Shaping Water Resource Governance: a Comparative Case Study of Five Reservoirs Within the Columbia River Basin

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Authorization to Submit Dissertation

This dissertation of Karen I. Trebitz, submitted for the degree of Doctor of Philosophy with a Major in Water Resources, and titled "Shaping Water Resource Governance: a Comparative Case Study of Five Reservoirs Within the Columbia River Basin," has been reviewed in final form. Permission, as indicated by the signatures and dates below, is now granted to submit final copies to the College of Graduate Studies for approval.

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Abstract

In an 1878 report to Congress, John Wesley Powell unsuccessfully advocated that political jurisdictions in the American west should be organized to conform to watersheds. Instead, governing North America's water resources remains fraught with cross-jurisdictional challenges, through which water flows with no concern for borders on maps. The Columbia River in the Pacific Northwest is the embodiment of boundary-spanning stories, as its arms cross and re-cross national and international borders on its journey to the Pacific Ocean. The Columbia River Basin spans seven U.S. states, Canada's British Columbia, and 30 recognized Indigenous tribes on both sides of the international border, with complex social and ecological interactions throughout.

Water governance styles in large river reaches and reservoir basins across the western U.S. and Canada vary greatly, related in part to the magnitude of federal investment in infrastructure and projects for irrigation, hydropower, and navigation. Yet even the more top-down, command-and-control situations have evolved towards collaborative arrangements of government and non-government organizations ranging from federal agencies to regional and local government and advocacy groups. The devolution of powers from a central government to place-based collaborative governance allows for local experimentation, one of the central tenets of adaptive co-management. Nobel Prize winner, Elinor Ostrom, champions this idea of independent, multi-level actors governing collectively in polycentric arrangements. It is still unclear, however, to what extent collaborative governance arrangements lead to positive outcomes in managing the resources.

Interactions among organizations that together govern the resources can be seen as a network, like a spiders web, where actors are the nodes, and connecting threads are avenues of communications between them. Social network analyses are rigorous scientific methods that are often applied to evaluate the structure and interrelations among actors in governance networks. But the relative paucity of comparable datasets leads to gaps in our understanding

of networks for governing water resources, such as whether the networks have a consistent or dominant shape or pattern.

This study examines water resource governance networks, with a focus on fisheries and water quality. I seek to answer three central research questions:

1. *Is there a dominant shape for water resource governance networks?*
2. *What qualities determine the position of an actor within a water resource governance network?*
3. *To what extent can internal dynamics of the water resource governance network be correlated with action outcomes in terms of changes in fisheries or water quality parameters?*

I use a mixed-methods approach of personal outreach and an online survey to collect data for lake health metrics, actors in the governance networks, and internal dynamics of those networks in five reservoir basins within a geographic transect of the Columbia River Basin. Lakes Chelan, Roosevelt are in the U.S. state of Washington, Lake Pend Oreille is Idaho, and čɬq̓etkʷ (Flathead) is in Montana. The fifth reservoir, Lake Koocanusa, is just over half in Montana, with the rest across the international border in British Columbia, Canada. Similarities, such as federal water quality standards, fisheries regulations, and federally licensed hydroelectric dams that impound each basin, provide a consistent regulatory framework for each governance network. Differences in local geography and social contexts contribute to individuality in the networks.

This dissertation is organized into five major chapters, of which the first three constitute the background needed before the analyses. Chapter one describes the methodology for survey development and the questions that are in the survey instrument. I describe the process of scoping to determine the network boundaries and actor lists for each basin. I explain the process of preparing data for analysis, and the analyses that are performed in course of this dissertation. The chapter finishes with an in-depth discussion of complexities in the process of in-person outreach to solicit survey responses, and subsequent richness in qualitative information that adds context to the networks in individual study basins.

Chapter two is a sketch of the geography and biography of each basin in this study. I present similarities among the settings, but also key differences. Qualitative data from both text entry survey responses and personal communications illustrate issues in governance scenarios in individual basins. Some overarching themes, such as calls for better funding, are common to all of the basins governance groups.

In chapter three I conduct a literature review to examine the prevalence of a core-periphery network pattern in water resource and natural resource governance case studies. The 30 pieces reviewed span nearly 60 years of research in both developed and developing nations. I approach the observed pattern from three disciplinary lenses: network structures, internal dynamics of social capital, and polycentric relations of multi-level collaborative governance. While the three lenses involve different scales and theoretical approaches to evaluating governance networks, results show considerable overlap in the concepts. Furthermore, the core-periphery pattern does appear to be commonly observed, which underscores the need for further examination of this phenomenon in governance networks.

Chapter four examines the core-periphery network pattern with a stepwise process of analytical methods. The central premise is that actors' positions in a network are based on what they do (the number of roles they fulfill in a suite of roles), rather than who they are (the actor type). I construct a suite of roles on three characteristics: resource roles (data, expertise, funding, political support), formal roles (land and resource tenure, regulatory, juridical), and informal roles (collaboration, information sharing by hosting forums and via websites, policy entrepreneurship or proactive networking). With the network data organized by actor types and management focus (all actors, fisheries focus, water quality focus) I first visualize the networks. The patterns are confirmed analytically using a core-periphery test in the social network analysis software. Comparing the network structure by quadratic assignment procedure reveals very low correlation of patterns by actor-type. Poisson regression of actor position (centralization on indegree, or how many nominations an actor receives) shows strong and significant correlations to the three role categories, with individual variations by basin and focus.

Chapter five explores internal dynamics of the governance networks in the five basins relative to changes in lake health indices. Literature for social-ecological systems shows that relating social factors with physical management outcomes remains challenging. Measurements are operationalized using Likert-scale responses from the surveys. Aggregated data across all five basins reveal few discernible trends in lake health outcomes. Strong correlation patterns emerge, however, when network dynamics are related with physical outcomes in individual basins. Qualitative information from the surveys, archival documents, and scoping meetings, supplemented adds basin-specific context and interpretive explanations to these differences.

The five main chapters are followed by discussions of overarching themes*,* limitations to the study, and future directions. This research makes contributions to both theoretical and practical applications of network analysis. The literature review and subsequent network analyses build understanding of core-periphery patterns in resource governance networks. This cross-basin study adds much needed data to a field that suffers from paucity in comparative, multi-community studies. Using the networks themselves as boundary objects to delimit the basins renders a network analysis approach more accessible to practitioners who wish to improve communications in their basin. Results suggest multiple directions for future studies, such as whether governance networks are actually approaching a polycentric government arrangement, or if they are achieving the goals adaptive management. A bold next step would be to expand this study to other large dam catchments of the Columbia River Basin, and on both sides of the U.S.-Canadian border.

Acknowledgements

My journey to this dissertation research began during my undergraduate studies in biology with an environmental/aquatic ecology focus. As a part of the semester-long program in 2009, I was interned in the Legislative Office for Research Liaison (LORL) in Pennsylvania's capital. The resulting published policy paper explored Pennsylvania's oil and gas laws as they pertained to the fairly new gas fracking industry. Inspired by the work at LORL that led to my Masters thesis on federal natural gas policy, and several key courses and faculty members, my focus turned increasingly to communications in water resource policy. It was a natural step to join the IGERT (Integrative Graduate Education and Research Traineeship)[1] fellowship in University of Idaho's Water Resource department, in the track for Law, Management & Policy.

Many people helped me along the way, more than can be listed here. Dr. Pat Kennedy, professor in a communications/law class, opened doors to the internship at LORL. Dr. Jerry Jewett-Smith, advisor and mentor to my bachelor's degree, taught me critical thinking and encouraged me to keep pushing back; "Quit deferring [to me], you are a scientist now!" Jerry and her husband, Dr. John Smith, were instrumental to my move to Washington. Dr. Allyson Beall, my supervisor and committee chair at Washington State University, endured my decidedly non-linear path through complexly intertwined disciplines of environmental studies by allowing eclectic choices in coursework. It is by Allyson's support that I was able to join the IGERT program at University of Idaho. In my introductory interview for the IGERT, Dr. Manoj Shrestha asserted that social network analyses in water resources governance are largely new territory—was I okay with it? Little did I anticipate the truth in his statement! At the beginning of my IGERT experience Dr. John Tracy facilitated my summer internship, which resulted in a published report for the Idaho Department of Water Resources. John, Allyson, and Dr. J.D. Wulfhorst improved the quality of my work with personal experience and insights into natural resources management, especially here in the Pacific Northwest.

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[1.1] Funded primarily by a USGS 104b grant for 2015-16, and A 2015 innovation grant from University of Idaho's College of Letters, Arts and Social Sciences, PI Manoj Shrestha. The

Dedications

Thanks go out to the following: Walter Chase counseled me to enroll in community college in 2003, with his classic Marines attitude: "Girl, you better get off your butt and do it." Walter passed on my first day of classes. Laura Bodwell, who kept encouraging me to keep going, and many other friends who have been highly supportive throughout. Our IGERT cohort at UIdaho is a group of extremely bright and talented, and the mutually supportive students. I am especially grateful for Scott Fennema and his wife, whose upbeat demeanors keep me going.

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Chapter 1: Introduction and Research Methodology

1.1. Introduction

Water basins are complex social-ecological systems, spanning political, legal, jurisdictional, socio-economic, geographic and biophysical boundaries (Bodin *et al*. 2011). One such area is the Columbia River Basin in the Pacific Northwest, which spans seven U.S. states, Canada's British Columbia, and 30 recognized Indigenous tribes on both sides of the international border, with complex social and ecological interactions throughout. Federal environmental laws on both sides of the U.S.-Canada border create a regulatory framework within which all watersheds must be managed. How water resources in individual river reaches or reservoirs are governed against these regulatory backdrops varies, however. Management schemes can range from a top-down, federally driven regulatory framework (Kraft, 2000; Layzer 2015), to bottom-up collaborative management rooted in self-organized collective action within communities, as described by Ostrom (1990; 2010), Carlsson (2000), and others.

History and local context further shape governance arrangements across the western regions of the U.S. and Canada, related in part to the extent of federal investments in infrastructure and projects for irrigation, hydropower, flood control, and navigation. Yet even the more top-down, command-and-control situations have evolved towards collaborative arrangements of government and non-government organizations ranging from federal agencies to regional and local government and advocacy groups. Nobel Prize winner, Elinor Ostrom, champions this idea of independent, multi-level actors governing collectively in polycentric arrangements. The devolution of powers from a central government towards place-based collaborative governance allows for local experimentation, one of the central tenets of adaptive co-management.

