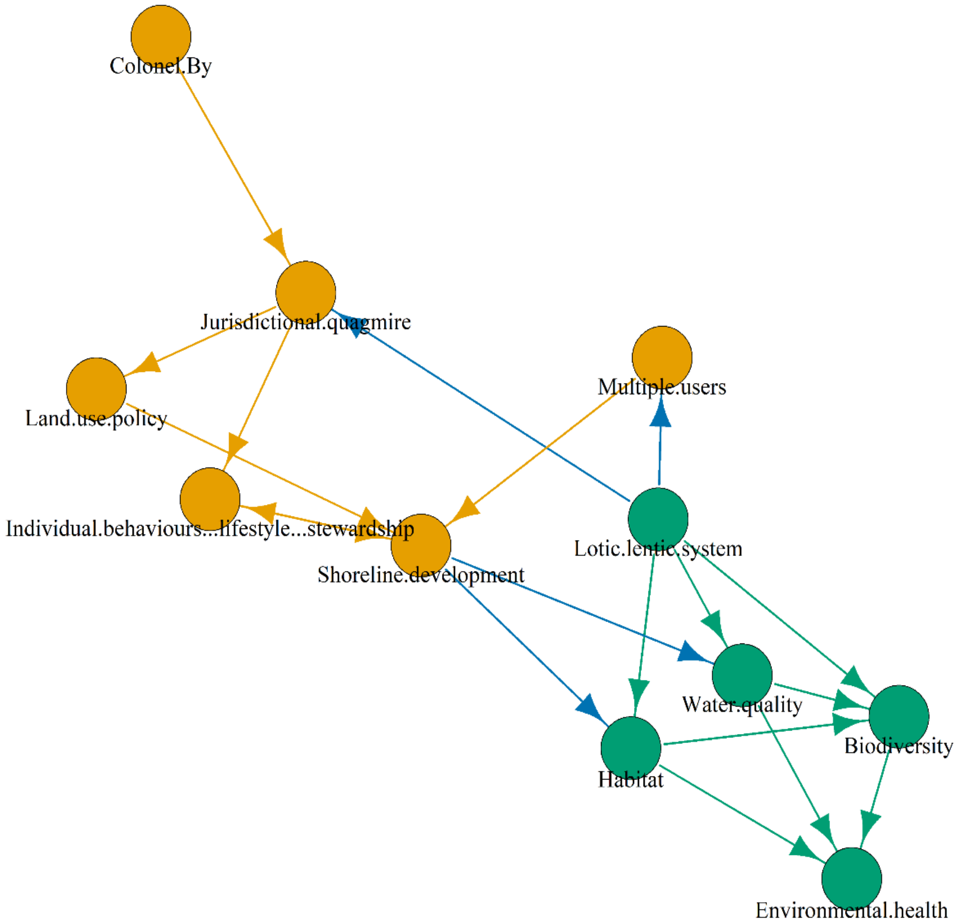


Pair-level networks for academics

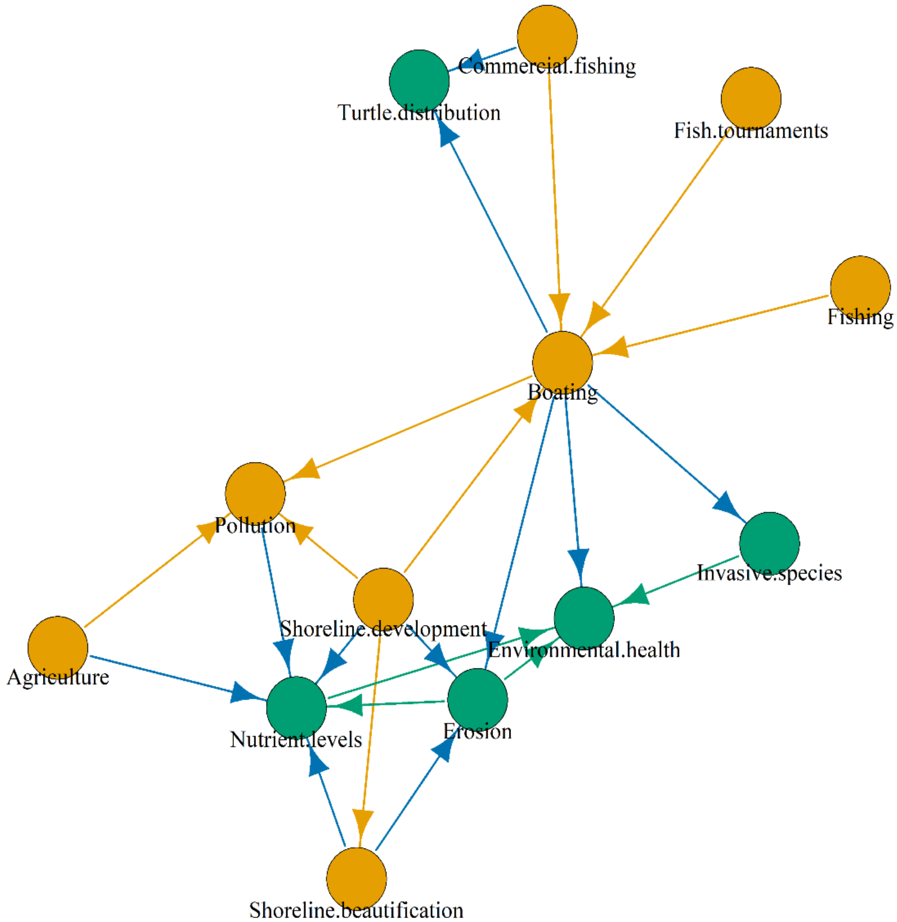
Pair 1, Academics



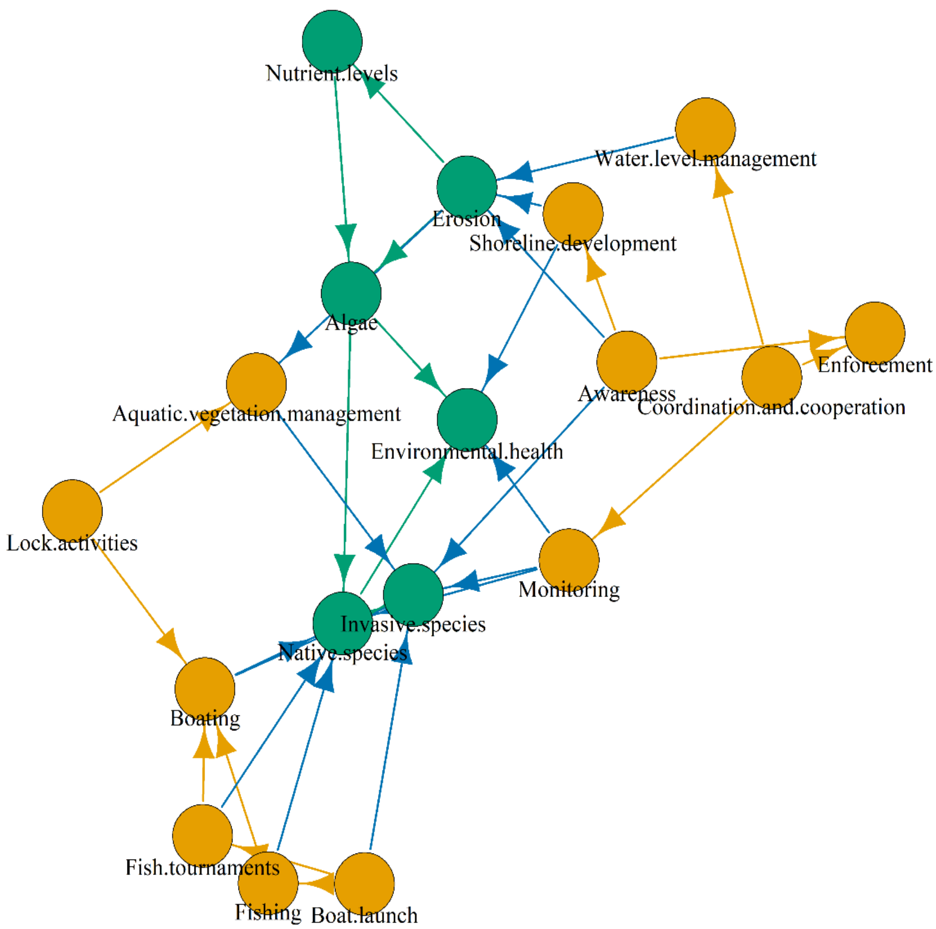
Pair 2, Academics



Pair 3, Academics

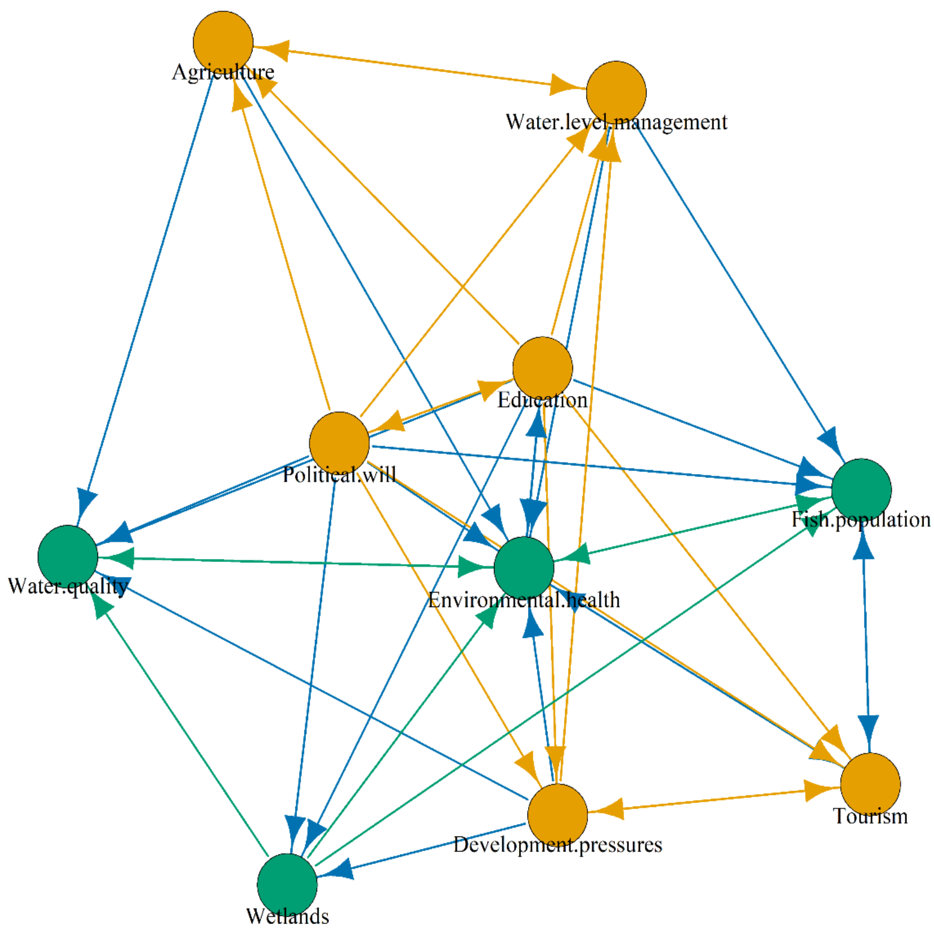


Pair 4, Academics

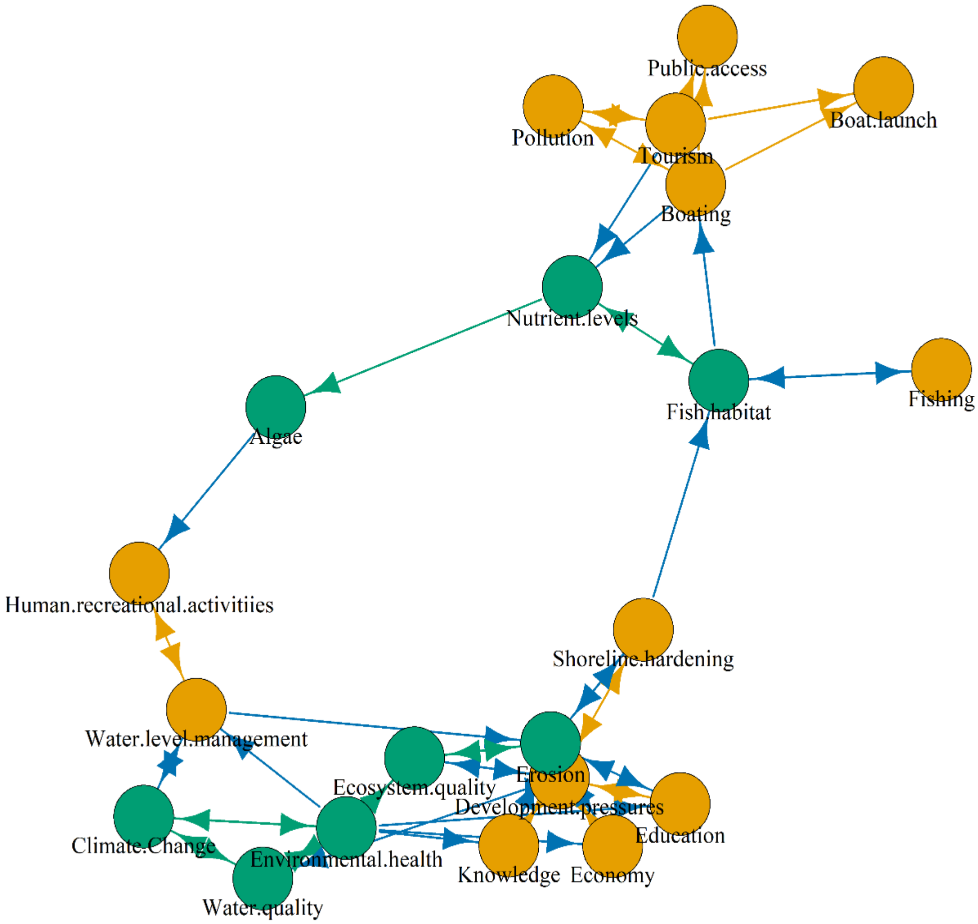


Pair-level networks for government representatives

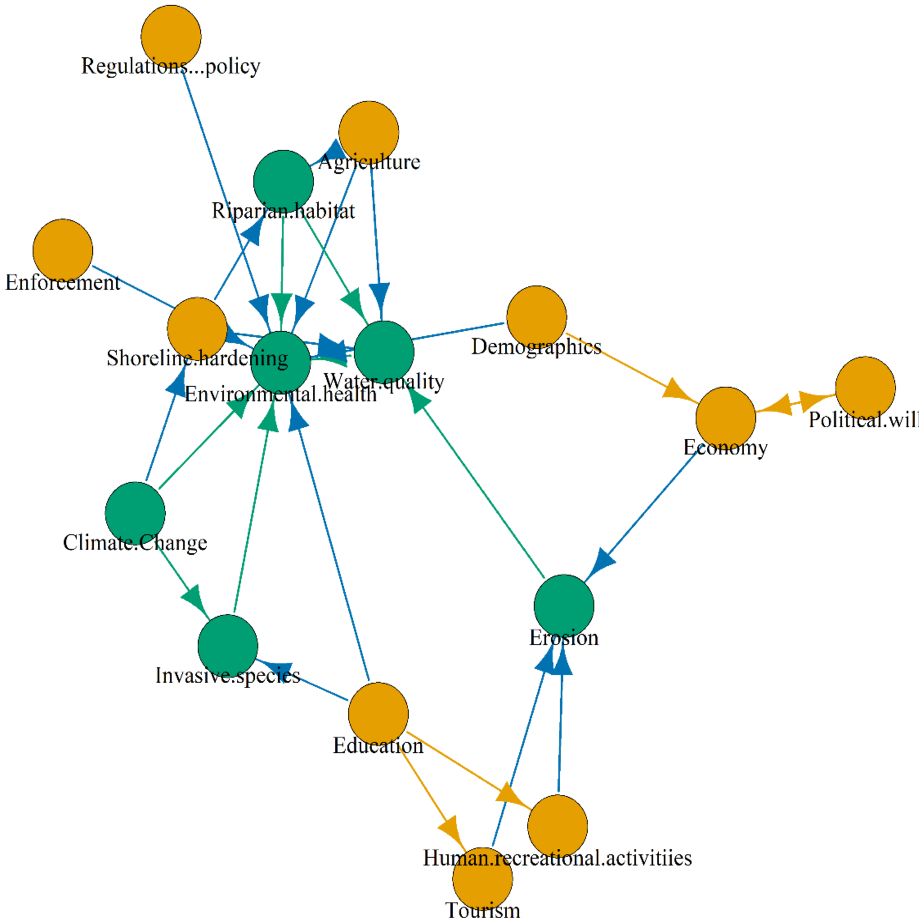
Pair 1, Government representatives



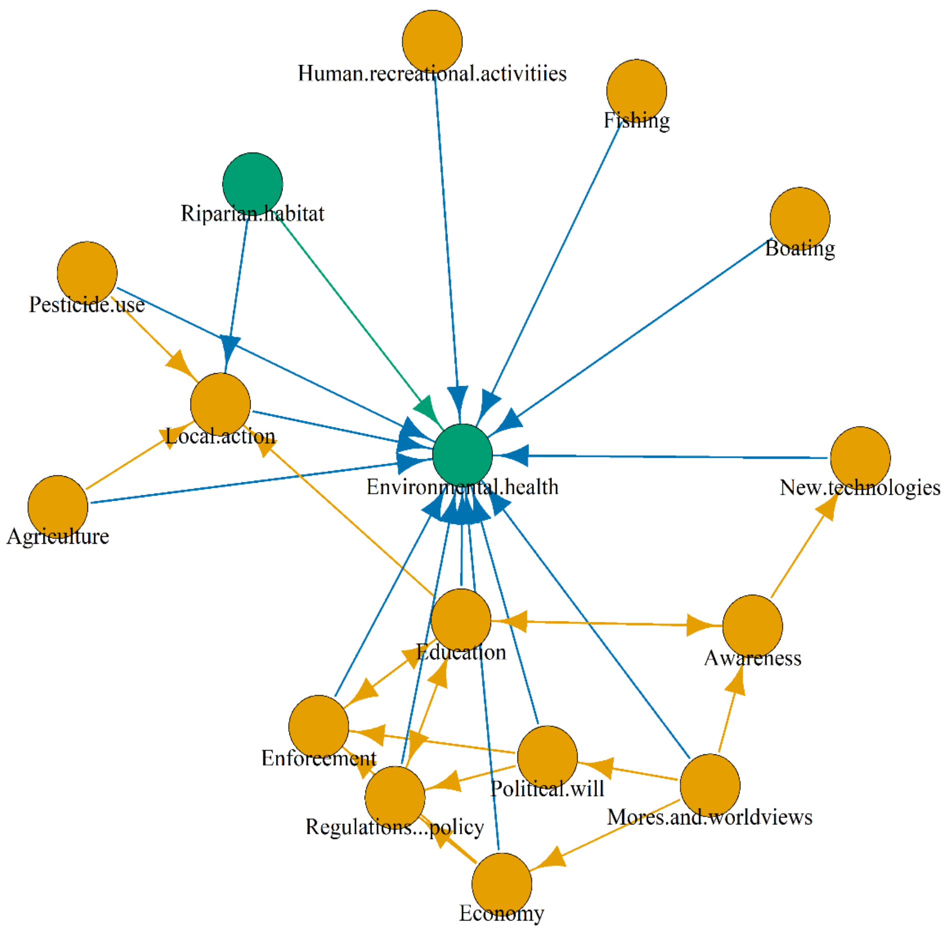
Pair 2, Government representatives



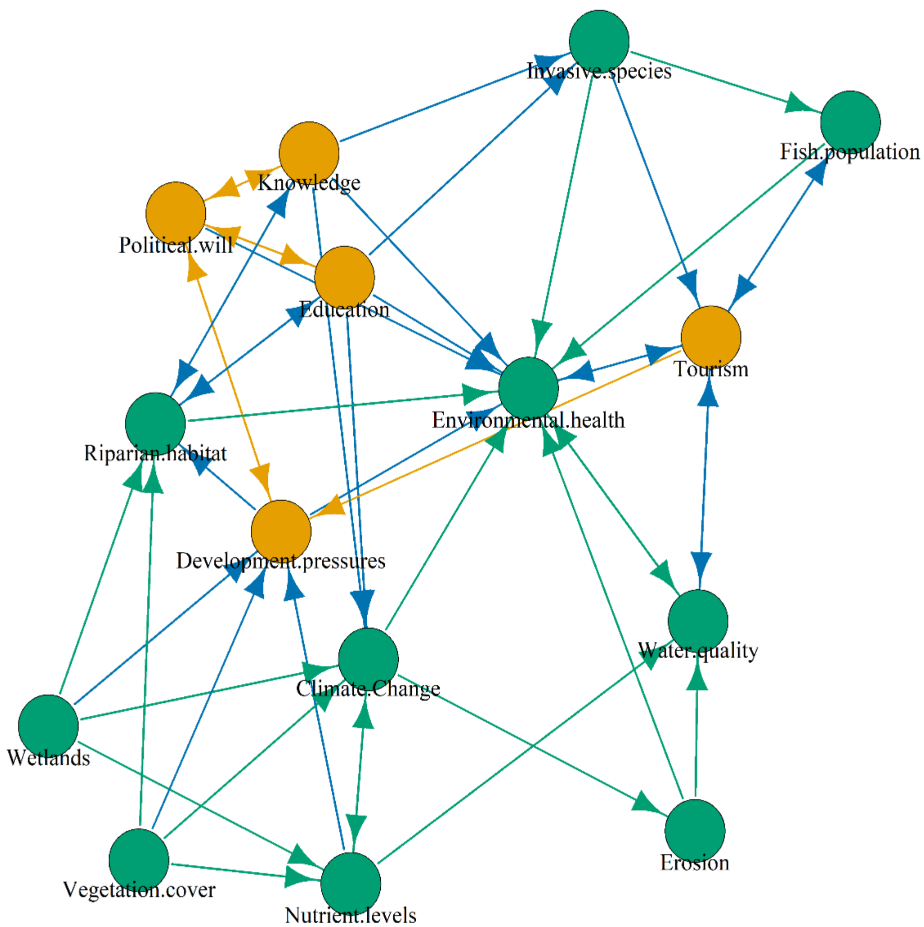
Pair 3, Government representatives



Pair 4, Government representatives

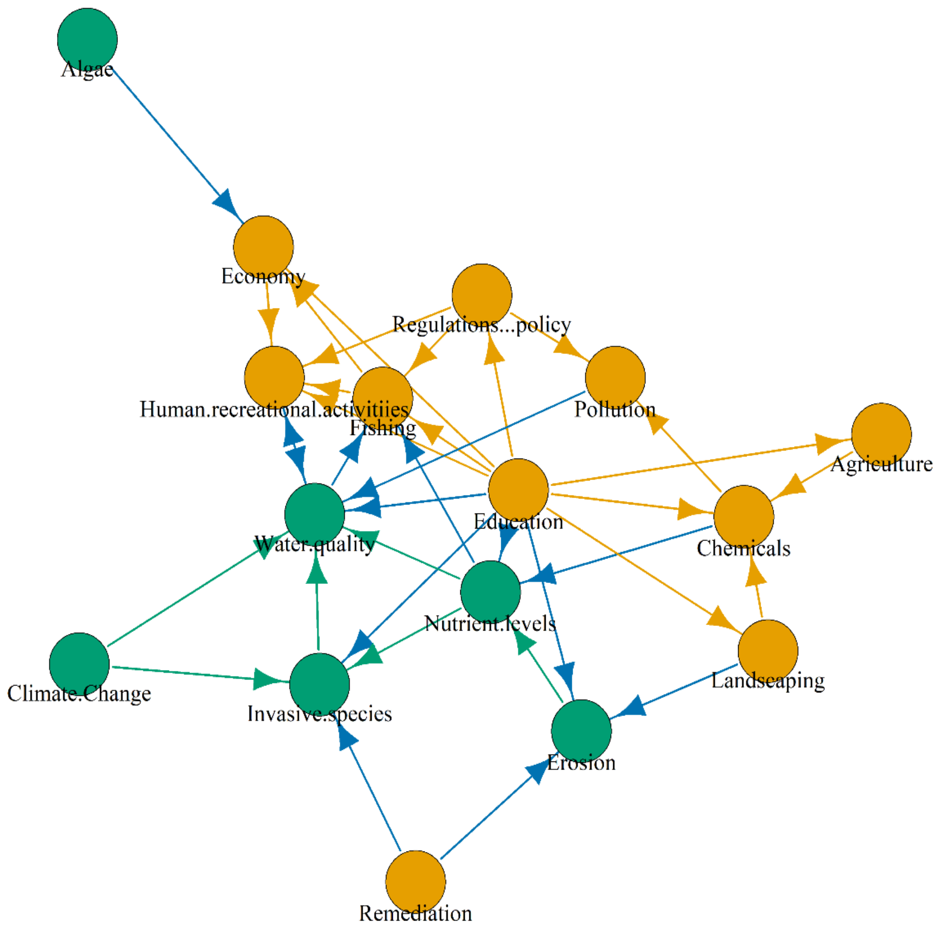


Pair 5, Government representatives

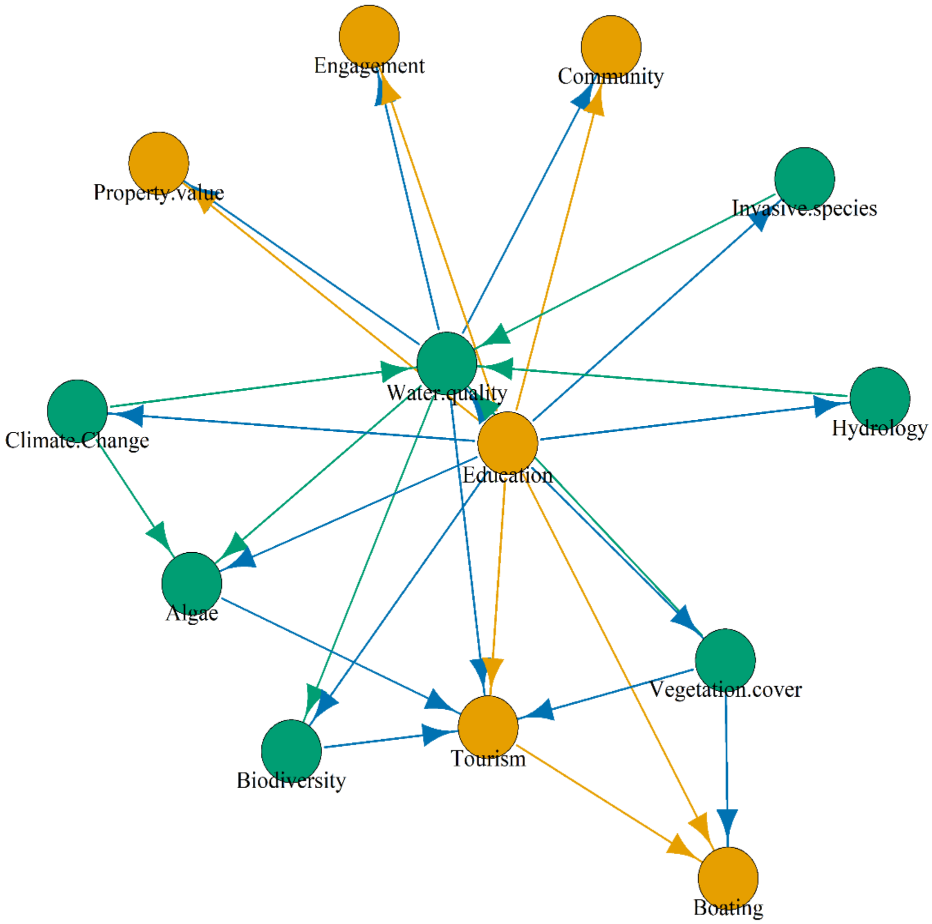


Pair-level networks for the water quality workshop

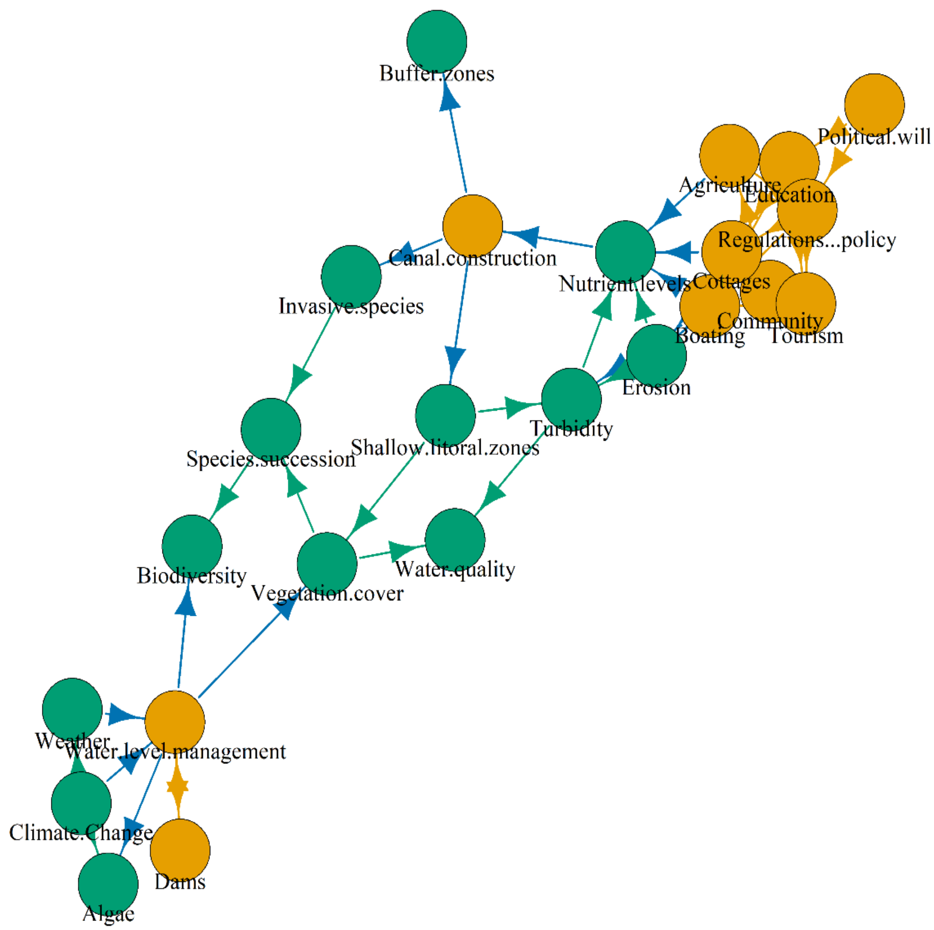
Pair 1, Water quality workshop



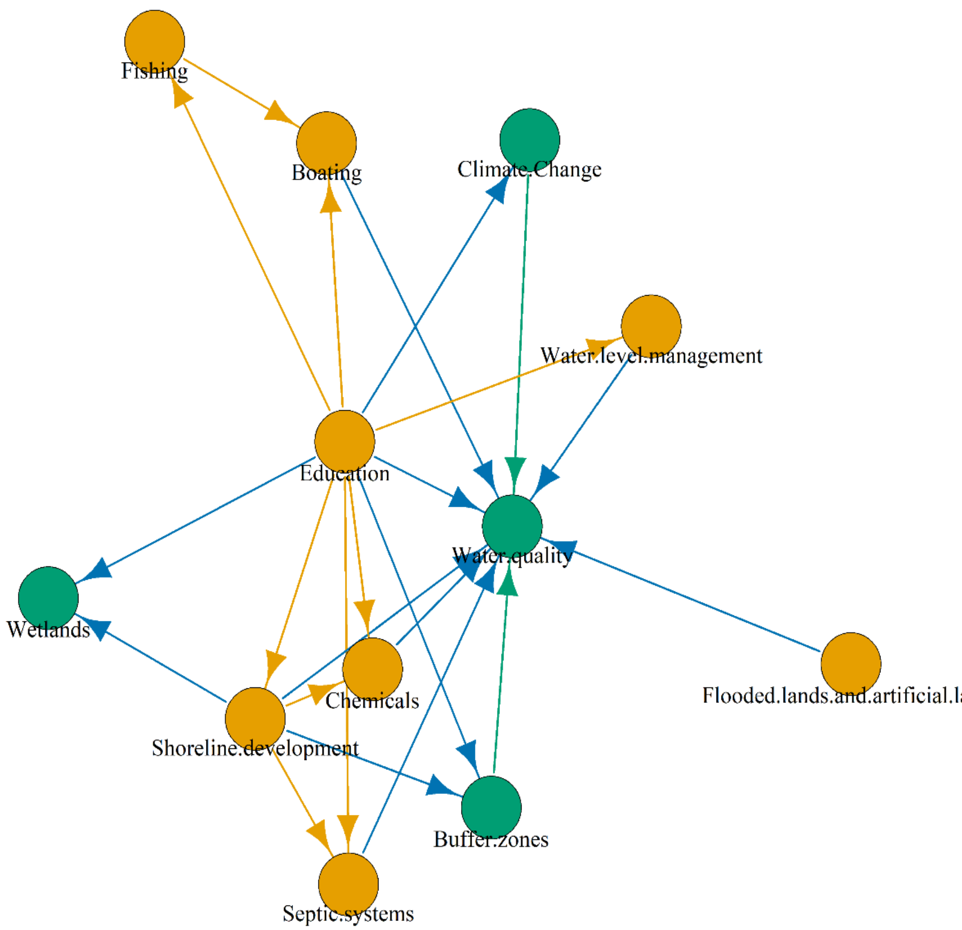
Pair 2, Water quality workshop



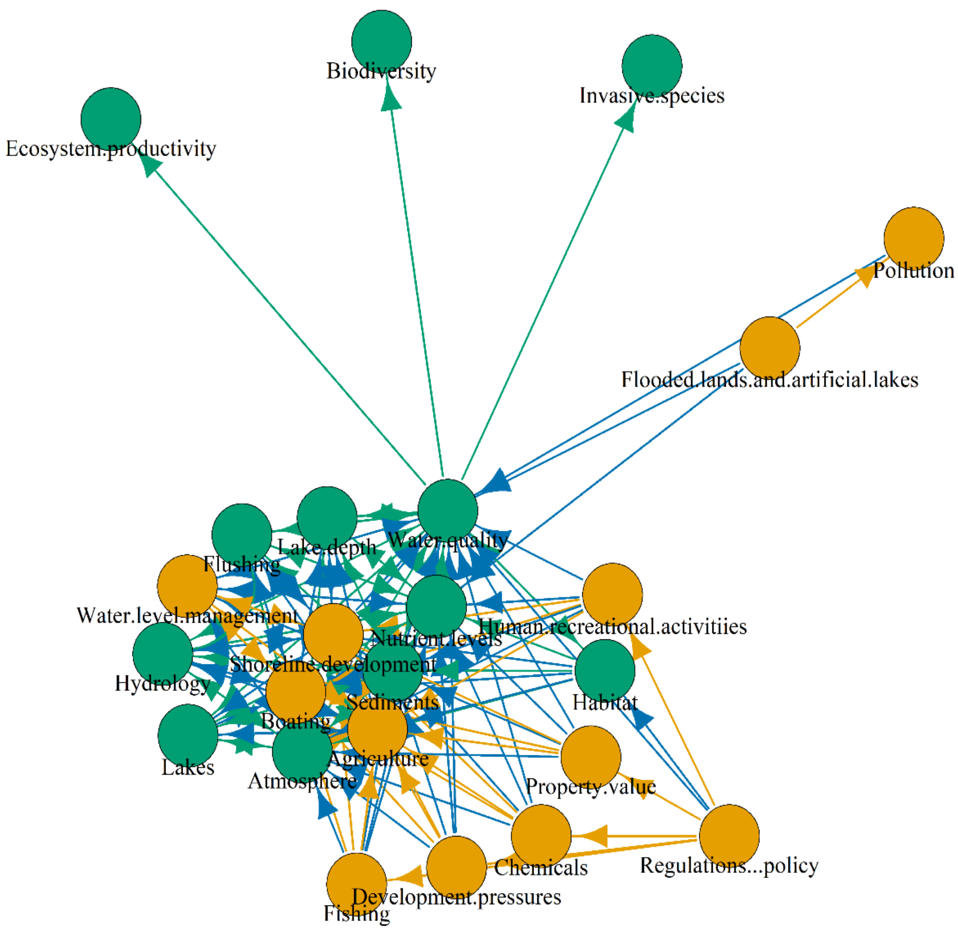
Pair 3, Water quality workshop



Pair 4, Water quality workshop



Pair 5, Water quality workshop



Pair-level network measures

	Workshop	Pair	Participants	Network size	Number of edges	Network density	Number of social nodes	Number of ecological nodes	Number of social ties	Number of social-ecological ties
1	Community and environmental groups	1.1	3	13	18	0,12	10	3	5	9
2		1.2	2	13	14	0,09	9	4	2	9
3		1.3	2	15	52	0,25	10	5	25	19
4		1.4	2	20	51	0,13	17	3	31	16
5		1.5	2	11	23	0,21	10	1	21	2
6		1.6	2	13	24	0,15	9	4	7	12
7		1.7	2	12	26	0,2	9	3	10	14
8	Economic interest groups	2.1	2	9	10	0,14	3	6	0	7
9		2.2	2	16	36	0,15	9	7	14	14
10		2.3	2	15	35	0,17	8	7	11	19
11		2.4	3	19	54	0,16	15	4	26	23
12	Academics	4.1	2	14	27	0,15	9	5	12	8
13		4.2	2	11	19	0,17	6	5	7	4
14		4.3	2	13	23	0,15	8	5	8	11
15		4.4	3	18	34	0,11	12	6	11	15
16	Government representatives	5.1	2	10	42	0,47	6	4	15	20
17		5.2	2	21	55	0,13	13	8	18	25
18		5.3	2	16	26	0,11	10	6	5	14
19		5.4	2	16	32	0,13	14	2	17	14
20		5.5	2	15	49	0,23	5	10	7	23
21	Water quality	3.1	2	16	36	0,15	10	6	16	14
22		3.2	2	13	28	0,18	6	7	6	15
23		3.3	2	24	45	0,08	11	13	18	15
24		3.4	2	12	23	0,17	8	4	9	12
25		3.5	2	24	144	0,26	12	12	27	69