Holling (1978) envisioned adaptive management as experimental, variable, and designed to be responsive to changing conditions. Adaptive co-management combines regional and local participation with learning and experimentation in a local context, whereby participant organizations in management efforts may be responsible for different aspects of the projects. Goals of adaptive co-management include sustainable resource use and social-ecological resilience (Armitage *et al*. 2007; Plummer & Armitage 2007; Smedstad & Gosnell 2013). Participatory processes in river basin management lead to greater social learning (Pahl-Wostl 2007), and water users can make a governance regime more adaptive when collaborations are used (Armitage *et al*. 2007). Co-management contributes to capacity building among engaged communities and building resilience in social-ecological systems (Olsson *et al*. 2004; Mitchell *et al*. 2014). Resilience to shocks from natural disturbances, policy changes, and economic fluctuations comes from internal flexibility built into the process of adaptive management (Holling, 1978; Allen *et al*. 2011; Montgomery 2013. Despite extensive literature about collaborative governance, it is still unclear to what extent these co-management arrangements lead to positive outcomes in managing natural resources in these complex social-ecological systems.

Interactions among organizations that together govern the resources can be seen as a network, like a spiders web. Nodes in the web are actors in the system, and connecting strings are the communications between them. Social networks thus represent patterns of relationships among a finite set or sets of actors. Social networks can be examined empirically in terms of their structures, or design patterns, such as the position of actors or nodes in the network and properties of the ties among them. Network concepts and social network analysis have been applied to research in natural and water resource management scenarios in various contexts and different socio-economic settings for at least two decades (e.g.: King 2000; Crona & Bodin 2006; Stein *et al*. 2011; Basurto *et al*. 2013; Jasny & Lubell 2015; Alcañiz & Berardo 2016; Bissonnette *et al*. 2019). Network research typically consists of individual case studies, however. A paucity of comparable data sets continues to make direct comparison across multiple communities difficult (personal communications, Steven Scheinert; Lorien Jasny).

This study examines the communication network structures and perception of success of collaborations among actors in five Columbia River headwaters reservoir basins, with a focus on water quality and fisheries. Three central questions guide the investigations:

1. *Is there a dominant shape for water resource governance networks?*
2. *What qualities determine the position of an actor within a water resource governance network?*
3. *To what extent can internal dynamics of the water resource governance network be correlated with action outcomes in terms of changes in fisheries or water quality parameters?*

The five reservoirs in this study occupy a regional transect of the Columbia River Basin, with similarities in size, geographic placement, regional climate, and their impoundment by hydroelectric dams. The basins are, from west to east (Figure 1): Lake Chelan, Franklin D. Roosevelt Lake, Lake Pend, Lake Koocanusa, and čłq̓etkʷ (Flathead) Lake. A sixth basin in the same geographic transect is Lake Coeur d'Alene, the location of the pilot study that preceded this study. While all six basins are similar in many ways, the social histories, legal structures, and membership configurations of water resources governance are quite different. The setting thus provides a unique opportunity to compare the water resource governance networks in this cross-basin research.

Each basin faces management challenges for water quality as well as fisheries. Water quality issues include nutrient loading and mine drainage problems. Fisheries issues range from invasive species to anadromous fish passage for a return to traditional food web and ecosystem function. With a backdrop of federal and state regulations on water quality and fisheries management, and in many cases, mandates for collaborative co-management or specific lake management agreements, diverse independent actors in a water basin must communicate to collectively address the issues (Ostrom 2010).

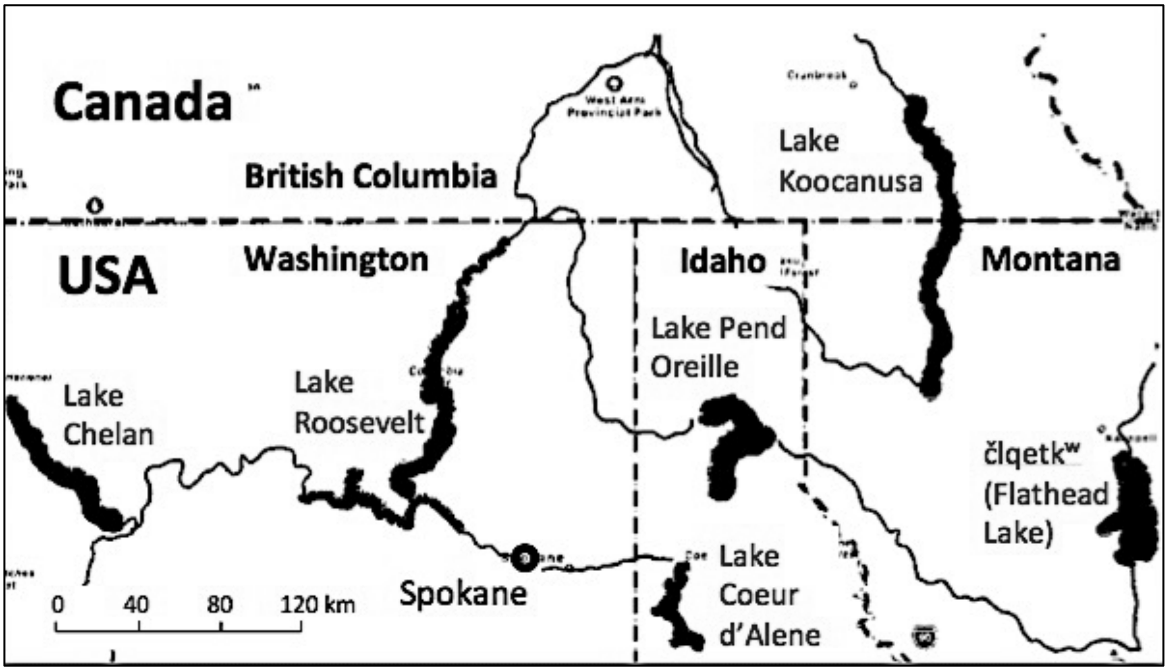


Figure 1.1. Locations of the reservoir basins in this study, from west to east: Lakes Chelan, Roosevelt, Pend Oreille, Koocanusa, and člqetk^{w} (Flathead). Lake Coeur d'Alene (bottom center) was the setting for the pilot study in this research.

In this chapter I present the methodology for developing and administering the survey that is the basis to this study, and the processing of data into network matrices for analysis. I begin with research development and scoping—in itself an exercise in network building—that aided in the survey design and distribution. I discuss, by survey sections, the questions in the surveys that were distributed to water resource practitioners in the five study basins, with supporting literature. Data output from surveys includes actors' perceptions of changes in fisheries and water quality measures, contact information to construct network matrices, perceptions of network dynamics and function, and the extent of public involvement in water governance in basins. I describe the process of cleaning and arranging data into usable network matrices, including handling missing data from non-responses. I finish by summarizing the data analysis methods used in chapters four and five.

1.2. Research development

This research was preceded by a pilot study in the St. Joe/ St. Maries River sub-basin of the Lake Coeur d'Alene basin [1.1]. Lake Coeur d'Alene basin is located in the same geographic transect as the current study basins (Figure 1, bottom center). As in the other basins, a hydroelectric dam controls the lake's levels; both water quality and fisheries are impacted by legacy heavy metals from a defunct smelting operation. The St. Joe/ St. Maries study (Trebitz & Shrestha, unpublished) was more general, in that it we sought only to identify the network of actors who are involved in water resources governance, without asking about disciplinary focus in fisheries or water quality management. The study additionally included an entire section on participation and experiences in forums, which is outside the research scope of the current project. However, elements of survey design, and—most critically—experiences gained from the St. Joe/St. Maries pilot, inform the research design of this much larger, five-basin study.

Initial scoping in this research was to determine the boundaries of the networks in each basin; that is, who interacts in the network for basin governance. Using network membership, rather than the basin's physical boundaries, allowed for the inclusion of actors who are important to the network, but whose offices may be located far from the target basin. I searched for organizations that were likely to play a role in the governance of each reservoir basin by using archived documents, such resource management documents, website searches, and published minutes from meetings (Wasserman & Faust 2009; Scheinert *et al*. 2015). Lubell & Lippert (2011) find this method to be effective, as very few actors in a basin network are not "at least listed as a planning partner for a project somewhere" in the various documents (p. 86). Personal outreach to a few key actors in each basin helped ascertain that my initial actor lists were complete, and also helped identify specific people in other basin organizations whom I should reach out to.

[1.1] Funded primarily by a USGS 104b grant for 2015-16, and A 2015 innovation grant from University of Idaho's College of Letters, Arts and Social Sciences, PI Manoj Shrestha. The student researcher was additionally supported by NSF award #1249400.

Outcomes from the St. Joe/St. Maries study resulted in two particular observations upon which the research questions of this five-basin study are built: First, I noted a core-periphery pattern in the basin's resource governance network—a structural network pattern, where a group of actors is densely connected in the network's center, but outer actors are connected to the central actors, but are only sparsely connected to each other. A literature review (chapter three) of case studies in water and natural resource governance networks confirms a prevalence of the core-periphery pattern, but also underscores that it is an under-recognized phenomenon (further examined in chapter four). Whether interactions and internal dynamics in these governance networks have measurable outcomes in terms of changes in lake health indicators, specifically in fisheries and water quality, is explored in chapter five.

Mark Lubell's (2014) California Delta Water Management Survey and the St. Joe/St. Maries pilot formed the basis to this survey's structure. Built on the Qualtrics™ platform (Qualtrics, Provo, Utah), the pilot study was designed for exploration of the three guiding research questions presented above. The survey questions themselves were further informed by, and refined with, active input from water governance practitioners throughout the upper Columbia River Basin, both in the U.S. and in Canada. Several informants generously test-drove the survey before its final version was activated. Next I present the context and content of the survey instrument, which can be found in its entirety in Appendix B, organized into five thematic sections:

(1) Information on the organization and the individual taking the survey
(2) Lake health indicators
(3) The network, or who interacts with whom
(4) Perceptions of network functions and success
(5) Whether or not, and how the public is engaged

1.2.1. Survey content

> *You are receiving this survey because you or your organization have been identified as participating in water resources management of the [XXX basin], in either fisheries or water quality management* (excerpt from consent page)

Background information on organization/actor

The background section captures organizational information of the respondent's organization, in terms of name, program or sub-unit, and office location (city and state). Of the respondent directly, the survey asks the job title and years of service in the organization. Early survey drafts included a question about the respondent's educational focus. Specifically, I was interested in how many were from a physical science major versus a social science education. During the scoping phase, however, several informants noted that their work did not necessarily accurately reflect their degree. Natural resource management, they generally agreed, is really more about managing people than managing the actual resources. One chuckled, and said:

> *[No] one told me when I got my degree in fisheries that I would have to deal with the public, but it has become an important part of my job.*

As a result, I modified the survey question to ask, on a 5-point scale, whether a respondent considered the work to be more in social sciences (e.g.: cultural anthropology, social psychology, political science, economics) or in physical sciences (biology, chemistry, geology, hydrology). Of seventy respondents who answered this question, less than half (31) stated that their work remained strictly in the physical sciences.

The last question in the background section asked about the respondent's work focus in terms of fisheries and water quality related activities. Respondents used a slider to indicate how their time was divided, with fisheries at zero, and water quality at one hundred. The balance was fairly even 52 percent worked more in water quality, and 48 percent in fisheries.

Perceived lake health indicators

This survey block targeted indicators of fishery and water quality health most commonly used by members of governance networks. Fishery and water quality issues vary between basins, thus the survey needed to allow for local variations. Inconsistencies often exist in measurements, quality control and reporting for ecological indicators data such as water quality measurement records (Sprague *et al*. 2017). Additionally, many citizen and non-agency groups face barriers to finding data in a basin because there are rarely directories to the "who, what, and where" of data storage and access (Trebitz 2017). Due to the variable access participants have to physical data, I chose to use individuals' perceived measures of lake health rather than real measurements.

Measuring ecosystem well-being in a social-ecological system has challenges to cut across cultures and disciplines. The *Mauri* Meter (see Morgan 2006; and Sterling *et al.* 2017) provides a metric to capture elements of those dynamics. Using *Mauri* Meter assessment, the scale of an ecosystem's health ranges from -2 (totally denigrated) to +2 (fully restored). This scale has an advantage by allowing for inclusivity and applying the same metric to measure all indicators, whether physical or perceived (Sterling *et al.* 2017). I adapted the *Mauri* Meter approach to measure ecosystem indicators on a five point Likert scale, pivoting around zero. Thus, common watershed indicators for the health of fisheries and water quality were operationalized on a perception scale of deteriorated, unchanged, or improved, in the past two years and ten years:

Fisheries indicators:

1. Available spawning and rearing habitat for resident fish
2. Available spawning and rearing habitat for anadromous fish
3. Availability of food for juvenile fish (e.g. macroinvertebrates)
4. Returning numbers of spawning anadromous adults
5. Success of fish passage and fish ladders
6. Available numbers of adult fish for fishing quotas

7. Increased average size or weight of adult fish caught
8. Success in preventing, controlling, or reducing invasive species
9. Success in stabilizing and/or restoring riparian zones
10. Improved ecological flows in river reaches and related lake levels
11. Did we miss an important one? Please fill in: ________________

Water quality indicators:

1. Meeting water quality mandates (e.g. TMDLs) in lake basin or tributary streams
2. Stabilizing lake levels
3. Keeping or lowering temperatures in lakes or streams
4. Lowering turbidity in lakes or streams
5. Lowering nutrient levels in lakes or streams
6. Success in controlling toxic algae blooms and dead zones
7. Reduction of toxic inflows (e.g. from mine seepage)
8. Did we miss an important one? Please fill in: ________________

Following the lake health indicator questions I asked three questions qualitative questions about available data. A weakness in information exchange in collaborative action is often in the lack of sufficient or suitable data, which is frequently also limited by funding difficulties (Genskow & Wood 2011). I first explored the perceived level of helpfulness of currently available scientific knowledge and data in understanding future impacts of water management decisions. There are many valuable ways of knowing, however, that do not necessarily produce data from formal scientific investigations. Therefore I asked respondents their opinions on how important it is to include local and traditional knowledge of the basin system into water management decisions. Incorporating other ways of knowing, into decision-making is an important aspect of scientific investigation and ecological and water resource planning that needs to be done intentionally respectfully (Moller *et al*. 2004; Tipa 2009; Polfus *et al*. 2014). On a five-point scale from never to always, I asked how frequently the respondent's organization considers local and/or traditional ecological knowledge in weighing management decisions.

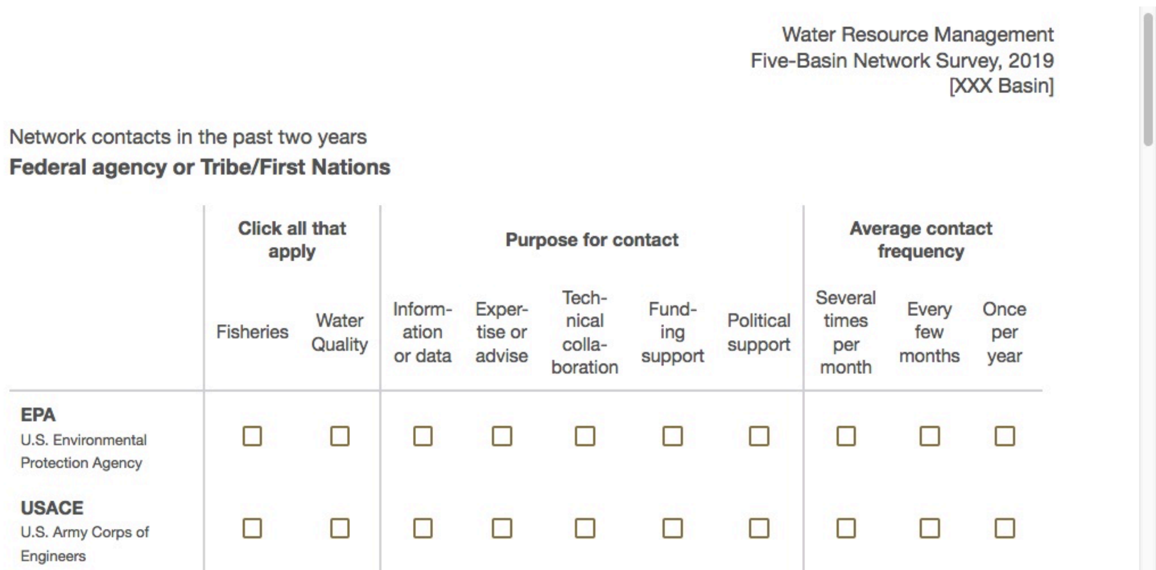
The networks

Social networks are patterns of relationships among a finite set or sets of actors, which can be presented graphically and can be evaluated empirically. Actors are social entities in a given network, which can be discrete individuals, or collections of social units, such as corporations, agencies, and governmental or non-governmental organizations. Actors are represented as nodes or points in a graph. Relational ties link pairs of nodes that are related in a specified way (Wasserman and Faust 2009). Ties can be mutual or non-directed (both A and B are friends), or ties can be directed (A calls B a friend, but B does not consider A a friend). Networks can be analyzed at the actor level (e.g., actor's individual or ego network size and its features) or at the global, or whole network level (e.g., size and distribution of actors in a network). In this study, actor contacts are directed, and weighted by frequency of interactions. Information about contacts, frequency, and purpose is provided through the survey responses.

For the network section of the survey I was interested in the communications among actors in the basin, specifically in the governance of fisheries and/or water qualities issues. I developed a hierarchy of actor levels: federal agencies; U.S. Tribes/Canadian First nations; state or provincial agencies; regional government or agencies; educational institutions, industry, irrigation and utilities, non-government organizations, and outfitters. Within these actor levels I identified 59 unique actor types. For each basin I created a list, based on information gained in initial scoping and outreach, of all actors groups likely to be active in the basin (Actor list table, Appendix C).

These possible actors were presented to respondents in tables organized by overall actor level or type: Federal and Tribes/First Nations; U.S. State or B.C. Provincial level; Special Districts, Local Government offices and Research Institutes; Industry and Non-Government Organizations. The number of organizations, corresponding to the original actor-types in the list, varied by basin: 39 organizations in Pend Oreille, 39 in Koocanusa, 34 in Flathead, 41 in Roosevelt, and 37 in Chelan, a total of 190 real organizations that were potential actors. Figure 2 is an excerpt from the survey master. The specific basin name replaces "[XXX Basin]" in the individual surveys, and the actor list is tailored to the basin.

Respondents were asked to indicate which other organizations they interacted with in the past two years [1.2]. They were instructed to skip actors with whom they had no contact. Respondents could choose ‘fisheries’, ‘water quality’, or both, and any combination boxes in the ‘purpose for contact’: information or data; expertise or advice; technical collaboration; funding support; political support. Respondents also indicated a frequency of contact, several times a month, every few months, or just once a year.



Water Resource Management
Five-Basin Network Survey, 2019
[XXX Basin]

Network contacts in the past two years
Federal agency or Tribe/First Nations

	Click all that apply		Purpose for contact					Average contact frequency		
	Fisheries	Water Quality	Inform-ation or data	Exper-tise or advise	Tech-nical colla-boration	Fund-ing support	Political support	Several times per month	Every few months	Once per year
EPA U.S. Environmental Protection Agency	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
USACE U.S. Army Corps of Engineers	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Figure 1.2. Excerpt of network section: actor list for federal and tribal organizations.

[1.2] I chose a table presentation over a free recall method as a result of early experiments in the pilot study. In the St. Joe/St. Maries study (Trebitz & Shrestha, unpublished), respondents only named a few actors when they were asked to recall their contacts. The actor identification nearly tripled when respondents were given presented with actor list tables.

> ***Perceived network function***
>
> *Successful collective action groups often exhibit particular strengths in their interactions. In contrast, progress in collaborative management can be hampered by both the regulatory framework in which you must operate, and frictions that arise among management participants. Please help us understand the factors in collaborations among the network members you identified in the [XXX basin]* (Excerpt from survey master)

As an alternative to an exclusive reliance on quantitative methods, analysts of watershed governance frequently use perceived success as a proxy for measuring the outcomes of collaborations (Dakins *et al*. 2005; Chaffin *et al*. 2011; Squires 2014). The network process section of the survey used Likert scale questions to assess how effective individual respondents felt their particular governance networks were in meeting goals around enhancing water quality and fisheries health. After some questions about the respondent's organizational culture and position in the network, the survey moved to elements of group process. While all of the questions are listed in Table 1.1, a few specific measurements are discussed here.