	Workshop	Number of mutual dyads	Number of asym-metric dyads	Number of null dyads	Dyadic reciprocity	Edgewise reciprocity	Number of strong components	Number of weak components	In degree centra-lization	Out degree centra-lization	Between-ness centra-lization	Eigen centra-lization
1	Community and environmental groups	5	8	65	0,9	0,56	7	1	0,33	0,24	0,36	0,41
2		0	14	64	0,82	0	10	1	0,63	0,26	0,32	0,13
3		24	4	77	0,96	0,92	2	1	0,19	0,27	0,24	0,24
4		15	21	154	0,89	0,59	6	1	0,36	0,25	0,47	0,28
5		5	13	37	0,76	0,43	6	1	0,21	0,54	0,13	0,53
6		9	6	63	0,92	0,75	4	2	0,28	0,19	0,27	0,22
7		4	18	44	0,73	0,31	6	1	0,68	0,18	0,2	0,46
8	Economic interest groups	1	8	27	0,78	0,2	8	1	0,69	0,13	0,17	0,29
9		3	30	87	0,75	0,17	14	1	0,48	0,2	0,09	0,32
10		6	23	76	0,78	0,34	9	1	0,13	0,28	0,07	0,55
11		20	14	137	0,92	0,74	4	1	0,42	0,24	0,54	0,28
12	Academics	3	21	67	0,77	0,22	9	1	0,25	0,17	0,11	0,55
13		1	17	37	0,69	0,11	10	1	0,14	0,36	0,21	0,48
14		0	23	55	0,71	0	13	1	0,29	0,29	0,14	-
15		1	32	120	0,79	0,06	17	1	0,26	0,13	0,05	0,33
16	Government representatives	8	26	11	0,42	0,38	1	1	0,59	0,59	0,41	0,36
17		19	17	174	0,92	0,69	3	1	0,18	0,23	0,23	0,36
18		1	24	95	0,8	0,08	15	1	0,52	0,17	0,04	0,57
19		3	26	91	0,78	0,19	13	1	0,85	0,21	0,08	0,45
20		10	29	66	0,72	0,41	3	1	0,59	0,13	0,24	0,18
21	Water quality	1	34	85	0,72	0,06	13	1	0,27	0,62	0,07	0,78
22		0	28	50	0,64	0	13	1	0,26	0,89	0,18	-
23		1	43	232	0,84	0,04	20	1	0,14	0,1	0,13	0,68
24		0	23	43	0,65	0	12	1	0,7	0,8	0,01	-
25		42	60	174	0,78	0,58	12	1	0,64	0,23	0,2	0,15

Appendix 5. Workshop-level network graphs and data

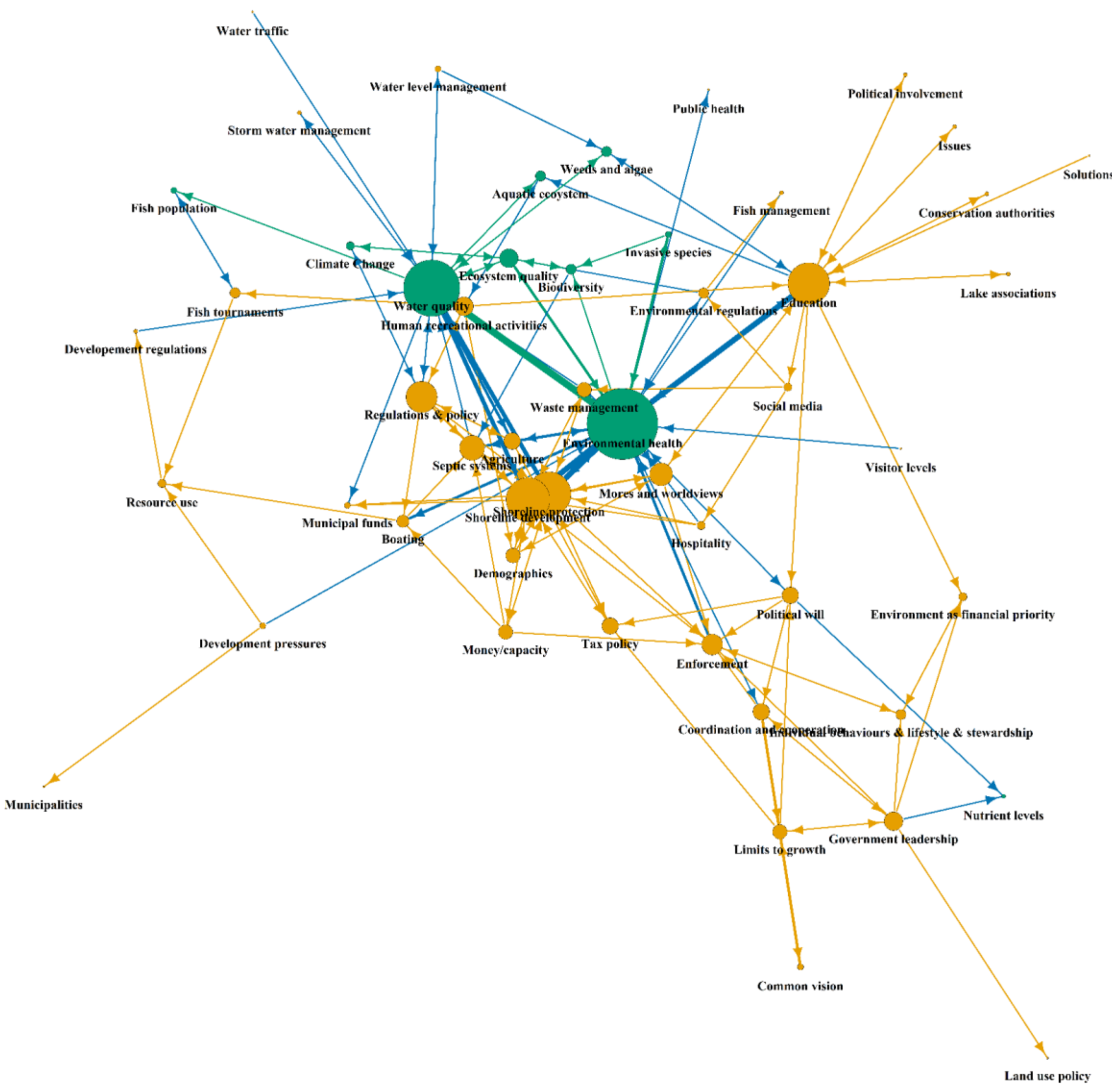
Chapter 1. Supplementary material 4: Workshop-level network graphs and data

Legend that applies to all network graphs in this appendix

Orange nodes: Social nodes **Green nodes:** Ecological nodes **Node size:** In + out degree centrality
Orange ties: Social ties **Green ties:** Ecological ties **Blue ties:** Social-ecological ties
**For all graphs, you can zoom in to see more details and zoom out to see the big picture.*

Workshop-level network data for community and environmental groups

Network graph for community and environmental groups



Node data for community and environmental groups

	Workshop 1 nodes	Node type	In degree centrality	Out degree centrality	Rescale In degree centrality	Rescale Out degree centrality	Rescale In + Out degree centrality	Betweenness centrality	Rescale Betweenness centrality
1	Mores and worldviews	Social	5	6	2,82	3,39	6,21	56,89	0,01
2	Agriculture	Social	4	4	2,26	2,26	4,52	28,93	0,01
3	Aquatic ecoystem	Ecological	3	2	1,69	1,13	2,82	30,24	0,01
4	Boating	Social	3	3	1,69	1,69	3,39	81,38	0,02
5	Climate Change	Ecological	2#	2	1,13	1,13	2,26	1,70	0,00
6	Common vision	Social	2	1	1,13	0,56	1,69	0	0
7	Conservation authorities	Social	1	1	0,56	0,56	1,13	0	0
8	Coordination and cooperation	Social	3	5	1,69	2,82	4,52	193,44	0,05
9	Demographics	Social	4	3	2,26	1,69	3,95	7,45	0,00
10	Development pressures	Social	0	3	0,00	1,69	1,69	0	0
11	Developement regulations	Social	1	1	0,56	0,56	1,13	45	0,01
12	Ecosystem quality	Ecological	5	4	2,82	2,26	5,08	71,39	0,02
13	Education	Social	9	11	5,08	6,21	11,30	571,54	0,14
14	Enforcement	Social	8	2	4,52	1,13	5,65	138,32	0,03
15	Environment as financial priority	Social	3	1	1,69	0,56	2,26	11,82	0,00
16	Environmental health	Ecological	19	15	10,73	8,47	19,21	1058,87	0,26
17	Environmental regulations	Social	2	3	1,13	1,69	2,82	54,37	0,01
18	Biodiversity	Ecological	3	2	1,69	1,13	2,82	2,29	0,00
19	Fish management	Social	1	1	0,56	0,56	1,13	0	0
20	Fish tournaments	Social	2	3	1,13	1,69	2,82	53	0,01
21	Government leadership	Social	2	7	1,13	3,95	5,08	56,99	0,01
22	Hospitality	Social	1	3	0,56	1,69	2,26	12,32	0,00
23	Invasive species	Ecological	1	2	0,56	1,13	1,69	0	0
24	Issues	Social	1	1	0,56	0,56	1,13	0	0
25	Lake associations	Social	1	1	0,56	0,56	1,13	0	0
26	Land use policy	Social	1	0	0,56	0,00	0,56	0	0
27	Individual behaviours & lifestyle & stewardship	Social	3	2	1,69	1,13	2,82	48,29	0,01
28	Limits to growth	Social	3	4	1,69	2,26	3,95	51,57	0,01
29	Money/capacity	Social	2	5	1,13	2,82	3,95	3,83	0,00
30	Municipal funds	Social	3	0	1,69	0,00	1,69	0	0
31	Municipalities	Social	1	0	0,56	0,00	0,56	0	0
32	Fish population	Ecological	2	1	1,13	0,56	1,69	32,58	0,01
33	Nutrient levels	Ecological	2	0	1,13	0,00	1,13	0	0
34	Septic systems	Social	7	5	3,95	2,82	6,78	51,72	0,01
35	Political involvement	Social	1	1	0,56	0,56	1,13	0	0
36	Political will	Social	3	5	1,69	2,82	4,52	121,84	0,03

	Workshop 1 nodes	Node type	In degree centrality	Out degree centrality	Rescale In degree centrality	Rescale Out degree centrality	Rescale In + Out degree centrality	Betweenness centrality	Rescale Betweenness centrality
37	Public health	Social	1	0	0,56	0,00	0,56	0	0
38	Human recreational activitiies	Social	3	6	1,69	3,39	5,08	127,51	0,03
39	Regulations & policy	Social	7	8	3,95	4,52	8,47	108,87	0,03
40	Resource use	Social	3	1	1,69	0,56	2,26	45	0,01
41	Shoreline protection	Social	10	11	5,65	6,21	11,86	160,19	0,04
42	Social media	Social	1	3	0,56	1,69	2,26	60,43	0,01
43	Solutions	Social	0	1	0,00	0,56	0,56	0	0
44	Storm water management	Social	1	1	0,56	0,56	1,13	0	0
45	Tax policy	Social	5	3	2,82	1,69	4,52	41,46	0,01
46	Visitor levels	Social	0	1	0,00	0,56	0,56	0	0
47	Waste management	Social	3	4	1,69	2,26	3,95	20,53	0,01
48	Water level management	Social	1	2	0,56	1,13	1,69	0	0
49	Water quality	Ecological	15	12	8,47	6,78	15,25	510,00	0,13
50	Water traffic	Social	0	1	0,00	0,56	0,56	0	0
51	Weeds and algae	Ecological	3	2	1,69	1,13	2,82	39,04	0,01
52	Shoreline development	Social	10	11	5,65	6,21	11,86	160,19	0,04

Edge list for community and environmental groups

	Sender node	Receiver node	Tie category	Pair-level frequency
1	Mores and worldviews	Demographics	Social	1
2	Mores and worldviews	Education	Social	1
3	Mores and worldviews	Enforcement	Social	1
4	Mores and worldviews	Environmental health	Social-ecological	1
5	Mores and worldviews	Shoreline protection	Social	1
6	Mores and worldviews	Shoreline development	Social	1
7	Agriculture	Environmental health	Social-ecological	1
8	Agriculture	Regulations & policy	Social	1
9	Agriculture	Tax policy	Social	1
10	Agriculture	Water quality	Social-ecological	2
11	Aquatic ecoystem	Human recreational activitiies	Social-ecological	1
12	Aquatic ecoystem	Water quality	Ecological	1
13	Boating	Environmental health	Social-ecological	2
14	Boating	Septic systems	Social	1
15	Boating	Resource use	Social	1
16	Climate Change	Ecosystem quality	Ecological	1
17	Climate Change	Regulations & policy	Social-ecological	1
18	Common vision	Limits to growth	Social	1
19	Conservation authorities	Education	Social	1
20	Coordination and cooperation	Common vision	Social	2
21	Coordination and cooperation	Enforcement	Social	1
22	Coordination and cooperation	Environmental health	Social-ecological	1
23	Coordination and cooperation	Government leadership	Social	1
24	Coordination and cooperation	Limits to growth	Social	1
25	Demographics	Mores and worldviews	Social	1
26	Demographics	Shoreline protection	Social	1
27	Demographics	Shoreline development	Social	1
28	Development pressures	Environmental health	Social-ecological	1
29	Development pressures	Municipalities	Social	1
30	Development pressures	Resource use	Social	1
31	Developement regulations	Water quality	Social-ecological	1
32	Ecosystem quality	Climate Change	Ecological	1
33	Ecosystem quality	Environmental health	Ecological	2
34	Ecosystem quality	Biodiversity	Ecological	1
35	Ecosystem quality	Water quality	Ecological	1
36	Education	Mores and worldviews	Social	1
37	Education	Aquatic ecoystem	Social-ecological	1
38	Education	Conservation authorities	Social	1
39	Education	Environment as financial priority	Social	1
40	Education	Environmental health	Social-ecological	2
41	Education	Issues	Social	1
42	Education	Lake associations	Social	1
43	Education	Political involvement	Social	1
44	Education	Political will	Social	1
45	Education	Social media	Social	1
46	Education	Weeds and algae	Social-ecological	1
47	Enforcement	Environmental health	Social-ecological	2
48	Enforcement	Individual behaviours & lifestyle & stewardship	Social	1
49	Environment as financial priority	Individual behaviours & lifestyle & stewardship	Social	1
50	Environmental health	Mores and worldviews	Social-ecological	1
51	Environmental health	Agriculture	Social-ecological	1
52	Environmental health	Boating	Social-ecological	1

	Sender node	Receiver node	Tie category	Pair-level frequency
53	Environmental health	Coordination and cooperation	Social-ecological	1
54	Environmental health	Ecosystem quality	Ecological	1
55	Environmental health	Education	Social-ecological	4
56	Environmental health	Environmental regulations	Social-ecological	1
57	Environmental health	Biodiversity	Ecological	1
58	Environmental health	Invasive species	Ecological	1
59	Environmental health	Septic systems	Social-ecological	1
60	Environmental health	Political will	Social-ecological	1
61	Environmental health	Public health	Social-ecological	1
62	Environmental health	Shoreline protection	Social-ecological	2
63	Environmental health	Water quality	Ecological	2
64	Environmental health	Shoreline development	Social-ecological	2
65	Environmental regulations	Ecosystem quality	Social-ecological	1
66	Environmental regulations	Environmental health	Social-ecological	1
67	Environmental regulations	Fish management	Social	1
68	Biodiversity	Ecosystem quality	Ecological	1
69	Biodiversity	Septic systems	Social-ecological	1
70	Fish management	Environmental health	Social-ecological	1
71	Fish tournaments	Fish population	Social-ecological	1
72	Fish tournaments	Human recreational activitiies	Social	1
73	Fish tournaments	Resource use	Social	1
74	Government leadership	Coordination and cooperation	Social	1
75	Government leadership	Enforcement	Social	1
76	Government leadership	Environment as financial priority	Social	1
77	Government leadership	Land use policy	Social	1
78	Government leadership	Individual behaviours & lifestyle & stewardship	Social	1
79	Government leadership	Limits to growth	Social	1
80	Government leadership	Nutrient levels	Social-ecological	1
81	Hospitality	Environmental health	Social-ecological	1
82	Hospitality	Shoreline protection	Social	1
83	Hospitality	Shoreline development	Social	1
84	Invasive species	Environmental health	Ecological	2
85	Invasive species	Biodiversity	Ecological	1
86	Issues	Education	Social	1
87	Lake associations	Education	Social	1
88	Individual behaviours & lifestyle & stewardship	Enforcement	Social	1
89	Individual behaviours & lifestyle & stewardship	Environment as financial priority	Social	1
90	Limits to growth	Common vision	Social	1
91	Limits to growth	Government leadership	Social	1
92	Limits to growth	Political will	Social	1
93	Limits to growth	Tax policy	Social	1
94	Money/capacity	Boating	Social	1
95	Money/capacity	Enforcement	Social	1
96	Money/capacity	Septic systems	Social	1
97	Money/capacity	Shoreline protection	Social	1
98	Money/capacity	Shoreline development	Social	1
99	Fish population	Fish tournaments	Social-ecological	1
100	Septic systems	Environmental health	Social-ecological	2
101	Septic systems	Regulations & policy	Social	1
102	Septic systems	Shoreline protection	Social	1
103	Septic systems	Water quality	Social-ecological	1
104	Septic systems	Shoreline development	Social	1
105	Political involvement	Education	Social	1
106	Political will	Coordination and cooperation	Social	1

	Sender node	Receiver node	Tie category	Pair-level frequency
107	Political will	Enforcement	Social	1
108	Political will	Environmental health	Social-ecological	1
109	Political will	Nutrient levels	Social-ecological	1
110	Political will	Tax policy	Social	1
111	Human recreational activitiies	Aquatic ecoystem	Social-ecological	1
112	Human recreational activitiies	Demographics	Social	1
113	Human recreational activitiies	Education	Social	1
114	Human recreational activitiies	Fish tournaments	Social	1
115	Human recreational activitiies	Regulations & policy	Social	1
116	Human recreational activitiies	Water quality	Social-ecological	1
117	Regulations & policy	Agriculture	Social	1
118	Regulations & policy	Boating	Social	1
119	Regulations & policy	Climate Change	Social-ecological	1
120	Regulations & policy	Septic systems	Social	1
121	Regulations & policy	Human recreational activitiies	Social	1
122	Regulations & policy	Shoreline protection	Social	1
123	Regulations & policy	Water quality	Social-ecological	1
124	Regulations & policy	Shoreline development	Social	1
125	Resource use	Developement regulations	Social	1
126	Shoreline protection	Mores and worldviews	Social	1
127	Shoreline protection	Demographics	Social	1
128	Shoreline protection	Enforcement	Social	1
129	Shoreline protection	Environmental health	Social-ecological	4
130	Shoreline protection	Money/capacity	Social	1
131	Shoreline protection	Municipal funds	Social	1
132	Shoreline protection	Septic systems	Social	1
133	Shoreline protection	Regulations & policy	Social	1
134	Shoreline protection	Tax policy	Social	1
135	Shoreline protection	Waste management	Social	1
136	Shoreline protection	Water quality	Social-ecological	3
137	Social media	Environmental regulations	Social	1
138	Social media	Hospitality	Social	1
139	Social media	Waste management	Social	1
140	Solutions	Education	Social	1
141	Storm water management	Water quality	Social-ecological	1
142	Tax policy	Agriculture	Social	1
143	Tax policy	Shoreline protection	Social	1
144	Tax policy	Shoreline development	Social	1
145	Visitor levels	Environmental health	Social-ecological	1
146	Waste management	Environmental health	Social-ecological	1
147	Waste management	Shoreline protection	Social	1
148	Waste management	Water quality	Social-ecological	1
149	Waste management	Shoreline development	Social	1
150	Water level management	Water quality	Social-ecological	1
151	Water level management	Weeds and algae	Social-ecological	1
152	Water quality	Agriculture	Social-ecological	1
153	Water quality	Aquatic ecoystem	Ecological	1
154	Water quality	Ecosystem quality	Ecological	1
155	Water quality	Environmental health	Ecological	5
156	Water quality	Municipal funds	Social-ecological	1
157	Water quality	Fish population	Ecological	1
158	Water quality	Regulations & policy	Social-ecological	1
159	Water quality	Shoreline protection	Social-ecological	1
160	Water quality	Storm water management	Social-ecological	1

	Sender node	Receiver node	Tie category	Pair-level frequency
161	Water quality	Water level management	Social-ecological	1
162	Water quality	Weeds and algae	Ecological	1
163	Water quality	Shoreline development	Social-ecological	1
164	Water traffic	Water quality	Social-ecological	1
165	Weeds and algae	Education	Social-ecological	1
166	Weeds and algae	Water quality	Ecological	1
167	Shoreline development	Mores and worldviews	Social	1
168	Shoreline development	Demographics	Social	1
169	Shoreline development	Enforcement	Social	1
170	Shoreline development	Environmental health	Social-ecological	4
171	Shoreline development	Money/capacity	Social	1
172	Shoreline development	Municipal funds	Social	1
173	Shoreline development	Septic systems	Social	1
174	Shoreline development	Regulations & policy	Social	1
175	Shoreline development	Tax policy	Social	1
176	Shoreline development	Waste management	Social	1
177	Shoreline development	Water quality	Social-ecological	3

Workshop-level network data for economic interest groups

Network for economic interest groups

Node data for economic interest groups

	Workshop 2 nodes	Node type	In degree centrality	Out degree centrality	Rescale In degree cen	Rescale Out degree cen.	Rescale In + Out degree centrality	Betweenness centrality	Rescale Betweenness centrality
1	Environmental health	Ecological	15	7	12,50	5,83	18,33	418,04	0,28
2	Water quality	Ecological	14	3	11,67	2,50	14,17	124,82	0,08
3	Boating	Social	6	7	5,00	5,83	10,83	135,23	0,09
4	Knowledge	Social	2	3	1,67	2,50	4,17	4,57	0,00
5	Improvements to canal	Social	0	1	0,00	0,83	0,83	0	0
6	Road salt	Social	0	1	0,00	0,83	0,83	0	0
7	Enforcement	Social	0	2	0,00	1,67	1,67	0	0
8	Climate Change	Ecological	5	5	4,17	4,17	8,33	63,75	0,04
9	Agriculture	Social	2	6	1,67	5,00	6,67	24,92	0,02
10	Buffer zones	Ecological	0	2	0,00	1,67	1,67	0	0
11	Aquatic ecoystem	Ecological	1	0	0,83	0,00	0,83	0	0
12	Awareness	Social	0	5	0,00	4,17	4,17	0	0
13	Rural infrastructure	Social	0	2	0,00	1,67	1,67	0	0
14	Fish population	Ecological	8	2	6,67	1,67	8,33	36,33	0,02
15	Boating and fishing regulations	Social	0	2	0,00	1,67	1,67	0	0
16	Resource use	Social	3	2	2,50	1,67	4,17	8,17	0,01
17	Economy	Social	8	7	6,67	5,83	12,50	174,61	0,12
18	Demographics	Social	0	1	0,00	0,83	0,83	0	0
19	Tourism	Social	4	8	3,33	6,67	10,00	75,01	0,05
20	Erosion	Ecological	2	1	1,67	0,83	2,50	0	0
21	Shoreline development	Social	1	4	0,83	3,33	4,17	37,40	0,02
22	Regulations & policy	Social	5	7	4,17	5,83	10,00	169,22	0,11
23	Fishing	Social	4	2	3,33	1,67	5,00	27	0,02
24	Commercial fishing	Social	3	6	2,50	5,00	7,50	77,61	0,05
25	Biodiversity	Ecological	4	1	3,33	0,83	4,17	5	0,00
26	Ecosystem quality	Ecological	3	2	2,50	1,67	4,17	4,54	0,00
27	Pollution	Social	1	5	0,83	4,17	5,00	0	0
28	Human recreational activitiies	Social	3	2	2,50	1,67	4,17	0,25	0,00
29	Money/capacity	Social	1	2	0,83	1,67	2,50	0	0
30	Partnerships	Social	2	2	1,67	1,67	3,33	0	0
31	Shoreline hardening	Social	1	1	0,83	0,83	1,67	0,33	0,00
32	Individual behaviours & lifestyle & stewardship	Social	4	2	3,33	1,67	5,00	1,08	0,00
33	Consumption	Social	5	4	4,17	3,33	7,50	75,50	0,05
34	Local action	Social	3	5	2,50	4,17	6,67	25,97	0,02
35	Global actions	Social	2	1	1,67	0,83	2,50	0	0
36	Weed cover	Ecological	3	2	2,50	1,67	4,17	4,54	0,00
37	Invasive species	Ecological	3	2	2,50	1,67	4,17	4,54	0,00
38	Education	Social	2	3	1,67	2,50	4,17	4,57	0,00

Edge list for economic interest groups

	Sender node	Receiver node	Tie category	Pair-level frequency
1	Environmental health	Climate Change	Ecological	2
2	Environmental health	Fish population	Ecological	1
3	Environmental health	Economy	Social-ecological	1
4	Environmental health	Regulations & policy	Social-ecological	1
5	Environmental health	Human recreational activitiies	Social-ecological	1
6	Environmental health	Individual behaviours & lifestyle & stewardship	Social-ecological	1
7	Environmental health	Consumption	Social-ecological	1
8	Water quality	Environmental health	Ecological	4
9	Water quality	Aquatic ecoystem	Ecological	1
10	Water quality	Fish population	Ecological	1
11	Boating	Environmental health	Social-ecological	1
12	Boating	Water quality	Social-ecological	1
13	Boating	Fish population	Social-ecological	1
14	Boating	Economy	Social	1
15	Boating	Tourism	Social	1
16	Boating	Erosion	Social-ecological	1
17	Boating	Fishing	Social	1
18	Knowledge	Water quality	Social-ecological	1
19	Knowledge	Consumption	Social	1
20	Knowledge	Local action	Social	1
21	Improvements to canal	Water quality	Social-ecological	1
22	Road salt	Water quality	Social-ecological	1
23	Enforcement	Water quality	Social-ecological	1
24	Enforcement	Climate Change	Social-ecological	1
25	Climate Change	Environmental health	Ecological	4
26	Climate Change	Fish population	Ecological	1
27	Climate Change	Regulations & policy	Social-ecological	1
28	Climate Change	Individual behaviours & lifestyle & stewardship	Social-ecological	1
29	Climate Change	Local action	Social-ecological	1
30	Agriculture	Environmental health	Social-ecological	1
31	Agriculture	Water quality	Social-ecological	1
32	Agriculture	Ecosystem quality	Social-ecological	1
33	Agriculture	Pollution	Social	1
34	Agriculture	Weed cover	Social-ecological	1
35	Agriculture	Invasive species	Social-ecological	1
36	Buffer zones	Water quality	Ecological	1
37	Buffer zones	Agriculture	Social-ecological	1
38	Awareness	Environmental health	Social-ecological	2
39	Awareness	Water quality	Social-ecological	1
40	Awareness	Boating	Social	1
41	Awareness	Economy	Social	1
42	Awareness	Human recreational activitiies	Social	1
43	Rural infrastructure	Resource use	Social	1
44	Rural infrastructure	Economy	Social	1
45	Fish population	Environmental health	Ecological	2
46	Fish population	Human recreational activitiies	Social-ecological	1
47	Boating and fishing regulations	Boating	Social	1
48	Boating and fishing regulations	Fish population	Social-ecological	1
49	Resource use	Environmental health	Social-ecological	1
50	Resource use	Fish population	Social-ecological	1
51	Economy	Environmental health	Social-ecological	1
52	Economy	Water quality	Social-ecological	1

	Sender node	Receiver node	Tie category	Pair-level frequency
53	Economy	Boating	Social	1
54	Economy	Resource use	Social	1
55	Economy	Tourism	Social	2
56	Economy	Money/capacity	Social	1
57	Economy	Partnerships	Social	1
58	Demographics	Economy	Social	1
59	Tourism	Environmental health	Social-ecological	1
60	Tourism	Water quality	Social-ecological	2
61	Tourism	Boating	Social	2
62	Tourism	Resource use	Social	1
63	Tourism	Economy	Social	2
64	Tourism	Erosion	Social-ecological	1
65	Tourism	Fishing	Social	1
66	Tourism	Partnerships	Social	1
67	Erosion	Environmental health	Ecological	1
68	Shoreline development	Environmental health	Social-ecological	1
69	Shoreline development	Water quality	Social-ecological	2
70	Shoreline development	Regulations & policy	Social	1
71	Shoreline development	Shoreline hardening	Social	1
72	Regulations & policy	Environmental health	Social-ecological	1
73	Regulations & policy	Climate Change	Social-ecological	2
74	Regulations & policy	Tourism	Social	1
75	Regulations & policy	Shoreline development	Social	1
76	Regulations & policy	Individual behaviours & lifestyle & stewardship	Social	1
77	Regulations & policy	Consumption	Social	1
78	Regulations & policy	Global actions	Social	1
79	Fishing	Water quality	Social-ecological	1
80	Fishing	Boating	Social	1
81	Commercial fishing	Boating	Social	1
82	Commercial fishing	Fishing	Social	1
83	Commercial fishing	Biodiversity	Social-ecological	1
84	Commercial fishing	Ecosystem quality	Social-ecological	1
85	Commercial fishing	Weed cover	Social-ecological	1
86	Commercial fishing	Invasive species	Social-ecological	1
87	Biodiversity	Fishing	Social-ecological	1
88	Ecosystem quality	Commercial fishing	Social-ecological	1
89	Ecosystem quality	Biodiversity	Ecological	1
90	Pollution	Water quality	Social-ecological	1
91	Pollution	Agriculture	Social	1
92	Pollution	Ecosystem quality	Social-ecological	1
93	Pollution	Weed cover	Social-ecological	1
94	Pollution	Invasive species	Social-ecological	1
95	Human recreational activitiies	Environmental health	Social-ecological	1
96	Human recreational activitiies	Fish population	Social-ecological	1
97	Money/capacity	Environmental health	Social-ecological	1
98	Money/capacity	Economy	Social	1
99	Partnerships	Economy	Social	1
100	Partnerships	Tourism	Social	1
101	Shoreline hardening	Fish population	Social-ecological	1
102	Individual behaviours & lifestyle & stewardship	Climate Change	Social-ecological	1
103	Individual behaviours & lifestyle & stewardship	Consumption	Social	1
104	Consumption	Environmental health	Social-ecological	1
105	Consumption	Knowledge	Social	1
106	Consumption	Individual behaviours & lifestyle & stewardship	Social	1

	Sender node	Receiver node	Tie category	Pair-level frequency
107	Consumption	Education	Social	1
108	Local action	Knowledge	Social	1
109	Local action	Climate Change	Social-ecological	1
110	Local action	Regulations & policy	Social	1
111	Local action	Global actions	Social	1
112	Local action	Education	Social	1
113	Global actions	Regulations & policy	Social	1
114	Weed cover	Commercial fishing	Social-ecological	1
115	Weed cover	Biodiversity	Ecological	1
116	Invasive species	Commercial fishing	Social-ecological	1
117	Invasive species	Biodiversity	Ecological	1
118	Education	Water quality	Social-ecological	1
119	Education	Consumption	Social	1
120	Education	Local action	Social	1

Workshop-level network data for academics

Network for academics

Node data for academics

	Workshop 4 nodes	Node type	In degree centrality	Out degree centrality	Rescale In degree cen	Rescale Out degree cen.	Rescale In + Out degree centrality	Betweenness centrality	Rescale Betweenness centrality
1	Environmental health	Ecological	13	1	14,13	1,09	15,22	152	0,18
2	Climate Change	Ecological	0	2	0,00	2,17	2,17	0	0
3	Land use policy	Social	1	2	1,09	2,17	3,26	21	0,02
4	Phosphorus	Ecological	2	1	2,17	1,09	3,26	7,58	0,01
5	Algae	Ecological	5	3	5,43	3,26	8,70	27,50	0,03
6	Invasive species	Ecological	9	3	9,78	3,26	13,04	30,67	0,04
7	Boating	Social	6	6	6,52	6,52	13,04	168,17	0,20
8	Tourism	Social	1	2	1,09	2,17	3,26	126	0,15
9	Coordination and cooperation	Social	0	3	0,00	3,26	3,26	0	0
10	Enforcement	Social	6	3	6,52	3,26	9,78	30,83	0,04
11	Monitoring	Social	3	4	3,26	4,35	7,61	16,42	0,02
12	Mores and worldviews	Social	1	2	1,09	2,17	3,26	0	0
13	Political will	Social	1	4	1,09	4,35	5,43	2,50	0,00
14	Money/capacity	Social	1	2	1,09	2,17	3,26	0	0
15	Water quality	Ecological	2	2	2,17	2,17	4,35	4,17	0,00
16	Habitat	Ecological	2	2	2,17	2,17	4,35	4,17	0,00
17	Biodiversity	Ecological	3	1	3,26	1,09	4,35	0,67	0,00
18	Lotic/lentic system	Ecological	0	5	0,00	5,43	5,43	0	0
19	Shoreline development	Social	4	9	4,35	9,78	14,13	90,33	0,11
20	Jurisdictional quagmire	Social	2	2	2,17	2,17	4,35	22,33	0,03
21	Colonel By	Social	0	1	0,00	1,09	1,09	0	0
22	Individual behaviours & lifestyle & stewardship	Social	2	1	2,17	1,09	3,26	14,33	0,02
23	Multiple users	Social	1	1	1,09	1,09	2,17	10,67	0,01
24	Nutrient levels	Ecological	5	2	5,43	2,17	7,61	23,67	0,03
25	Erosion	Ecological	5	4	5,43	4,35	9,78	67,25	0,08
26	Agriculture	Social	0	2	0,00	2,17	2,17	0	0
27	Pollution	Social	3	1	3,26	1,09	4,35	11	0,01
28	Shoreline beautification	Social	1	2	1,09	2,17	3,26	0	0
29	Turtle distribution	Ecological	2	0	2,17	0,00	2,17	0	0
30	Commercial fishing	Social	0	2	0,00	2,17	2,17	0	0
31	Fishing	Social	1	2	1,09	2,17	3,26	3,33	0,00
32	Awareness	Social	0	4	0,00	4,35	4,35	0	0
33	Water level management	Social	1	1	1,09	1,09	2,17	3,25	0,00
34	Native species	Ecological	6	2	6,52	2,17	8,70	3,67	0,00
35	Boat launch	Social	0	3	0,00	3,26	3,26	0	0
36	Lock activities	Social	0	2	0,00	2,17	2,17	0	0
37	Aquatic vegetation management	Social	2	1	2,17	1,09	3,26	2,17	0,00
38	Fish tournaments	Social	1	2	1,09	2,17	3,26	3,33	0,00