Respondents were asked how they felt about the group's level of collaboration, as "adaptive management without collaboration lacks legitimacy" (Berkes 2009, p. 1698). Since planning is also a political process, collaborative groups must be inclusive, exploring value and position differences of demographics, scales, and a wide range of knowledge bases (Smedstad & Gosnell 2013; Blackstock *et al*. 2012). Working in an inclusive setting improves the chances of settling on common goals and employing common strategies towards management needs. As a notable addition to the process questions, several respected water resource managers who were contacted in the scoping phase of this research stated that their ultimate measure of cohesion is whether groups are able to first identify issues, and subsequently, to implement action. Two questions explored more personal opinions about basin collaborations, in that they invited a text-entry answer describing: A) barriers to collaborations, and, B) what conditions would encourage the respondent to collaborate more.

Table 1.1. Dimensions of social network interactions used in survey questions

Social factors for lake basins, organizations, networks, and the public*; Likert scales vary*		Scale
Organization; culture, mandates, and influence (O)		
O-1	Extent to which participation is voluntary (0) vs. mandatory (100)	0-100
O-2	Level of influence in management outcomes	11-pt.
O-3	Extent to which organization includes TEK/LEK in weighing management decisions	5-pt.
Authority or influence of network in lake basin governance (A)		
A-1	Level of authority of network to produce binding decisions	11-pt.
A-2	Network input non-binding, but valuable in assisting management efforts	11-pt.
Group dynamics of network towards collaboration (G)		
G-1	Level of collaboration	11-pt.
G-2	Effectiveness in identifying issues (2-year and 10-year)	11-pt.
G-3	Effectiveness in implementing planned actions (2-year and 10-year)	11-pt.
G-4	Inclusiveness in process of coming to policy decisions	11-pt.
G-5	Extent of shared common goals	11-pt.
G-6	Extent of shared common strategies or approaches	11-pt.
G-7	Barriers to collaboration	(text)
G-8	Factors that enhance collaboration	(text)
Public participation (P)		
P-1	Extent to which the public is encouraged to participate	11-pt.
P-2	Adequacy of public participation (e.g. forums, meetings, on-ground efforts)	11-pt.
P-3	Public forum: name one (or more) in the basin	(text)
P-4	Public forum: personally (0) did not attend, (1) attended only, (2) presented at	3-pt.

Perception of public engagement

From the St. Joe/St. Maries study we learned that while public participation is welcome, the public is continually underrepresented in water resource governance (Trebitz & Shrestha, unpublished). As this study is at an organizational level, the public can be represented through non-government organizations, but not at an individual level. Nevertheless, many of the actor organizations—on the entire scale from federal agencies to local groups—appear to make efforts to connect with the interested citizens. The last four survey questions (Table 1, bottom) ascertain the level of perceived public involvement, and which forums are available to the public in each basin.

Survey distribution

Distributing surveys presented a unique challenge in not just contacting each potential actor-organization in the network, but also in finding the appropriate person in each organization to fill the survey. Finding an actual survey respondent sometimes involved considerable efforts, via phone calls or referrals through a string of other people. Before each contact attempt I researched the organization, its mission and function, and determined—if possible—who might be the right person to approach with my survey.

I reached out to each actor in each basin using a mixed-mode approach (Vaske 2011) of email, phone, in person contacts, and via public forums. I developed an email template, which was adjusted to each situation, basin, and recipient organization. For Indigenous groups (U.S. Tribes/Canadian First Nations) I additionally acknowledged that the project might need approval by a tribal council, and asked about the tribe's protocols. If organizations requested to see the survey, I sent a pdf copy of the master survey (Appendix B). In all cases I offered to provide a frequently asked questions (FAQ) document (Appendix D).

Organizations themselves designated the person best qualified to fill the survey. In many cases the decision of who was best-suited involved many more emails—on which I was generally cc'd—and not infrequently, an in-person phone conversation initiated by the respondent. For each actor who agreed to fill the survey, I created an individual link to the online survey tool. During the pilot study we had found that mailings from the internal Qualtrics™ system are often routed to the junk folders, especially in government agency email systems. Rather, I sent all survey links with a personalized email note of thanks, and to please contact me with any issues [1.3]. Reminder emails were only sent if surveys were unopened for two weeks.

[1.3] The survey platform did have an issue, which the Qualtrics support team could not resolve: Once a box was marked for a particular indicator or actor in the lake health indicators tables and the actor tables, it could be changed but not removed. The few respondents who had trouble with this feature communicated with me directly. In the data cleaning process I adjusted responses on particular lines as per their instructions.

The individual outreach strategy resulted in personal referrals and introductions that facilitated further connections. Some respondents further identified a few actors that were not included in the original list, adding to it in a form of snowball sampling (Schneider *et al*. 2003). I also received invitations to attend information forums, to present my research in public meetings, and to tour dams and reservoir basins with local experts.

I concentrated on outreach by basin, and one basin after the other, rather than all simultaneously. Each survey link was activated for 30 days. While some respondents filled the survey immediately, there was often considerable lag time between initial contact and final completion of a survey. In some cases it was necessary to generate fresh links after the initial ones had expired. Survey responses thus date from 8-April to 19-November 2020, with the majority of responses being collected from May through August.

Response rates

Reporting response rates is considered best practice in research, but the American Association for Public Opinion Research (AAPOR)(n.d.) web report notes that the relationships between response rates and survey quality remain unclear. While AAPOR provides several response rate calculators, a consistent approach is still elusive in research literature. Difficulties arise both in defining the sample population as well as in defining what constitutes a response. Kelley *et al*. (2003) and Raugalis *et al*. (2008) stress the importance of careful description of a study's response statistics and transparency in reporting.

The 190 potential actors across the five basins were just that: potential actors. Of the actors identified in the scoping process, some could neither be reached in the survey outreach phase, nor were identified by survey respondents. In the social network analysis portion of the study they appear as "isolates", or actors who have no contacts with others in the basin. Without 100 percent response, it cannot be known if the knowledge of the universe is imperfect, so there will always be some error. Retaining these unknowable actors in the potential actor count depresses reported response rates. By this reasoning, however, the response rates are simply calculated as: the number of respondents (n), divided by the number of potential actors (N) in the basins times 100.

Response rates in this study varied by basin, with eight to eighteen respondents per basin filling the survey. Additionally, several potential actors in each basin asserted that they were not active in the network conversations, even though some of them received in-coming contacts from others in the network. While these actors did not fill the surveys, they are not considered non-respondents (unknown; contact = NA). Since network analyses are sensitive to missing data, the NA contact data were reconstructed or imputed as described later in the network processing section. Table 1.2 shows the response rates, by surveys filled and in-active status, as well as reconstructed and imputed contacts. Response rates in this study are comparable to results in other water governance studies conducted in the U.S. and Canada (see Schneider *et al*. 2003; Lubell & Lippert 2011; Vance-Borland & Holley 2011; Scheinert *et al*. 2015; Horning *et al*. 2017; Lubell *et al*. 2020).

Table 1.2. Response rates and treatments for non-responses

	Network size	**Surveys filled**		**Stated "not active"**		**Responses overall (surveys + "not active")**		**Reconstructed**		**Imputed**	
Basin	N =	n =	(%)	n =	(%)	n =	(%)	n =	(%)	n =	(%)
Pend Oreille	39	17	43.6	3	7.7	20	51.3	10	25.6	9	23.1
Koocanusa	39	16	41.0	3	7.7	19	48.7	10	25.6	10	25.6
Flathead	34	18	52.9	3	8.8	21	61.8	8	23.5	5	14.7
Roosevelt	41	16	39.0	3	7.3	19	46.3	12	29.3	10	24.4
Chelan	37	8	21.6	6	16.2	14	37.8	11	29.7	12	32.4
All basins:	**190**	75	**39.6**	18	**9.5**	93	**49.2**	51	**26.7**	46	**24.0**

Not all respondents filled all survey parts, but for different reasons. Some of the more peripheral actors in the systems felt that much of the survey did not pertain to them or their organization (personal communications). Through personal communications, most of these individuals agreed to fill at least the background and network sections. One respondent informed me that they had just finally come to a signed agreement, after over five years of negotiation. This individual requested that only the network contacts be used, and that the remaining answers be redacted. Such partial responses are very important to the social network portion study, though they unfortunately limit data for other analyses.

1.2. Processing network data

Survey data from the Qualtrics platform were downloaded in csv files, one for each basin. I used randomly generated identification number to actors to replace the respondents' names. I separated the Likert responses for the background (lake health, network function, and public engagement sections) from the network identification sections in each basin, and recombined qualitative responses from all basins into a single comprehensive dataset, used for background information and the analyses in chapter five. Basin networks responses were organized into matrices for the social network analyses.

1.3.1. Constructing networks

For each basin I constructed a directional communication matrix, using frequency measures from survey responses: (0) no contact, (1) once per year, (2) every few months, or (3) several times per month. In an identical actor list matrix I entered governance focus areas, (1) for fisheries, (2) for water quality, and (1,2) for both. A third actor matrix contains responses for the five possible purposes for the contact: (1) information/data, (2) expertise/advice, (3) technical collaboration, (4) funding support, (5) political support, or any combination of those purposes. In each matrix, no contact (0) was entered for actors who stated they had no active communications, as opposed to "NA" (non-response). Unknown actors, refusals to participate, and actors who never opened, never filled, or abandoned the surveys were marked "NA" in the initial network matrices.

1.3.2. Treatment of missing data

Non-responses are problematic in social network analyses, as missing data has effects on network density, clustering, and other network properties (Wasserman & Faust 2009; Žnidaršič *et al*. 2012). Vance-Borland & Holley (2011) find that while the 47 survey respondents constitute only 17 percent of 344 named participants in a conservation network, named non-respondents make up 60 percent of the networks' core membership, which suggests that the data Data may still give a good likeness of the whole network despite missing information. In early experiments with data from the current 5-basin study, I observed that after plotting the first eight responses, the overall network configuration and structural importance of actors (on in-degree) in the networks did not appreciably change with the addition of more respondents.

In recent study, however, Žnidaršič *et al*. 2017 find that different approaches to treating missing ties in valued network data differ significantly in the reliability of analytic outcomes. On the recommendations of Žnidaršič and her co-author Patrick Doreian (personal communications), I reconstructed missing contacts, where possible, from archival data collected during the scoping and survey distribution phases[1.4]. I imputed remaining missing contacts using the median of 3-nearest neighbors based on the smallest calculated (Euclidian) distance of incoming ties to the actors; this method was found far superior to other methods in reliably imputing missing ties for up to fifty percent non-response (see Žnidaršič *et al*. 2017). In the current research imputed non-responses constitute 14 to 32 percent of the whole network (Table 2, right panel).

[1.4] This method of reconstruction is further supported by experimentation with the pilot study data: In a network constructed for information exchange (focused on data), using only archival information and Internet hyperlinks, the total, or "Freeman degree" centralization on actors nevertheless correlated to 0.69 (Kendall's tau) with Freeman degree centralizations on the more generalized water governance network that was produced using only survey data from St. Joe/ St. Maries study (unpublished).

1.3.3. Actor types networks

The complete basin networks were established using the actual actor name in each basin. The investigations of chapter four, however, require that the network lists are identical. Thus next procedural step was to match each actor in each basin to one of 59 corresponding actor types identified during the survey development. As an example, the basin's state department of environmental quality would be coded "S-DEQ"; if a neighboring state's department of environmental quality was also engaged, it was coded "S_o_DEQ". I coded the individual, sovereign indigenous tribes as separate entities: (e.g.) "T1", "T2", "T3"… etc., the order of importance being deduced in the scoping process. Universities and colleges, however, I considered as a general actor type, an "educational institution". Non-government organizations were separated by focus area, but each retained as a unique entity: lake, river, fish (specifically Trout Unlimited), sports anglers, bird, land, and other conservation non-profits. I combined the data of a few actors to fit these actor-type coding rules. For example, there are two research institutes that contribute to the Flathead basin's networking, Flathead Lake Biological Station, and Whitefish Lake Institute [1.5]. While the first was in the original basin network list, the second was added by respondent nomination. These two are folded together as the "research institute" actor type. A few such manipulations account for the slightly different network sizes reported used in chapter four: 38 actor type organizations in Pend Oreille, 35 in Koocanusa, 32 in Flathead, 39 in Roosevelt, and 35 in Chelan.

In this study all but one of the basins are entirely in one state. Koocanusa, however, straddles an international border, with just over half the lake in Montana, and the other half in British Columbia. Unintentional bias could be introduced by constructing the actor type network only from the U.S. view. To create a counterpoint, I modeled the Koocanusa networks a second time, using a Canadian-centric view. In the federal Canadian agencies and B.C. provincial agencies and organizations are listed first in the Canadian perspective of the actor type network. As an example, in the U.S., or Montana-centric view, the U.S. Environmental Protection Agency would fill "F_Env" and Montana Department of Environmental Quality

[1.5] Whitefish Lake drains into the Whitefish River, a tributary to the Flathead River just before its inflow to Flathead Lake. Thus the Whitefish Lake Institute is also an actor in the Flathead basin governance network.

fills "S_DEQ"; Environment Canada would be coded as the "F_o_Env" (other), and the B.C. Ministry of the Environment fills "S_o_DEQ". For the Canadian/provincial perspective, these positions are reversed. This approach is also tested in chapter four's investigations.

Once the actor-type networks were established across all five basins—six networks, including the second perspective of Koocanusa—the matrices could be filtered to the disciplinary focus level. I separated each network into a fisheries focus and a water quality focus.

I applied quality control procedures to every step of data processing. Quality control during data processing involved randomly checking entries on each working sheet of data against the original raw data as it had been downloaded from the Qualtrics platform. To check for response validity I compared individual survey responses with information contained in archived planning documents, emails communications, and notes from phone and in-person interactions. This cross-validation revealed that for the most part, respondents took exceptional care to accurately depict their basin's circumstances. Respondent accuracy was confirmed also by personal feedback from several respondents in emails letting me know they had completed the survey, and what they thought of the survey.

1.4. Data Analyses

Analysis approaches differed depending on whether responses were for the governance network itself, or for lake health indicators and measures of network dynamics. The cleaned and processed data were used for data analysis in chapters four and five. I worked entirely in the Microsoft Excel for basic data cleaning and standard (Pearson's) correlation. Here I describe analytical tools used for analyses of network data.

I used two social network analysis platforms, with which all of the analytical calculations and model visualizations can be completed. UCINET (Borgatti *et al*. 2002) with the associated visualization tool, Netdraw (Borgatti 2002), together form a relatively user-friendly (and free) platform combination commonly used in social network analyses and literature. The open access platform R is a currently dominant analytic tool (Rexer *et al*. 2015), with the "sna", "statnet", and "igraph" packages, which are versatile in general network analytic techniques, easily extensible, and well-integrated with visualization tools (Butts 2008).

In chapter two I present a qualitative description of each reservoir basin, where I am interested in visualizing the entire network in each basin, before sorting actors into their corresponding actor types. This "first cut" provides a good comparative view of the five basins' networks. For chapter three, however, I begin by visualizing the actor-type networks, for water resource governance in general, and also filtered to the focus-specific groups of fisheries and water quality governance.

After visualizing the networks and recording basic descriptions, I ask to what extent are the actor type networks similar, or different, based on the actor type. I apply quadratic assignment procedure (QAP) to determine the correlations between any two networks, a method not uncommon in comparing governance networks (Scheinert *et al*. 2015). I determine statistical significance using 1,000 permutations of the correlation procedure (Butts 2008).

Central to chapter four is the premise that, how central actors are in the network depends on what they do for, or provide to, other actors (i.e. roles), rather than who they are (actor type). I thus construct matrices of basin actors by a suite of 13 possible roles, sorted into resource, formal, and informal categories. After testing for multi-collinearity, I use Poisson regression in R to determine to which extent an actor's centrality on in-degree is dependent on the three role categories. The central question in chapter five is whether the perceived network interaction dynamics have measurable outcomes in the lake health indicators. For this analysis I make use of Pearson's correlations to compare the variables pairwise.

1.5. Navigating the complexity in network surveys and in collecting network data

Study outcomes suggest that some dimensions of these research methods merit further discussion. The first is a process issue within the survey tool itself. Another expands on the highly variable group of non-respondents. I conclude with some observations on the personal outreach for scoping and response solicitation.

The initial intent of this study was to ask separately about a fisheries-focused network, and a water quality-focused network in each basin. It soon became evident that this approach was too complicated. While some organizations are mission-focused (e.g. department of fish and wildlife; Trout Unlimited; department of environmental quality), or have specialized positions in fisheries or water quality, many actor organizations are generalists with one or more employees working on all issues. Separating surveys into one disciplinary track or the other would require finding two different respondents in each organization with specialized positions. In other organizations, one respondent would have to fill two parallel surveys. As a compromise solution, I built a slider to gage how respondents' time was divided between fisheries management and water quality management activities [1.6].

This issue of separating fisheries and water quality activities continued into the network identification section, where I asked respondents to mark whether they contact another actor for fisheries issues, water quality issues, or both. Respondents were remarkably thorough in marking their relations to actors with which they associated. Respondents also appreciated that they were to simply skip actors with whom they had no contact (various personal communications). The actor-list tables worked very well in terms of survey efficiency and completeness of responses, but they created some ambiguity in the evaluation phase. If a respondent marked both fisheries and water quality, it was not possible to assign purpose and frequency differently to the two focus areas. For example, an organization might collaborate regularly with a particular actor on a water quality improvement project, while receiving

[1.6] Survey responses revealed that time was relatively evenly distributed between the focus areas: 52 percent in water quality, and 48 percent in fisheries

fisheries data from the same actor organization only once in a year. The binary actor matrix (contact = 1, no contact = 0) on the entire network was not sensitive to these ambiguities. The inability to completely separate focus, purpose, and frequency, however, reduces the accuracy of the weighted matrices, as well as the accuracy in evaluating networks that were filtered to a fisheries or water quality focus.

A further complexity emerged in that some actors appear in multiple basins. When different individuals from the same organization were responsible for communications in different basins, it was possible to ask each to fill the survey in that particular capacity. But a few individuals were the designated contact person responsible for more than one basin, which I discovered during phone conversations with them. In these specific instances we agreed that they would fill one survey for the basin in which they had the highest involvement. Certain contacts in the network section could be extrapolated to the other basins' networks, but the lake health indicators and network function sections of the surveys could not. These individuals are marked as respondents in one basin, but are included only as reconstructed ties of the response statistics for the other relevant basins.

Reported response rates are important for validation in terms of research bias, but the more interesting questions might be about the non-respondents. Some potential actors identified in the scoping process may actually not be part of the governance network; these remained unknowable if they were not marked as contacts by respondents and additionally did not respond to my requests to communicate. Some said they were inactive in the network, even though others identified them as communications partners—in some cases they were even statistically central in the network. Some would not engage in my attempts to communicate, some refused to participate, and some expressed willingness, but never opened the survey.

In some cases the reasons for non-responses can be deduced. The U.S. Army Corps of Engineers (USACE), for example, is an active member of the Pend Oreille and Koocanusa basins because it owns and operates the dams. In the Flathead basin, however, it is only involved in engineering issues relative to flood control (USACE, personal communications).

While the basin network considers the USACE an integral part of the network, there is no reason for this organization to reach out in times when there is no imminent flood risk. The U.S. Environmental Protection Agency (USEPA) may similarly be a passive member in some governance networks. Certain water quality, biological, and physical measurements are reported into the USEPA's storage and retrieval data warehouse (known as STORET), and agencies as well as citizens can freely download these data. The USEPA is an active member of four basin networks in this study because of specific water quality/ toxins issues. In Chelan, however, there are no water quality issues currently being addressed, so the USEPA's presence in the network is non-active.

The reasons for other refusals were less clear, however. One federal agency took issue, in an email, with the measurement scale on the lake health indicators:

> *I looked at the survey and am going to decline to participate. I don't think we have time to put together defensible answers to several of the questions about status of species and status of habitat without investing a lot of time. As an agency directly involved in these issues we have to be consistent in our positions and the responses are to narrow with 3 choices; dramatic decline, no change and dramatic increase.*

In a follow-up email I acknowledged this concern, and asked if the organization could at least fill the network lists, but there was no further response.