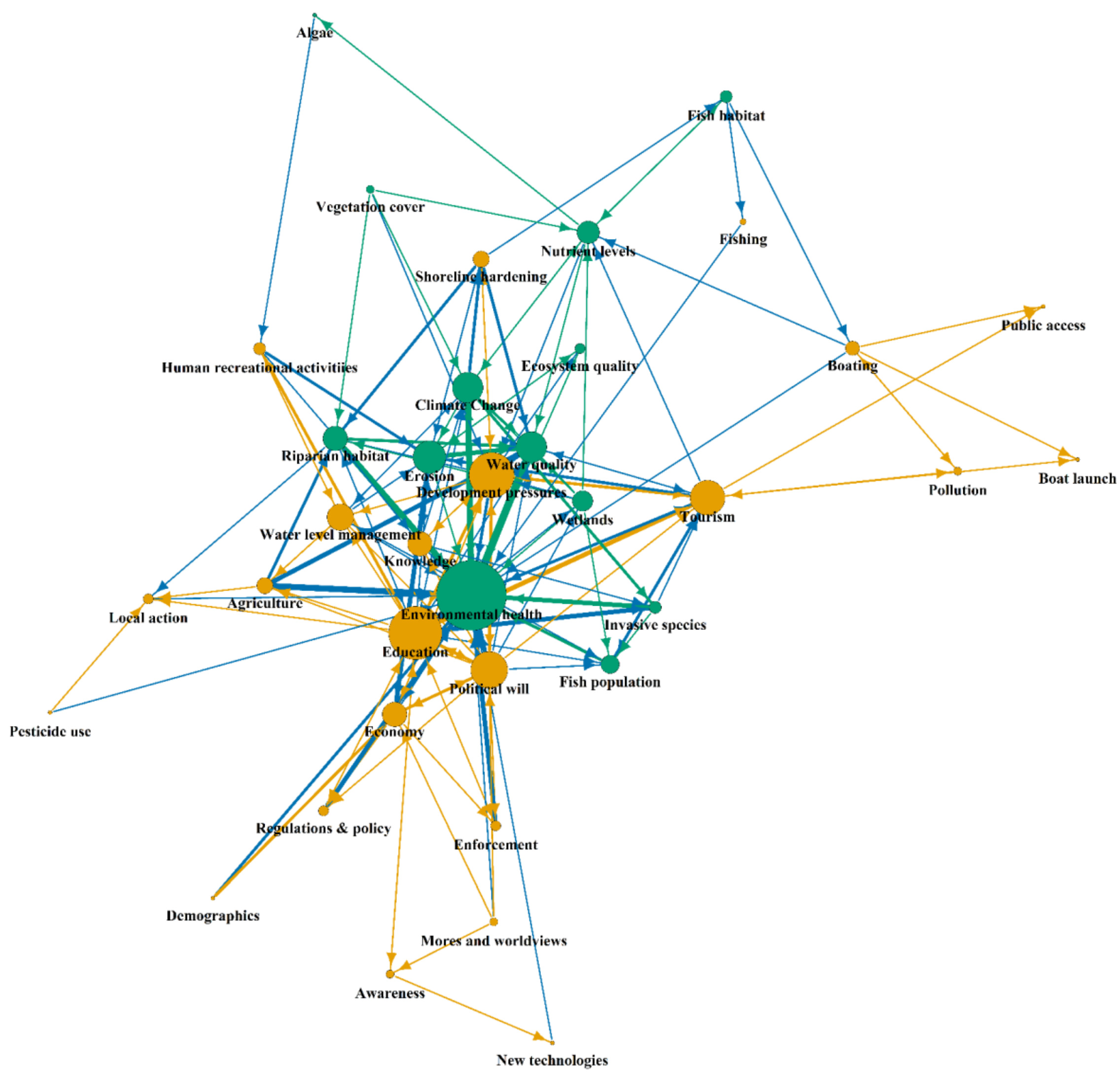
Edge list for academics

	Sender node	Receiver node	Tie category	Pair-level frequency
1	Environmental health	Tourism	Social-ecological	1
2	Climate Change	Algae	Ecological	1
3	Climate Change	Invasive species	Ecological	1
4	Land use policy	Phosphorus	Social-ecological	1
5	Land use policy	Shoreline development	Social	1
6	Phosphorus	Algae	Ecological	1
7	Algae	Environmental health	Ecological	2
8	Algae	Invasive species	Ecological	1
9	Algae	Native species	Ecological	1
10	Invasive species	Environmental health	Ecological	2
11	Invasive species	Algae	Ecological	1
12	Invasive species	Native species	Ecological	1
13	Boating	Environmental health	Social-ecological	1
14	Boating	Invasive species	Social-ecological	3
15	Boating	Erosion	Social-ecological	1
16	Boating	Pollution	Social	1
17	Boating	Turtle distribution	Social-ecological	1
18	Boating	Native species	Social-ecological	1
19	Tourism	Environmental health	Social-ecological	1
20	Tourism	Boating	Social	1
21	Coordination and cooperation	Enforcement	Social	2
22	Coordination and cooperation	Monitoring	Social	2
23	Coordination and cooperation	Water level management	Social	1
24	Enforcement	Environmental health	Social-ecological	1
25	Enforcement	Phosphorus	Social-ecological	1
26	Enforcement	Invasive species	Social-ecological	1
27	Monitoring	Environmental health	Social-ecological	2
28	Monitoring	Invasive species	Social-ecological	1
29	Monitoring	Enforcement	Social	1
30	Monitoring	Native species	Social-ecological	1
31	Mores and worldviews	Enforcement	Social	1
32	Mores and worldviews	Political will	Social	1
33	Political will	Enforcement	Social	1
34	Political will	Monitoring	Social	1
35	Political will	Mores and worldviews	Social	1
36	Political will	Money/capacity	Social	1
37	Money/capacity	Enforcement	Social	1
38	Money/capacity	Monitoring	Social	1
39	Water quality	Environmental health	Ecological	1
40	Water quality	Biodiversity	Ecological	1
41	Habitat	Environmental health	Ecological	1
42	Habitat	Biodiversity	Ecological	1
43	Biodiversity	Environmental health	Ecological	1
44	Lotic/lentic system	Water quality	Ecological	1
45	Lotic/lentic system	Habitat	Ecological	1
46	Lotic/lentic system	Biodiversity	Ecological	1
47	Lotic/lentic system	Jurisdictional quagmire	Social-ecological	1
48	Lotic/lentic system	Multiple users	Social-ecological	1
49	Shoreline development	Environmental health	Social-ecological	1
50	Shoreline development	Boating	Social	1
51	Shoreline development	Water quality	Social-ecological	1
52	Shoreline development	Habitat	Social-ecological	1

	Sender node	Receiver node	Tie category	Pair-level frequency
53	Shoreline development	Individual behaviours & lifestyle & stewardship	Social	1
54	Shoreline development	Nutrient levels	Social-ecological	1
55	Shoreline development	Erosion	Social-ecological	2
56	Shoreline development	Pollution	Social	1
57	Shoreline development	Shoreline beautification	Social	1
58	Jurisdictional quagmire	Land use policy	Social	1
59	Jurisdictional quagmire	Individual behaviours & lifestyle & stewardship	Social	1
60	Colonel By	Jurisdictional quagmire	Social	1
61	Individual behaviours & lifestyle & stewardship	Shoreline development	Social	1
62	Multiple users	Shoreline development	Social	1
63	Nutrient levels	Environmental health	Ecological	1
64	Nutrient levels	Algae	Ecological	1
65	Erosion	Environmental health	Ecological	1
66	Erosion	Algae	Ecological	1
67	Erosion	Nutrient levels	Ecological	2
68	Erosion	Aquatic vegetation management	Social-ecological	1
69	Agriculture	Nutrient levels	Social-ecological	1
70	Agriculture	Pollution	Social	1
71	Pollution	Nutrient levels	Social-ecological	1
72	Shoreline beautification	Nutrient levels	Social-ecological	1
73	Shoreline beautification	Erosion	Social-ecological	1
74	Commercial fishing	Boating	Social	1
75	Commercial fishing	Turtle distribution	Social-ecological	1
76	Fishing	Boating	Social	2
77	Fishing	Native species	Social-ecological	1
78	Awareness	Invasive species	Social-ecological	1
79	Awareness	Enforcement	Social	1
80	Awareness	Shoreline development	Social	1
81	Awareness	Erosion	Social-ecological	1
82	Water level management	Erosion	Social-ecological	1
83	Native species	Environmental health	Ecological	1
84	Native species	Invasive species	Ecological	1
85	Boat launch	Invasive species	Social-ecological	1
86	Boat launch	Fishing	Social	1
87	Boat launch	Fish tournaments	Social	1
88	Lock activities	Boating	Social	1
89	Lock activities	Aquatic vegetation management	Social	1
90	Aquatic vegetation management	Invasive species	Social-ecological	1
91	Fish tournaments	Boating	Social	2
92	Fish tournaments	Native species	Social-ecological	1

Workshop-level network data for government representatives

Network for government representatives



Node data for government representatives

	Workshop 5 nodes	Node type	In degree centrality	Out degree centrality	Rescale In degree centrality	Rescale Out degree centrality	Rescale In + Out degree centrality	Betweenness centrality	Rescale Betweenness centrality
1	Environmental health	Ecological	25	9	14,97	5,39	20,36	329,87	0,22
2	Water level management	Social	7	6	4,19	3,59	7,78	33,38	0,02
3	Agriculture	Social	3	5	1,80	2,99	4,79	4,69	0,00
4	Education	Social	8	18	4,79	10,78	15,57	235,96	0,16
5	Fish population	Ecological	7	2	4,19	1,20	5,39	3,28	0,00
6	Tourism	Social	8	9	4,79	5,39	10,18	175,07	0,12
7	Political will	Social	5	13	2,99	7,78	10,78	32,28	0,02
8	Development pressures	Social	10	12	5,99	7,19	13,17	118,95	0,08
9	Wetlands	Ecological	3	7	1,80	4,19	5,99	10,23	0,01
10	Water quality	Ecological	12	3	7,19	1,80	8,98	18,63	0,01
11	Climate Change	Ecological	8	7	4,79	4,19	8,98	71,85	0,05
12	Human recreational activitiies	Social	3	3	1,80	1,80	3,59	30	0,02
13	Nutrient levels	Ecological	6	5	3,59	2,99	6,59	89,43	0,06
14	Algae	Ecological	1	1	0,60	0,60	1,20	3,07	0,00
15	Public access	Social	2	0	1,20	0,00	1,20	0	0
16	Pollution	Social	2	2	1,20	1,20	2,40	21,14	0,01
17	Boat launch	Social	2	0	1,20	0,00	1,20	0	0
18	Boating	Social	2	5	1,20	2,99	4,19	18,49	0,01
19	Fish habitat	Ecological	3	3	1,80	1,80	3,59	50,56	0,03
20	Fishing	Social	1	2	0,60	1,20	1,80	4,52	0,00
21	Shoreline hardening	Social	3	5	1,80	2,99	4,79	36,50	0,02
22	Erosion	Ecological	9	7	5,39	4,19	9,58	64,89	0,04
23	Ecosystem quality	Ecological	3	2	1,80	1,20	2,99	2,81	0,00
24	Knowledge	Social	5	7	2,99	4,19	7,19	24,98	0,02
25	Economy	Social	6	6	3,59	3,59	7,19	40,11	0,03
26	Enforcement	Social	3	2	1,80	1,20	2,99	0,83	0,00
27	Riparian habitat	Ecological	7	5	4,19	2,99	7,19	20,19	0,01
28	Invasive species	Ecological	3	3	1,80	1,80	3,59	3,31	0,00
29	Demographics	Social	0	2	0,00	1,20	1,20	0	0
30	New technologies	Social	1	1	0,60	0,60	1,20	1,12	0,00
31	Local action	Social	4	1	2,40	0,60	2,99	0	0
32	Pesticide use	Social	0	2	0,00	1,20	1,20	0	0
33	Mores and worldviews	Social	0	4	0,00	2,40	2,40	0	0
34	Awareness	Social	2	2	1,20	1,20	2,40	33,06	0,02
35	Vegetation cover	Ecological	0	4	0,00	2,40	2,40	0	0
36	Regulations & policy	Social	3	2	1,80	1,20	2,99	0,83	0,00

Edge list for government representatives

	Sender node	Receiver node	Tie category	Pair-level frequency
1	Environmental health	Water level management	Social-ecological	1
2	Environmental health	Education	Social-ecological	2
3	Environmental health	Fish population	Ecological	1
4	Environmental health	Tourism	Social-ecological	2
5	Environmental health	Water quality	Ecological	3
6	Environmental health	Climate Change	Ecological	1
7	Environmental health	Ecosystem quality	Ecological	1
8	Environmental health	Knowledge	Social-ecological	1
9	Environmental health	Economy	Social-ecological	1
10	Water level management	Environmental health	Social-ecological	1
11	Water level management	Agriculture	Social	1
12	Water level management	Fish population	Social-ecological	1
13	Water level management	Climate Change	Social-ecological	1
14	Water level management	Human recreational activitiies	Social	1
15	Water level management	Erosion	Social-ecological	1
16	Agriculture	Environmental health	Social-ecological	4
17	Agriculture	Water level management	Social	1
18	Agriculture	Water quality	Social-ecological	3
19	Agriculture	Riparian habitat	Social-ecological	2
20	Agriculture	Local action	Social	1
21	Education	Environmental health	Social-ecological	5
22	Education	Water level management	Social	1
23	Education	Agriculture	Social	1
24	Education	Fish population	Social-ecological	1
25	Education	Tourism	Social	3
26	Education	Political will	Social	2
27	Education	Development pressures	Social	2
28	Education	Wetlands	Social-ecological	1
29	Education	Water quality	Social-ecological	1
30	Education	Climate Change	Social-ecological	1
31	Education	Human recreational activitiies	Social	2
32	Education	Erosion	Social-ecological	1
33	Education	Enforcement	Social	1
34	Education	Riparian habitat	Social-ecological	1
35	Education	Invasive species	Social-ecological	3
36	Education	Local action	Social	1
37	Education	Awareness	Social	1
38	Education	Regulations & policy	Social	1
39	Fish population	Environmental health	Ecological	2
40	Fish population	Tourism	Social-ecological	2
41	Tourism	Environmental health	Social-ecological	2
42	Tourism	Fish population	Social-ecological	2
43	Tourism	Development pressures	Social	2
44	Tourism	Water quality	Social-ecological	1
45	Tourism	Nutrient levels	Social-ecological	1
46	Tourism	Public access	Social	1
47	Tourism	Pollution	Social	1
48	Tourism	Boat launch	Social	1
49	Tourism	Erosion	Social-ecological	2
50	Political will	Environmental health	Social-ecological	3
51	Political will	Water level management	Social	1
52	Political will	Agriculture	Social	1

	Sender node	Receiver node	Tie category	Pair-level frequency
53	Political will	Education	Social	2
54	Political will	Fish population	Social-ecological	1
55	Political will	Tourism	Social	1
56	Political will	Development pressures	Social	2
57	Political will	Wetlands	Social-ecological	1
58	Political will	Water quality	Social-ecological	1
59	Political will	Knowledge	Social	1
60	Political will	Economy	Social	2
61	Political will	Enforcement	Social	1
62	Political will	Regulations & policy	Social	1
63	Development pressures	Environmental health	Social-ecological	2
64	Development pressures	Water level management	Social	1
65	Development pressures	Education	Social	1
66	Development pressures	Tourism	Social	1
67	Development pressures	Political will	Social	1
68	Development pressures	Wetlands	Social-ecological	1
69	Development pressures	Water quality	Social-ecological	2
70	Development pressures	Shoreline hardening	Social	1
71	Development pressures	Ecosystem quality	Social-ecological	1
72	Development pressures	Knowledge	Social	1
73	Development pressures	Economy	Social	1
74	Development pressures	Riparian habitat	Social-ecological	1
75	Wetlands	Environmental health	Ecological	1
76	Wetlands	Fish population	Ecological	1
77	Wetlands	Development pressures	Social-ecological	1
78	Wetlands	Water quality	Ecological	1
79	Wetlands	Climate Change	Ecological	1
80	Wetlands	Nutrient levels	Ecological	1
81	Wetlands	Riparian habitat	Ecological	1
82	Water quality	Environmental health	Ecological	5
83	Water quality	Tourism	Social-ecological	1
84	Water quality	Climate Change	Ecological	1
85	Climate Change	Environmental health	Ecological	4
86	Climate Change	Water level management	Social-ecological	1
87	Climate Change	Water quality	Ecological	1
88	Climate Change	Nutrient levels	Ecological	1
89	Climate Change	Shoreline hardening	Social-ecological	2
90	Climate Change	Erosion	Ecological	1
91	Climate Change	Invasive species	Ecological	2
92	Human recreational activitiies	Environmental health	Social-ecological	1
93	Human recreational activitiies	Water level management	Social	1
94	Human recreational activitiies	Erosion	Social-ecological	2
95	Nutrient levels	Development pressures	Social-ecological	1
96	Nutrient levels	Water quality	Ecological	1
97	Nutrient levels	Climate Change	Ecological	1
98	Nutrient levels	Algae	Ecological	1
99	Nutrient levels	Fish habitat	Ecological	1
100	Algae	Human recreational activitiies	Social-ecological	1
101	Pollution	Tourism	Social	1
102	Pollution	Boating	Social	1
103	Boating	Environmental health	Social-ecological	1
104	Boating	Nutrient levels	Social-ecological	1
105	Boating	Public access	Social	1
106	Boating	Pollution	Social	1

	Sender node	Receiver node	Tie category	Pair-level frequency
107	Boating	Boat launch	Social	1
108	Fish habitat	Nutrient levels	Ecological	1
109	Fish habitat	Boating	Social-ecological	1
110	Fish habitat	Fishing	Social-ecological	1
111	Fishing	Environmental health	Social-ecological	1
112	Fishing	Fish habitat	Social-ecological	1
113	Shoreline hardening	Development pressures	Social	1
114	Shoreline hardening	Water quality	Social-ecological	2
115	Shoreline hardening	Fish habitat	Social-ecological	1
116	Shoreline hardening	Erosion	Social-ecological	1
117	Shoreline hardening	Riparian habitat	Social-ecological	2
118	Erosion	Environmental health	Ecological	1
119	Erosion	Education	Social-ecological	1
120	Erosion	Water quality	Ecological	3
121	Erosion	Shoreline hardening	Social-ecological	1
122	Erosion	Ecosystem quality	Ecological	1
123	Erosion	Knowledge	Social-ecological	1
124	Erosion	Economy	Social-ecological	1
125	Ecosystem quality	Development pressures	Social-ecological	1
126	Ecosystem quality	Erosion	Ecological	1
127	Knowledge	Environmental health	Social-ecological	1
128	Knowledge	Political will	Social	1
129	Knowledge	Development pressures	Social	1
130	Knowledge	Climate Change	Social-ecological	1
131	Knowledge	Erosion	Social-ecological	1
132	Knowledge	Riparian habitat	Social-ecological	1
133	Knowledge	Invasive species	Social-ecological	1
134	Economy	Environmental health	Social-ecological	1
135	Economy	Political will	Social	2
136	Economy	Development pressures	Social	1
137	Economy	Erosion	Social-ecological	3
138	Economy	Enforcement	Social	1
139	Economy	Regulations & policy	Social	1
140	Enforcement	Environmental health	Social-ecological	3
141	Enforcement	Education	Social	1
142	Riparian habitat	Environmental health	Ecological	4
143	Riparian habitat	Education	Social-ecological	1
144	Riparian habitat	Water quality	Ecological	2
145	Riparian habitat	Knowledge	Social-ecological	1
146	Riparian habitat	Local action	Social-ecological	1
147	Invasive species	Environmental health	Ecological	3
148	Invasive species	Fish population	Ecological	1
149	Invasive species	Tourism	Social-ecological	1
150	Demographics	Environmental health	Social-ecological	2
151	Demographics	Economy	Social	2
152	New technologies	Environmental health	Social-ecological	1
153	Local action	Environmental health	Social-ecological	1
154	Pesticide use	Environmental health	Social-ecological	1
155	Pesticide use	Local action	Social	1
156	Mores and worldviews	Environmental health	Social-ecological	1
157	Mores and worldviews	Political will	Social	1
158	Mores and worldviews	Economy	Social	1
159	Mores and worldviews	Awareness	Social	1
160	Awareness	Education	Social	1

	Sender node	Receiver node	Tie category	Pair-level frequency
161	Awareness	New technologies	Social	1
162	Vegetation cover	Development pressures	Social-ecological	1
163	Vegetation cover	Climate Change	Ecological	1
164	Vegetation cover	Nutrient levels	Ecological	1
165	Vegetation cover	Riparian habitat	Ecological	1
166	Regulations & policy	Environmental health	Social-ecological	3
167	Regulations & policy	Education	Social	1

Workshop-level network data for the water quality workshop

Network for the water quality workshop

Node data for the water quality workshop

	Workshop 3 nodes	Node type	In degree centrality	Out degree centrality	Rescale In degree centrality	Rescale Out degree centrality	Rescale In + Out degree centrality	Betweenness centrality	Rescale Betweenness centrality
1	Water quality	Ecological	27	17	11,07	6,97	18,03	584,29	0,26
2	Algae	Ecological	4	2	1,64	0,82	2,46	18,81	0,01
3	Atmosphere	Ecological	12	7	4,92	2,87	7,79	13,35	0,01
4	Biodiversity	Ecological	4	1	1,64	0,41	2,05	36,35	0,02
5	Boating	Social	17	10	6,97	4,10	11,07	207,72	0,09
6	Buffer zones	Ecological	3	1	1,23	0,41	1,64	13,07	0,01
7	Canal construction	Social	1	3	0,41	1,23	1,64	49,44	0,02
8	Chemicals	Social	5	8	2,05	3,28	5,33	71,33	0,03
9	Climate Change	Ecological	1	5	0,41	2,05	2,46	2	0,00
10	Community	Social	2	4	0,82	1,64	2,46	18,39	0,01
11	Cottages	Social	4	2	1,64	0,82	2,46	15,50	0,01
12	Dams	Social	1	1	0,41	0,41	0,82	0	0
13	Lake depth	Ecological	7	7	2,87	2,87	5,74	25,77	0,01
14	Development pressures	Social	1	7	0,41	2,87	3,28	1,43	0,00
15	Economy	Social	3	1	1,23	0,41	1,64	14,97	0,01
16	Education	Social	1	27	0,41	11,07	11,48	30,62	0,01
17	Engagement	Social	2	0	0,82	0,00	0,82	0	0
18	Erosion	Ecological	5	2	2,05	0,82	2,87	19,50	0,01
19	Fishing	Social	4	9	1,64	3,69	5,33	39,24	0,02
20	Flooded lands and artificial lakes	Social	0	3	0,00	1,23	1,23	0	0
21	Flushing	Ecological	7	7	2,87	2,87	5,74	25,77	0,01
22	Vegetation cover	Ecological	3	4	1,23	1,64	2,87	28,46	0,01
23	Habitat	Ecological	2	6	0,82	2,46	3,28	10,60	0,00
24	Human recreational activitiies	Social	5	7	2,05	2,87	4,92	60,14	0,03
25	Hydrology	Ecological	8	7	3,28	2,87	6,15	26,17	0,01
26	Invasive species	Ecological	6	2	2,46	0,82	3,28	66,41	0,03
27	Lakes	Ecological	7	7	2,87	2,87	5,74	25,77	0,01
28	Landscaping	Social	1	2	0,41	0,82	1,23	0	0
29	Nutrient levels	Ecological	19	10	7,79	4,10	11,89	229,58	0,10
30	Regulations & policy	Social	2	12	0,82	4,92	5,74	12,38	0,01
31	Political will	Social	0	2	0,00	0,82	0,82	0	0
32	Pollution	Social	3	1	1,23	0,41	1,64	0	0
33	Ecosystem productivity	Ecological	1	0	0,41	0,00	0,41	0	0
34	Property value	Social	3	7	1,23	2,87	4,10	11,17	0,00
35	Remediation	Social	0	2	0,00	0,82	0,82	0	0
36	Sediments	Ecological	16	11	6,56	4,51	11,07	37,79	0,02

	Workshop 3 nodes	Node type	In degree centrality	Out degree centrality	Rescale In degree centrality	Rescale Out degree centrality	Rescale In + Out degree centrality	Betweenness centrality	Rescale Betweenness centrality
37	Septic systems	social	2	1	0,82	0,41	1,23	0	0
38	Shallow litoral zones	ecological	1	2	0,41	0,82	1,23	5,71	0,00
39	Shoreline development	social	13	11	5,33	4,51	9,84	156,81	0,07
40	Species succession	ecological	2	1	0,82	0,41	1,23	2,17	0,00
41	Tourism	social	7	2	2,87	0,82	3,69	109,15	0,05
42	Turbidity	ecological	3	2	1,23	0,82	2,05	22,37	0,01
43	Water level management	social	11	11	4,51	4,51	9,02	203,36	0,09
44	Agriculture	social	15	9	6,15	3,69	9,84	67,41	0,03
45	Weather	ecological	1	1	0,41	0,41	0,82	0	0
46	Wetlands	ecological	2	0	0,82	0,00	0,82	0	0

Edge list for the water quality workshop

	Sender node	Receiver node	Tie category	Pair-level frequency
1	Water quality	Algae	Ecological	1
2	Water quality	Biodiversity	Ecological	2
3	Water quality	Community	Social-ecological	1
4	Water quality	Lake depth	Ecological	1
5	Water quality	Engagement	Social-ecological	1
6	Water quality	Fishing	Social-ecological	1
7	Water quality	Flushing	Ecological	1
8	Water quality	Habitat	Ecological	1
9	Water quality	Human recreational activitiies	Social-ecological	1
10	Water quality	Hydrology	Ecological	1
11	Water quality	Invasive species	Ecological	1
12	Water quality	Lakes	Ecological	1
13	Water quality	Ecosystem productivity	Ecological	1
14	Water quality	Property value	Social-ecological	1
15	Water quality	Sediments	Ecological	1
16	Water quality	Tourism	Social-ecological	1
17	Water quality	Water level management	Social-ecological	1
18	Algae	Economy	Social-ecological	1
19	Algae	Tourism	Social-ecological	1
20	Atmosphere	Water quality	Ecological	1
21	Atmosphere	Lake depth	Ecological	1
22	Atmosphere	Flushing	Ecological	1
23	Atmosphere	Hydrology	Ecological	1
24	Atmosphere	Lakes	Ecological	1
25	Atmosphere	Sediments	Ecological	1
26	Atmosphere	Water level management	Social-ecological	1
27	Biodiversity	Tourism	Social-ecological	1
28	Boating	Water quality	Social-ecological	2
29	Boating	Lake depth	Social-ecological	1
30	Boating	Erosion	Social-ecological	1
31	Boating	Flushing	Social-ecological	1
32	Boating	Hydrology	Social-ecological	1
33	Boating	Lakes	Social-ecological	1
34	Boating	Nutrient levels	Social-ecological	1
35	Boating	Sediments	Social-ecological	1
36	Boating	Turbidity	Social-ecological	1
37	Boating	Water level management	Social	1
38	Buffer zones	Water quality	Ecological	1
39	Canal construction	Buffer zones	Social-ecological	1
40	Canal construction	Invasive species	Social-ecological	1
41	Canal construction	Shallow litoral zones	Social-ecological	1
42	Chemicals	Water quality	Social-ecological	2
43	Chemicals	Atmosphere	Social-ecological	1
44	Chemicals	Boating	Social	1
45	Chemicals	Nutrient levels	Social-ecological	2
46	Chemicals	Pollution	Social	1
47	Chemicals	Sediments	Social-ecological	1
48	Chemicals	Shoreline development	Social	1
49	Chemicals	Agriculture	Social	1
50	Climate Change	Water quality	Ecological	3
51	Climate Change	Algae	Ecological	2
52	Climate Change	Invasive species	Ecological	1

	Sender node	Receiver node	Tie category	Pair-level frequency
53	Climate Change	Water level management	Social-ecological	1
54	Climate Change	Weather	Ecological	1
55	Community	Boating	Social	1
56	Community	Cottages	Social	1
57	Community	Tourism	Social	1
58	Community	Agriculture	Social	1
59	Cottages	Erosion	Social-ecological	1
60	Cottages	Nutrient levels	Social-ecological	1
61	Dams	Water level management	Social	1
62	Lake depth	Water quality	Ecological	1
63	Lake depth	Atmosphere	Ecological	1
64	Lake depth	Boating	Social-ecological	1
65	Lake depth	Nutrient levels	Ecological	1
66	Lake depth	Sediments	Ecological	1
67	Lake depth	Shoreline development	Social-ecological	1
68	Lake depth	Agriculture	Social-ecological	1
69	Development pressures	Water quality	Social-ecological	1
70	Development pressures	Atmosphere	Social-ecological	1
71	Development pressures	Boating	Social	1
72	Development pressures	Nutrient levels	Social-ecological	1
73	Development pressures	Sediments	Social-ecological	1
74	Development pressures	Shoreline development	Social	1
75	Development pressures	Agriculture	Social	1
76	Economy	Human recreational activitiies	Social	1
77	Education	Water quality	Social-ecological	3
78	Education	Algae	Social-ecological	1
79	Education	Biodiversity	Social-ecological	1
80	Education	Boating	Social	3
81	Education	Buffer zones	Social-ecological	1
82	Education	Chemicals	Social	2
83	Education	Climate Change	Social-ecological	2
84	Education	Community	Social	1
85	Education	Cottages	Social	1
86	Education	Economy	Social	1
87	Education	Engagement	Social	1
88	Education	Erosion	Social-ecological	1
89	Education	Fishing	Social	2
90	Education	Vegetation cover	Social-ecological	1
91	Education	Human recreational activitiies	Social	1
92	Education	Hydrology	Social-ecological	1
93	Education	Invasive species	Social-ecological	2
94	Education	Landscaping	Social	1
95	Education	Nutrient levels	Social-ecological	1
96	Education	Regulations & policy	Social	1
97	Education	Property value	Social	1
98	Education	Septic systems	Social	1
99	Education	Shoreline development	Social	1
100	Education	Tourism	Social	2
101	Education	Water level management	Social	1
102	Education	Agriculture	Social	2
103	Education	Wetlands	Social-ecological	1
104	Erosion	Nutrient levels	Ecological	2
105	Erosion	Turbidity	Ecological	1
106	Fishing	Water quality	Social-ecological	1

	Sender node	Receiver node	Tie category	Pair-level frequency
107	Fishing	Atmosphere	Social-ecological	1
108	Fishing	Boating	Social	2
109	Fishing	Economy	Social	1
110	Fishing	Human recreational activitiies	Social	1
111	Fishing	Nutrient levels	Social-ecological	1
112	Fishing	Sediments	Social-ecological	1
113	Fishing	Shoreline development	Social	1
114	Fishing	Agriculture	Social	1
115	Flooded lands and artificial lakes	Water quality	Social-ecological	2
116	Flooded lands and artificial lakes	Nutrient levels	Social-ecological	1
117	Flooded lands and artificial lakes	Pollution	Social	1
118	Flushing	Water quality	Ecological	1
119	Flushing	Atmosphere	Ecological	1
120	Flushing	Boating	Social-ecological	1
121	Flushing	Nutrient levels	Ecological	1
122	Flushing	Sediments	Ecological	1
123	Flushing	Shoreline development	Social-ecological	1
124	Flushing	Agriculture	Social-ecological	1
125	Vegetation cover	Water quality	Ecological	2
126	Vegetation cover	Boating	Social-ecological	1
127	Vegetation cover	Species succession	Ecological	1
128	Vegetation cover	Tourism	Social-ecological	1
129	Habitat	Water quality	Ecological	1
130	Habitat	Atmosphere	Ecological	1
131	Habitat	Boating	Social-ecological	1
132	Habitat	Nutrient levels	Ecological	1
133	Habitat	Shoreline development	Social-ecological	1
134	Habitat	Agriculture	Social-ecological	1
135	Human recreational activitiies	Water quality	Social-ecological	2
136	Human recreational activitiies	Atmosphere	Social-ecological	1
137	Human recreational activitiies	Boating	Social	1
138	Human recreational activitiies	Nutrient levels	Social-ecological	1
139	Human recreational activitiies	Sediments	Social-ecological	1
140	Human recreational activitiies	Shoreline development	Social	1
141	Human recreational activitiies	Agriculture	Social	1
142	Hydrology	Water quality	Ecological	2
143	Hydrology	Atmosphere	Ecological	1
144	Hydrology	Boating	Social-ecological	1
145	Hydrology	Nutrient levels	Ecological	1
146	Hydrology	Sediments	Ecological	1
147	Hydrology	Shoreline development	Social-ecological	1
148	Hydrology	Agriculture	Social-ecological	1
149	Invasive species	Water quality	Ecological	2
150	Invasive species	Species succession	Ecological	1
151	Lakes	Water quality	Ecological	1
152	Lakes	Atmosphere	Ecological	1
153	Lakes	Boating	Social-ecological	1
154	Lakes	Nutrient levels	Ecological	1
155	Lakes	Sediments	Ecological	1
156	Lakes	Shoreline development	Social-ecological	1
157	Lakes	Agriculture	Social-ecological	1
158	Landscaping	Chemicals	Social	1
159	Landscaping	Erosion	Social-ecological	1
160	Nutrient levels	Water quality	Ecological	2

	Sender node	Receiver node	Tie category	Pair-level frequency
161	Nutrient levels	Canal construction	Social-ecological	1
162	Nutrient levels	Lake depth	Ecological	1
163	Nutrient levels	Fishing	Social-ecological	1
164	Nutrient levels	Flushing	Ecological	1
165	Nutrient levels	Hydrology	Ecological	1
166	Nutrient levels	Invasive species	Ecological	1
167	Nutrient levels	Lakes	Ecological	1
168	Nutrient levels	Sediments	Ecological	1
169	Nutrient levels	Water level management	Social-ecological	1
170	Regulations & policy	Water quality	Social-ecological	1
171	Regulations & policy	Boating	Social	1
172	Regulations & policy	Chemicals	Social	1
173	Regulations & policy	Cottages	Social	1
174	Regulations & policy	Development pressures	Social	1
175	Regulations & policy	Fishing	Social	2
176	Regulations & policy	Habitat	Social-ecological	1
177	Regulations & policy	Human recreational activitiies	Social	2
178	Regulations & policy	Pollution	Social	1
179	Regulations & policy	Property value	Social	1
180	Regulations & policy	Tourism	Social	1
181	Regulations & policy	Agriculture	Social	1
182	Political will	Education	Social	1
183	Political will	Regulations & policy	Social	1
184	Pollution	Water quality	Social-ecological	2
185	Property value	Water quality	Social-ecological	1
186	Property value	Atmosphere	Social-ecological	1
187	Property value	Boating	Social	1
188	Property value	Nutrient levels	Social-ecological	1
189	Property value	Sediments	Social-ecological	1
190	Property value	Shoreline development	Social	1
191	Property value	Agriculture	Social	1
192	Remediation	Erosion	Social-ecological	1
193	Remediation	Invasive species	Social-ecological	1
194	Sediments	Water quality	Ecological	1
195	Sediments	Atmosphere	Ecological	1
196	Sediments	Boating	Social-ecological	1
197	Sediments	Lake depth	Ecological	1
198	Sediments	Flushing	Ecological	1
199	Sediments	Hydrology	Ecological	1
200	Sediments	Lakes	Ecological	1
201	Sediments	Nutrient levels	Ecological	1
202	Sediments	Shoreline development	Social-ecological	1
203	Sediments	Water level management	Social-ecological	1
204	Sediments	Agriculture	Social-ecological	1
205	Septic systems	Water quality	Social-ecological	1
206	Shallow litoral zones	Vegetation cover	Ecological	1
207	Shallow litoral zones	Turbidity	Ecological	1
208	Shoreline development	Water quality	Social-ecological	2
209	Shoreline development	Buffer zones	Social-ecological	1
210	Shoreline development	Chemicals	Social	1
211	Shoreline development	Lake depth	Social-ecological	1
212	Shoreline development	Flushing	Social-ecological	1
213	Shoreline development	Hydrology	Social-ecological	1
214	Shoreline development	Lakes	Social-ecological	1

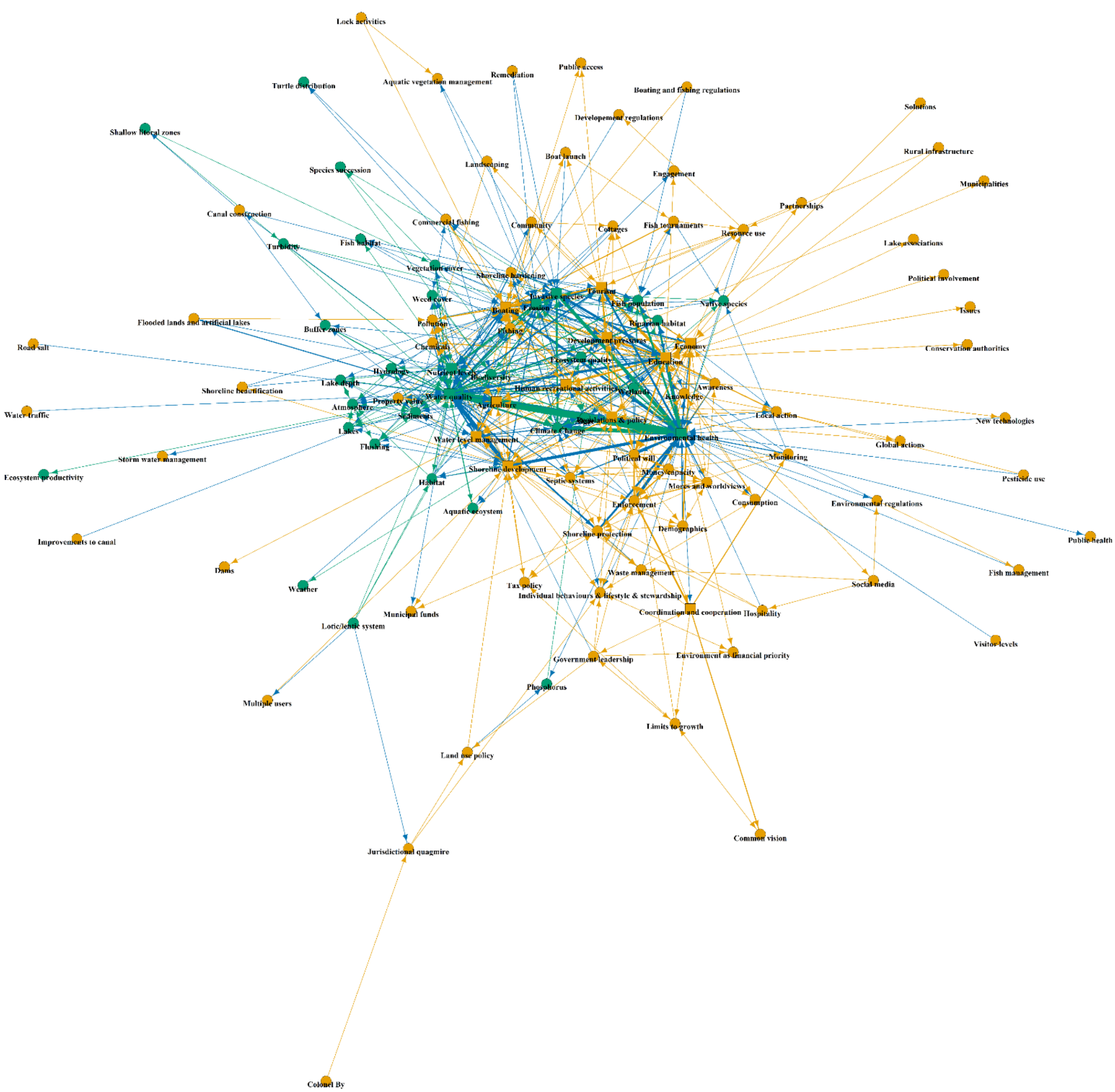
	Sender node	Receiver node	Tie category	Pair-level frequency
215	Shoreline development	Sediments	Social-ecological	1
216	Shoreline development	Septic systems	Social	1
217	Shoreline development	Water level management	Social	1
218	Shoreline development	Wetlands	Social-ecological	1
219	Species succession	Biodiversity	Ecological	1
220	Tourism	Boating	Social	2
221	Tourism	Cottages	Social	1
222	Turbidity	Water quality	Ecological	1
223	Turbidity	Nutrient levels	Ecological	1
224	Water level management	Water quality	Social-ecological	2
225	Water level management	Algae	Social-ecological	1
226	Water level management	Atmosphere	Social-ecological	1
227	Water level management	Biodiversity	Social-ecological	1
228	Water level management	Boating	Social	1
229	Water level management	Dams	Social	1
230	Water level management	Vegetation cover	Social-ecological	1
231	Water level management	Nutrient levels	Social-ecological	1
232	Water level management	Sediments	Social-ecological	1
233	Water level management	Shoreline development	Social	1
234	Water level management	Agriculture	Social	1
235	Agriculture	Water quality	Social-ecological	1
236	Agriculture	Chemicals	Social	1
237	Agriculture	Lake depth	Social-ecological	1
238	Agriculture	Flushing	Social-ecological	1
239	Agriculture	Hydrology	Social-ecological	1
240	Agriculture	Lakes	Social-ecological	1
241	Agriculture	Nutrient levels	Social-ecological	1
242	Agriculture	Sediments	Social-ecological	1
243	Agriculture	Water level management	Social	1
244	Weather	Water level management	Social-ecological	1

Appendix 6. Collective-level network graphs and data

Chapter 1. Supplementary material 5: Collective-level network graphs and data

Collective-level network graph

Orange nodes: Social nodes **Green nodes:** Ecological nodes **Node size:** In + out degree centrality
Orange ties: Social ties **Green ties:** Ecological ties **Blue ties:** Social-ecological ties
Square node: High betweenness centrality **Tie width:** Pair-level frequency
**You can zoom in to see more details and zoom out to see the big picture.*



Collective-level node list

	Node	Type	Pair frequency	Workshop frequency	In degree centrality	Out degree centrality	Betweenness centrality
1	Environmental health	Ecological	20	4	45	25	2429,58
2	Agriculture	Social	11	5	21	18	351,26
3	Algae	Ecological	5	3	8	6	125,93
4	Aquatic vegetation management	Social	1	1	2	1	2,29
5	Aquatic ecoystem	Ecological	2	2	3	2	0,00
6	Atmosphere	Ecological	1	1	12	7	13,13
7	Mores and worldviews	Social	4	3	6	9	117,28
8	Awareness	Social	4	3	2	11	106,00
9	Biodiversity	Ecological	8	4	11	5	132,47
10	Boat launch	Social	2	2	2	3	7,30
11	Boating	Social	15	5	28	23	823,78
12	Boating and fishing regulations	Social	1	1	0	2	0,00
13	Buffer zones	Ecological	3	2	3	2	20,53
14	Canal construction	Social	1	1	1	3	108,47
15	Chemicals	Social	3	1	5	8	42,27
16	Climate Change	Ecological	13	5	13	14	299,28
17	Colonel By	Social	1	1	0	1	0,00
18	Commercial fishing	Social	2	2	3	7	24,76
19	Common vision	Social	2	1	2	1	0,00
20	Community	Social	1	1	2	4	6,94
21	Lotic/lentic system	Ecological	1	1	0	5	0,00
22	Conservation authorities	Social	1	1	1	1	0,00
23	Consumption	Social	1	1	5	4	46,84
24	Coordination and cooperation	Social	5	2	3	7	431,86
25	Cottages	Social	1	1	4	2	4,32
26	Dams	Social	1	1	1	1	0,00
27	Demographics	Social	3	3	4	5	4,59
28	Lake depth	Ecological	1	1	7	7	18,61
29	Development pressures	Social	7	3	11	20	326,72
30	Developement regulations	Social	1	1	1	1	4,55
31	Economy	Social	6	3	15	13	330,92
32	Ecosystem quality	Ecological	5	3	10	7	101,61
33	Education	Social	16	4	18	45	1805,57
34	Enforcement	Social	7	4	12	7	242,07
35	Engagement	Social	1	1	2	0	0,00
36	Environment as financial priority	Social	1	1	3	1	0,94
37	Environmental regulations	Social	1	1	2	3	121,61
38	Erosion	Ecological	8	4	16	11	460,09
39	Fish habitat	Ecological	1	1	3	3	4,55
40	Fish management	Social	1	1	1	1	0,00
41	Fish tournaments	Social	3	2	3	5	16,04
42	Fishing	Social	7	4	10	12	199,10
43	Flooded lands and artificial lakes	Social	2	1	0	3	0,00
44	Flushing	Ecological	1	1	7	7	18,61
45	Global actions	Social	1	1	2	1	0,00
46	Government leadership	Social	1	1	2	7	119,74
47	Habitat	Ecological	2	2	4	8	28,91
48	Shoreline hardening	Social	3	2	4	6	25,23
49	Hospitality	Social	1	1	1	3	28,23
50	Human recreational activitiies	Social	8	4	12	16	330,44
51	Hydrology	Ecological	2	1	8	7	20,45
52	Improvements to canal	Social	1	1	0	1	0,00

	Node	Type	Pair frequency	Workshop frequency	In degree centrality	Out degree centrality	Betweenness centrality
53	Individual behaviours & lifestyle & stewardship	Social	3	3	9	5	296,96
54	Invasive species	Ecological	12	5	19	9	431,22
55	Issues	Social	1	1	1	1	0,00
56	Jurisdictional quagmire	Social	1	1	2	2	101,40
57	Knowledge	Social	4	2	7	10	51,18
58	Lake associations	Social	1	1	1	1	0,00
59	Lakes	Ecological	1	1	7	7	18,61
60	Land use policy	Social	3	2	2	2	61,28
61	Landscaping	Social	1	1	1	2	0,00
62	Limits to growth	Social	1	1	3	4	101,28
63	Local action	Social	2	2	6	6	49,80
64	Lock activities	Social	1	1	0	2	0,00
65	Money/capacity	Social	3	3	4	8	41,42
66	Monitoring	Social	2	1	3	4	7,13
67	Multiple users	Social	1	1	1	1	3,51
68	Municipal funds	Social	1	1	3	0	0,00
69	Municipalities	Social	1	1	1	0	0,00
70	Native species	Ecological	1	1	6	2	5,17
71	New technologies	Social	1	1	1	1	0,00
72	Fish population	Ecological	5	3	15	4	95,42
73	Nutrient levels	Ecological	8	4	29	15	609,17
74	Partnerships	Social	1	1	2	2	0,00
75	Pesticide use	Social	1	1	0	2	0,00
76	Phosphorus	Ecological	1	1	2	1	4,54
77	Political involvement	Social	1	1	1	1	0,00
78	Political will	Social	8	4	7	19	287,05
79	Pollution	Social	5	4	7	8	31,47
80	Ecosystem productivity	Ecological	1	1	1	0	0,00
81	Property value	Social	2	1	3	7	6,98
82	Public access	Social	1	1	2	0	0,00
83	Public health	Social	1	1	1	0	0,00
84	Regulations & policy	Social	10	4	13	21	420,80
85	Remediation	Social	1	1	0	2	0,00
86	Resource use	Social	2	2	6	3	117,40
87	Riparian habitat	Ecological	3	1	7	5	43,47
88	Road salt	Social	1	1	0	1	0,00
89	Rural infrastructure	Social	1	1	0	2	0,00
90	Sediments	Ecological	1	1	16	11	30,49
91	Septic systems	Social	4	2	8	5	22,97
92	Shallow litoral zones	Ecological	1	1	1	2	5,46
93	Shoreline protection	Social	4	1	10	11	145,79
94	Shoreline beautification	Social	1	1	1	2	0,00
95	Shoreline development	Social	11	4	27	28	1252,72
96	Social media	Social	1	1	1	3	113,87
97	Solutions	Social	1	1	0	1	0,00
98	Species succession	Ecological	1	1	2	1	0,83
99	Storm water management	Social	1	1	1	1	0,00
100	Tax policy	Social	1	1	5	3	27,62
101	Tourism	Social	10	4	16	15	451,04
102	Turbidity	Ecological	1	1	3	2	18,88
103	Turtle distribution	Ecological	1	1	2	0	0,00
104	Vegetation cover	Ecological	3	2	3	8	94,53
105	Visitor levels	Social	1	1	0	1	0,00

	Node	Type	Pair frequency	Workshop frequency	In degree centrality	Out degree centrality	Betweenness centrality
106	Waste management	Social	1	1	3	4	46,34
107	Water level management	Social	7	4	16	17	481,74
108	Water quality	Ecological	20	5	49	29	1895,03
109	Water traffic	Social	1	1	0	1	0,00
110	Weather	Ecological	1	1	1	1	0,00
111	Weed cover	Ecological	2	2	6	4	91,95
112	Wetlands	Ecological	3	2	4	7	9,61

Collective-level edge list

	Sender node	Receiver node	Type	Pair frequency	Workshop frequency
1	Environmental health	Agriculture	Social-ecological	1	1
2	Environmental health	Mores and worldviews	Social-ecological	1	1
3	Environmental health	Biodiversity	Ecological	1	1
4	Environmental health	Boating	Social-ecological	1	1
5	Environmental health	Climate Change	Ecological	3	2
6	Environmental health	Consumption	Social-ecological	1	1
7	Environmental health	Coordination and cooperation	Social-ecological	1	1
8	Environmental health	Economy	Social-ecological	2	2
9	Environmental health	Ecosystem quality	Ecological	2	2
10	Environmental health	Education	Social-ecological	6	2
11	Environmental health	Environmental regulations	Social-ecological	1	1
12	Environmental health	Human recreational activitiies	Social-ecological	1	1
13	Environmental health	Individual behaviours & lifestyle & stewardship	Social-ecological	1	1
14	Environmental health	Invasive species	Ecological	1	1
15	Environmental health	Knowledge	Social-ecological	1	1
16	Environmental health	Fish population	Ecological	2	2
17	Environmental health	Political will	Social-ecological	1	1
18	Environmental health	Public health	Social-ecological	1	1
19	Environmental health	Regulations & policy	Social-ecological	1	1
20	Environmental health	Septic systems	Social-ecological	1	1
21	Environmental health	Shoreline protection	Social-ecological	2	1
22	Environmental health	Shoreline development	Social-ecological	2	1
23	Environmental health	Tourism	Social-ecological	3	2
24	Environmental health	Water level management	Social-ecological	1	1
25	Environmental health	Water quality	Ecological	5	2
26	Agriculture	Environmental health	Social-ecological	6	3
27	Agriculture	Chemicals	Social	1	1
28	Agriculture	Lake depth	Social-ecological	1	1
29	Agriculture	Ecosystem quality	Social-ecological	1	1
30	Agriculture	Flushing	Social-ecological	1	1
31	Agriculture	Hydrology	Social-ecological	1	1
32	Agriculture	Invasive species	Social-ecological	1	1
33	Agriculture	Lakes	Social-ecological	1	1
34	Agriculture	Local action	Social	1	1
35	Agriculture	Nutrient levels	Social-ecological	2	2
36	Agriculture	Pollution	Social	2	2
37	Agriculture	Regulations & policy	Social	1	1
38	Agriculture	Riparian habitat	Social-ecological	2	1
39	Agriculture	Sediments	Social-ecological	1	1
40	Agriculture	Tax policy	Social	1	1
41	Agriculture	Water level management	Social	2	2
42	Agriculture	Water quality	Social-ecological	7	4
43	Agriculture	Weed cover	Social-ecological	1	1
44	Algae	Environmental health	Ecological	2	1
45	Algae	Economy	Social-ecological	1	1
46	Algae	Human recreational activitiies	Social-ecological	1	1
47	Algae	Invasive species	Ecological	1	1
48	Algae	Native species	Ecological	1	1
49	Algae	Tourism	Social-ecological	1	1
50	Aquatic vegetation management	Invasive species	Social-ecological	1	1
51	Aquatic ecoystem	Human recreational activitiies	Social-ecological	1	1

	Sender node	Receiver node	Type	Pair frequency	Workshop frequency
52	Aquatic ecoystem	Water quality	Ecological	1	1
53	Atmosphere	Lake depth	Ecological	1	1
54	Atmosphere	Flushing	Ecological	1	1
55	Atmosphere	Hydrology	Ecological	1	1
56	Atmosphere	Lakes	Ecological	1	1
57	Atmosphere	Sediments	Ecological	1	1
58	Atmosphere	Water level management	Social-ecological	1	1
59	Atmosphere	Water quality	Ecological	1	1
60	Mores and worldviews	Environmental health	Social-ecological	2	2
61	Mores and worldviews	Awareness	Social	1	1
62	Mores and worldviews	Demographics	Social	1	1
63	Mores and worldviews	Economy	Social	1	1
64	Mores and worldviews	Education	Social	1	1
65	Mores and worldviews	Enforcement	Social	2	2
66	Mores and worldviews	Political will	Social	2	2
67	Mores and worldviews	Shoreline protection	Social	1	1
68	Mores and worldviews	Shoreline development	Social	1	1
69	Awareness	Environmental health	Social-ecological	2	1
70	Awareness	Boating	Social	1	1
71	Awareness	Economy	Social	1	1
72	Awareness	Education	Social	1	1
73	Awareness	Enforcement	Social	1	1
74	Awareness	Erosion	Social-ecological	1	1
75	Awareness	Human recreational activitiies	Social	1	1
76	Awareness	Invasive species	Social-ecological	1	1
77	Awareness	New technologies	Social	1	1
78	Awareness	Shoreline development	Social	1	1
79	Awareness	Water quality	Social-ecological	1	1
80	Biodiversity	Environmental health	Ecological	1	1
81	Biodiversity	Ecosystem quality	Ecological	1	1
82	Biodiversity	Fishing	Social-ecological	1	1
83	Biodiversity	Septic systems	Social-ecological	1	1
84	Biodiversity	Tourism	Social-ecological	1	1
85	Boat launch	Fish tournaments	Social	1	1
86	Boat launch	Fishing	Social	1	1
87	Boat launch	Invasive species	Social-ecological	1	1
88	Boating	Environmental health	Social-ecological	5	4
89	Boating	Boat launch	Social	1	1
90	Boating	Lake depth	Social-ecological	1	1
91	Boating	Economy	Social	1	1
92	Boating	Erosion	Social-ecological	3	3
93	Boating	Fishing	Social	1	1
94	Boating	Flushing	Social-ecological	1	1
95	Boating	Hydrology	Social-ecological	1	1
96	Boating	Invasive species	Social-ecological	3	1
97	Boating	Lakes	Social-ecological	1	1
98	Boating	Native species	Social-ecological	1	1
99	Boating	Fish population	Social-ecological	1	1
100	Boating	Nutrient levels	Social-ecological	2	2
101	Boating	Pollution	Social	2	2
102	Boating	Public access	Social	1	1
103	Boating	Resource use	Social	1	1
104	Boating	Sediments	Social-ecological	1	1
105	Boating	Septic systems	Social	1	1

	Sender node	Receiver node	Type	Pair frequency	Workshop frequency
106	Boating	Tourism	Social	1	1
107	Boating	Turbidity	Social-ecological	1	1
108	Boating	Turtle distribution	Social-ecological	1	1
109	Boating	Water level management	Social	1	1
110	Boating	Water quality	Social-ecological	3	2
111	Boating and fishing regulations	Boating	Social	1	1
112	Boating and fishing regulations	Fish population	Social-ecological	1	1
113	Buffer zones	Agriculture	Social-ecological	1	1
114	Buffer zones	Water quality	Ecological	2	2
115	Canal construction	Buffer zones	Social-ecological	1	1
116	Canal construction	Invasive species	Social-ecological	1	1
117	Canal construction	Shallow litoral zones	Social-ecological	1	1
118	Chemicals	Agriculture	Social	1	1
119	Chemicals	Atmosphere	Social-ecological	1	1
120	Chemicals	Boating	Social	1	1
121	Chemicals	Nutrient levels	Social-ecological	2	1
122	Chemicals	Pollution	Social	1	1
123	Chemicals	Sediments	Social-ecological	1	1
124	Chemicals	Shoreline development	Social	1	1
125	Chemicals	Water quality	Social-ecological	2	1
126	Climate Change	Environmental health	Ecological	8	2
127	Climate Change	Algae	Ecological	3	2
128	Climate Change	Ecosystem quality	Ecological	1	1
129	Climate Change	Erosion	Ecological	1	1
130	Climate Change	Shoreline hardening	Social-ecological	2	1
131	Climate Change	Individual behaviours & lifestyle & stewardship	Social-ecological	1	1
132	Climate Change	Invasive species	Ecological	4	3
133	Climate Change	Local action	Social-ecological	1	1
134	Climate Change	Fish population	Ecological	1	1
135	Climate Change	Nutrient levels	Ecological	1	1
136	Climate Change	Regulations & policy	Social-ecological	2	2
137	Climate Change	Water level management	Social-ecological	2	2
138	Climate Change	Water quality	Ecological	4	2
139	Climate Change	Weather	Ecological	1	1
140	Colonel By	Jurisdictional quagmire	Social	1	1
141	Commercial fishing	Biodiversity	Social-ecological	1	1
142	Commercial fishing	Boating	Social	2	2
143	Commercial fishing	Ecosystem quality	Social-ecological	1	1
144	Commercial fishing	Fishing	Social	1	1
145	Commercial fishing	Invasive species	Social-ecological	1	1
146	Commercial fishing	Turtle distribution	Social-ecological	1	1
147	Commercial fishing	Weed cover	Social-ecological	1	1
148	Common vision	Limits to growth	Social	1	1
149	Community	Agriculture	Social	1	1
150	Community	Boating	Social	1	1
151	Community	Cottages	Social	1	1
152	Community	Tourism	Social	1	1
153	Lotic/lentic system	Biodiversity	Ecological	1	1
154	Lotic/lentic system	Habitat	Ecological	1	1
155	Lotic/lentic system	Jurisdictional quagmire	Social-ecological	1	1
156	Lotic/lentic system	Multiple users	Social-ecological	1	1
157	Lotic/lentic system	Water quality	Ecological	1	1
158	Conservation authorities	Education	Social	1	1

	Sender node	Receiver node	Type	Pair frequency	Workshop frequency
159	Consumption	Environmental health	Social-ecological	1	1
160	Consumption	Education	Social	1	1
161	Consumption	Individual behaviours & lifestyle & stewardship	Social	1	1
162	Consumption	Knowledge	Social	1	1
163	Coordination and cooperation	Environmental health	Social-ecological	1	1
164	Coordination and cooperation	Common vision	Social	2	1
165	Coordination and cooperation	Enforcement	Social	3	2
166	Coordination and cooperation	Government leadership	Social	1	1
167	Coordination and cooperation	Limits to growth	Social	1	1
168	Coordination and cooperation	Monitoring	Social	2	1
169	Coordination and cooperation	Water level management	Social	1	1
170	Cottages	Erosion	Social-ecological	1	1
171	Cottages	Nutrient levels	Social-ecological	1	1
172	Dams	Water level management	Social	1	1
173	Demographics	Environmental health	Social-ecological	2	1
174	Demographics	Mores and worldviews	Social	1	1
175	Demographics	Economy	Social	3	2
176	Demographics	Shoreline protection	Social	1	1
177	Demographics	Shoreline development	Social	1	1
178	Lake depth	Agriculture	Social-ecological	1	1
179	Lake depth	Atmosphere	Ecological	1	1
180	Lake depth	Boating	Social-ecological	1	1
181	Lake depth	Nutrient levels	Ecological	1	1
182	Lake depth	Sediments	Ecological	1	1
183	Lake depth	Shoreline development	Social-ecological	1	1
184	Lake depth	Water quality	Ecological	1	1
185	Development pressures	Environmental health	Social-ecological	3	2
186	Development pressures	Agriculture	Social	1	1
187	Development pressures	Atmosphere	Social-ecological	1	1
188	Development pressures	Boating	Social	1	1
189	Development pressures	Economy	Social	1	1
190	Development pressures	Ecosystem quality	Social-ecological	1	1
191	Development pressures	Education	Social	1	1
192	Development pressures	Shoreline hardening	Social	1	1
193	Development pressures	Knowledge	Social	1	1
194	Development pressures	Municipalities	Social	1	1
195	Development pressures	Nutrient levels	Social-ecological	1	1
196	Development pressures	Political will	Social	1	1
197	Development pressures	Resource use	Social	1	1
198	Development pressures	Riparian habitat	Social-ecological	1	1
199	Development pressures	Sediments	Social-ecological	1	1
200	Development pressures	Shoreline development	Social	1	1
201	Development pressures	Tourism	Social	1	1
202	Development pressures	Water level management	Social	1	1
203	Development pressures	Water quality	Social-ecological	3	2
204	Development pressures	Wetlands	Social-ecological	1	1
205	Developement regulations	Water quality	Social-ecological	1	1
206	Economy	Environmental health	Social-ecological	2	2
207	Economy	Boating	Social	1	1
208	Economy	Development pressures	Social	1	1
209	Economy	Enforcement	Social	1	1
210	Economy	Erosion	Social-ecological	3	1
211	Economy	Human recreational activitiies	Social	1	1

	Sender node	Receiver node	Type	Pair frequency	Workshop frequency
212	Economy	Money/capacity	Social	1	1
213	Economy	Partnerships	Social	1	1
214	Economy	Political will	Social	2	1
215	Economy	Regulations & policy	Social	1	1
216	Economy	Resource use	Social	1	1
217	Economy	Tourism	Social	2	1
218	Economy	Water quality	Social-ecological	1	1
219	Ecosystem quality	Environmental health	Ecological	2	1
220	Ecosystem quality	Biodiversity	Ecological	2	2
221	Ecosystem quality	Climate Change	Ecological	1	1
222	Ecosystem quality	Commercial fishing	Social-ecological	1	1
223	Ecosystem quality	Development pressures	Social-ecological	1	1
224	Ecosystem quality	Erosion	Ecological	1	1
225	Ecosystem quality	Water quality	Ecological	1	1
226	Education	Environmental health	Social-ecological	7	2
227	Education	Agriculture	Social	3	2
228	Education	Algae	Social-ecological	1	1
229	Education	Aquatic ecoystem	Social-ecological	1	1
230	Education	Mores and worldviews	Social	1	1
231	Education	Awareness	Social	1	1
232	Education	Biodiversity	Social-ecological	1	1
233	Education	Boating	Social	3	1
234	Education	Buffer zones	Social-ecological	1	1
235	Education	Chemicals	Social	2	1
236	Education	Climate Change	Social-ecological	3	2
237	Education	Community	Social	1	1
238	Education	Conservation authorities	Social	1	1
239	Education	Consumption	Social	1	1
240	Education	Cottages	Social	1	1
241	Education	Development pressures	Social	2	1
242	Education	Economy	Social	1	1
243	Education	Enforcement	Social	1	1
244	Education	Engagement	Social	1	1
245	Education	Environment as financial priority	Social	1	1
246	Education	Erosion	Social-ecological	2	2
247	Education	Fishing	Social	2	1
248	Education	Human recreational activitiies	Social	3	2
249	Education	Hydrology	Social-ecological	1	1
250	Education	Invasive species	Social-ecological	5	2
251	Education	Issues	Social	1	1
252	Education	Lake associations	Social	1	1
253	Education	Landscaping	Social	1	1
254	Education	Local action	Social	2	2
255	Education	Fish population	Social-ecological	1	1
256	Education	Nutrient levels	Social-ecological	1	1
257	Education	Political involvement	Social	1	1
258	Education	Political will	Social	3	2
259	Education	Property value	Social	1	1
260	Education	Regulations & policy	Social	2	2
261	Education	Riparian habitat	Social-ecological	1	1
262	Education	Septic systems	Social	1	1
263	Education	Shoreline development	Social	1	1
264	Education	Social media	Social	1	1
265	Education	Tourism	Social	5	2

	Sender node	Receiver node	Type	Pair frequency	Workshop frequency
266	Education	Vegetation cover	Social-ecological	1	1
267	Education	Water level management	Social	2	2
268	Education	Water quality	Social-ecological	5	3
269	Education	Weed cover	Social-ecological	1	1
270	Education	Wetlands	Social-ecological	2	2
271	Enforcement	Environmental health	Social-ecological	6	3
272	Enforcement	Climate Change	Social-ecological	1	1
273	Enforcement	Education	Social	1	1
274	Enforcement	Individual behaviours & lifestyle & stewardship	Social	1	1
275	Enforcement	Invasive species	Social-ecological	1	1
276	Enforcement	Phosphorus	Social-ecological	1	1
277	Enforcement	Water quality	Social-ecological	1	1
278	Environment as financial priority	Individual behaviours & lifestyle & stewardship	Social	1	1
279	Environmental regulations	Environmental health	Social-ecological	1	1
280	Environmental regulations	Ecosystem quality	Social-ecological	1	1
281	Environmental regulations	Fish management	Social	1	1
282	Erosion	Environmental health	Ecological	3	3
283	Erosion	Algae	Ecological	1	1
284	Erosion	Aquatic vegetation management	Social-ecological	1	1
285	Erosion	Economy	Social-ecological	1	1
286	Erosion	Ecosystem quality	Ecological	1	1
287	Erosion	Education	Social-ecological	1	1
288	Erosion	Shoreline hardening	Social-ecological	1	1
289	Erosion	Knowledge	Social-ecological	1	1
290	Erosion	Nutrient levels	Ecological	4	2
291	Erosion	Turbidity	Ecological	1	1
292	Erosion	Water quality	Ecological	3	1
293	Fish habitat	Boating	Social-ecological	1	1
294	Fish habitat	Fishing	Social-ecological	1	1
295	Fish habitat	Nutrient levels	Ecological	1	1
296	Fish management	Environmental health	Social-ecological	1	1
297	Fish tournaments	Boating	Social	2	1
298	Fish tournaments	Human recreational activitiies	Social	1	1
299	Fish tournaments	Native species	Social-ecological	1	1
300	Fish tournaments	Fish population	Social-ecological	1	1
301	Fish tournaments	Resource use	Social	1	1
302	Fishing	Environmental health	Social-ecological	1	1
303	Fishing	Agriculture	Social	1	1
304	Fishing	Atmosphere	Social-ecological	1	1
305	Fishing	Boating	Social	5	3
306	Fishing	Economy	Social	1	1
307	Fishing	Fish habitat	Social-ecological	1	1
308	Fishing	Human recreational activitiies	Social	1	1
309	Fishing	Native species	Social-ecological	1	1
310	Fishing	Nutrient levels	Social-ecological	1	1
311	Fishing	Sediments	Social-ecological	1	1
312	Fishing	Shoreline development	Social	1	1
313	Fishing	Water quality	Social-ecological	2	2
314	Flooded lands and artificial lakes	Nutrient levels	Social-ecological	1	1
315	Flooded lands and artificial lakes	Pollution	Social	1	1
316	Flooded lands and artificial lakes	Water quality	Social-ecological	2	1
317	Flushing	Agriculture	Social-ecological	1	1

	Sender node	Receiver node	Type	Pair frequency	Workshop frequency
318	Flushing	Atmosphere	Ecological	1	1
319	Flushing	Boating	Social-ecological	1	1
320	Flushing	Nutrient levels	Ecological	1	1
321	Flushing	Sediments	Ecological	1	1
322	Flushing	Shoreline development	Social-ecological	1	1
323	Flushing	Water quality	Ecological	1	1
324	Global actions	Regulations & policy	Social	1	1
325	Government leadership	Coordination and cooperation	Social	1	1
326	Government leadership	Enforcement	Social	1	1
327	Government leadership	Environment as financial priority	Social	1	1
328	Government leadership	Individual behaviours & lifestyle & stewardship	Social	1	1
329	Government leadership	Land use policy	Social	1	1
330	Government leadership	Limits to growth	Social	1	1
331	Government leadership	Nutrient levels	Social-ecological	1	1
332	Habitat	Environmental health	Ecological	1	1
333	Habitat	Agriculture	Social-ecological	1	1
334	Habitat	Atmosphere	Ecological	1	1
335	Habitat	Biodiversity	Ecological	1	1
336	Habitat	Boating	Social-ecological	1	1
337	Habitat	Nutrient levels	Ecological	1	1
338	Habitat	Shoreline development	Social-ecological	1	1
339	Habitat	Water quality	Ecological	1	1
340	Shoreline hardening	Development pressures	Social	1	1
341	Shoreline hardening	Erosion	Social-ecological	1	1
342	Shoreline hardening	Fish habitat	Social-ecological	1	1
343	Shoreline hardening	Fish population	Social-ecological	1	1
344	Shoreline hardening	Riparian habitat	Social-ecological	2	1
345	Shoreline hardening	Water quality	Social-ecological	2	1
346	Hospitality	Environmental health	Social-ecological	1	1
347	Hospitality	Shoreline protection	Social	1	1
348	Hospitality	Shoreline development	Social	1	1
349	Human recreational activitiies	Environmental health	Social-ecological	2	2
350	Human recreational activitiies	Agriculture	Social	1	1
351	Human recreational activitiies	Aquatic ecoystem	Social-ecological	1	1
352	Human recreational activitiies	Atmosphere	Social-ecological	1	1
353	Human recreational activitiies	Boating	Social	1	1
354	Human recreational activitiies	Demographics	Social	1	1
355	Human recreational activitiies	Education	Social	1	1
356	Human recreational activitiies	Erosion	Social-ecological	2	1
357	Human recreational activitiies	Fish tournaments	Social	1	1
358	Human recreational activitiies	Fish population	Social-ecological	1	1
359	Human recreational activitiies	Nutrient levels	Social-ecological	1	1
360	Human recreational activitiies	Regulations & policy	Social	1	1
361	Human recreational activitiies	Sediments	Social-ecological	1	1
362	Human recreational activitiies	Shoreline development	Social	1	1
363	Human recreational activitiies	Water level management	Social	1	1
364	Human recreational activitiies	Water quality	Social-ecological	3	2
365	Hydrology	Agriculture	Social-ecological	1	1
366	Hydrology	Atmosphere	Ecological	1	1
367	Hydrology	Boating	Social-ecological	1	1
368	Hydrology	Nutrient levels	Ecological	1	1
369	Hydrology	Sediments	Ecological	1	1
370	Hydrology	Shoreline development	Social-ecological	1	1

	Sender node	Receiver node	Type	Pair frequency	Workshop frequency
371	Hydrology	Water quality	Ecological	2	1
372	Improvements to canal	Water quality	Social-ecological	1	1
373	Individual behaviours & lifestyle & stewardship	Climate Change	Social-ecological	1	1
374	Individual behaviours & lifestyle & stewardship	Consumption	Social	1	1
375	Individual behaviours & lifestyle & stewardship	Enforcement	Social	1	1
376	Individual behaviours & lifestyle & stewardship	Environment as financial priority	Social	1	1
377	Individual behaviours & lifestyle & stewardship	Shoreline development	Social	1	1
378	Invasive species	Environmental health	Ecological	7	3
379	Invasive species	Algae	Ecological	1	1
380	Invasive species	Biodiversity	Ecological	2	2
381	Invasive species	Commercial fishing	Social-ecological	1	1
382	Invasive species	Native species	Ecological	1	1
383	Invasive species	Fish population	Ecological	1	1
384	Invasive species	Species succession	Ecological	1	1
385	Invasive species	Tourism	Social-ecological	1	1
386	Invasive species	Water quality	Ecological	2	1
387	Issues	Education	Social	1	1
388	Jurisdictional quagmire	Individual behaviours & lifestyle & stewardship	Social	1	1
389	Jurisdictional quagmire	Land use policy	Social	1	1
390	Knowledge	Environmental health	Social-ecological	1	1
391	Knowledge	Climate Change	Social-ecological	1	1
392	Knowledge	Consumption	Social	1	1
393	Knowledge	Development pressures	Social	1	1
394	Knowledge	Erosion	Social-ecological	1	1
395	Knowledge	Invasive species	Social-ecological	1	1
396	Knowledge	Local action	Social	1	1
397	Knowledge	Political will	Social	1	1
398	Knowledge	Riparian habitat	Social-ecological	1	1
399	Knowledge	Water quality	Social-ecological	1	1
400	Lake associations	Education	Social	1	1
401	Lakes	Agriculture	Social-ecological	1	1
402	Lakes	Atmosphere	Ecological	1	1
403	Lakes	Boating	Social-ecological	1	1
404	Lakes	Nutrient levels	Ecological	1	1
405	Lakes	Sediments	Ecological	1	1
406	Lakes	Shoreline development	Social-ecological	1	1
407	Lakes	Water quality	Ecological	1	1
408	Land use policy	Phosphorus	Social-ecological	1	1
409	Land use policy	Shoreline development	Social	1	1
410	Landscaping	Chemicals	Social	1	1
411	Landscaping	Erosion	Social-ecological	1	1
412	Limits to growth	Common vision	Social	1	1
413	Limits to growth	Government leadership	Social	1	1
414	Limits to growth	Political will	Social	1	1
415	Limits to growth	Tax policy	Social	1	1
416	Local action	Environmental health	Social-ecological	1	1
417	Local action	Climate Change	Social-ecological	1	1
418	Local action	Education	Social	1	1
419	Local action	Global actions	Social	1	1