In the pilot study, not a single local or regional politician filled the survey. In this study, two county commissioners agreed to fill the survey, but only one actually did. One state legislator spoke with me at length on the phone, but never opened the survey. Nevertheless, city council members and/or county commissioners are nominated as contacts in the basin networks. I could not ascertain why these individuals were reticent to participate.

Tribes also each act as sovereigns, each with their own rules. Most of the tribes in this study were happy to participate; only one required me to submit the FAQ and survey master for tribal approval. One tribe, however, ignored multiple contact attempts through different channels, and finally sent an email turning me down with no stated reason.

One might think that certain reactions were from an organizations' institutional culture, but I found this to be not at all true. For example, Teck Metals, Ltd., in Spokane refused out of hand to respond in the Lake Roosevelt survey, while its sister company, Teck Coal, Ltd., in Vancouver B.C. filled the survey for Koocanusa. Teck is embroiled in legal actions about pollutants in both basins, so I was not surprised by the refusal.

From my observations, the willingness to participate is expressed via regional or local offices, or even in a particular person in an organization, whom we might call a rock star actor, or policy entrepreneur—I investigate this idea more deeply in chapter four. A good example is the USACE, whose regional office is in Seattle. The person to whom I emailed my first inquiry sent an enthusiastic reply, which was cc'd to the particular individuals in each lake basins who could help me with information and respond to the surveys. In the Koocanusa basin, the USACE actively partners with state fisheries and water quality agencies, and also hosts an annual public forum, to which I was immediately invited. The USEPA's responses were slightly different. In Montana (Koocanusa and Flathead basins), the survey had to be vetted first by agency's regional press office. In Idaho I sent the initial request to a person who was in my personal network from the pilot study and other professional interactions; he forwarded it to the appropriate person in the Boise office where the survey was filled without questions. In the Lake Roosevelt basin (Washington), the survey was assigned to an intern, who called me several times for clarifications, and later to ask that I adjust a few responses in the data processing phase.

One of the most critical lessons learned from both this research and the St. Joe/St. Maries pilot was the extent of personal network building that was needed throughout the study. This networking facilitated many interactions with personal introductions, or at the very least, as recommendation of whom to call. I researched each actor organization first, and entered each conversation with prepared notes or questions. My education background in biology and aquatic ecology allowed me to connect quickly with the many physical scientists to whom I spoke. Doing "my homework" resulted in some unexpected survey results. An email from one potential respondent said:

> *You must have googled me! Ha! Yes, I am trained as a lawyer but I work in a different capacity on this file and yes, I am directly involved in "those conversations". Thank you for your interest in our work. Time is an in demand commodity these days as you can imagine! Please do send along your questionnaire.*

Getting this survey filled required three more follow-ups, but it was eventually submitted.

I conclude with some feedback that I received about the survey. Respondents found the survey mostly logical and easy to navigate, and one even said he had enjoyed taking it. Another asked whether the network approach could be applied also to forestry practices in wildfire risk abatement. A few expressed a wish for a narrower focus, such as a sub-basin, small tributary, or individual restoration project in their greater basin. A tribal member asked why I had not included cultural uses in the lake health indicators. A director of a non-profit who had just recently begun in his position asked if I could provide contact information to help him rebuild the organization's basin network. I sent him a handful of links to important organizations in the basin, as well as some contact names—but not until he had completed the survey. All of these comments speak to the need for communications in resource governance networks, and to the broader applicability of such studies in social-ecological systems.

While much information about the study basins is available through archived documents, respondents themselves provided invaluable linkages and context during the scoping process, in the process of soliciting respondents, and in the surveys themselves. Rissman & Gillan (2016) suggest the use of methodological pluralism with a mixed-methods approach to social science research, where quantitative and qualitative data are collected concurrently, analyzed, and ultimately integrated for more complete findings than the individual methods can provide by themselves (Onwuegbuzie & Collins, 2007). Based on literature, and the experiences both in the pilot and in this much larger study, I include notes from the more than 30 scoping meetings, and from many informative emails, to supplement and enrich discussions of survey results through contextual interpretation (Creswell & Piano Clark 2017). The insights of my informants give shape to the place-based, human dimensions of this dissertation.

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Chapter 2: Description of the basins

2.1. Introduction

> *But, in fact, this is a river subdivided into separate spaces whose users speak to each other in a babel of discourses: law, religion, nature talk, economics, science, and more. The experts and regulators empowered to solve the river's problems only bare our divisions.* (White 1995, p. 113)

In his 1995 book, *The Organic Machine*, Richard White describes the division of the Columbia River into many little pieces, with each segment, or reach, serving many purposes in society's desire to harness and control its powers. On the industrial scale, the river's resources are needed for navigation, hydroelectric power production, resource extraction (manufacture, mining, smelting), irrigation, and flood control. Community needs include drinking water, municipal and household-level uses, recreational uses, fishing (both recreational and for subsistence), and other cultural uses, especially for tribes. Ecological health and ecosystem function are needed to bind the system together from source to sea.

In this study I examine the networks of diverse actors that have evolved to govern the water resources for the fisheries and water quality management of five basins in the Columbia River headwaters along the northern U.S. border. On a map, each of these basins is called a lake: Lake Chelan, Lake Roosevelt, Lake Pend Oreille, Lake Koocanusa, and člq̓etkʷ (Flathead) Lake. But, a hydroelectric dam impounds each of these water bodies. Furthermore, different water users also have differing definitions of the basins *"You must understand that these are not lakes,"* a tribal member stressed to me in a conversation, *"[t]hese are reservoirs*."

Introducing the dams before all else also introduces a critical friction point in the management of these complex water resource systems individually, and for the Columbia River Basin in general. Flathead, Pend Oreille, and Chelan were natural lake basins before the construction of the dams that raised their surface levels, controlled the flows, and harnessed the water for hydroelectric power. The impoundments on Roosevelt and Koocanusa, however, backed up free-flowing rivers, inundated lands and river reaches that Indigenous peoples depended upon for sustenance, and prevented all upstream migration for anadromous fishes such as the iconic salmon. In fact, dams throughout the Columbia River system permanently block more than 55 percent of spawning and rearing habitat once available to salmon and steelhead (Northwest Power and Conservation Council n.d.).

In this chapter, I describe the five reservoir basins and their governance networks. While dam operations affect water quality, fish survival, and other parameters in the social-ecological system, they are not alone responsible for the fisheries and water quality management challenges in the basins. Despite similarities of the study basins in a general overview, every basin has its own unique shape in terms of geography, history, resource use, culture, and circumstances. I begin with a brief comparison of the basins in terms of geographical locations and power production statistics. I then present a brief overview of each basin, in terms of geography and local historical context. I sketch the network interactions for water resource governance using information from the surveys (see methods, chapter one) and the many personal communications I received in the scoping process and in soliciting survey responses. I close with some general respondent observations that were common across all five basins.

2.2. Settings

The reservoirs basins in this study are, from west to east, (Figure 1): Lake Chelan with the public utility district's Chelan Dam on the east slope of the Cascade Mountains in Washington; Franklin D. Roosevelt Lake, impounded by Grand Coulee dam in Washington; Albeni Falls Dam and Lake Pend Oreille in the Kootenai Mountains of the Panhandle region of Idaho; Lake Koocanusa, which lies in both Montana and Canada's British Columbia (BC) and was created by Libby Dam under the Columbia River Treaty; and northern Montana's čłq̓etkʷ (Flathead) Lake, which is enhanced by Seli'š Ksanka Qlispe' (formerly Kerr) Dam.

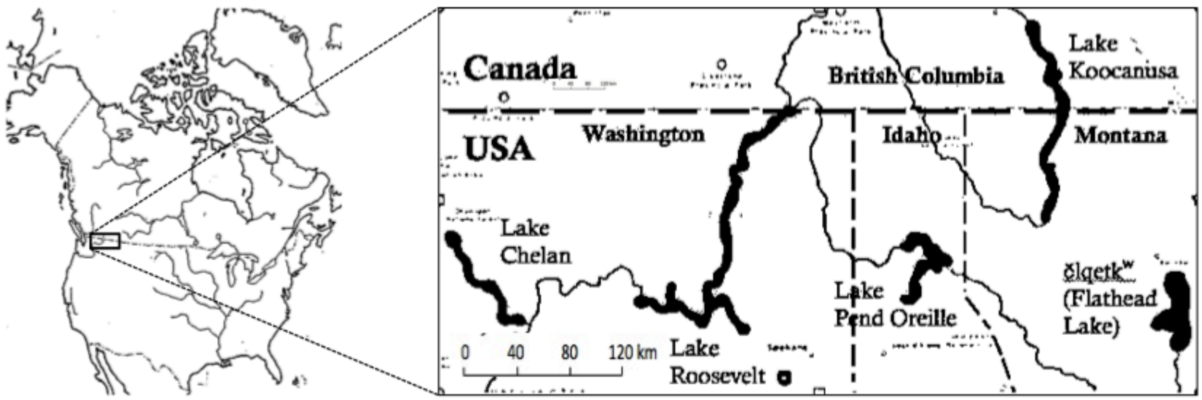

Figure 2.1. Locations of the five reservoirs in the study area, from west to east: Lakes Chelan and Roosevelt in Washington, Pend Oreille in Idaho, Koocanusa in Montana and British Columbia, and člqetkʷ (Flathead) in Montana.

While all five basins are part of the Columbia River system, only Lake Roosevelt is directly on the mainstem. The Chelan River, which drains Lake Chelan, meets the mainstem Columbia River below Lake Roosevelt. The other four basins are intertwined in complex geographic interrelations of the Columbia's major tributaries, both in the U.S. and in Canada.

Flathead Lake's drainage is mostly in Montana, but some of the remote headwaters streams are in British Columbia. Flathead Lake and the Flathead River feed the Clark Fork River in Montana, which eventually runs into Lake Pend Oreille in Idaho. Flathead Lake is itself impacted by management of the U.S. Bureau of Reclamation's (USBR) Hungry Horse Dam, whose flows take approximately two weeks to reach Lake Pend Oreille. Lake Pend Oreille receives about 90 percent of its water from Montana watersheds via the Clark Fork River. Fifty-three percent of upstream flow comes from the Flathead drainage, 15 percent comes all the way from Hungry Horse (USBR, personal communications). From Lake Pend Oreille, the Pend Oreille River winds its way north through Washington and into Canada, where it is called Pendoray. It continues over Waneta Dam to merge with the mainstem Columbia River only a few miles upriver of the US-Canada border and Lake Roosevelt.

The Kootenay River begins on the northeast side of British Columbia's Beaverfoot Mountains. As they flow south through British Columbia, the headwaters of the Kootenay River pass within two kilometers of the source springs of the mainstem Columbia River. The Kootenay River runs south to the U.S., crossing over the international border into Montana roughly at the center of Lake Koocanusa. After flowing over Koocanusa's Libby Dam, the Kootenai River (note the spelling change) turns north again through Idaho, and back into Canada, feeding Kootenay Lake before the Kootenay River joins the mainstem Columbia River at Castlegar, B.C. through Corra Lin dam and a series of diked canals.

The mainstem of the Columbia River runs undammed for 56 km (35 mi.), from Castlegar to the U.S. border, before it enters Lake Roosevelt just downstream of the Northport, Washington. After Lake Roosevelt's Grand Coulee Dam, the Columbia River spills over a series of federal and private run-of-river dams on its remaining 1,050-km (800 mi.) journey to the ocean. Lake Chelan feeds the Chelan River, which meets the mainstem of the Columbia River from the west, far downriver from Lake Roosevelt.

The dams on these five reservoirs vary in ownership and stewardship, including the US Army Corps of Engineers (USACE), USBR, municipal (e.g. Chelan County Public Utility District) and the Confederated Salish and Kootenai Tribe (CSKT). Primary purposes and operations of the dams include power production privatized utility, irrigation, and flood control. Secondary purposes are recreation and ecological services. Table 1 is a summary of the reservoir sizes and power production. All dams in the U.S. are subject to Federal Energy Regulatory Commission (FERC) licensing. In the Columbia River basin, dam releases and power production are largely coordinated by the Bonneville Power Administration (BPA), a self-funded entity within the U.S. Department of Energy that markets the hydropower from the federal facilities on the U.S. side of the basin (Congressional Resource Service 2019). In British Columbia most hydroelectric power is controlled by BC Hydro or the Columbia Power Corporation, which are both Crown Corporations under the B.C. Ministry of Mines.

Table 2.1. Reservoir/dam operations values in surface area, volume, and power production

	Year dam completed/ opened	Operator	Installed power production (megawatts)	Power production annual (kw-hrs)	Surface area (mi^2)	Volume/ active capacity (MAF)	Total catchment area (mi^2)
Chelan	1927	Chelan County P.U.D	59.2	380,871	52.1	15.8	924
Roosevelt	1942	US Bureau of Reclamation	6,809	21,000,000,000	125.0	5.2	74,100
Pend Oreille	1955	US Army Corps of Engineers	42	200,000,000	148.0	43.9	24,400
Koocanusa	1975	US Army Corps of Engineers	600	1,574,400,000	73.0	5.8	8,985
Flathead (čłqʼetkʷ)	1938	Energy Keepers, Inc., CSKT	208	1,100,000,000	191.5	1.2	8,587

Regulatory and administrative provisions throughout the Columbia River Basin help determine the network memberships in each basin. Federal regulations govern the ecological side of water resources in both countries [2.1]. BPA coordinates dam releases and markets power across the Columbia River system, the USACE oversees flood control in the basins, and the U.S. Forest Service owns large swaths of National Forest lands in all of the basins. Unsurprisingly, federal actor-types far outstrip other actor types in terms of presence in the networks (for a full comparison, see Appendix C). Eight federal entities are present in all five basins, and two more federal agencies are present in at least four basins. Other consistent actor types, though to a much lesser level, are tribal and state-level agencies, county-level conservation districts, education, industry, and non-government organizations. Fishing outfitters are also present in all basins, which underscores the resource value of the fisheries to local business. The degrees of centralization of these common actors—or which position in the network they occupy—appear to be different in each basin, however, as I describe next.

[2.1] Federal environmental regulations include: [U.S.] Clean Water Act (33 U.S.C §§ 1251 *et seq*.); Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. §§ 1801 *et seq*.); Endangered Species Act (16 U.S.C. §§1531-1544)**;** Canada Water Act (R.S.C., 1985, c. C-11), Fisheries Act (R.S.C. 1985, c F-14); [Can.] Endangered Species Act (S.O. 2007, c 6)

Lake Chelan

Located on the east slope of Washington's Cascade Mountain region, Lake Chelan is often overlooked in the Columbia River system. Lake Chelan is the smallest lake basin in the study, by surface area (135 km^2 /52.1 mi^2), and a catchment (drainage) area of 2,400 km^2 (924 mi^2). It is the 3rd deepest lake in the US, and the 28th deepest on Earth. Because of its depth, Chelan ranks third among the lakes in this study for lake volume, 15.8 million acre-feet (MAF). The lake itself is entirely in Chelan County, but neighboring Okanogan, Snohomish, and Skagit counties are part of the overall drainage. The Okanogan-Wenatchee National Forest surrounds much of the lake. The towns of Manson and Chelan are on the lake. Stehekin River and Railroad Creek are the lake's two major tributaries, and its outflow, the Chelan River, connects it to the Columbia River only 22 km (13.5 mi.) downstream from Wells Dam.

Lake Chelan's first dam was built in 1897, to raise the surface level by 6.4 m (21 ft.), but it was destroyed by flood in the same year. The first hydroelectric dam was privately owned and first delivered power in 1903, but was also washed out. The currently existing structure has been operational since 1927. Chelan County's Public Utility District No. 1 (Chelan County PUD) was created by public vote in 1936. The Utility District owns and operates Lake Chelan Dam, and has delivered power from the 59.2-megawatt (mw) turbines to the community since 1947 (Chelan County PUD, 2014).

Lake Chelan is known for its recreation opportunities, including sport fishing. It has both native and stocked fish species, and a ladder allows for fish passage past the dam. Chelan County PUD, the town of Manson, Washington State Parks, and the City of Chelan maintain multiple boat accesses (Public Utility District No. 1, Chelan County PUD, 2014). Chelan County PUD's fish habitat programs listed partners include US Department of Fish and Wildlife (USF&W), Washington Department of Fish and Wildlife (WDFW) the Confederated Tribes of the Colville Reservation, and the Confederated Tribes and Bands of the Yakima Nation. Both of these Tribes, however, state that they have no regular involvement in water governance issues in Lake Chelan.

Lake Chelan and the surrounding area are not immune to ecological threats. The US Forest Service has ongoing efforts to clean up mine tailings from the abandoned Holden Mine that contaminated groundwater sources to Railroad Creek with aluminum, cadmium, copper, iron, and zinc (USDS Forest Service 2012). The lake has high legacy DDT and PCB levels in fish tissue and sediments (WECY 2008), the highest DDT levels in the nation. To date, no follow-up sediment or fish tissue sampling has been conducted (WA Dept. of Health, personal communications).

Despite concerns about toxic chemicals, and a long-term monitoring plan written in 2008, water quality data for the lake is sparse. Chelan County PUD monitors the lake and environmental conditions (Chelan County PUD 2014) as required in its license. Standard water quality data is available through Washington Department of Ecology (ECY), the U.S. Environmental Protection Agency's (USEPA) STORET repository, and some United States Geological Survey (USGS) gages. The Lake Chelan Institute, a water quality focused non-profit formed in 2016, now has one year of base-line data and two years of monitoring data from its probes in the lake (personal communications).

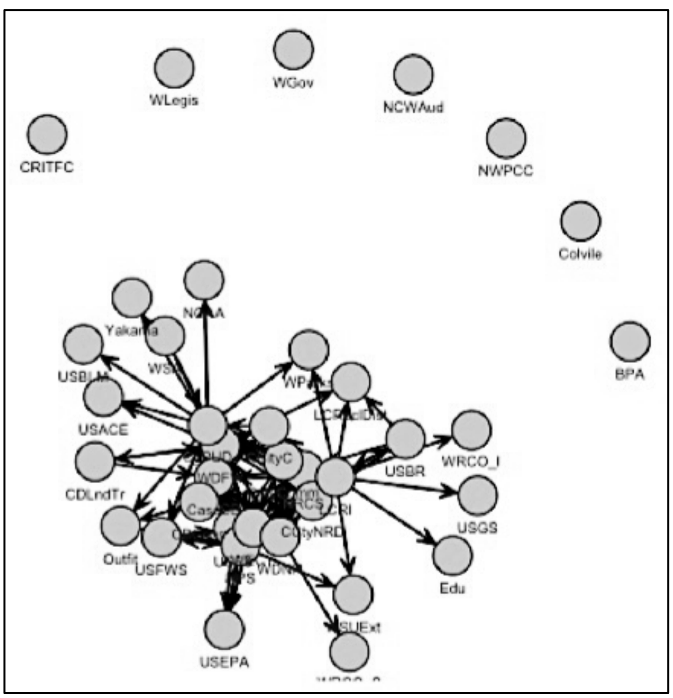

Figure 2.2. Lake Chelan's governance network. Unconnected actors are called isolates.

The Lake Chelan governance network is quite sparse (Figure 2.2; figure created in "statnet" package in R). I identified 37 possible actors during the scoping phase for the survey, but seven were not chosen as contacts by other actors, and seven more received only one nomination each. Chelan's small network was dominated by Chelan PUD, the National Park Service, and U.S. Forest Service; supplemented by strong communications with WECY, Washington's Department of Fish and Wildlife, and the Chelan County Natural Resource Department. The Lake Chelan Institute, whose "Keep it Blue" campaign is modeled on an initiative in Lake Tahoe, is a recent addition to the network's center. Other major federal entities present in the other basins of this study are either extremely peripheral or completely missing from the network. A representative from the Yakama Tribe asserted that the Tribe was not normally involved in the lake's management, as Chelan Falls form a natural barrier to salmonid fish migration into the basin from the Columbia River.