	Sender node	Receiver node	Type	Pair frequency	Workshop frequency
420	Local action	Knowledge	Social	1	1
421	Local action	Regulations & policy	Social	1	1
422	Lock activities	Aquatic vegetation management	Social	1	1
423	Lock activities	Boating	Social	1	1
424	Money/capacity	Environmental health	Social-ecological	1	1
425	Money/capacity	Boating	Social	1	1
426	Money/capacity	Economy	Social	1	1
427	Money/capacity	Enforcement	Social	2	2
428	Money/capacity	Monitoring	Social	1	1
429	Money/capacity	Septic systems	Social	1	1
430	Money/capacity	Shoreline protection	Social	1	1
431	Money/capacity	Shoreline development	Social	1	1
432	Monitoring	Environmental health	Social-ecological	2	1
433	Monitoring	Enforcement	Social	1	1
434	Monitoring	Invasive species	Social-ecological	1	1
435	Monitoring	Native species	Social-ecological	1	1
436	Multiple users	Shoreline development	Social	1	1
437	Native species	Environmental health	Ecological	1	1
438	Native species	Invasive species	Ecological	1	1
439	New technologies	Environmental health	Social-ecological	1	1
440	Fish population	Environmental health	Ecological	4	2
441	Fish population	Fish tournaments	Social-ecological	1	1
442	Fish population	Human recreational activitiies	Social-ecological	1	1
443	Fish population	Tourism	Social-ecological	2	1
444	Nutrient levels	Environmental health	Ecological	1	1
445	Nutrient levels	Algae	Ecological	2	2
446	Nutrient levels	Canal construction	Social-ecological	1	1
447	Nutrient levels	Climate Change	Ecological	1	1
448	Nutrient levels	Lake depth	Ecological	1	1
449	Nutrient levels	Development pressures	Social-ecological	1	1
450	Nutrient levels	Fish habitat	Ecological	1	1
451	Nutrient levels	Fishing	Social-ecological	1	1
452	Nutrient levels	Flushing	Ecological	1	1
453	Nutrient levels	Hydrology	Ecological	1	1
454	Nutrient levels	Invasive species	Ecological	1	1
455	Nutrient levels	Lakes	Ecological	1	1
456	Nutrient levels	Sediments	Ecological	1	1
457	Nutrient levels	Water level management	Social-ecological	1	1
458	Nutrient levels	Water quality	Ecological	3	2
459	Partnerships	Economy	Social	1	1
460	Partnerships	Tourism	Social	1	1
461	Pesticide use	Environmental health	Social-ecological	1	1
462	Pesticide use	Local action	Social	1	1
463	Phosphorus	Algae	Ecological	1	1
464	Political involvement	Education	Social	1	1
465	Political will	Environmental health	Social-ecological	4	2
466	Political will	Agriculture	Social	1	1
467	Political will	Mores and worldviews	Social	1	1
468	Political will	Coordination and cooperation	Social	1	1
469	Political will	Development pressures	Social	2	1
470	Political will	Economy	Social	2	1
471	Political will	Education	Social	3	2
472	Political will	Enforcement	Social	3	3
473	Political will	Knowledge	Social	1	1

	Sender node	Receiver node	Type	Pair frequency	Workshop frequency
474	Political will	Money/capacity	Social	1	1
475	Political will	Monitoring	Social	1	1
476	Political will	Fish population	Social-ecological	1	1
477	Political will	Nutrient levels	Social-ecological	1	1
478	Political will	Regulations & policy	Social	2	2
479	Political will	Tax policy	Social	1	1
480	Political will	Tourism	Social	1	1
481	Political will	Water level management	Social	1	1
482	Political will	Water quality	Social-ecological	1	1
483	Political will	Wetlands	Social-ecological	1	1
484	Pollution	Agriculture	Social	1	1
485	Pollution	Boating	Social	1	1
486	Pollution	Ecosystem quality	Social-ecological	1	1
487	Pollution	Invasive species	Social-ecological	1	1
488	Pollution	Nutrient levels	Social-ecological	1	1
489	Pollution	Tourism	Social	1	1
490	Pollution	Water quality	Social-ecological	3	2
491	Pollution	Weed cover	Social-ecological	1	1
492	Property value	Agriculture	Social	1	1
493	Property value	Atmosphere	Social-ecological	1	1
494	Property value	Boating	Social	1	1
495	Property value	Nutrient levels	Social-ecological	1	1
496	Property value	Sediments	Social-ecological	1	1
497	Property value	Shoreline development	Social	1	1
498	Property value	Water quality	Social-ecological	1	1
499	Regulations & policy	Environmental health	Social-ecological	4	2
500	Regulations & policy	Agriculture	Social	2	2
501	Regulations & policy	Boating	Social	2	2
502	Regulations & policy	Chemicals	Social	1	1
503	Regulations & policy	Climate Change	Social-ecological	3	2
504	Regulations & policy	Consumption	Social	1	1
505	Regulations & policy	Cottages	Social	1	1
506	Regulations & policy	Development pressures	Social	1	1
507	Regulations & policy	Education	Social	1	1
508	Regulations & policy	Fishing	Social	2	1
509	Regulations & policy	Global actions	Social	1	1
510	Regulations & policy	Habitat	Social-ecological	1	1
511	Regulations & policy	Human recreational activitiies	Social	3	2
512	Regulations & policy	Individual behaviours & lifestyle & stewardship	Social	1	1
513	Regulations & policy	Pollution	Social	1	1
514	Regulations & policy	Property value	Social	1	1
515	Regulations & policy	Septic systems	Social	1	1
516	Regulations & policy	Shoreline protection	Social	1	1
517	Regulations & policy	Shoreline development	Social	2	2
518	Regulations & policy	Tourism	Social	2	2
519	Regulations & policy	Water quality	Social-ecological	2	2
520	Remediation	Erosion	Social-ecological	1	1
521	Remediation	Invasive species	Social-ecological	1	1
522	Resource use	Environmental health	Social-ecological	1	1
523	Resource use	Developement regulations	Social	1	1
524	Resource use	Fish population	Social-ecological	1	1
525	Riparian habitat	Environmental health	Ecological	4	1
526	Riparian habitat	Education	Social-ecological	1	1

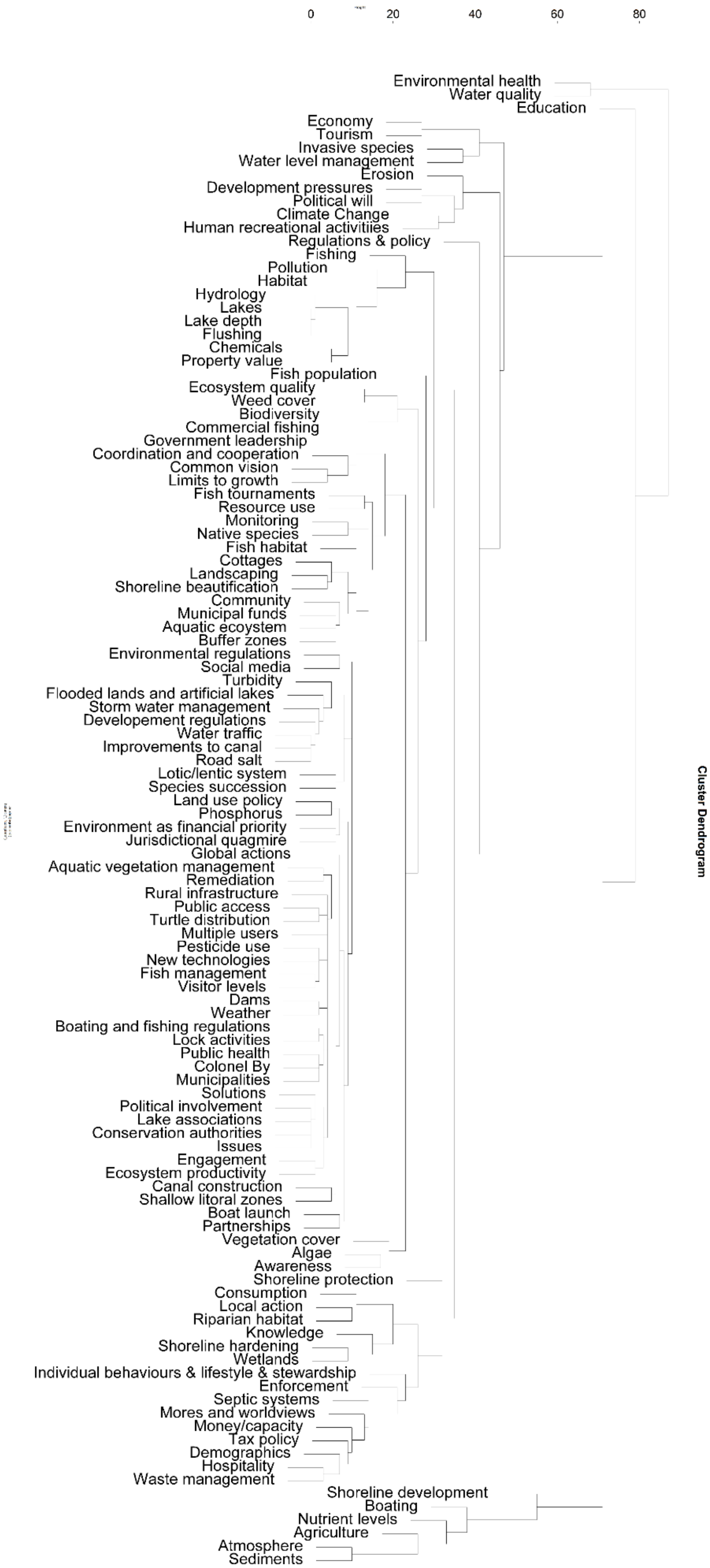
	Sender node	Receiver node	Type	Pair frequency	Workshop frequency
527	Riparian habitat	Knowledge	Social-ecological	1	1
528	Riparian habitat	Local action	Social-ecological	1	1
529	Riparian habitat	Water quality	Ecological	2	1
530	Road salt	Water quality	Social-ecological	1	1
531	Rural infrastructure	Economy	Social	1	1
532	Rural infrastructure	Resource use	Social	1	1
533	Sediments	Agriculture	Social-ecological	1	1
534	Sediments	Atmosphere	Ecological	1	1
535	Sediments	Boating	Social-ecological	1	1
536	Sediments	Lake depth	Ecological	1	1
537	Sediments	Flushing	Ecological	1	1
538	Sediments	Hydrology	Ecological	1	1
539	Sediments	Lakes	Ecological	1	1
540	Sediments	Nutrient levels	Ecological	1	1
541	Sediments	Shoreline development	Social-ecological	1	1
542	Sediments	Water level management	Social-ecological	1	1
543	Sediments	Water quality	Ecological	1	1
544	Septic systems	Environmental health	Social-ecological	2	1
545	Septic systems	Regulations & policy	Social	1	1
546	Septic systems	Shoreline protection	Social	1	1
547	Septic systems	Shoreline development	Social	1	1
548	Septic systems	Water quality	Social-ecological	2	2
549	Shallow litoral zones	Turbidity	Ecological	1	1
550	Shallow litoral zones	Vegetation cover	Ecological	1	1
551	Shoreline protection	Environmental health	Social-ecological	4	1
552	Shoreline protection	Mores and worldviews	Social	1	1
553	Shoreline protection	Demographics	Social	1	1
554	Shoreline protection	Enforcement	Social	1	1
555	Shoreline protection	Money/capacity	Social	1	1
556	Shoreline protection	Municipal funds	Social	1	1
557	Shoreline protection	Regulations & policy	Social	1	1
558	Shoreline protection	Septic systems	Social	1	1
559	Shoreline protection	Tax policy	Social	1	1
560	Shoreline protection	Waste management	Social	1	1
561	Shoreline protection	Water quality	Social-ecological	3	1
562	Shoreline beautification	Erosion	Social-ecological	1	1
563	Shoreline beautification	Nutrient levels	Social-ecological	1	1
564	Shoreline development	Environmental health	Social-ecological	6	3
565	Shoreline development	Mores and worldviews	Social	1	1
566	Shoreline development	Boating	Social	1	1
567	Shoreline development	Buffer zones	Social-ecological	1	1
568	Shoreline development	Chemicals	Social	1	1
569	Shoreline development	Demographics	Social	1	1
570	Shoreline development	Lake depth	Social-ecological	1	1
571	Shoreline development	Enforcement	Social	1	1
572	Shoreline development	Erosion	Social-ecological	2	1
573	Shoreline development	Flushing	Social-ecological	1	1
574	Shoreline development	Habitat	Social-ecological	1	1
575	Shoreline development	Shoreline hardening	Social	1	1
576	Shoreline development	Hydrology	Social-ecological	1	1
577	Shoreline development	Individual behaviours & lifestyle & stewardship	Social	1	1
578	Shoreline development	Lakes	Social-ecological	1	1
579	Shoreline development	Money/capacity	Social	1	1

	Sender node	Receiver node	Type	Pair frequency	Workshop frequency
580	Shoreline development	Municipal funds	Social	1	1
581	Shoreline development	Nutrient levels	Social-ecological	1	1
582	Shoreline development	Pollution	Social	1	1
583	Shoreline development	Regulations & policy	Social	2	2
584	Shoreline development	Sediments	Social-ecological	1	1
585	Shoreline development	Septic systems	Social	2	2
586	Shoreline development	Shoreline beautification	Social	1	1
587	Shoreline development	Tax policy	Social	1	1
588	Shoreline development	Waste management	Social	1	1
589	Shoreline development	Water level management	Social	1	1
590	Shoreline development	Water quality	Social-ecological	8	4
591	Shoreline development	Wetlands	Social-ecological	1	1
592	Social media	Environmental regulations	Social	1	1
593	Social media	Hospitality	Social	1	1
594	Social media	Waste management	Social	1	1
595	Solutions	Education	Social	1	1
596	Species succession	Biodiversity	Ecological	1	1
597	Storm water management	Water quality	Social-ecological	1	1
598	Tax policy	Agriculture	Social	1	1
599	Tax policy	Shoreline protection	Social	1	1
600	Tax policy	Shoreline development	Social	1	1
601	Tourism	Environmental health	Social-ecological	4	3
602	Tourism	Boat launch	Social	1	1
603	Tourism	Boating	Social	5	3
604	Tourism	Cottages	Social	1	1
605	Tourism	Development pressures	Social	2	1
606	Tourism	Economy	Social	2	1
607	Tourism	Erosion	Social-ecological	3	2
608	Tourism	Fishing	Social	1	1
609	Tourism	Fish population	Social-ecological	2	1
610	Tourism	Nutrient levels	Social-ecological	1	1
611	Tourism	Partnerships	Social	1	1
612	Tourism	Pollution	Social	1	1
613	Tourism	Public access	Social	1	1
614	Tourism	Resource use	Social	1	1
615	Tourism	Water quality	Social-ecological	3	2
616	Turbidity	Nutrient levels	Ecological	1	1
617	Turbidity	Water quality	Ecological	1	1
618	Vegetation cover	Boating	Social-ecological	1	1
619	Vegetation cover	Climate Change	Ecological	1	1
620	Vegetation cover	Development pressures	Social-ecological	1	1
621	Vegetation cover	Nutrient levels	Ecological	1	1
622	Vegetation cover	Riparian habitat	Ecological	1	1
623	Vegetation cover	Species succession	Ecological	1	1
624	Vegetation cover	Tourism	Social-ecological	1	1
625	Vegetation cover	Water quality	Ecological	2	2
626	Visitor levels	Environmental health	Social-ecological	1	1
627	Waste management	Environmental health	Social-ecological	1	1
628	Waste management	Shoreline protection	Social	1	1
629	Waste management	Shoreline development	Social	1	1
630	Waste management	Water quality	Social-ecological	1	1
631	Water level management	Environmental health	Social-ecological	1	1
632	Water level management	Agriculture	Social	2	2
633	Water level management	Algae	Social-ecological	1	1

	Sender node	Receiver node	Type	Pair frequency	Workshop frequency
634	Water level management	Atmosphere	Social-ecological	1	1
635	Water level management	Biodiversity	Social-ecological	1	1
636	Water level management	Boating	Social	1	1
637	Water level management	Climate Change	Social-ecological	1	1
638	Water level management	Dams	Social	1	1
639	Water level management	Erosion	Social-ecological	2	2
640	Water level management	Human recreational activitiies	Social	1	1
641	Water level management	Fish population	Social-ecological	1	1
642	Water level management	Nutrient levels	Social-ecological	1	1
643	Water level management	Sediments	Social-ecological	1	1
644	Water level management	Shoreline development	Social	1	1
645	Water level management	Vegetation cover	Social-ecological	1	1
646	Water level management	Water quality	Social-ecological	3	2
647	Water level management	Weed cover	Social-ecological	1	1
648	Water quality	Environmental health	Ecological	15	4
649	Water quality	Agriculture	Social-ecological	1	1
650	Water quality	Algae	Ecological	1	1
651	Water quality	Aquatic ecoystem	Ecological	2	2
652	Water quality	Biodiversity	Ecological	3	2
653	Water quality	Climate Change	Ecological	1	1
654	Water quality	Community	Social-ecological	1	1
655	Water quality	Lake depth	Ecological	1	1
656	Water quality	Ecosystem quality	Ecological	1	1
657	Water quality	Engagement	Social-ecological	1	1
658	Water quality	Fishing	Social-ecological	1	1
659	Water quality	Flushing	Ecological	1	1
660	Water quality	Habitat	Ecological	1	1
661	Water quality	Human recreational activitiies	Social-ecological	1	1
662	Water quality	Hydrology	Ecological	1	1
663	Water quality	Invasive species	Ecological	1	1
664	Water quality	Lakes	Ecological	1	1
665	Water quality	Municipal funds	Social-ecological	1	1
666	Water quality	Fish population	Ecological	2	2
667	Water quality	Ecosystem productivity	Ecological	1	1
668	Water quality	Property value	Social-ecological	1	1
669	Water quality	Regulations & policy	Social-ecological	1	1
670	Water quality	Sediments	Ecological	1	1
671	Water quality	Shoreline protection	Social-ecological	1	1
672	Water quality	Shoreline development	Social-ecological	1	1
673	Water quality	Storm water management	Social-ecological	1	1
674	Water quality	Tourism	Social-ecological	2	2
675	Water quality	Water level management	Social-ecological	2	2
676	Water quality	Weed cover	Ecological	1	1
677	Water traffic	Water quality	Social-ecological	1	1
678	Weather	Water level management	Social-ecological	1	1
679	Weed cover	Biodiversity	Ecological	1	1
680	Weed cover	Commercial fishing	Social-ecological	1	1
681	Weed cover	Education	Social-ecological	1	1
682	Weed cover	Water quality	Ecological	1	1
683	Wetlands	Environmental health	Ecological	1	1
684	Wetlands	Climate Change	Ecological	1	1
685	Wetlands	Development pressures	Social-ecological	1	1
686	Wetlands	Fish population	Ecological	1	1
687	Wetlands	Nutrient levels	Ecological	1	1

	Sender node	Receiver node	Type	Pair frequency	Workshop frequency
688	Wetlands	Riparian habitat	Ecological	1	1
689	Wetlands	Water quality	Ecological	1	1

Collective-level structural equivalence clusters



Appendix 7. Louvain clusters network graphs

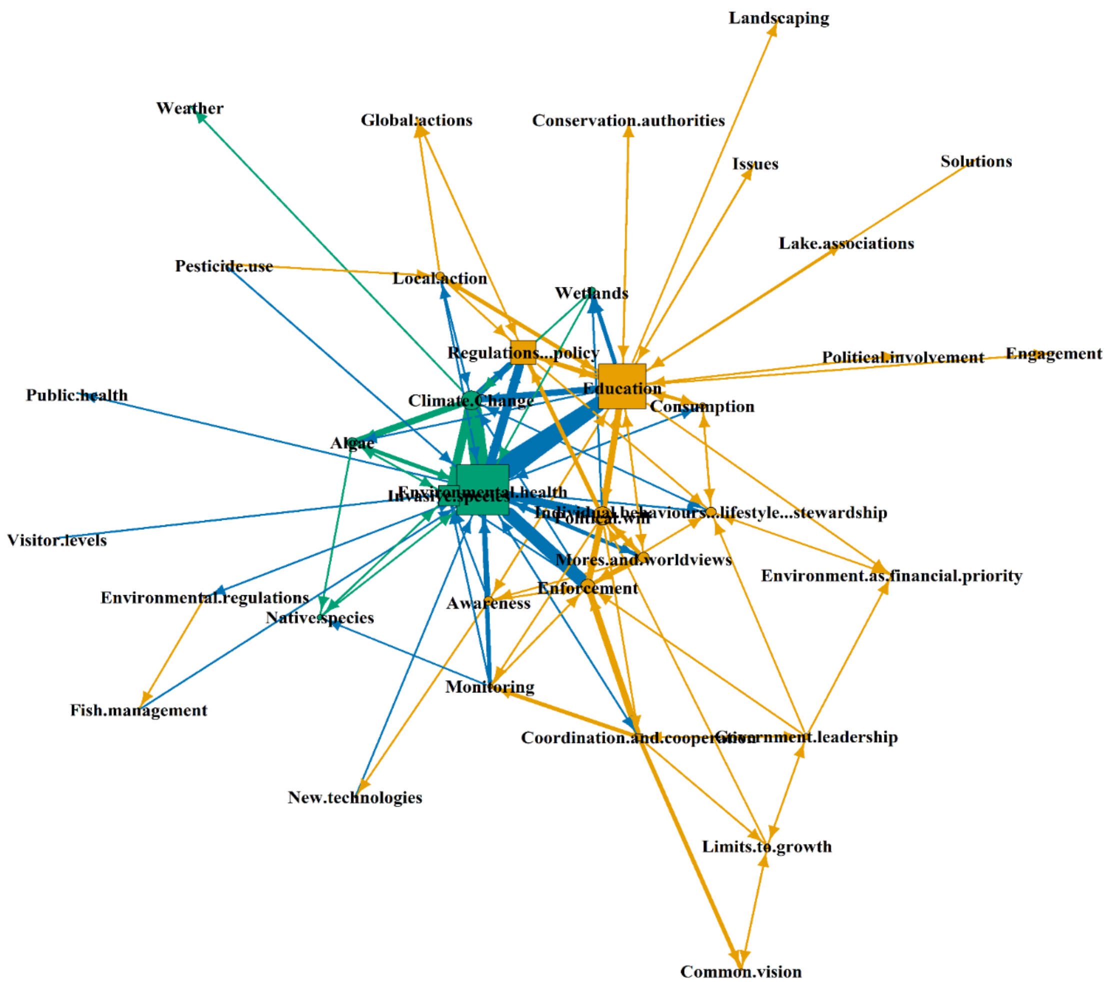
Chapter 1. Supplementary material 6: Louvain clusters network graphs

Legend that applies to all network graphs in this appendix

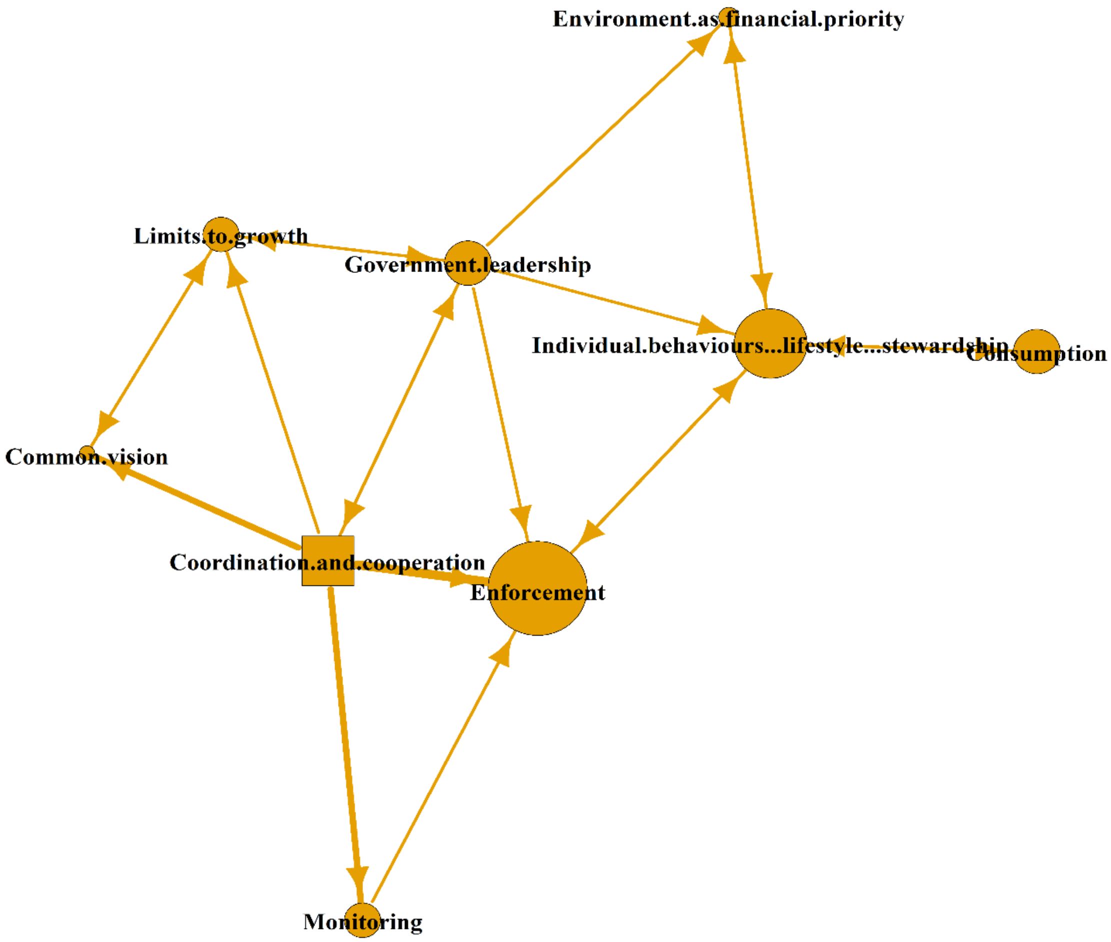
Orange nodes: Social nodes **Green nodes:** Ecological nodes **Node size:** In + out degree centrality
Orange ties: Social ties **Green ties:** Ecological ties **Blue ties:** Social-ecological ties
Square node: High betweenness centrality **Tie width:** Pair-level frequency

Louvain cluster 1

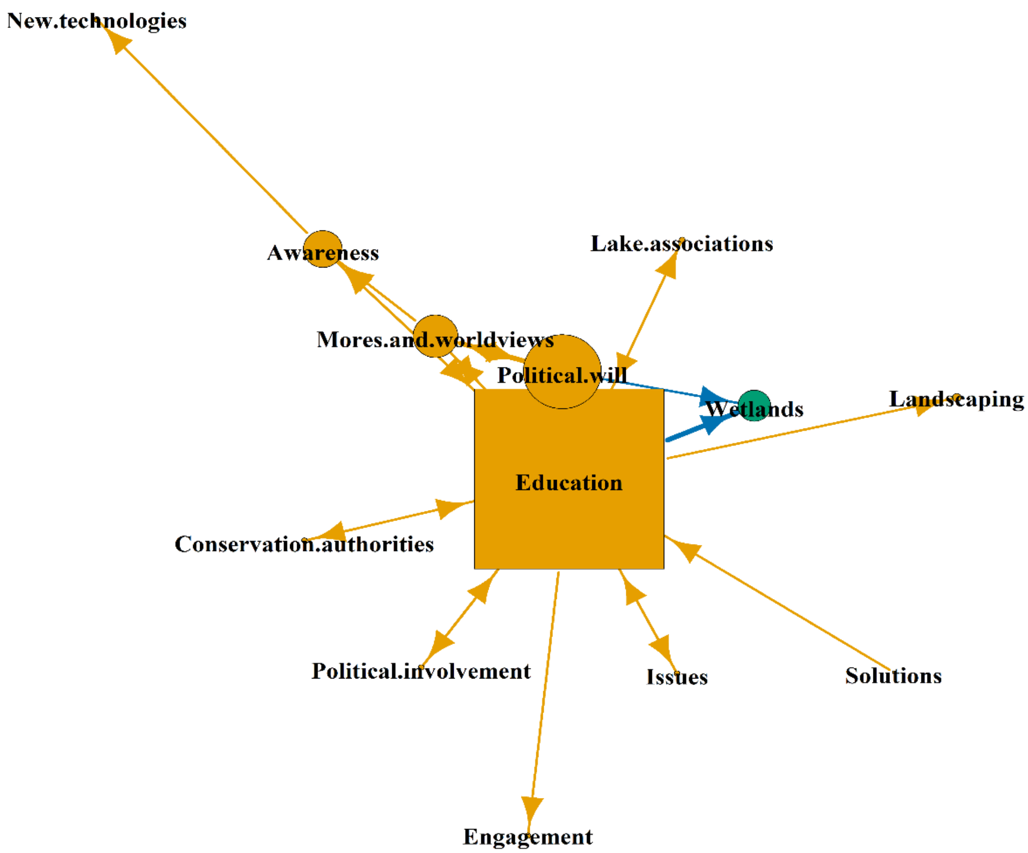
Louvain cluster 2



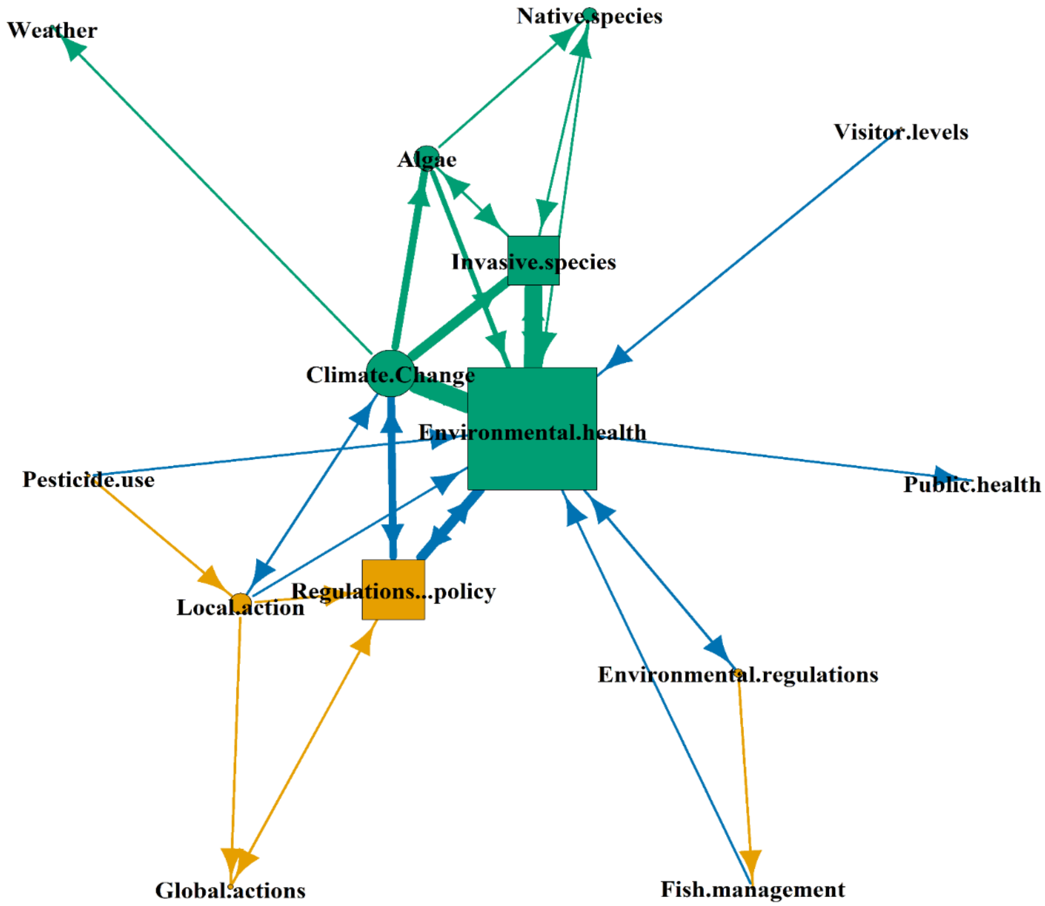
Louvain cluster 2.1



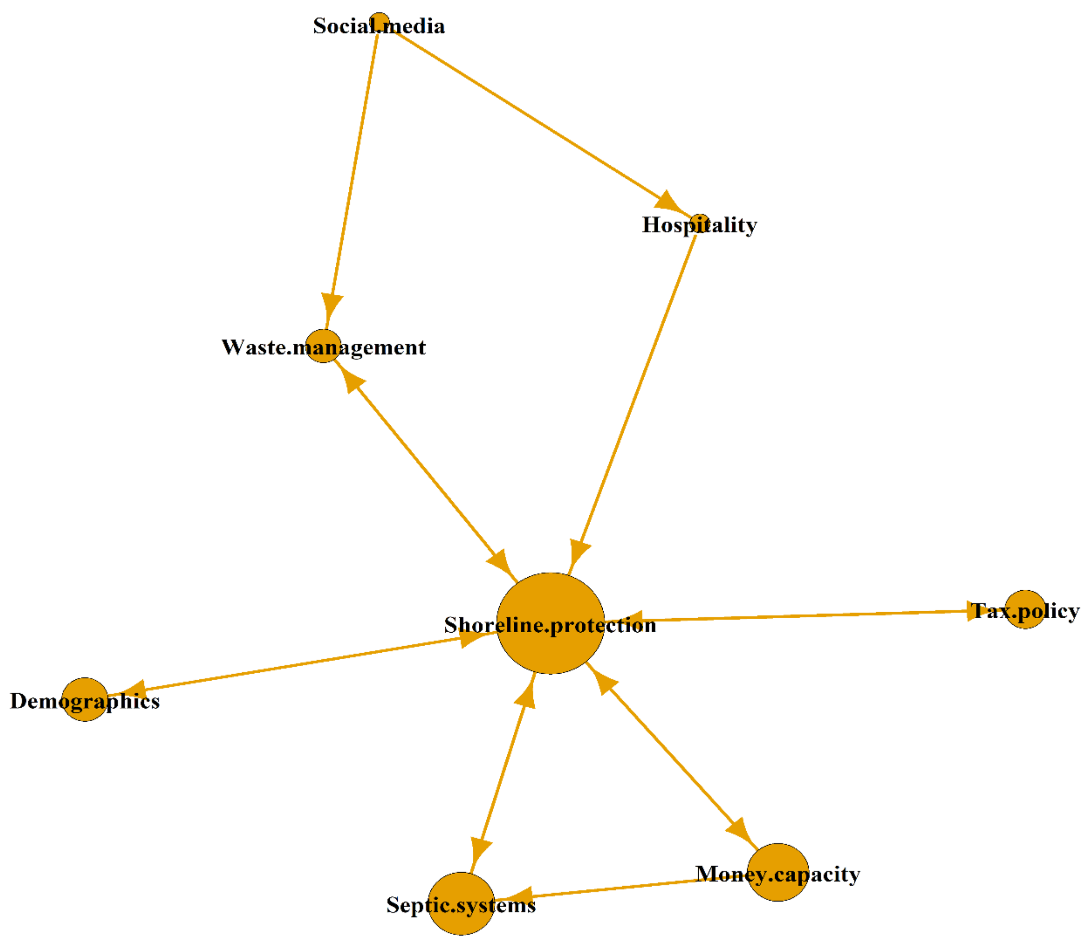
Louvain cluster 2.2



Louvain cluster 2.3

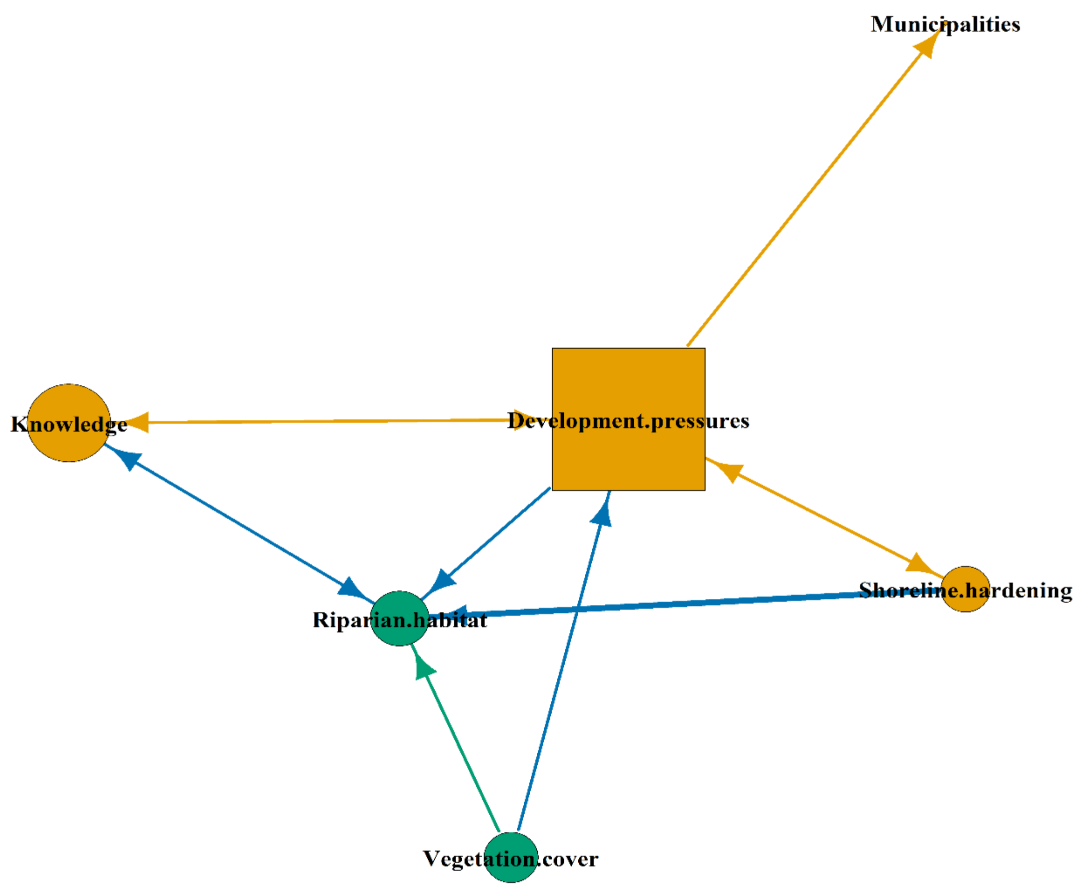


Louvain cluster 3

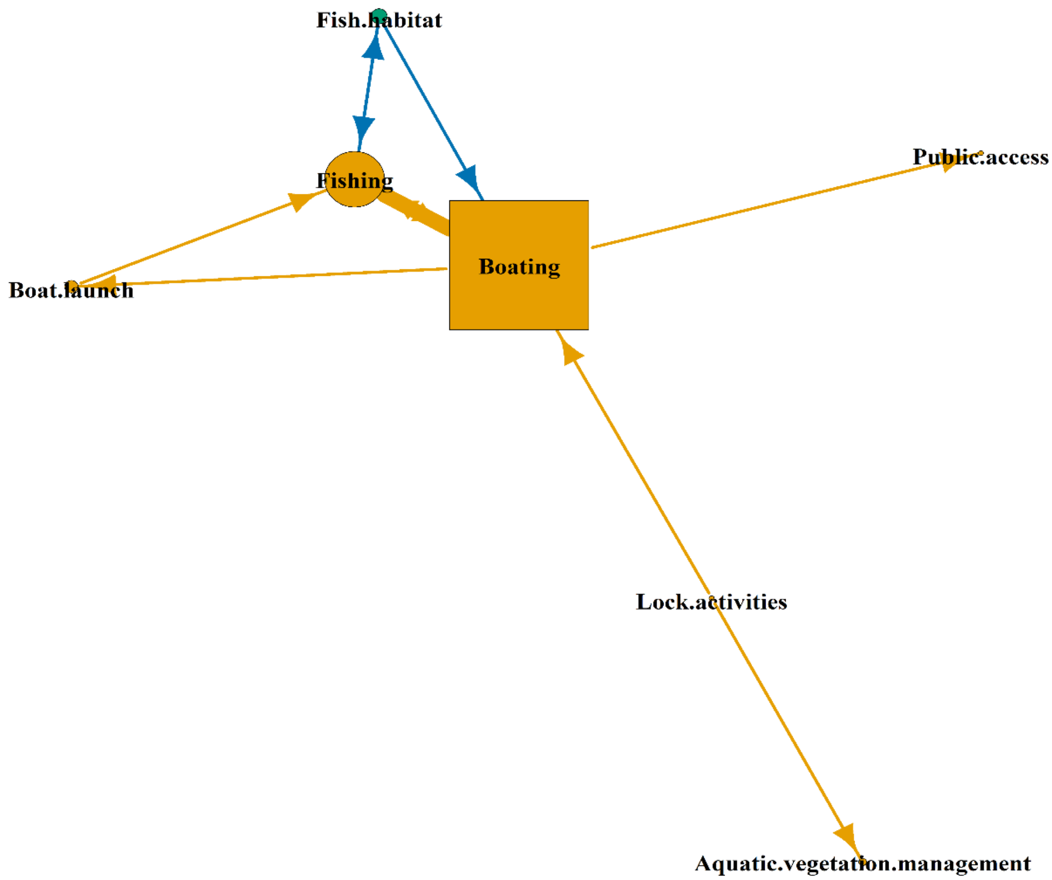


Louvain cluster 4

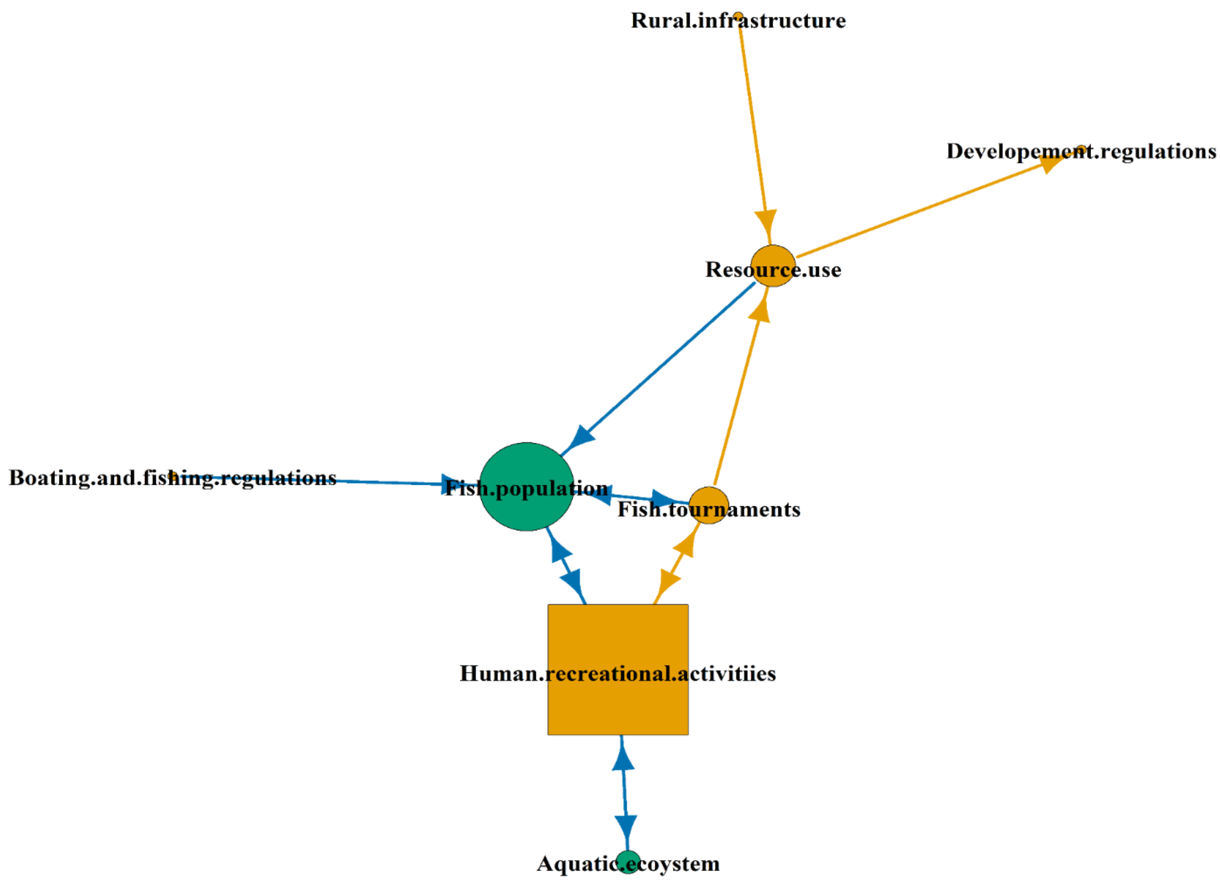
Louvain cluster 4.1



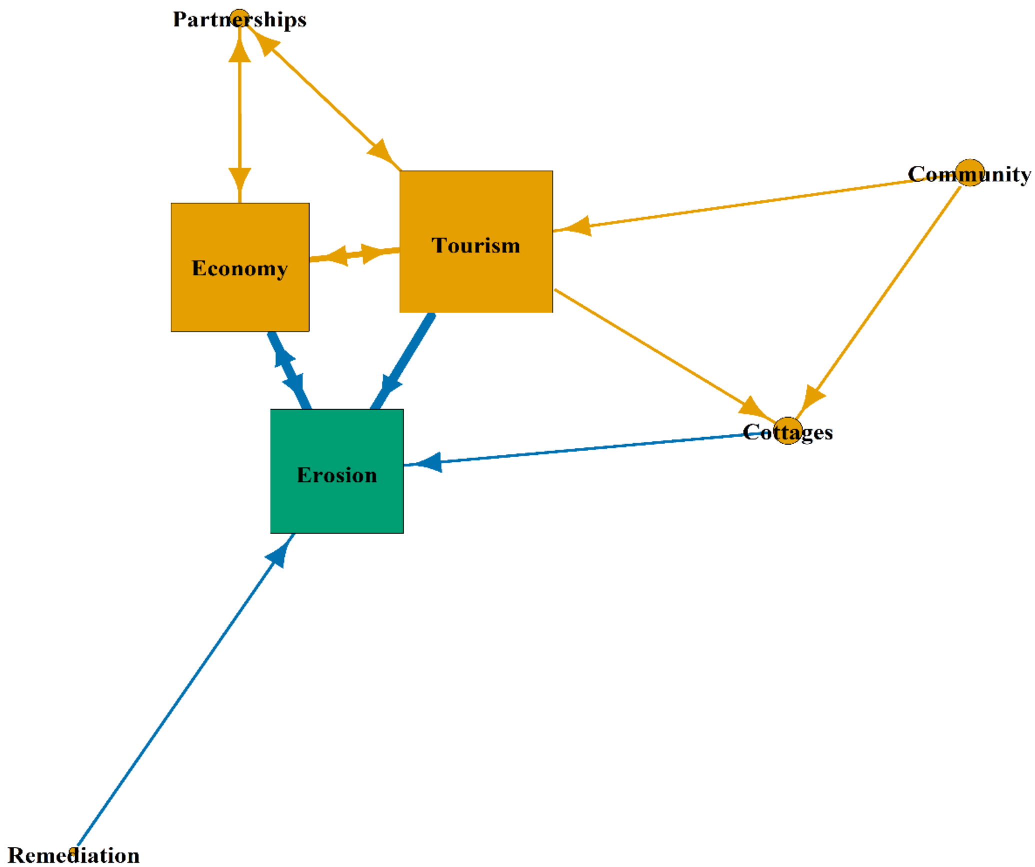
Louvain cluster 4.2



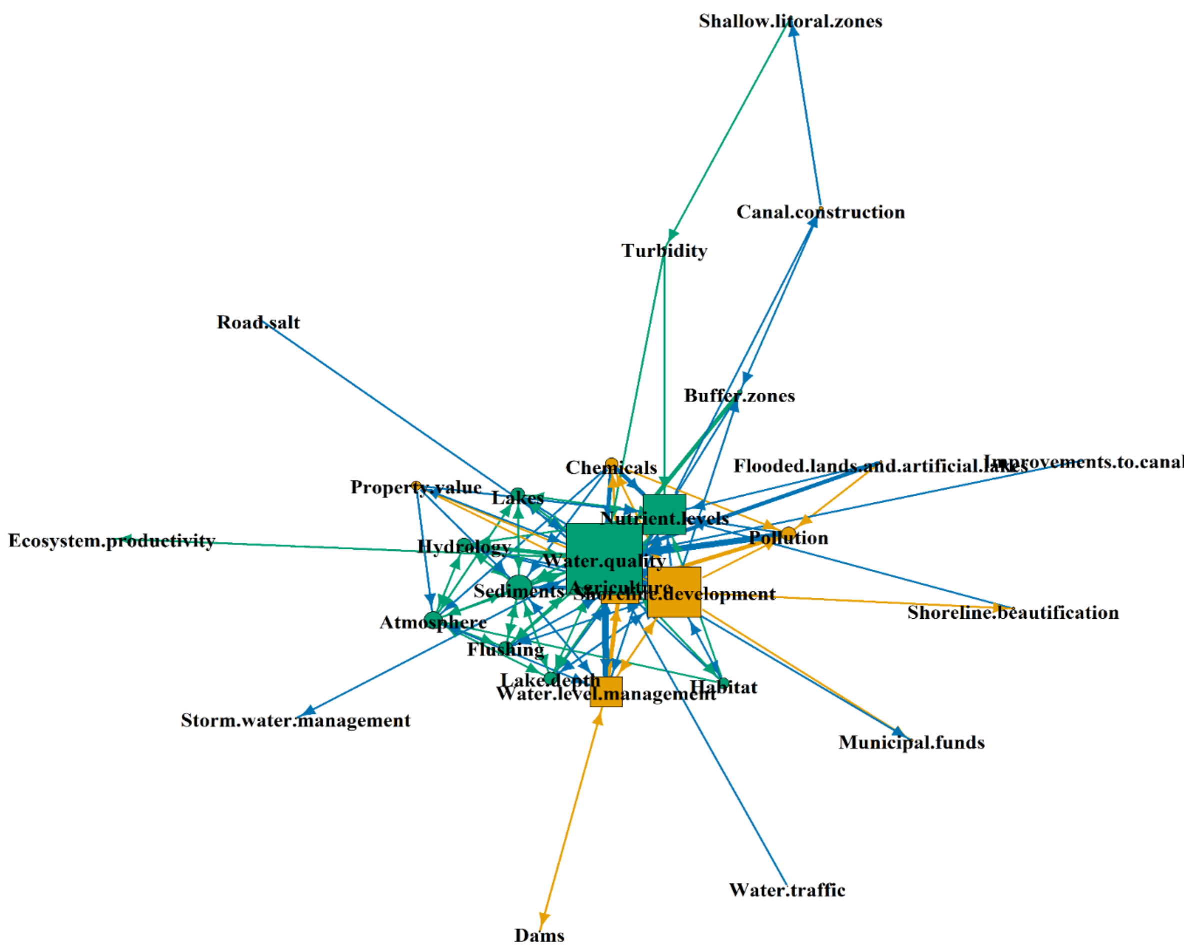
Louvain cluster 4.3



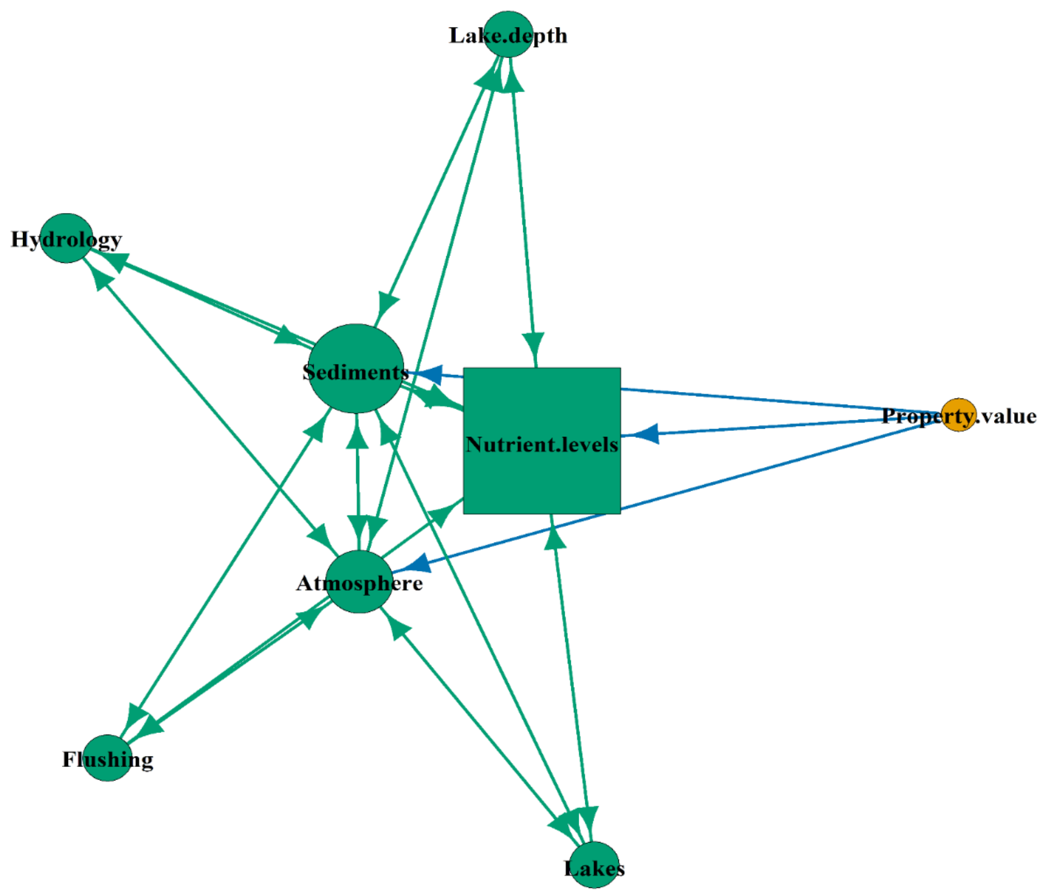
Louvain cluster 4.4



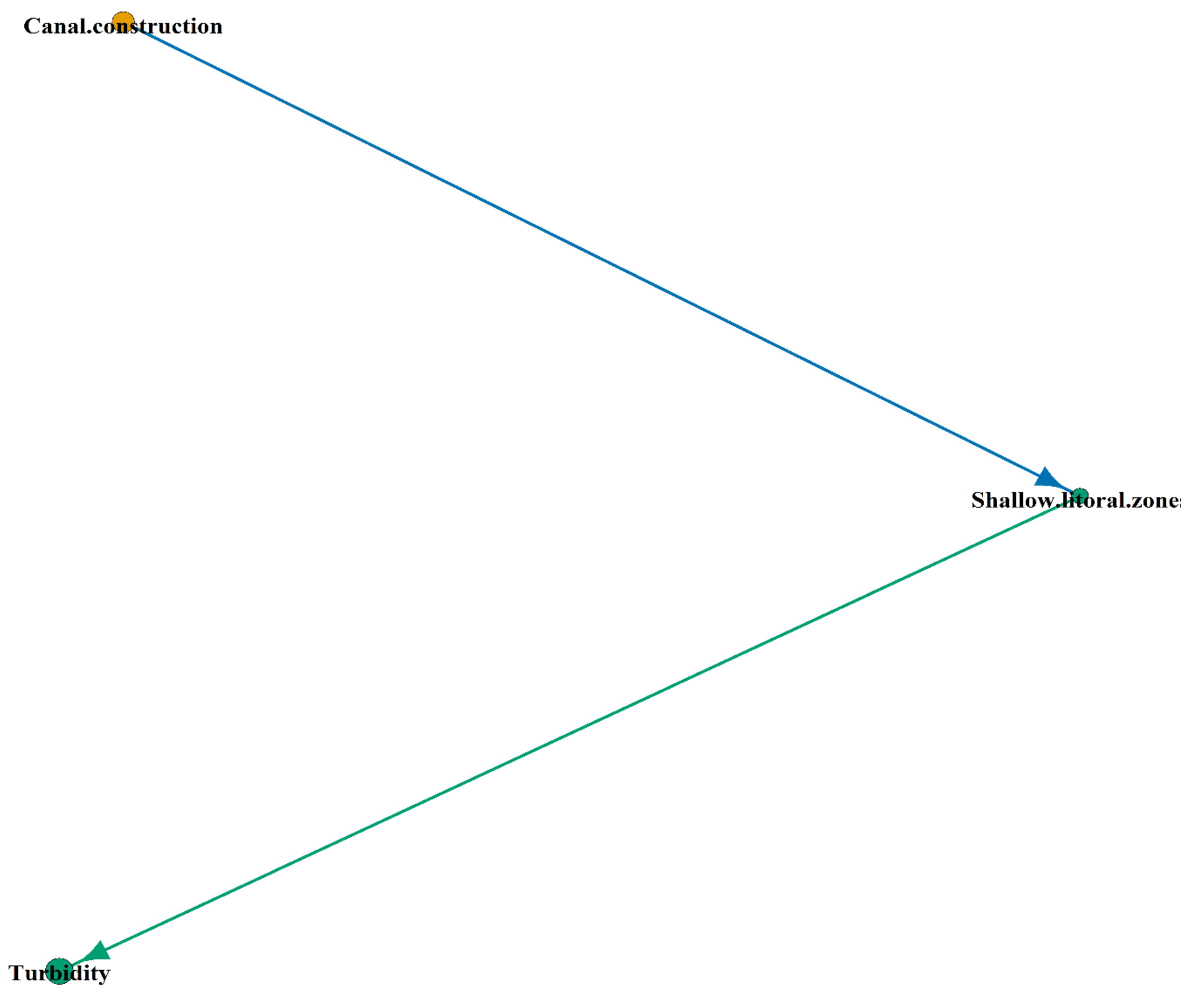
Louvain cluster 5



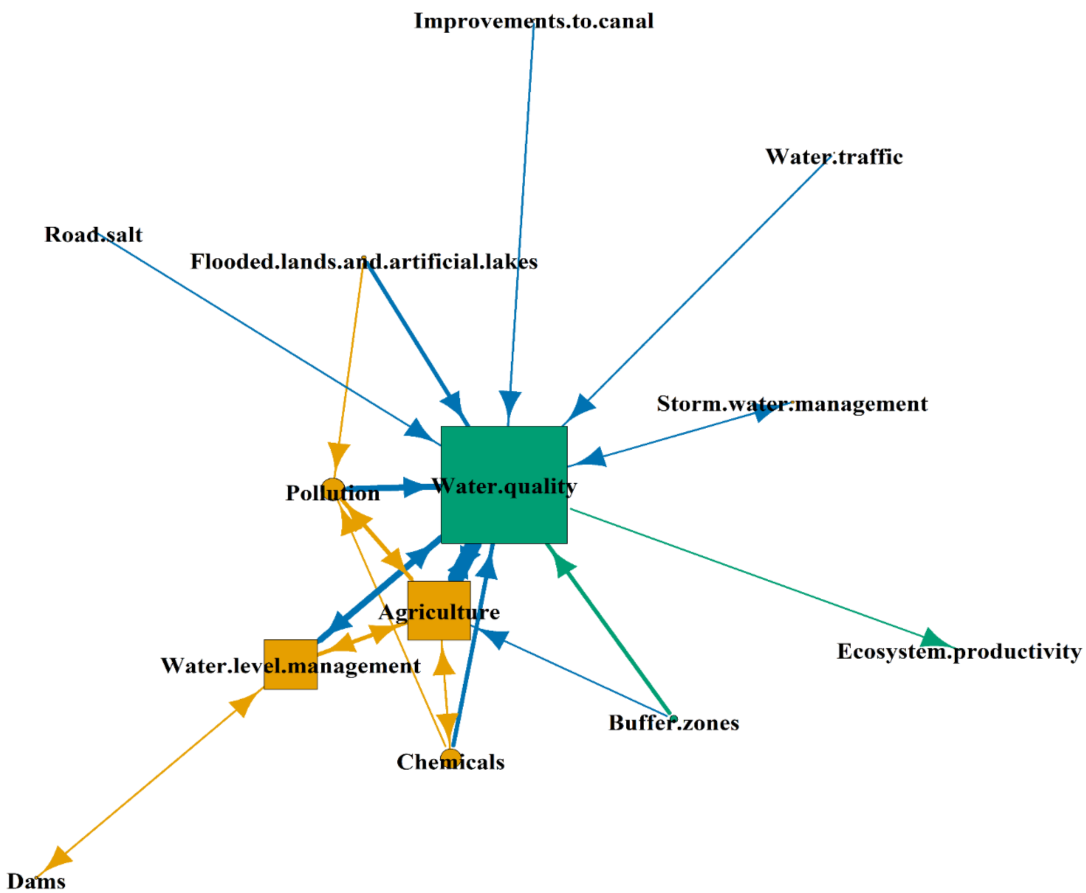
Louvain cluster 5.1



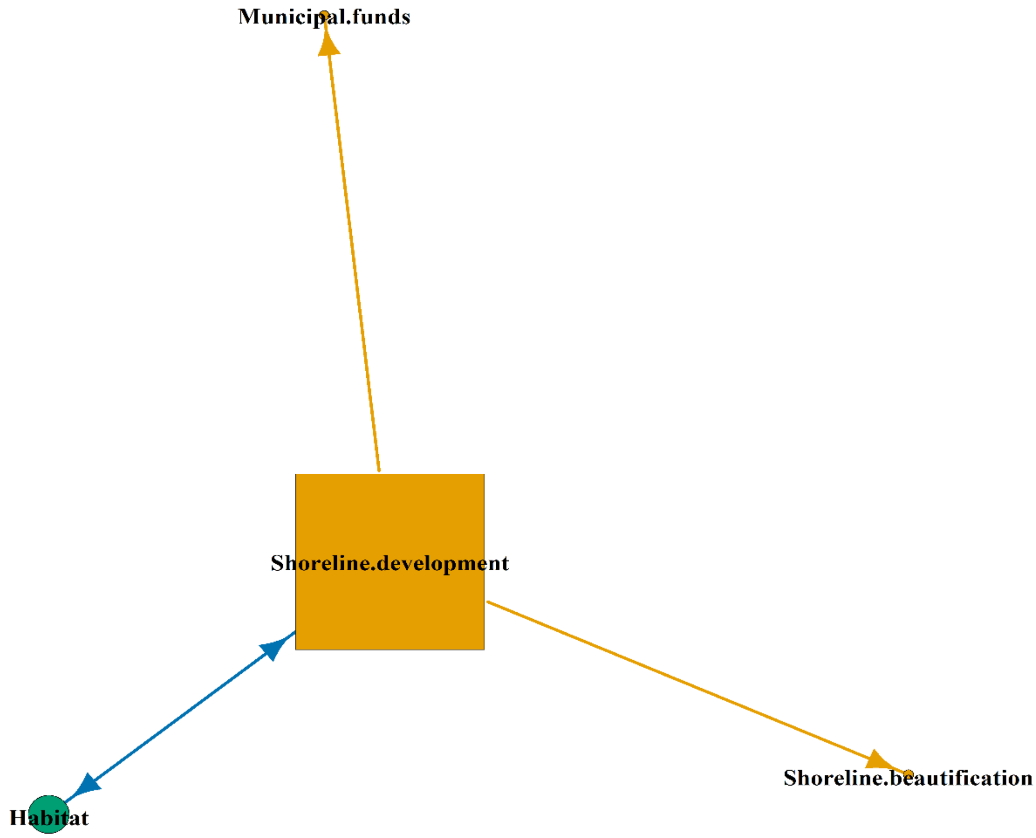
Louvain cluster 5.2



Louvain cluster 5.3



Louvain cluster 5.4



Louvain clusters network data

Louvain cluster	Total nodes	Social nodes	Ecological nodes	% Social ties	% Ecological ties	% Socia-ecological ties	% ties from collective network
1	12	5	7	12,5	31,25	56,25	7,41
2.1	9	9	0	100	0	0	9,26
2.2	13	12	1	91,3	0	8,7	10,65
2.3	14	8	6	18,18	42,42	39,39	15,28
3	8	8	0	100	0	0	6,48
4.1	6	4	2	45,45	9,09	45,45	5,09
4.2	7	6	1	70	0	30	4,63
4.3	8	6	2	38,46	0	61,54	6,02
4.4	7	6	1	64,29	0	35,71	6,48
5.1	8	1	7	0	90,32	9,68	14,35
5.2	3	1	2	0	50	50	0,93
5.3	13	10	3	40	8	52	11,57
5.4	4	3	1	50	0	50	1,85
Mean	8.62	6.08	2.54	48.48	17.78	33.75	7.7
SD	3.48	3.29	2.50	35.3	28.1	22.01	4.38
Total clusters	79	33	112	46,76	23,61	29,63	100
Total full graph	79	33	112	37,27	39,53	22,15	31,35

Appendix 8. Sample from network data collection tool

Chapters 2 and 3: Sample from the SurveyMonkey network data collection tool. This sample shows the section collecting data about relationships with fish in the context of the NSERC SPG.

Collaboration in an NSERC SPG on Ontario Waterways - Social-Ecological Network Data

NonHuman collaborations1

This page asks about your interactions with fish

If you have not interacted with fish, you can skip this page

28. Can you provide a list of species? (max 5)

If you have collected data - can you provide me with a complete list of individuals and species you encountered after the interview so they can be included in the network?

Species 1 ☐

Species 2 ☐

Species 3 ☐

Species 4 ☐

Species 5 ☐

29. Have you worked with these living creatures as part of the NSERC SPG grant on the RC and TSW?

	Yes	I've worked with them, but not as part of the NSERC SPG	No
Species 1	☐	☐	☐
Species 2	☐	☐	☐
Species 3	☐	☐	☐
Species 4	☐	☐	☐
Species 5	☐	☐	☐

30. From 1 to 5, how strong is your relationship ?

	0 - No interactions	1 - I have heard of this species, but we have not been in contact or met	2 - I rarely encounter this species but we have been in contact or met at least once	3 - I encounter this species every once in a while (at least once every field season)	4 - I encounter this species somewhat regularly (at least once a month)	5 - I encounter this species regularly (at least once a week)
Species 1	○	○	○	○	○	○
Species 2	○	○	○	○	○	○
Species 3	○	○	○	○	○	○
Species 4	○	○	○	○	○	○
Species 5	○	○	○	○	○	○

31. What is the nature of your relationship? (Select all that apply)

	Reciprocal collaboration	Work individually and come together around a common goal	Review outputs, supervise, monitor/regulate	Communication-focused	Provide data for your research	Informal/random encounters	Conflictual/tense
Species 1	☐	☐	☐	☐	☐	☐	☐
Species 2	☐	☐	☐	☐	☐	☐	☐
Species 3	☐	☐	☐	☐	☐	☐	☐
Species 4	☐	☐	☐	☐	☐	☐	☐
Species 5	☐	☐	☐	☐	☐	☐	☐

Other (please specify)

32. What is exchanged during your interaction with these living beings? Does this vary per species? (indirect relationship with data, direct collection of a sample or information, emotions, etc.)

33. Where do these interactions take place? Does this vary per species?

Please cite approximate location(s). These could be university or government building, or a location along the waterway where fieldwork was conducted.

*locations can be vague for sensitive species whose area must not be identified

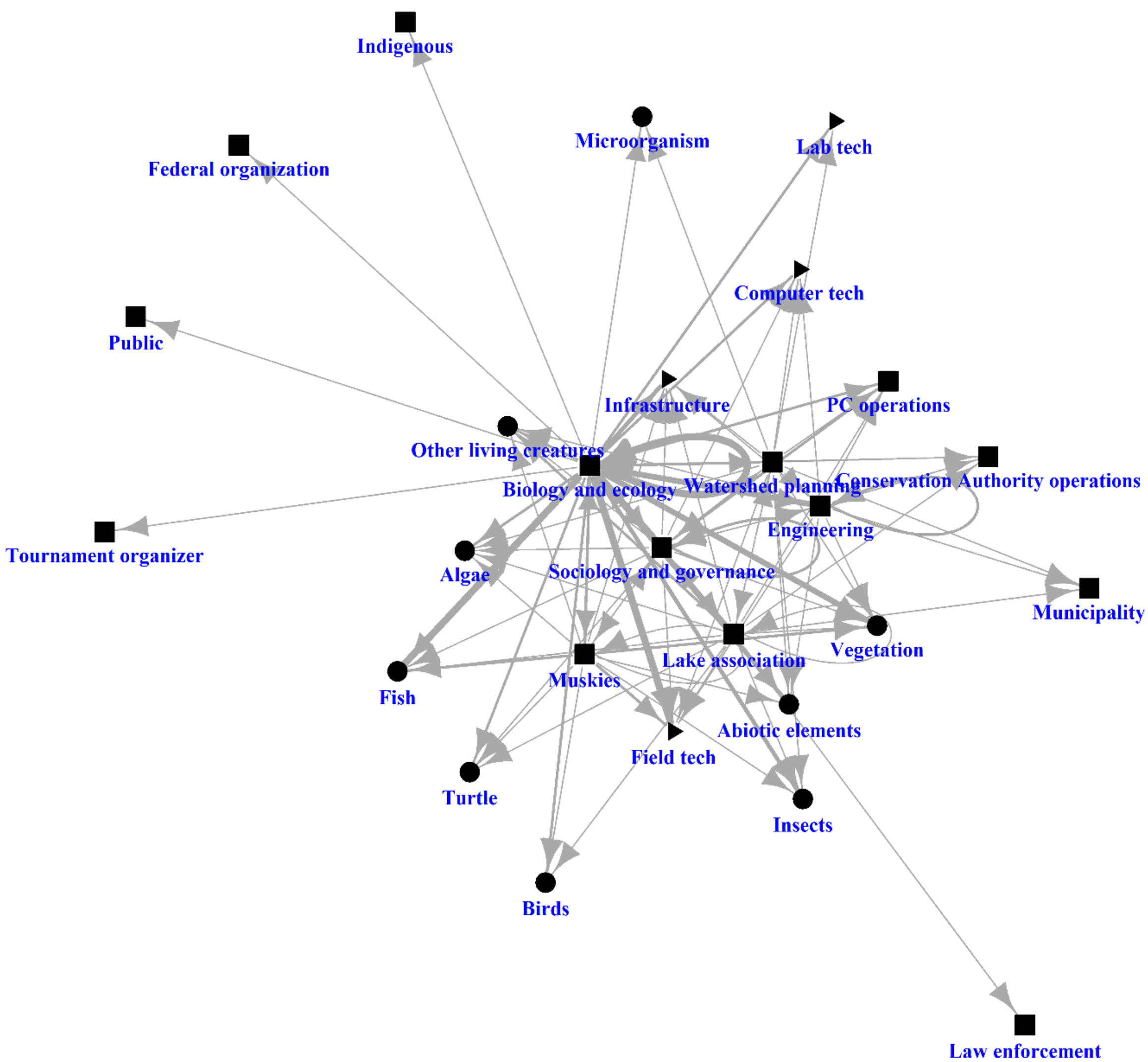
Species 1	
Species 2	
Species 3	
Species 4	
Species 5	

Appendix 9. Network data for the NSERC SPG

Chapters 2 and 3: Node list, edge list, and a reduced network graph of all relationships in the NSERC SPG. Networks in Chapter 2 built on social relations within the NSERC grant (all humans nodes that were interviewed, with a code starting with J, A, G or C), ecological nodes, and technical nodes. Chapter 3 used the same data, but also include other humans non that were not interviewed (with a code starting with O). The reduced network graph was cited in Chapter 3.

Reduced graph for the NSERC SPG

Square node: Human category **Circle node:** Ecological category **Triangle node:** Technical category
Tie width: Number of relationships between each node category **Arrow:** Direction of the tie



Node list for the NSERC SPG

	Node	Category	Type	Interview	Chapters
1	J9	Sociology and governance	Anthropos	Yes	2 + 3
2	A7	Sociology and governance	Anthropos	Yes	2 + 3
3	G3	Biology and ecology	Anthropos	Yes	2 + 3
4	G2	Biology and ecology	Anthropos	Yes	2 + 3
5	G1	Watershed planning	Anthropos	Yes	2 + 3
6	C5	Muskies	Anthropos	Yes	2 + 3
7	C4	Muskies	Anthropos	Yes	2 + 3
8	C3	Muskies	Anthropos	Yes	2 + 3
9	C2	Lake association	Anthropos	Yes	2 + 3
10	J8	Biology and ecology	Anthropos	Yes	2 + 3
11	J7	Biology and ecology	Anthropos	Yes	2 + 3
12	J6	Biology and ecology	Anthropos	Yes	2 + 3
13	J5	Engineering	Anthropos	Yes	2 + 3
14	J4	Biology and ecology	Anthropos	Yes	2 + 3
15	P2	Biology and ecology	Anthropos	Yes	2 + 3
16	P1	Biology and ecology	Anthropos	Yes	2 + 3
17	A5	Engineering	Anthropos	Yes	2 + 3
18	A4	Biology and ecology	Anthropos	Yes	2 + 3
19	A3	Biology and ecology	Anthropos	Yes	2 + 3
20	J3	Biology and ecology	Anthropos	Yes	2 + 3
21	A2	Biology and ecology	Anthropos	Yes	2 + 3
22	A1	Biology and ecology	Anthropos	Yes	2 + 3
23	J2	Biology and ecology	Anthropos	Yes	2 + 3
24	J1	Sociology and governance	Anthropos	Yes	2 + 3
25	C1	Lake association	Anthropos	Yes	2 + 3
26	A6	Biology and ecology	Anthropos	Yes	2 + 3
27	Fish-NS	Fish	Ecological	No	2 + 3
28	Common carp	Fish	Ecological	No	2 + 3
29	Muskellunge	Fish	Ecological	No	2 + 3
30	Northern Pike	Fish	Ecological	No	2 + 3
31	Walleye	Fish	Ecological	No	2 + 3
32	Smallmouth bass	Fish	Ecological	No	2 + 3
33	Largemouth bass	Fish	Ecological	No	2 + 3
34	Other bycatch	Fish	Ecological	No	2 + 3
35	Rock bass	Fish	Ecological	No	2 + 3
36	Bluegill	Fish	Ecological	No	2 + 3
37	Yellow perch	Fish	Ecological	No	2 + 3
38	Round goby	Fish	Ecological	No	2 + 3
39	Pumpkinseed	Fish	Ecological	No	2 + 3
40	Turtle-NS	Turtle	Ecological	No	2 + 3
41	Watersnake	Other living creatures	Ecological	No	2 + 3
42	Painted turtle	Turtle	Ecological	No	2 + 3
43	Snapping turtle	Turtle	Ecological	No	2 + 3
44	Northern map turtle	Turtle	Ecological	No	2 + 3
45	Blanding's turtle	Turtle	Ecological	No	2 + 3
46	Musk turtles	Turtle	Ecological	No	2 + 3
47	Algae-NS	Algae	Ecological	No	2 + 3
48	AquaVeg-NS	Vegetation	Ecological	No	2 + 3

	Node	Category	Type	Interview	Chapters
49	Eurasian watermilfoil	Vegetation	Ecological	No	2 + 3
50	European forgbit	Vegetation	Ecological	No	2 + 3
51	Lily pads	Vegetation	Ecological	No	2 + 3
52	Green algae	Algae	Ecological	No	2 + 3
53	Forest covers and buffers	Vegetation	Ecological	No	2 + 3
54	InvasivePlant-NS	Vegetation	Ecological	No	2 + 3
55	Pondweed-NS	Vegetation	Ecological	No	2 + 3
56	Coontail	Vegetation	Ecological	No	2 + 3
57	Water celery	Vegetation	Ecological	No	2 + 3
58	Cattail	Vegetation	Ecological	No	2 + 3
59	White oak	Vegetation	Ecological	No	2 + 3
60	Wood debris	Vegetation	Ecological	No	2 + 3
61	Eelgrass	Vegetation	Ecological	No	2 + 3
62	Duckweed	Vegetation	Ecological	No	2 + 3
63	Chara	Algae	Ecological	No	2 + 3
64	Hydrilla	Vegetation	Ecological	No	2 + 3
65	RiparianVeg-NS	Vegetation	Ecological	No	2 + 3
66	Benthic	Microorganism	Ecological	No	2 + 3
67	Zebra mussel	Other living creatures	Ecological	No	2 + 3
68	Mayfly	Insects	Ecological	No	2 + 3
69	Caddisfly	Insects	Ecological	No	2 + 3
70	Stonefly	Insects	Ecological	No	2 + 3
71	Spiny Waterflea	Insects	Ecological	No	2 + 3
72	BugsFishStomach	Insects	Ecological	No	2 + 3
73	Mosquitoe	Insects	Ecological	No	2 + 3
74	Black fly	Insects	Ecological	No	2 + 3
75	Dragonfly	Insects	Ecological	No	2 + 3
76	Tick	Insects	Ecological	No	2 + 3
77	Deer fly	Insects	Ecological	No	2 + 3
78	Zookplankton	Microorganism	Ecological	No	2 + 3
79	Chydoridae	Insects	Ecological	No	2 + 3
80	Midge	Insects	Ecological	No	2 + 3
81	Phytoplankton	Algae	Ecological	No	2 + 3
82	Damselfly	Insects	Ecological	No	2 + 3
83	Spiders	Insects	Ecological	No	2 + 3
84	Diatom	Algae	Ecological	No	2 + 3
85	Blue-green algae	Algae	Ecological	No	2 + 3
86	Amphibians-NS	Other living creatures	Ecological	No	2 + 3
87	Reptiles-NS	Other living creatures	Ecological	No	2 + 3
88	Birds-NS	Birds	Ecological	No	2 + 3
89	Mammals-NS	Other living creatures	Ecological	No	2 + 3
90	Peregrine	Birds	Ecological	No	2 + 3
91	Water fowls	Birds	Ecological	No	2 + 3
92	Coyote	Other living creatures	Ecological	No	2 + 3
93	Eel	Fish	Ecological	No	2 + 3
94	Bald eagle	Birds	Ecological	No	2 + 3
95	Osprey	Birds	Ecological	No	2 + 3
96	Blue heron	Birds	Ecological	No	2 + 3
97	Muskrat	Other living creatures	Ecological	No	2 + 3

	Node	Category	Type	Interview	Chapters
98	Mink	Other living creatures	Ecological	No	2 + 3
99	Otter	Other living creatures	Ecological	No	2 + 3
100	Loon	Birds	Ecological	No	2 + 3
101	Deer	Other living creatures	Ecological	No	2 + 3
102	Racoon	Other living creatures	Ecological	No	2 + 3
103	Fisher	Other living creatures	Ecological	No	2 + 3
104	Fox	Other living creatures	Ecological	No	2 + 3
105	Porcupine	Other living creatures	Ecological	No	2 + 3
106	Eastern rat snake	Other living creatures	Ecological	No	2 + 3
107	Green heron	Birds	Ecological	No	2 + 3
108	Tern	Birds	Ecological	No	2 + 3
109	Cryptophyceae	Insects	Ecological	No	2 + 3
110	Dinophyta	Algae	Ecological	No	2 + 3
111	Duck	Birds	Ecological	No	2 + 3
112	Frog	Other living creatures	Ecological	No	2 + 3
113	Cormorant	Birds	Ecological	No	2 + 3
114	Water	Abiotic elements	Ecological	No	2 + 3
115	Water quality	Abiotic elements	Ecological	No	2 + 3
116	Nutrients	Abiotic elements	Ecological	No	2 + 3
117	Rocks and substrate	Abiotic elements	Ecological	No	2 + 3
118	Sediments	Abiotic elements	Ecological	No	2 + 3
119	Turkey	Birds	Ecological	No	2 + 3
120	Woodpecker	Birds	Ecological	No	2 + 3
121	Water temperature	Abiotic elements	Ecological	No	2 + 3
122	Dissolved oxygen	Abiotic elements	Ecological	No	2 + 3
123	Bathymetry	Abiotic elements	Ecological	No	2 + 3
124	Microplastics	Abiotic elements	Ecological	No	2 + 3
125	Eutrophication	Abiotic elements	Ecological	No	2 + 3
126	Bridge	Infrastructure	Technical	No	2 + 3
127	Lock station	Infrastructure	Technical	No	2 + 3
128	Dam	Infrastructure	Technical	No	2 + 3
129	Paths	Infrastructure	Technical	No	2 + 3
130	Skateway	Infrastructure	Technical	No	2 + 3
131	Canal walls	Infrastructure	Technical	No	2 + 3
132	Flood control	Infrastructure	Technical	No	2 + 3
133	Abandoned infrastructure	Infrastructure	Technical	No	2 + 3
134	Boat launch	Infrastructure	Technical	No	2 + 3
135	Canoe	Field tech	Technical	No	2 + 3
136	Recorder	Field tech	Technical	No	2 + 3
137	Underwater camera	Field tech	Technical	No	2 + 3
138	Nvivo	Computer tech	Technical	No	2 + 3
139	Excel	Computer tech	Technical	No	2 + 3
140	Kayak	Field tech	Technical	No	2 + 3
141	R	Computer tech	Technical	No	2 + 3
142	Boat	Field tech	Technical	No	2 + 3
143	Water level gauge	Field tech	Technical	No	2 + 3
144	Beach	Infrastructure	Technical	No	2 + 3
145	Water meter	Field tech	Technical	No	2 + 3
146	Laboratory	Lab tech	Technical	No	2 + 3

	Node	Category	Type	Interview	Chapters
147	Data management system	Computer tech	Technical	No	2 + 3
148	Survey123 App	Computer tech	Technical	No	2 + 3
149	Sonar	Field tech	Technical	No	2 + 3
150	Fishing rod and gear	Field tech	Technical	No	2 + 3
151	Release tools	Field tech	Technical	No	2 + 3
152	Cell phone	Field tech	Technical	No	2 + 3
153	GPS	Field tech	Technical	No	2 + 3
154	Nets	Field tech	Technical	No	2 + 3
155	Water Rangers kit	Field tech	Technical	No	2 + 3
156	Bubblers	Field tech	Technical	No	2 + 3
157	Boat lift	Field tech	Technical	No	2 + 3
158	Boat traffic	Field tech	Technical	No	2 + 3
159	Electric fish handling gloves	Field tech	Technical	No	2 + 3
160	Electronic navigation chart	Field tech	Technical	No	2 + 3
161	Tournament participant boat	Field tech	Technical	No	2 + 3
162	Lab vehicle	Field tech	Technical	No	2 + 3
163	YSI probe	Field tech	Technical	No	2 + 3
164	Microscope	Lab tech	Technical	No	2 + 3
165	Safety equipment	Field tech	Technical	No	2 + 3
166	Zooplankton net	Field tech	Technical	No	2 + 3
167	Water sampler	Field tech	Technical	No	2 + 3
168	Ekman dredge	Field tech	Technical	No	2 + 3
169	Spectrophotometer	Lab tech	Technical	No	2 + 3
170	Lab consumables	Lab tech	Technical	No	2 + 3
171	Electrofishing boat	Field tech	Technical	No	2 + 3
172	Biologger	Field tech	Technical	No	2 + 3
173	Floyd tags	Field tech	Technical	No	2 + 3
174	Remote control boat	Field tech	Technical	No	2 + 3
175	Acoustic Doppler Current Profiler	Field tech	Technical	No	2 + 3
176	Water level and temprature logger	Field tech	Technical	No	2 + 3
177	Acoustic receivers	Field tech	Technical	No	2 + 3
178	ArcGIS	Computer tech	Technical	No	2 + 3
179	Acoustic tags	Field tech	Technical	No	2 + 3
180	QGIS	Computer tech	Technical	No	2 + 3
181	Thermocycler	Lab tech	Technical	No	2 + 3
182	STRUCTURE	Computer tech	Technical	No	2 + 3
183	DNA sequencer	Lab tech	Technical	No	2 + 3
184	GeneMapper	Computer tech	Technical	No	2 + 3
185	Field equipment to sample turtles	Field tech	Technical	No	2 + 3
186	Dissolved organic carbon	Lab tech	Technical	No	2 + 3
187	Modelling software	Computer tech	Technical	No	2 + 3
188	Matlab	Computer tech	Technical	No	2 + 3
189	Field software	Field tech	Technical	No	2 + 3
190	3D modelling software	Computer tech	Technical	No	2 + 3
191	QUBS housing	Infrastructure	Technical	No	2 + 3
192	Instrument	Field tech	Technical	No	2 + 3
193	O1	Biology and ecology	Anthropos	No	3
194	O2	Biology and ecology	Anthropos	No	3
195	O3	Biology and ecology	Anthropos	No	3

	Node	Category	Type	Interview	Chapters
196	O4	Biology and ecology	Anthropos	No	3
197	O5	PC operations	Anthropos	No	3
198	O6	PC operations	Anthropos	No	3
199	O7	PC operations	Anthropos	No	3
200	O8	Biology and ecology	Anthropos	No	3
201	O9	PC operations	Anthropos	No	3
202	O10	PC operations	Anthropos	No	3
203	O11	Engineering	Anthropos	No	3
204	O12	Engineering	Anthropos	No	3
205	O13	PC operations	Anthropos	No	3
206	O14	PC operations	Anthropos	No	3
207	O15	PC operations	Anthropos	No	3
208	O16	PC operations	Anthropos	No	3
209	O17	PC operations	Anthropos	No	3
210	O18	PC operations	Anthropos	No	3
211	O19	PC operations	Anthropos	No	3
212	O20	PC operations	Anthropos	No	3
213	O21	PC operations	Anthropos	No	3
214	O23	PC operations	Anthropos	No	3
215	O24	Engineering	Anthropos	No	3
216	O25	Engineering	Anthropos	No	3
217	O26	Engineering	Anthropos	No	3
218	O27	Lake association	Anthropos	No	3
219	O28	Conservation Authority operations	Anthropos	No	3
220	O29	Municipality	Anthropos	No	3
221	O30	Muskies Canada	Anthropos	No	3
222	O31	Muskies Canada	Anthropos	No	3
223	O32	Conservation Authority operations	Anthropos	No	3
224	O33	Muskies Canada	Anthropos	No	3
225	O34	Muskies Canada	Anthropos	No	3
226	O35	Conservation Authority operations	Anthropos	No	3
227	O36	Lake association	Anthropos	No	3
228	O37	Conservation Authority operations	Anthropos	No	3
229	O38	Sociology and governance	Anthropos	No	3
230	O39	Biology and ecology	Anthropos	No	3
231	O40	Lake association	Anthropos	No	3
232	O41	Lake association	Anthropos	No	3
233	O42	Lake association	Anthropos	No	3
234	O43	Lake association	Anthropos	No	3
235	O44	Lake association	Anthropos	No	3
236	O45	Municipality	Anthropos	No	3
237	O46	Conservation Authority operations	Anthropos	No	3
238	O47	Conservation Authority operations	Anthropos	No	3
239	O48	Biology and ecology	Anthropos	No	3
240	O49	Biology and ecology	Anthropos	No	3
241	O50	Lake association	Anthropos	No	3
242	O51	Watershed planning	Anthropos	No	3
243	O52	Lake association	Anthropos	No	3
244	O53	Municipality	Anthropos	No	3

	Node	Category	Type	Interview	Chapters
245	O54	Law enforcement	Anthropos	No	3
246	O55	Lake association	Anthropos	No	3
247	O56	Lake association	Anthropos	No	3
248	O57	Lake association	Anthropos	No	3
249	O58	Tournament organizer	Anthropos	No	3
250	O59	Tournament organizer	Anthropos	No	3
251	O60	Tournament organizer	Anthropos	No	3
252	O61	Conservation Authority operations	Anthropos	No	3
253	O62	Lake association	Anthropos	No	3
254	O63	Conservation Authority operations	Anthropos	No	3
255	O64	Federal organization	Anthropos	No	3
256	O65	Conservation Authority operations	Anthropos	No	3
257	O66	Lake association	Anthropos	No	3
258	O67	Lake association	Anthropos	No	3
259	O68	Biology and ecology	Anthropos	No	3
260	O69	PC operations	Anthropos	No	3
261	O70	PC operations	Anthropos	No	3
262	O71	Biology and ecology	Anthropos	No	3
263	O72	Biology and ecology	Anthropos	No	3
264	O73	Indigenous	Anthropos	No	3
265	O74	Biology and ecology	Anthropos	No	3
266	O75	Biology and ecology	Anthropos	No	3
267	O76	Biology and ecology	Anthropos	No	3
268	O77	Biology and ecology	Anthropos	No	3
269	O78	Biology and ecology	Anthropos	No	3
270	O79	Biology and ecology	Anthropos	No	3
271	O80	Lake association	Anthropos	No	3
272	O81	Public	Anthropos	No	3
273	O82	Biology and ecology	Anthropos	No	3
274	O83	Biology and ecology	Anthropos	No	3
275	O84	Biology and ecology	Anthropos	No	3
276	O85	Biology and ecology	Anthropos	No	3
277	O86	Biology and ecology	Anthropos	No	3
278	O87	Lake association	Anthropos	No	3
279	O88	Biology and ecology	Anthropos	No	3
280	O89	Biology and ecology	Anthropos	No	3
281	O90	Biology and ecology	Anthropos	No	3
282	O91	Biology and ecology	Anthropos	No	3
283	O92	Lake association	Anthropos	No	3

Edge list for the NSERC SPG

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
1	J9	A6	4	Social	1	1	1	0	0
2	A7	A6	5	Social	1	1	1	1	0
3	G3	A6	3	Social	1	0	0	0	0
4	G2	A6	4	Social	0	1	0	0	0
5	G1	A6	3	Social	0	1	1	0	0
6	C5	A6	5	Social	1	1	0	1	0
7	C4	A6	3	Social	0	0	1	0	0
8	C3	A6	3	Social	1	1	0	0	0
9	C2	A6	3	Social	1	0	0	0	0
10	J8	A6	5	Social	1	1	1	1	0
11	J7	A6	3	Social	0	1	0	1	0
12	J6	A6	5	Social	1	1	0	0	0
13	J5	A6	4	Social	1	1	1	1	0
14	J4	A6	4	Social	1	1	0	0	0
15	P2	A6	5	Social	1	1	0	0	0
16	P1	A6	5	Social	1	1	0	0	0
17	A5	A6	5	Social	1	0	0	0	0
18	A4	A6	5	Social	1	0	0	0	0
19	A3	A6	3	Social	0	0	1	0	0
20	J3	A6	3	Social	1	0	0	0	0
21	A2	A6	4	Social	1	0	0	0	0
22	A1	A6	4	Social	1	1	0	0	0
23	J2	A6	5	Social	1	1	1	0	0
24	J1	A6	3	Social	1	1	0	0	0
25	J9	A7	5	Social	1	1	1	1	0
26	G2	A7	3	Social	0	1	0	0	0
27	G1	A7	3	Social	1	0	0	0	0
28	C2	A7	2	Social	1	0	0	0	0
29	C1	A7	4	Social	1	0	0	0	0
30	J8	A7	3	Social	1	1	1	0	0
31	A6	A7	5	Social	1	0	0	0	0
32	J7	A7	2	Social	0	0	0	1	0
33	J5	A7	2	Social	0	1	0	0	0
34	J4	A7	2	Social	1	0	0	0	0
35	P2	A7	3	Social	1	1	0	0	0
36	P1	A7	4	Social	1	0	0	0	0
37	A5	A7	3	Social	0	1	0	0	0
38	A4	A7	4	Social	1	0	0	0	0
39	A3	A7	1	Social	0	1	0	0	0
40	A2	A7	3	Social	0	1	0	0	0
41	A1	A7	3	Social	0	0	1	0	0
42	J2	A7	3	Social	0	1	0	1	0
43	J1	A7	5	Social	1	1	0	0	0
44	J9	A5	3	Social	1	1	1	0	0
45	A7	A5	3	Social	0	1	0	1	0
46	G3	A5	3	Social	1	0	0	0	0
47	G2	A5	2	Social	0	1	0	0	0

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
48	A6	A5	5	Social	1	0	0	0	0
49	J7	A5	2	Social	0	0	0	1	0
50	J5	A5	5	Social	1	1	1	1	0
51	P2	A5	3	Social	1	0	1	0	0
52	P1	A5	3	Social	1	1	0	0	0
53	A4	A5	3	Social	1	0	0	0	0
54	A3	A5	1	Social	0	1	0	0	0
55	A2	A5	3	Social	0	1	0	0	0
56	J2	A5	3	Social	1	1	1	1	0
57	J1	A5	2	Social	1	1	0	0	0
58	J9	A2	3	Social	1	0	1	0	0
59	A7	A2	3	Social	0	1	0	1	0
60	G3	A2	3	Social	1	0	0	0	0
61	G2	A2	4	Social	1	1	0	0	0
62	G1	A2	3	Social	1	0	0	0	0
63	C3	A2	2	Social	0	1	0	0	0
64	C2	A2	2	Social	1	0	0	0	0
65	C1	A2	2	Social	0	1	0	0	0
66	A6	A2	5	Social	1	0	0	0	0
67	J7	A2	5	Social	1	1	1	0	0
68	J5	A2	3	Social	1	0	0	0	0
69	J4	A2	5	Social	1	1	1	1	0
70	P2	A2	3	Social	1	0	1	0	0
71	P1	A2	4	Social	1	1	0	0	0
72	A5	A2	3	Social	0	0	1	0	0
73	A4	A2	3	Social	1	0	0	0	0
74	A3	A2	1	Social	0	1	0	0	0
75	J2	A2	3	Social	0	1	0	1	0
76	J1	A2	2	Social	1	1	0	0	0
77	J9	A1	3	Social	1	1	1	0	0
78	A7	A1	2	Social	0	1	0	1	0
79	G2	A1	2	Social	0	1	0	0	0
80	A6	A1	4	Social	1	0	0	0	0
81	P2	A1	2	Social	1	0	0	0	0
82	P1	A1	4	Social	1	0	0	0	0
83	A5	A1	3	Social	0	1	0	0	0
84	A4	A1	3	Social	1	0	0	0	0
85	A3	A1	4	Social	1	0	0	0	0
86	J3	A1	5	Social	1	0	0	0	0
87	A2	A1	2	Social	0	0	0	1	0
88	J2	A1	3	Social	0	1	0	1	0
89	J1	A1	2	Social	1	0	0	0	0
90	J9	A4	3	Social	1	1	1	0	0
91	A7	A4	4	Social	1	1	0	1	0
92	G2	A4	3	Social	0	1	0	0	0
93	A6	A4	5	Social	1	0	0	0	0
94	J7	A4	2	Social	0	0	0	1	0
95	J5	A4	3	Social	1	1	0	0	0
96	J4	A4	2	Social	0	1	0	0	0

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
97	P2	A4	5	Social	1	1	0	0	0
98	P1	A4	4	Social	1	0	0	0	0
99	A5	A4	3	Social	0	1	0	0	0
100	A3	A4	1	Social	0	1	0	0	0
101	J3	A4	4	Social	0	1	0	0	0
102	A2	A4	3	Social	0	1	0	0	0
103	J2	A4	4	Social	1	1	0	0	0
104	J1	A4	2	Social	1	0	0	0	0
105	J9	A3	2	Social	1	1	1	0	0
106	P1	A3	1	Social	1	1	0	0	0
107	A5	A3	3	Social	0	1	0	0	0
108	J3	A3	5	Social	1	0	0	0	0
109	A2	A3	2	Social	0	0	0	1	0
110	A1	A3	4	Social	1	1	0	0	0
111	J2	A3	3	Social	0	1	0	1	0
112	J9	P1	3	Social	0	1	1	0	0
113	A7	P1	2	Social	0	1	0	0	0
114	G3	P1	3	Social	1	1	0	0	0
115	G2	P1	4	Social	0	1	0	0	0
116	C3	P1	2	Social	0	1	0	0	0
117	C2	P1	1	Social	0	1	0	0	0
118	J8	P1	3	Social	1	0	0	1	0
119	A6	P1	5	Social	1	1	0	0	0
120	J7	P1	2	Social	0	0	0	1	0
121	J4	P1	1	Social	0	1	0	1	0
122	A5	P1	3	Social	0	1	0	0	0
123	A4	P1	2	Social	0	1	0	0	0
124	A3	P1	3	Social	0	1	0	0	0
125	J3	P1	2	Social	0	1	0	0	0
126	A2	P1	2	Social	0	1	0	1	0
127	J2	P1	2	Social	1	1	0	1	0
128	J9	P2	3	Social	1	1	0	0	0
129	A7	P2	2	Social	0	1	0	0	0
130	G2	P2	4	Social	0	1	1	0	0
131	G1	P2	3	Social	0	0	1	0	0
132	J8	P2	2	Social	1	0	0	0	0
133	A6	P2	5	Social	1	1	0	0	0
134	J7	P2	2	Social	0	1	1	0	0
135	J5	P2	3	Social	0	1	0	0	0
136	J4	P2	2	Social	1	0	1	0	0
137	A5	P2	2	Social	0	1	0	0	0
138	A4	P2	5	Social	1	0	0	0	0
139	J3	P2	3	Social	1	0	0	0	0
140	J2	P2	3	Social	1	1	0	1	0
141	J1	P2	2	Social	1	0	1	0	0
142	J9	J2	4	Social	1	1	1	0	0
143	A7	J2	3	Social	1	1	0	0	0
144	G3	J2	3	Social	1	1	0	0	0
145	G2	J2	4	Social	0	1	1	0	0

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
146	G1	J2	3	Social	0	1	0	0	0
147	C5	J2	5	Social	1	1	0	1	0
148	C4	J2	4	Social	0	1	1	0	0
149	C3	J2	3	Social	1	1	0	0	0
150	C2	J2	3	Social	0	1	0	0	0
151	C1	J2	2	Social	0	1	0	0	0
152	J8	J2	3	Social	1	0	0	0	0
153	A6	J2	5	Social	1	1	0	0	0
154	J7	J2	4	Social	1	1	0	1	0
155	J6	J2	4	Social	1	1	1	1	0
156	J5	J2	4	Social	1	1	1	1	0
157	J4	J2	2	Social	1	1	0	0	0
158	P2	J2	5	Social	1	1	1	0	0
159	P1	J2	5	Social	1	0	0	0	0
160	A5	J2	4	Social	0	1	0	0	0
161	A4	J2	5	Social	1	0	0	0	0
162	A3	J2	3	Social	0	1	0	0	0
163	J3	J2	5	Social	1	0	0	0	0
164	A2	J2	3	Social	0	1	0	1	0
165	J1	J2	3	Social	1	1	0	0	0
166	J9	J8	3	Social	1	1	0	0	0
167	A7	J8	2	Social	0	1	0	0	0
168	G3	J8	3	Social	1	1	0	0	0
169	C2	J8	3	Social	0	1	0	0	0
170	A6	J8	5	Social	1	1	0	0	0
171	J6	J8	3	Social	0	1	1	1	0
172	J5	J8	3	Social	1	1	0	1	0
173	J4	J8	1	Social	1	0	0	0	0
174	P1	J8	5	Social	1	0	0	0	0
175	A4	J8	2	Social	0	1	0	0	0
176	J3	J8	2	Social	1	0	0	0	0
177	J2	J8	3	Social	1	0	0	1	0
178	J9	J1	5	Social	1	1	1	1	0
179	A7	J1	5	Social	1	1	1	1	0
180	G3	J1	3	Social	1	0	0	0	0
181	G2	J1	3	Social	0	1	0	0	0
182	G1	J1	5	Social	1	1	0	0	0
183	C3	J1	3	Social	0	0	1	0	0
184	C2	J1	3	Social	0	1	0	0	0
185	C1	J1	4	Social	1	1	1	0	0
186	J8	J1	2	Social	1	0	0	0	0
187	A6	J1	5	Social	1	0	0	0	0
188	J7	J1	2	Social	0	0	0	1	0
189	J5	J1	2	Social	1	0	0	0	0
190	J4	J1	2	Social	1	0	1	0	0
191	P2	J1	3	Social	1	0	0	0	0
192	P1	J1	3	Social	1	0	0	0	0
193	A5	J1	3	Social	0	1	0	0	0
194	A4	J1	2	Social	0	1	0	0	0

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
195	J3	J1	2	Social	1	0	0	0	0
196	A2	J1	3	Social	1	0	0	0	0
197	A1	J1	4	Social	1	0	1	0	0
198	J2	J1	5	Social	1	1	1	1	0
199	A7	J9	5	Social	1	1	1	1	0
200	G3	J9	3	Social	1	0	0	0	0
201	G2	J9	3	Social	0	1	0	0	0
202	G1	J9	5	Social	1	1	0	0	0
203	C5	J9	2	Social	1	0	0	0	0
204	C3	J9	3	Social	0	0	1	0	0
205	C2	J9	3	Social	0	1	0	0	0
206	C1	J9	4	Social	1	1	1	0	0
207	J8	J9	2	Social	1	0	0	0	0
208	A6	J9	5	Social	1	0	0	0	0
209	J7	J9	3	Social	0	1	1	0	0
210	J5	J9	2	Social	1	0	0	0	0
211	J4	J9	3	Social	1	0	1	0	0
212	P2	J9	3	Social	1	0	0	0	0
213	P1	J9	3	Social	1	0	0	0	0
214	A5	J9	3	Social	0	1	0	0	0
215	A4	J9	2	Social	0	1	0	0	0
216	J3	J9	2	Social	1	0	0	0	0
217	A2	J9	3	Social	1	0	0	0	0
218	A1	J9	4	Social	1	0	1	0	0
219	J2	J9	5	Social	1	1	1	1	0
220	J1	J9	5	Social	1	1	1	0	0
221	J9	J3	3	Social	1	1	0	0	0
222	G2	J3	2	Social	0	1	1	0	0
223	J8	J3	2	Social	1	0	0	0	0
224	A6	J3	5	Social	0	1	0	0	0
225	J4	J3	1	Social	1	0	0	0	0
226	P2	J3	2	Social	0	0	1	0	0
227	P1	J3	3	Social	1	0	0	0	0
228	A4	J3	2	Social	0	1	0	0	0
229	A3	J3	5	Social	1	0	0	0	0
230	A1	J3	5	Social	1	1	0	0	0
231	J2	J3	3	Social	1	1	0	1	0
232	J1	J3	3	Social	1	0	0	0	0
233	J9	J5	3	Social	1	1	0	0	0
234	G3	J5	3	Social	1	1	1	0	0
235	G2	J5	3	Social	0	1	1	0	0
236	J8	J5	2	Social	1	0	0	0	0
237	A6	J5	4	Social	1	0	0	0	0
238	J4	J5	1	Social	1	0	0	0	0
239	P2	J5	3	Social	0	0	1	0	0
240	P1	J5	3	Social	1	0	0	0	0
241	A5	J5	5	Social	1	0	0	0	0
242	A4	J5	2	Social	0	1	0	0	0
243	J3	J5	2	Social	1	0	0	0	0

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
244	A2	J5	2	Social	1	0	0	1	0
245	J2	J5	5	Social	1	1	1	1	0
246	J1	J5	3	Social	1	1	0	0	0
247	J9	J4	3	Social	1	0	0	0	0
248	G2	J4	3	Social	0	1	0	0	0
249	J8	J4	1	Social	1	0	0	0	0
250	J7	J4	5	Social	1	1	0	1	0
251	P2	J4	3	Social	0	0	1	0	0
252	P1	J4	3	Social	1	0	0	0	0
253	A5	J4	2	Social	0	1	0	0	0
254	A4	J4	2	Social	0	1	0	0	0
255	J3	J4	2	Social	1	0	0	0	0
256	A2	J4	5	Social	1	0	0	0	0
257	J2	J4	2	Social	0	0	0	1	0
258	J1	J4	2	Social	1	0	0	0	0
259	J9	J7	3	Social	1	0	0	0	0
260	G2	J7	3	Social	0	1	0	0	0
261	J8	J7	1	Social	1	0	0	0	0
262	J4	J7	5	Social	1	1	1	1	0
263	P1	J7	3	Social	0	0	0	1	0
264	A4	J7	2	Social	0	1	0	0	0
265	J3	J7	2	Social	1	0	0	0	0
266	A2	J7	5	Social	1	0	0	0	0
267	J2	J7	2	Social	0	0	0	1	0
268	J1	J7	2	Social	1	0	0	0	0
269	C5	J6	4	Social	1	1	0	1	0
270	J8	J6	2	Social	1	0	0	1	0
271	A6	J6	5	Social	1	1	0	0	0
272	J3	J6	2	Social	1	0	0	0	0
273	J9	G2	4	Social	1	1	1	0	1
274	A7	G2	3	Social	0	1	0	0	0
275	G3	G2	2	Social	1	0	0	0	0
276	G1	G2	5	Social	0	0	1	0	0
277	A6	G2	5	Social	1	0	1	0	1
278	J7	G2	4	Social	1	1	1	1	0
279	J5	G2	2	Social	0	1	1	0	0
280	J4	G2	3	Social	1	1	1	0	0
281	P2	G2	5	Social	1	1	1	0	0
282	P1	G2	5	Social	1	1	1	0	0
283	A5	G2	3	Social	1	1	1	0	0
284	A4	G2	3	Social	1	1	1	1	0
285	A3	G2	2	Social	0	0	1	0	0
286	J3	G2	4	Social	1	0	0	0	0
287	A2	G2	4	Social	1	0	0	0	0
288	A1	G2	3	Social	0	0	1	0	0
289	J2	G2	4	Social	1	1	0	0	0
290	J1	G2	3	Social	0	1	0	0	0
291	J9	C1	4	Social	1	1	1	1	0
292	A7	C1	4	Social	1	1	1	0	0

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
293	G2	C1	2	Social	0	1	0	1	0
294	G1	C1	5	Social	1	1	1	0	0
295	C2	C1	4	Social	1	0	0	0	0
296	J7	C1	2	Social	0	0	0	1	0
297	P1	C1	2	Social	0	0	0	1	0
298	A2	C1	3	Social	1	0	0	0	0
299	J1	C1	3	Social	1	1	0	0	0
300	J9	C2	3	Social	1	1	1	0	0
301	A7	C2	3	Social	0	1	1	0	0
302	G1	C2	3	Social	0	0	1	0	0
303	C5	C4	4	Social	1	1	1	1	0
304	C1	C2	4	Social	1	0	0	0	0
305	J8	C2	3	Social	1	1	0	0	0
306	A6	C2	4	Social	1	0	0	0	0
307	J7	C2	2	Social	0	0	0	1	0
308	P1	C2	2	Social	0	0	0	1	0
309	C5	C3	5	Social	1	1	1	1	0
310	J9	G1	4	Social	1	1	1	0	0
311	A7	G1	2	Social	0	1	0	0	0
312	G3	G1	4	Social	1	0	0	0	0
313	G2	G1	2	Social	0	1	1	0	0
314	C2	G1	3	Social	0	1	1	0	0
315	C1	G1	4	Social	1	0	1	0	0
316	J7	G1	2	Social	0	0	0	1	0
317	P2	G1	3	Social	0	0	1	0	0
318	P1	G1	3	Social	1	0	0	0	0
319	A2	G1	3	Social	1	0	1	0	0
320	J2	G1	2	Social	0	0	1	0	0
321	J1	G1	3	Social	1	1	0	0	0
322	J9	G3	3	Social	1	1	1	0	0
323	G2	G3	2	Social	0	1	1	0	0
324	G1	G3	4	Social	1	1	1	1	0
325	C3	G3	3	Social	0	1	0	0	0
326	A6	G3	4	Social	0	0	1	0	0
327	J7	G3	2	Social	0	0	0	1	0
328	J5	G3	3	Social	0	1	1	0	0
329	P1	G3	4	Social	1	0	0	0	0
330	A5	G3	3	Social	1	0	1	0	0
331	A2	G3	3	Social	1	0	1	0	0
332	J2	G3	2	Social	0	0	1	0	0
333	J1	G3	2	Social	0	1	0	0	0
334	J9	C3	2	Social	0	1	1	0	0
335	G3	C3	3	Social	1	0	0	0	0
336	P1	C3	4	Social	1	0	0	0	0
337	J2	C4	5	Social	1	0	0	0	0
338	J2	C3	5	Social	1	0	0	0	0
339	J2	C5	5	Social	1	0	0	0	0
340	A6	C5	4	Social	1	0	0	0	0
341	A6	C4	4	Social	1	0	0	0	0

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
342	A6	C3	4	Social	1	0	0	0	0
343	C4	C5	5	Social	1	0	0	0	0
344	C4	C3	4	Social	0	1	0	0	0
345	J2	C5	5	Social	1	1	1	0	0
346	J9	Fish-NS	2	Social-ecological	0	0	1	1	0
347	A7	Common carp	2	Social-ecological	0	0	0	1	0
348	G3	Muskellunge	2	Social-ecological	0	1	0	0	0
349	G3	Northern Pike	3	Social-ecological	0	1	0	0	0
350	G3	Walleye	2	Social-ecological	0	1	0	0	0
351	G3	Smallmouth bass	3	Social-ecological	0	1	0	0	0
352	G3	Largemouth bass	3	Social-ecological	0	1	0	0	0
353	C5	Muskellunge	5	Social-ecological	0	1	1	1	0
354	C5	Walleye	4	Social-ecological	0	1	0	1	0
355	C5	Smallmouth bass	3	Social-ecological	0	1	0	1	0
356	C5	Northern Pike	4	Social-ecological	0	1	0	1	0
357	C4	Muskellunge	5	Social-ecological	0	0	1	0	0
358	C4	Northern Pike	5	Social-ecological	0	0	0	1	0
359	C4	Other bycatch	5	Social-ecological	0	0	0	1	0
360	C3	Muskellunge	5	Social-ecological	0	1	1	0	0
361	C3	Northern Pike	5	Social-ecological	0	0	0	1	0
362	C2	Smallmouth bass	4	Social-ecological	0	0	0	0	1
363	C2	Largemouth bass	4	Social-ecological	0	0	0	0	1
364	C2	Rock bass	4	Social-ecological	0	0	0	0	1
365	C1	Smallmouth bass	3	Social-ecological	0	0	0	1	1
366	C1	Largemouth bass	3	Social-ecological	0	0	0	1	1
367	C1	Rock bass	3	Social-ecological	0	0	0	1	1
368	J8	Largemouth bass	5	Social-ecological	0	1	1	1	0
369	J8	Smallmouth bass	5	Social-ecological	0	1	1	1	0
370	J8	Rock bass	5	Social-ecological	0	0	0	1	0
371	J8	Bluegill	5	Social-ecological	0	0	0	1	0
372	J8	Yellow perch	5	Social-ecological	0	0	0	1	0
373	A6	Largemouth bass	5	Social-ecological	0	1	1	1	0
374	A6	Smallmouth bass	5	Social-ecological	0	1	1	1	0
375	A6	Northern Pike	5	Social-ecological	0	1	1	1	0
376	A6	Muskellunge	3	Social-ecological	0	1	1	1	0
377	A6	Bluegill	5	Social-ecological	0	1	1	1	0
378	J7	Smallmouth bass	3	Social-ecological	0	0	0	1	0
379	J7	Rock bass	3	Social-ecological	0	0	0	1	0
380	J7	Bluegill	3	Social-ecological	0	0	0	1	0
381	J6	Smallmouth bass	5	Social-ecological	1	0	1	1	0
382	J6	Largemouth bass	5	Social-ecological	1	0	1	1	0
383	J6	Muskellunge	4	Social-ecological	0	0	1	0	0
384	J6	Northern Pike	5	Social-ecological	0	0	1	0	0
385	J6	Common carp	5	Social-ecological	0	0	1	0	0
386	P2	Largemouth bass	4	Social-ecological	0	1	1	0	0
387	P2	Northern Pike	4	Social-ecological	0	1	1	0	0
388	P1	Smallmouth bass	5	Social-ecological	1	0	1	0	0
389	P1	Muskellunge	5	Social-ecological	1	0	1	0	0
390	P1	Largemouth bass	5	Social-ecological	1	0	1	0	0

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
391	P1	Rock bass	5	Social-ecological	1	0	1	0	0
392	A4	Northern Pike	4	Social-ecological	0	0	1	0	0
393	A4	Largemouth bass	4	Social-ecological	0	0	1	0	0
394	A4	Round goby	3	Social-ecological	0	0	1	0	0
395	J3	Pumpkinseed	5	Social-ecological	0	0	1	0	1
396	J3	Bluegill	5	Social-ecological	0	0	1	0	1
397	J3	Northern Pike	5	Social-ecological	0	0	0	0	1
398	J3	Rock bass	5	Social-ecological	0	0	0	0	1
399	J3	Largemouth bass	5	Social-ecological	0	0	1	0	1
400	A1	Bluegill	5	Social-ecological	0	0	1	0	0
401	A1	Pumpkinseed	5	Social-ecological	0	0	1	0	0
402	A1	Rock bass	5	Social-ecological	0	0	1	0	0
403	A1	Smallmouth bass	5	Social-ecological	0	0	1	0	0
404	J2	Round goby	3	Social-ecological	0	1	1	1	1
405	J2	Common carp	4	Social-ecological	0	1	1	0	0
406	J2	Largemouth bass	5	Social-ecological	0	1	1	0	0
407	J2	Northern Pike	5	Social-ecological	0	1	1	0	0
408	J2	Muskellunge	3	Social-ecological	0	1	1	0	1
409	J9	Turtle-NS	2	Social-ecological	0	0	0	1	0
410	J9	Watersnake	2	Social-ecological	0	0	0	1	0
411	G3	Painted turtle	4	Social-ecological	0	1	0	0	0
412	G3	Snapping turtle	4	Social-ecological	0	1	0	0	0
413	G3	Northern map turtle	3	Social-ecological	0	1	0	0	0
414	G3	Blanding's turtle	2	Social-ecological	0	1	0	0	0
415	C5	Snapping turtle	3	Social-ecological	0	0	0	1	0
416	C5	Painted turtle	3	Social-ecological	0	0	0	1	0
417	C4	Turtle-NS	5	Social-ecological	0	0	0	1	0
418	C3	Snapping turtle	4	Social-ecological	0	0	0	1	0
419	C3	Painted turtle	4	Social-ecological	0	0	0	1	0
420	C2	Snapping turtle	3	Social-ecological	0	0	0	1	0
421	C1	Snapping turtle	3	Social-ecological	1	0	0	0	0
422	A6	Turtle-NS	2	Social-ecological	0	0	0	1	0
423	J7	Painted turtle	2	Social-ecological	0	0	0	1	0
424	J7	Snapping turtle	2	Social-ecological	0	0	0	1	1
425	J3	Painted turtle	5	Social-ecological	0	0	1	0	1
426	J3	Snapping turtle	5	Social-ecological	0	0	1	0	1
427	J3	Musk turtles	5	Social-ecological	0	0	1	0	1
428	A1	Painted turtle	5	Social-ecological	0	0	1	0	0
429	A1	Musk turtles	5	Social-ecological	0	0	1	0	0
430	A1	Snapping turtle	5	Social-ecological	0	0	1	0	0
431	A1	Northern map turtle	5	Social-ecological	0	0	1	0	0
432	J1	Turtle-NS	2	Social-ecological	0	0	0	1	0
433	J9	Algae-NS	2	Social-ecological	0	0	0	0	1
434	J9	AquaVeg-NS	3	Social-ecological	0	0	0	1	0
435	G3	Algae-NS	4	Social-ecological	0	1	0	0	1
436	G3	Eurasian watermilfoil	4	Social-ecological	0	1	0	0	1
437	G3	European forgbit	4	Social-ecological	0	1	0	0	1
438	G3	Lily pads	4	Social-ecological	0	1	0	0	0
439	G2	Green algae	3	Social-ecological	0	0	1	1	0

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
440	G1	Algae-NS	2	Social-ecological	1	1	0	0	0
441	G1	Forest covers and buffers	1	Social-ecological	0	1	0	0	0
442	G1	InvasivePlant-NS	1	Social-ecological	0	1	0	0	0
443	C5	Eurasian watermilfoil	5	Social-ecological	0	0	0	1	0
444	C5	Pondweed-NS	5	Social-ecological	0	0	0	1	0
445	C5	Coontail	4	Social-ecological	0	0	0	1	0
446	C5	Water celery	5	Social-ecological	0	0	0	1	1
447	C5	Cattail	5	Social-ecological	0	0	0	1	0
448	C4	AquaVeg-NS	5	Social-ecological	0	0	0	1	0
449	C3	Eurasian watermilfoil	5	Social-ecological	0	1	0	0	0
450	C3	Pondweed-NS	5	Social-ecological	0	1	0	0	0
451	C3	Cattail	5	Social-ecological	0	1	0	0	0
452	C3	Lily pads	5	Social-ecological	0	1	0	0	0
453	C3	Water celery	5	Social-ecological	0	1	0	0	0
454	C2	Algae-NS	5	Social-ecological	0	0	0	0	1
455	C1	Eurasian watermilfoil	5	Social-ecological	0	0	0	0	1
456	C1	White oak	5	Social-ecological	1	0	0	0	0
457	C1	Algae-NS	5	Social-ecological	0	0	0	0	1
458	J8	Lily pads	5	Social-ecological	0	0	0	1	0
459	J8	AquaVeg-NS	5	Social-ecological	0	0	0	1	0
460	J8	Wood debris	5	Social-ecological	0	0	0	1	0
461	J7	Eurasian watermilfoil	5	Social-ecological	0	0	1	0	1
462	J7	Eelgrass	5	Social-ecological	0	0	0	1	1
463	J7	Pondweed-NS	5	Social-ecological	0	0	0	1	0
464	J7	Duckweed	5	Social-ecological	0	0	0	1	0
465	J7	Chara	5	Social-ecological	0	0	0	1	0
466	J6	Eelgrass	5	Social-ecological	0	0	0	1	1
467	J6	Lily pads	5	Social-ecological	0	0	0	1	1
468	J6	Pondweed-NS	5	Social-ecological	0	0	0	1	1
469	J6	Coontail	5	Social-ecological	0	0	0	1	1
470	J6	Hydrilla	5	Social-ecological	0	0	0	1	1
471	J5	AquaVeg-NS	5	Social-ecological	0	0	0	0	1
472	J4	Eurasian watermilfoil	5	Social-ecological	0	1	1	0	1
473	J4	Pondweed-NS	5	Social-ecological	1	0	1	0	0
474	J4	Duckweed	4	Social-ecological	1	0	1	0	0
475	J4	Eelgrass	5	Social-ecological	1	0	1	0	0
476	J4	Chara	5	Social-ecological	0	1	1	0	1
477	P2	Eurasian watermilfoil	5	Social-ecological	0	0	0	1	1
478	A5	RiparianVeg-NS	1	Social-ecological	0	0	1	0	0
479	J3	AquaVeg-NS	5	Social-ecological	0	0	0	0	1
480	A2	Eurasian watermilfoil	5	Social-ecological	1	0	1	0	0
481	A2	Algae-NS	5	Social-ecological	1	0	1	0	0
482	J2	AquaVeg-NS	5	Social-ecological	0	0	0	0	1
483	G3	Benthic	4	Social-ecological	0	1	0	0	0
484	G3	Zebra mussel	4	Social-ecological	0	1	0	0	1
485	G3	Mayfly	4	Social-ecological	0	1	0	0	0
486	G3	Caddisfly	4	Social-ecological	0	1	0	0	0
487	G3	Stonefly	4	Social-ecological	0	1	0	0	0
488	G1	Benthic	5	Social-ecological	0	0	1	0	0

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
489	G1	Spiny Waterflea	2	Social-ecological	0	1	0	0	0
490	C5	BugsFishStomach	3	Social-ecological	0	0	0	1	1
491	C5	Mosquitoe	4	Social-ecological	0	1	0	1	0
492	C4	Mosquitoe	5	Social-ecological	0	0	0	0	1
493	C4	Black fly	5	Social-ecological	0	0	0	0	1
494	C3	Dragonfly	5	Social-ecological	0	0	0	1	0
495	C3	Mosquitoe	5	Social-ecological	0	0	0	1	1
496	C3	Tick	5	Social-ecological	0	0	0	1	1
497	C2	Zebra mussel	5	Social-ecological	0	0	0	0	1
498	C2	Tick	5	Social-ecological	0	0	0	0	1
499	C2	Mosquitoe	5	Social-ecological	0	0	0	0	1
500	C2	Deer fly	4	Social-ecological	0	0	0	0	1
501	C2	Black fly	4	Social-ecological	0	0	0	0	1
502	C1	Tick	1	Social-ecological	0	0	0	0	1
503	J8	Zebra mussel	3	Social-ecological	0	0	0	0	1
504	J7	Zookplankton	5	Social-ecological	0	0	1	0	0
505	J7	Algae-NS	5	Social-ecological	0	0	1	0	0
506	J7	Benthic	5	Social-ecological	0	0	1	0	0
507	J7	Chydoridae	5	Social-ecological	0	0	1	0	0
508	J7	Midge	5	Social-ecological	0	0	1	0	0
509	J6	Zookplankton	1	Social-ecological	0	0	0	1	0
510	J6	Phytoplankton	1	Social-ecological	0	0	0	1	0
511	J4	Mayfly	5	Social-ecological	0	1	1	0	0
512	J4	Damselfly	5	Social-ecological	0	1	1	0	0
513	J4	Caddisfly	5	Social-ecological	0	1	1	0	0
514	J4	Midge	5	Social-ecological	1	1	1	0	0
515	J3	Spiders	5	Social-ecological	0	0	0	0	1
516	J3	Mosquitoe	5	Social-ecological	0	0	0	0	1
517	J3	Dragonfly	5	Social-ecological	0	0	0	1	0
518	J3	Deer fly	5	Social-ecological	0	0	0	0	1
519	A2	Zookplankton	5	Social-ecological	1	0	0	0	0
520	A2	Diatom	5	Social-ecological	1	0	0	0	0
521	A2	Blue-green algae	5	Social-ecological	1	0	0	0	0
522	J2	Mosquitoe	3	Social-ecological	0	0	0	0	1
523	G3	Amphibians-NS	4	Social-ecological	0	0	0	1	0
524	G3	Reptiles-NS	4	Social-ecological	0	0	0	1	0
525	G3	Birds-NS	4	Social-ecological	0	0	0	1	0
526	G3	Mammals-NS	4	Social-ecological	0	0	0	1	0
527	C5	Peregrine	2	Social-ecological	0	0	0	1	0
528	C5	Water fowls	5	Social-ecological	0	0	0	1	1
529	C5	Coyote	1	Social-ecological	0	0	0	1	0
530	C4	Eel	3	Social-ecological	0	0	0	1	0
531	C4	Bald eagle	5	Social-ecological	0	0	0	1	0
532	C4	Osprey	5	Social-ecological	0	0	0	1	0
533	C4	Blue heron	5	Social-ecological	0	0	0	1	0
534	C3	Algae-NS	5	Social-ecological	0	0	0	1	1
535	C3	Muskrat	4	Social-ecological	0	0	0	1	0
536	C3	Mink	4	Social-ecological	0	0	0	1	0
537	C3	Otter	4	Social-ecological	0	0	0	1	0

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
538	C2	Loon	5	Social-ecological	0	0	0	1	0
539	C2	Deer	4	Social-ecological	0	0	0	1	0
540	C2	Racoon	5	Social-ecological	0	0	0	1	0
541	C2	Coyote	3	Social-ecological	0	0	0	1	0
542	C2	Fisher	3	Social-ecological	0	0	0	1	0
543	C2	Fox	4	Social-ecological	0	0	0	1	0
544	C2	Porcupine	5	Social-ecological	0	0	0	1	0
545	C1	Eastern rat snake	3	Social-ecological	1	0	0	0	0
546	C1	Osprey	5	Social-ecological	0	0	0	1	0
547	J7	Muskrat	3	Social-ecological	0	0	0	1	0
548	J7	Osprey	4	Social-ecological	0	0	0	1	1
549	J7	Green heron	4	Social-ecological	0	0	0	1	0
550	J7	Loon	5	Social-ecological	0	0	0	1	0
551	J7	Tern	2	Social-ecological	0	0	0	1	0
552	J6	Algae-NS	3	Social-ecological	0	0	0	0	1
553	J6	Watersnake	2	Social-ecological	0	0	0	1	0
554	J6	Bluegill	5	Social-ecological	0	0	1	1	0
555	J5	Zebra mussel	5	Social-ecological	0	0	0	0	1
556	J4	Diatom	5	Social-ecological	1	1	1	0	0
557	J4	Green algae	5	Social-ecological	0	0	1	0	0
558	J4	Blue-green algae	5	Social-ecological	0	1	1	0	1
559	J4	Cryptophyceae	5	Social-ecological	0	0	1	0	0
560	J4	Dinophyta	4	Social-ecological	0	0	1	0	0
561	J3	Watersnake	3	Social-ecological	0	0	0	0	1
562	J3	Duck	2	Social-ecological	0	0	0	0	1
563	J3	Frog	5	Social-ecological	0	0	0	1	0
564	J3	Cormorant	2	Social-ecological	0	0	0	0	1
565	A1	Muskrat	4	Social-ecological	0	0	0	0	1
566	A1	Otter	4	Social-ecological	0	0	0	0	1
567	J9	Water	5	Social-ecological	1	0	0	1	0
568	G3	Water quality	4	Social-ecological	0	1	0	0	0
569	G3	Nutrients	4	Social-ecological	0	1	0	0	0
570	G2	Water	5	Social-ecological	0	0	0	1	0
571	G1	Water quality	1	Social-ecological	0	1	0	0	0
572	G1	Rocks and substrate	1	Social-ecological	0	1	0	0	0
573	C5	Water	5	Social-ecological	0	1	1	1	1
574	C5	Sediments	4	Social-ecological	0	0	0	1	1
575	C5	Algae-NS	4	Social-ecological	0	0	0	1	1
576	C2	Water	5	Social-ecological	0	1	0	0	0
577	C2	Nutrients	1	Social-ecological	0	1	0	0	0
578	C2	Water fowls	5	Social-ecological	0	0	0	1	0
579	C2	Bald eagle	5	Social-ecological	0	0	0	1	0
580	C2	Turkey	5	Social-ecological	0	0	0	1	0
581	C2	Sediments	1	Social-ecological	0	1	0	0	0
582	C2	Woodpecker	5	Social-ecological	0	0	0	1	0
583	C1	Nutrients	5	Social-ecological	0	0	0	0	1
584	C1	Wood debris	3	Social-ecological	0	0	0	1	0
585	J8	Water temperature	5	Social-ecological	0	1	1	0	0
586	J8	Dissolved oxygen	4	Social-ecological	0	1	1	0	0

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
587	J7	Water	5	Social-ecological	0	0	1	0	1
588	J7	Sediments	5	Social-ecological	0	0	1	0	1
589	J7	Nutrients	5	Social-ecological	0	0	1	0	1
590	J7	Bathymetry	2	Social-ecological	0	0	1	0	0
591	J5	Sediments	5	Social-ecological	0	0	1	0	0
592	J5	Water	5	Social-ecological	0	0	1	0	0
593	J5	Microplastics	5	Social-ecological	0	0	1	0	0
594	J4	Nutrients	5	Social-ecological	0	1	1	0	1
595	J4	Water	5	Social-ecological	1	1	1	0	0
596	J4	Microplastics	5	Social-ecological	0	1	1	0	1
597	J4	Sediments	5	Social-ecological	0	0	1	0	0
598	P2	Eutrophication	3	Social-ecological	0	0	1	1	0
599	J3	Water	5	Social-ecological	0	0	0	0	1
600	A2	Water quality	5	Social-ecological	1	0	0	0	0
601	A2	Sediments	4	Social-ecological	1	0	0	0	0
602	J2	Water quality	4	Social-ecological	0	0	1	0	1
603	J2	Zebra mussel	4	Social-ecological	0	0	0	0	1
604	J1	Water	2	Social-ecological	0	0	0	1	0
605	J9	Bridge	5	Social-technical	0	0	0	1	0
606	J9	Lock station	4	Social-technical	0	0	0	1	0
607	J9	Dam	2	Social-technical	0	0	0	1	0
608	J9	Paths	5	Social-technical	0	0	0	1	0
609	J9	Skateway	3	Social-technical	0	0	0	1	0
610	A7	Canal walls	3	Social-technical	0	0	0	1	0
611	G2	Lock station	2	Social-technical	0	1	1	0	0
612	G1	Dam	4	Social-technical	0	1	0	0	0
613	G1	Lock station	4	Social-technical	0	1	0	0	0
614	G1	Flood control	5	Social-technical	0	1	0	0	0
615	C5	Dam	3	Social-technical	0	0	0	1	0
616	C5	Lock station	4	Social-technical	0	0	1	1	0
617	C5	Bridge	5	Social-technical	0	0	0	1	0
618	C4	Dam	4	Social-technical	0	0	0	1	0
619	C4	Bridge	4	Social-technical	0	0	0	1	0
620	C3	Dam	5	Social-technical	0	0	0	1	0
621	C3	Lock station	5	Social-technical	0	0	0	1	0
622	C2	Lock station	3	Social-technical	0	0	0	1	0
623	C1	Lock station	5	Social-technical	1	0	0	0	0
624	J8	Bridge	5	Social-technical	0	0	0	1	0
625	J6	Lock station	3	Social-technical	0	0	0	1	0
626	J6	Dam	3	Social-technical	0	0	0	1	1
627	J5	Dam	5	Social-technical	0	0	1	1	0
628	J5	Lock station	5	Social-technical	0	0	1	1	0
629	J5	Bridge	5	Social-technical	0	0	1	1	0
630	J5	Abandoned infrastructure	4	Social-technical	0	0	1	1	1
631	J4	Lock station	5	Social-technical	1	0	0	0	0
632	J4	Bridge	5	Social-technical	1	0	0	0	0
633	P2	Lock station	5	Social-technical	0	0	1	1	0
634	A5	Lock station	2	Social-technical	0	0	1	1	0
635	A4	Lock station	5	Social-technical	0	0	0	1	0

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
636	A4	Dam	5	Social-technical	0	0	0	1	0
637	J3	Bridge	3	Social-technical	0	0	0	0	1
638	J3	Boat launch	3	Social-technical	0	0	0	1	0
639	A2	Boat launch	5	Social-technical	0	0	0	1	0
640	A1	Lock station	5	Social-technical	0	0	0	1	0
641	J2	Lock station	5	Social-technical	0	0	1	1	1
642	J9	Canoe	3	Social-technical	0	0	1	0	0
643	J9	Recorder	3	Social-technical	0	0	1	0	0
644	J9	Underwater camera	3	Social-technical	0	1	1	0	0
645	J9	Nvivo	5	Social-technical	0	0	1	0	1
646	J9	Excel	5	Social-technical	0	0	1	0	1
647	J9	Kayak	3	Social-technical	0	0	1	0	0
648	J9	R	5	Social-technical	0	0	1	0	1
649	A7	Nvivo	2	Social-technical	0	0	1	0	0
650	G3	Boat	4	Social-technical	0	1	0	0	0
651	G3	Water level gauge	4	Social-technical	0	1	0	0	0
652	G3	Beach	5	Social-technical	0	1	0	0	0
653	G1	Boat	3	Social-technical	0	0	0	1	0
654	G1	Water meter	4	Social-technical	0	0	1	0	0
655	G1	Laboratory	4	Social-technical	0	0	1	0	0
656	G1	Data management system	4	Social-technical	0	0	1	0	0
657	G1	Survey123 App	4	Social-technical	0	0	1	0	0
658	C5	Sonar	5	Social-technical	1	1	1	0	0
659	C5	Boat	5	Social-technical	0	0	1	1	1
660	C5	Fishing rod and gear	5	Social-technical	0	0	1	0	0
661	C4	Sonar	5	Social-technical	0	0	1	0	0
662	C4	Boat	5	Social-technical	0	0	1	0	0
663	C4	Fishing rod and gear	5	Social-technical	0	0	1	0	0
664	C4	Release tools	5	Social-technical	0	0	1	0	0
665	C4	Cell phone	5	Social-technical	0	0	1	0	0
666	C4	GPS	5	Social-technical	0	0	1	0	0
667	C3	Boat	5	Social-technical	0	0	1	0	0
668	C3	Sonar	5	Social-technical	0	0	1	0	0
669	C3	Fishing rod and gear	5	Social-technical	0	0	1	0	0
670	C3	Nets	5	Social-technical	0	0	1	0	0
671	C3	GPS	5	Social-technical	0	0	1	0	0
672	C2	Boat	5	Social-technical	0	0	0	1	0
673	C2	Water Rangers kit	4	Social-technical	0	1	0	0	0
674	C2	Bubblers	5	Social-technical	0	0	0	1	0
675	C2	Boat lift	5	Social-technical	0	0	0	1	0
676	C1	Boat	5	Social-technical	0	0	0	1	0
677	C1	Boat traffic	5	Social-technical	0	0	0	0	1
678	J8	Electric fish handling gloves	5	Social-technical	0	0	1	0	0
679	J8	Electronic navigation chart	5	Social-technical	0	0	1	0	0
680	J8	Boat	5	Social-technical	0	0	1	0	0
681	J8	Tournament participant boat	4	Social-technical	0	0	1	0	0
682	J7	Boat	5	Social-technical	0	0	1	0	1
683	J7	Lab vehicle	5	Social-technical	0	0	1	0	1
684	J7	YSI probe	5	Social-technical	0	0	1	0	1

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
685	J7	Microscope	5	Social-technical	0	0	1	0	1
686	J7	Safety equipment	5	Social-technical	0	0	1	0	1
687	J7	Canoe	5	Social-technical	0	0	1	0	1
688	J7	Zooplankton net	5	Social-technical	0	0	1	0	1
689	J7	Water sampler	5	Social-technical	0	0	1	0	1
690	J7	Ekman dredge	5	Social-technical	0	0	1	0	1
691	J7	Spectrophotometer	5	Social-technical	0	0	1	0	1
692	J7	Lab consumables	5	Social-technical	0	0	1	0	1
693	J6	Electrofishing boat	3	Social-technical	0	0	0	1	0
694	J6	Boat	5	Social-technical	0	0	0	1	0
695	J6	Biologger	5	Social-technical	0	0	1	0	0
696	J6	Floyd tags	5	Social-technical	0	0	1	0	0
697	J5	Remote control boat	5	Social-technical	0	1	0	0	1
698	J5	Acoustic Doppler Current Profiler	5	Social-technical	0	1	0	0	0
699	J5	Water level and temprature logger	4	Social-technical	0	1	0	0	0
700	J5	Ekman dredge	4	Social-technical	0	1	0	0	0
701	J5	Acoustic receivers	3	Social-technical	0	1	0	0	0
702	J4	Boat	5	Social-technical	1	0	1	0	0
703	J4	YSI probe	5	Social-technical	0	0	1	0	0
704	J4	Microscope	5	Social-technical	0	0	1	0	0
705	J4	R	5	Social-technical	0	0	1	0	1
706	J4	ArcGIS	5	Social-technical	0	1	1	0	0
707	P2	Acoustic tags	3	Social-technical	0	0	1	0	0
708	P2	Boat	3	Social-technical	0	0	1	0	0
709	P2	QGIS	4	Social-technical	0	0	1	0	0
710	P2	R	4	Social-technical	0	0	1	0	0
711	P1	Boat	5	Social-technical	0	0	0	1	0
712	P1	Electrofishing boat	5	Social-technical	0	0	0	1	0
713	A3	Thermocycler	5	Social-technical	1	0	1	0	1
714	A3	R	5	Social-technical	0	0	1	0	1
715	A3	STRUCTURE	4	Social-technical	0	0	1	0	0
716	A3	DNA sequencer	5	Social-technical	1	0	1	0	1
717	J3	Boat	5	Social-technical	0	0	0	1	0
718	J3	Lab vehicle	5	Social-technical	0	0	0	1	0
719	J3	DNA sequencer	5	Social-technical	0	0	1	0	0
720	J3	GeneMapper	5	Social-technical	0	0	1	0	0
721	J3	Nets	5	Social-technical	0	0	1	0	0
722	J3	Lab consumables	5	Social-technical	0	0	1	0	0
723	J3	R	5	Social-technical	0	0	1	0	0
724	J3	ArcGIS	5	Social-technical	0	0	1	0	0
725	J3	STRUCTURE	5	Social-technical	0	0	1	0	0
726	J3	Field equipment to sample turtles	5	Social-technical	0	0	1	0	0
727	A2	Boat	5	Social-technical	0	0	0	1	0
728	A2	Microscope	4	Social-technical	0	0	1	0	0
729	A2	YSI probe	4	Social-technical	0	0	1	0	0
730	A2	Spectrophotometer	4	Social-technical	0	0	1	0	0
731	A2	Dissolved organic carbon	4	Social-technical	0	0	1	0	0
732	A1	Boat	5	Social-technical	0	0	0	1	0
733	A1	Nets	5	Social-technical	0	0	1	0	0

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
734	A1	DNA sequencer	5	Social-technical	0	0	1	0	0
735	A1	Thermocycler	5	Social-technical	0	0	1	0	0
736	A1	Lab consumables	5	Social-technical	0	0	1	0	0
737	J2	Acoustic tags	5	Social-technical	0	0	1	0	0
738	J2	Acoustic receivers	3	Social-technical	0	0	1	0	0
739	J2	Boat	5	Social-technical	0	0	1	0	0
740	J2	Electrofishing boat	5	Social-technical	0	0	1	0	0
741	J2	R	5	Social-technical	0	0	1	0	0
742	J1	Nvivo	5	Social-technical	0	0	1	0	0
743	J1	R	3	Social-technical	0	0	1	0	0
744	J1	ArcGIS	2	Social-technical	0	1	0	0	0
745	J1	Canoe	2	Social-technical	1	0	0	1	0
746	J6	R	4	Social-technical	0	0	1	0	1
747	J5	Modelling software	5	Social-technical	0	0	1	0	0
748	J5	Matlab	4	Social-technical	0	0	1	0	0
749	J5	ArcGIS	4	Social-technical	0	0	1	0	0
750	J5	Field software	5	Social-technical	0	0	1	0	0
751	J5	3D modelling software	5	Social-technical	0	0	1	0	0
752	J4	Zebra mussel	5	Social-ecological	0	1	1	0	1
753	A1	QUBS housing	5	Social-technical	0	0	0	1	0
754	C1	Loon	2	Social-ecological	1	0	0	0	0
755	G2	AquaVeg-NS	1	Social-ecological	0	1	0	0	0
756	G2	Instrument	1	Social-technical	0	0	1	0	0
757	J8	O1	2	Social	1	0	0	0	0
758	A6	O1	3	Social	0	1	0	0	0
759	J6	O1	4	Social	1	1	0	0	0
760	P1	O1	4	Social	1	0	0	0	0
761	J3	O1	4	Social	1	0	0	0	0
762	J2	O1	2	Social	0	1	0	0	0
763	J8	O2	1	Social	1	0	0	0	0
764	J3	O2	5	Social	1	0	0	0	0
765	A1	O2	3	Social	0	1	0	0	0
766	J8	O3	2	Social	1	0	0	0	0
767	A6	O3	3	Social	0	1	0	0	0
768	J2	O3	5	Social	0	1	0	0	0
769	J9	O4	3	Social	1	0	0	0	1
770	A7	O4	3	Social	0	1	0	0	0
771	G3	O4	2	Social	1	0	0	0	0
772	G2	O4	5	Social	1	1	1	1	0
773	G1	O4	2	Social	1	1	0	0	0
774	C3	O4	1	Social	0	1	0	0	0
775	C1	O4	2	Social	1	0	0	0	0
776	A6	O4	5	Social	1	0	1	0	1
777	J7	O4	3	Social	1	1	1	1	0
778	J5	O4	2	Social	0	1	1	0	0
779	J4	O4	2	Social	1	0	0	0	0
780	P2	O4	5	Social	1	1	1	0	0
781	P1	O4	5	Social	1	1	1	0	0
782	A5	O4	3	Social	1	1	1	0	0

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
783	A4	O4	3	Social	1	1	1	1	0
784	A3	O4	2	Social	0	0	1	0	0
785	J3	O4	4	Social	1	0	0	0	0
786	A2	O4	2	Social	0	1	0	0	0
787	A1	O4	3	Social	0	0	1	0	0
788	J2	O4	4	Social	1	1	1	0	0
789	J1	O4	3	Social	0	1	0	0	0
790	J9	O5	3	Social	0	1	0	0	0
791	A7	O5	3	Social	0	1	0	0	0
792	G3	O5	2	Social	1	0	0	0	0
793	G2	O5	3	Social	0	1	0	0	0
794	G1	O6	3	Social	1	0	0	0	0
795	P1	O5	3	Social	0	1	1	0	0
796	J9	O7	3	Social	0	1	0	0	0
797	A7	O7	3	Social	0	1	0	0	0
798	G2	O7	3	Social	0	1	0	0	0
799	C2	O7	2	Social	0	1	0	1	0
800	P1	O7	2	Social	0	0	0	1	0
801	J9	O8	3	Social	0	1	1	0	0
802	J9	O9	3	Social	1	1	0	0	0
803	J9	O10	3	Social	0	1	0	0	0
804	G3	O8	3	Social	1	0	1	0	0
805	G2	O11	3	Social	0	0	1	0	0
806	G2	O12	3	Social	0	0	1	0	0
807	G2	O8	3	Social	0	0	1	0	0
808	G2	O13	3	Social	0	0	1	0	0
809	G2	O14	3	Social	0	0	1	0	0
810	G2	O15	3	Social	0	0	1	0	0
811	G2	O16	3	Social	0	0	1	0	0
812	G2	O17	2	Social	0	0	1	0	0
813	G1	O12	5	Social	1	1	1	0	0
814	G1	O18	5	Social	1	1	1	0	0
815	G1	O9	5	Social	1	1	0	0	0
816	C2	O19	1	Social	0	1	0	0	1
817	C2	O9	1	Social	0	1	0	0	1
818	C2	O20	1	Social	0	1	0	0	0
819	C1	O19	3	Social	0	1	0	0	1
820	C1	O21	2	Social	0	0	0	0	1
821	J6	O23	3	Social	0	1	0	0	0
822	J5	O12	4	Social	1	1	1	0	0
823	J5	O11	3	Social	0	0	1	0	1
824	J5	O24	3	Social	0	0	1	1	1
825	A5	O11	4	Social	1	1	1	0	0
826	A5	O12	4	Social	1	1	1	0	0
827	J3	O8	2	Social	0	0	1	0	0
828	J2	O23	5	Social	0	0	1	0	0
829	J1	O10	2	Social	0	1	0	0	0
830	J1	O9	2	Social	0	1	0	0	0
831	J5	O25	3	Social	1	0	1	0	0

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
832	J5	O26	2	Social	0	1	1	0	0
833	A2	O27	2	Social	1	0	0	0	0
834	C2	O28	3	Social	0	1	1	0	0
835	J5	O29	3	Social	0	1	1	0	0
836	C5	O30	3	Social	0	1	1	1	0
837	C5	O31	3	Social	0	1	0	1	0
838	C2	O32	4	Social	0	0	1	1	0
839	A7	O33	2	Social	0	1	0	0	0
840	G3	O33	3	Social	1	0	0	0	0
841	C5	O34	3	Social	0	1	1	1	0
842	P1	O33	4	Social	1	0	0	0	0
843	A5	O25	3	Social	1	0	1	0	0
844	J5	O35	3	Social	0	1	1	0	0
845	C2	O36	4	Social	1	0	0	0	0
846	C2	O37	4	Social	0	0	1	1	0
847	J9	O38	3	Social	1	1	0	0	0
848	J9	O39	3	Social	1	1	0	0	0
849	J9	O36	3	Social	1	0	1	0	0
850	A7	O38	3	Social	0	1	1	0	0
851	G3	O40	4	Social	1	0	0	0	0
852	G3	O41	4	Social	1	0	0	0	0
853	G3	O42	4	Social	1	0	0	0	0
854	G3	O43	4	Social	1	0	0	0	0
855	G1	O44	1	Social	0	1	0	0	0
856	G1	O8	1	Social	0	1	0	0	0
857	G1	O45	3	Social	0	1	0	0	0
858	G1	O46	3	Social	0	1	0	0	0
859	G1	O47	4	Social	0	1	0	0	0
860	G1	O48	3	Social	1	0	0	0	0
861	G1	O39	4	Social	1	0	0	0	0
862	C3	O49	3	Social	1	0	0	0	0
863	C2	O50	3	Social	0	1	0	0	0
864	C2	O51	2	Social	0	1	0	0	0
865	C2	O52	2	Social	0	1	0	0	0
866	C2	O53	2	Social	1	0	0	0	0
867	C2	O54	3	Social	0	1	0	0	0
868	C1	O55	5	Social	1	1	0	0	0
869	J8	O56	3	Social	1	1	0	1	0
870	J8	O57	3	Social	1	1	0	1	0
871	J8	O58	2	Social	1	0	1	0	0
872	J8	O59	2	Social	1	0	1	0	0
873	J8	O60	2	Social	1	0	1	0	0
874	J7	O61	2	Social	0	1	0	1	0
875	J7	O62	4	Social	1	1	1	1	0
876	J7	O63	2	Social	0	1	0	1	0
877	J7	O64	2	Social	0	1	0	1	0
878	J7	O65	2	Social	0	0	1	1	0
879	J7	O66	2	Social	0	1	0	1	0
880	J7	O44	2	Social	0	1	0	1	0

	Outgoing node	Incoming node	Fre-quency	Type	Collab.	Comms.	Data	Random	Friction
881	J7	O67	2	Social	0	1	0	1	0
882	J6	O68	5	Social	1	1	1	1	0
883	J5	O15	3	Social	0	1	1	1	0
884	J5	O69	2	Social	0	1	1	0	0
885	J5	O23	5	Social	0	0	1	0	0
886	J5	O70	5	Social	0	0	1	0	0
887	J4	O71	4	Social	1	0	1	1	0
888	J4	O72	5	Social	0	0	1	1	0
889	A4	O73	4	Social	1	1	1	1	0
890	A4	O74	2	Social	1	0	0	0	0
891	A4	O75	1	Social	1	0	0	0	0
892	A4	O76	1	Social	1	0	0	0	0
893	A3	O77	5	Social	1	0	0	0	0
894	J3	O78	3	Social	0	1	0	0	0
895	J3	O79	3	Social	0	1	0	0	0
896	J3	O80	2	Social	0	1	0	0	0
897	J3	O81	5	Social	0	1	0	0	0
898	J3	O82	5	Social	1	0	1	0	0
899	J3	O83	5	Social	1	0	1	0	0
900	J3	O84	5	Social	1	0	1	0	0
901	J3	O85	5	Social	1	0	1	0	0
902	J3	O86	5	Social	1	0	1	0	0
903	A2	O87	4	Social	1	0	0	0	0
904	A1	O82	3	Social	0	1	0	0	0
905	A1	O83	3	Social	0	1	0	0	0
906	A1	O84	3	Social	0	1	0	0	0
907	A1	O85	3	Social	0	1	0	0	0
908	A1	O86	3	Social	0	1	0	0	0
909	J2	O88	5	Social	0	1	1	0	0
910	J2	O89	5	Social	0	1	1	0	0
911	J2	O90	5	Social	0	1	1	0	0
912	J2	O49	5	Social	1	0	1	0	0
913	J1	O38	3	Social	1	1	0	0	0
914	J1	O39	2	Social	0	1	0	0	0
915	J1	O91	2	Social	0	1	0	0	0
916	J1	O92	3	Social	0	1	0	0	0