In-person outreach to solicit survey responses suggests good working relations in the network. But several attested that there was not much monitoring on Lake Chelan. One lamented the little decisive management action, such as implementing a clean-drain-dry campaign to help prevent an influx of invasive species. Qualitative survey responses revealed that collaboration is a complex problem in the basin. One wrote that other leadership facilitating the watershed governance group is needed to improve the willingness to collaborate. Furthermore, interests are divided between resource users and water management focus. One respondent complained that residents who moved into lakefront properties primarily from the westside of the state,

> *"… did not participate in relicensing lake level operation negotiations but are regularly critical of lake elevation: Not high enough for more of the year. [They are] totally oblivious to other multiple uses of the lake and Chelan River, and the need for balance."*

Lake Roosevelt

The USBR created Franklin Delano Roosevelt Lake when it built Grand Coulee Dam across the mainstem of the Upper Columbia River in 1942. The dam backs up the Columbia River for 240 km (150 mi), almost to the Canadian border, with a drainage area of 192,000 km^2 (74,100 mi^2) (USBR, n.d.). Because the lake is a filled river corridor, the actual surface area is smaller than other lakes in this study, only about 324 km^2 (125 $mi^{2)}$. Located in north-central

Washington, counties at least partly in the watershed include Ferry, Okanogan, Stevens, Grant, Lincoln, and Pend Oreille. The lakeshores are sparsely populated, as much of the area is either owned by the Spokane Tribe, or stewarded as the NPS Lake Roosevelt National Recreation Area. Towns near the dam are Grand Coulee, Coulee Dam, and Elmer City. Towns towards the upper end of the lake are Fruitland and Hunters, Inchelium and Gifford, Rice, Kettle Falls, Marcus, Boyds, and Evans.

Irrigation was the original primary purpose for the dam, and Planning for power production was added after the project was already underway (White 1995). Flow regulation was added under the 1964 Columbia River Treaty [2.2]. With an installed power capacity of 6,809 mw, the dam produces about 21 billion kilowatt-hours (kwh) of electricity per year. USBR operates the dam, and power is marketed through Bonneville Power Administration. Irrigated lands from Lake Roosevelt are estimated at 272,000 hectares (671,000 acres). Collaborative lake management is by a formal partnership of five entities: the Spokane Tribe, and the Confederated Tribes of the Colville Reservation, the National Park Service (NPS), the Bureau of Indian Affairs, and the USBR (BIA 1990).

Lake Roosevelt is a popular recreation site for boating and fishing. The Spokane Tribe's fishery department has been so successful in its sturgeon recovery that there was a 2017 open catch-and-keep sturgeon season – for the first time in decades (2018, Lake Roosevelt Forum). Invasive northern Pike have become become prolific to where there is a bounty offered for each fish caught and killed—a massive effort that is being financially supported by many partners in the governance network. Grand Coulee dam blocks all fish passage, and has cut off a significant portion of the Columbia River headwaters to salmonid migration. The immense size of the dam precludes using fish ladders, and the waters above the dam provide no current or habitat for spawning salmon for many miles. This creates ongoing hardships for Colville and Spokane Tribes (and also First Nations in BC, Canada), whose cultures and histories are

[2.2] Treaty Between the United States of America and Canada Relating to Cooperative Development of the Water Resources of The Columbia River Basin, U.S.-Can., Jan. 17, 1961, 15.2 U.S.T 1555. This international treaty entered into force in 1964; current processes have the U.S. and Canada renegotiating Treaty terms.

dependent on salmon. Long-term efforts to reintroduce salmon have led to ceremonial releases of 90 adult spawning salmon in summer 2019, thirty of which were put in Lake Roosevelt at Kettle Falls.

Legacy resource extraction industries threaten water quality in and around Lake Roosevelt. The Midnite Mine Superfund [2.3] site is on lands held in trust for Indian allottees and the Spokane Tribe within the Spokane Reservation near Wellpinit. The 350-acre open pit uranium mine drained to groundwater and directly to the Columbia River via Blue Creek. Cleanup and capping efforts are well underway, and a piping system from a new groundwater filtration plant bypasses Blue Creek to discharge the scrubbed water, into the thalweg (the deepest part of a riverbed) of Lake Roosevelt "in perpetuity" (personal communications, 2017 Lake Roosevelt Forum bus trip). Another Superfund cleanup is on the decommissioned Le Roi Smelter site at Northport, WA.

A very current pollution item in the Lake Roosevelt basin is that Teck Metals, Ltd (formerly Cominco) still operates a zinc smelter just upriver, in Trail, British Columbia. In the midst of my survey response collections in this study, Teck Metals lost its bid to have a Ninth Circuit decision overturned that holds the company liable for pollution along the upper Columbia River corridor under the Superfund act. The company argued that American courts could not hold jurisdiction over the pollution liability of a foreign company, especially considering its voluntarily participation in ongoing cleanup efforts. On June 10, 2019, however, the Supreme Court of the United States refused to take up the case, leaving the earlier ruling against Teck Metals in place (Wohlfeil 2019).

Given Lake Roosevelt's formal resource partnership, and the complexity fisheries issues and of pollution issues, it is not surprising that it had the largest potential actor list (41 actors, Figure 2.3) of the five basins. In addition to the signatories to the 1990 agreement, central actors in the network include the EPA, WECY, WDFW, USFWS, and Teck Metals.

[2.3] Hazardous waste cleanups authorized under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or Superfund Act, 42 U.S.C §9601 *et seq*. (1980)

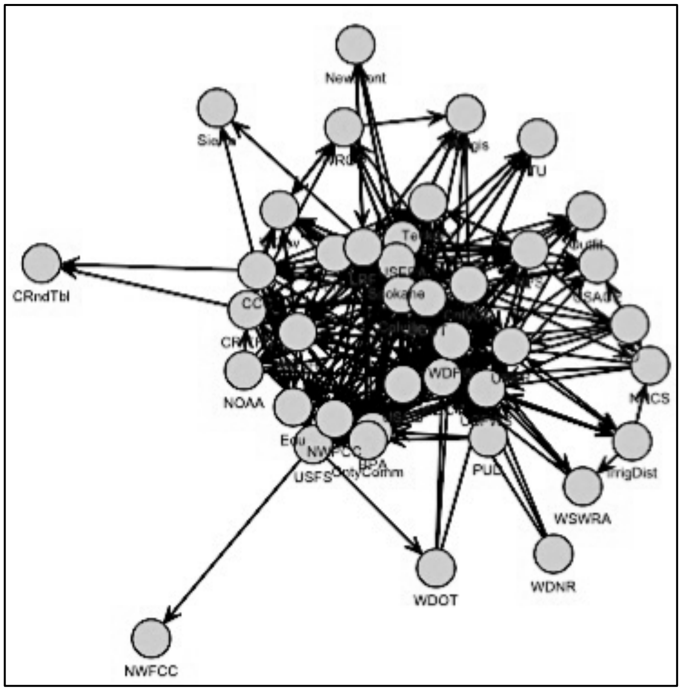

Figure 2.3. The Lake Roosevelt governance network

In addition to signatories on the 1990 agreement, central actors in the network include the EPA, WECY, WDFW, USFWS, and Teck Metals. The Lake Roosevelt Forum performs a critical bridging role in the basin. The non-profit organization was named exclusively for its informative and collaborative platform space, and as venue for public participation in the basin.

In the scoping and outreach phases of my research I found the actors in the Lake Roosevelt basin particularly difficult to identify and approach. Many calls and emails were never returned, or I was referred to yet another person in the organization, as “perhaps more qualified” to respond. Two central actors in the system refused to participate in the survey outright. The Colville and Spokane Tribes, USEPA, and Washington’s Department of Health were notable exceptions, in that they were extremely outgoing and informative.

Personal communications across the basin’s actors hinted at underlying tensions, which were echoed in qualitative survey data for Lake Roosevelt. Actors in the basin would like to see increased communication, “*less combative communication styles*,” better consultation with tribes, and more science-based decision-making. One complained of violation of trust responsibility in delegated authorities, another noted about inconsistent and differing management goals, and a third even said that outcomes seemed predetermined. Respondents included very specific observations about barriers to collaboration that especially revolve around trust issues:

> *In a few situations, data is not willingly shared between agencies or tribal parties. In those situations, it can be incredibly frustrating to provide the best collaboration and doesn't build trust between the groups*.

When asked what would increase collaboration, one wrote, "*more opportunities to meet in field with collaborators on common issues to exchange/ brainstorm possible solutions*." Several respondents found, however, that even if there are more collaborative opportunities, they could not participate for financial reasons.

Lake Pend Oreille

Located in Idaho's Panhandle region, Lake Pend Oreille is the 4th deepest lake in US, and 8th largest by volume. The Clark Fork is the lake's largest tributary, delivering the majority of its inflow, including water from Flathead Lake. The drainage includes parts of Shoshone, Bonner, Boundary, Spokane, Kootanai, and Pend Oreille counties, in both Washington and Idaho. The Kootenai Reservation is in the northern reaches of the drainage, and it is in traditional (aboriginal) territory of the Kalispels. The town of Sandpoint is at the northern end of the lake. Recreational uses of the lake include boating and fishing for native trout species, stocked fish, and kokanee. Economical activities include large resorts serving both lake activities and Schweitzer Mtn. ski area, farming, timber, light industry, and a relatively large residential population, all of which potentially impact the lake's water resources.

The reservoir's outflow at Albeni Falls Dam is between the cities of Priest River and Newport, WA, and just east of the WA-ID state line. Designed for flood control, hydropower, and navigation, the dam's inception is from the federal Flood Control Act of 1950. The USACE-owned and operated dam, which has been operational since 1955, has 42-megawatt capacity. The dam produces only 2 million kwh electricity per year, which the BPA administrates.

There is no formal lake management plan for Lake Pend Oreille. The now defunct Tri-State Council was responsible for decades of research, education, and water quality monitoring in the lake. Currently, the Idaho Department of Environmental Quality (IDEQ) monitors water quality in the lake, with its working partners, the non-profit Lake Pend Oreille Waterkeeper and the Lakes Commission. IDEQ's forum platform for public engagement in this basin is the Pend Oreille River and Tributaries Watershed Advisory Group, which only actively meets in years ahead of required TMDL (total maximum daily load) reports.

The governor-appointed Lakes Commission [2.4] was formed in response to lake level issues from dams operations, and related issues in native fisheries and water quality. The Lakes Commission, which operates as a federal watchdog, has no regulatory authority. However, the organization partners with area agencies on projects, coordinates public information sessions, and acts as an advocate for water quality and fisheries in the Pend Oreille and Priest Lake drainages (personal communications). The Lakes Commission supports Bonner County's Soil and Water Conservation District in a watercraft program aimed in part at preventing invasive species from being transported into the lakes. Another water quality and environmental concern is a current proposal to build a silica smelter on 180 acres in Newport, WA, just downriver from Albeni Falls Dam.

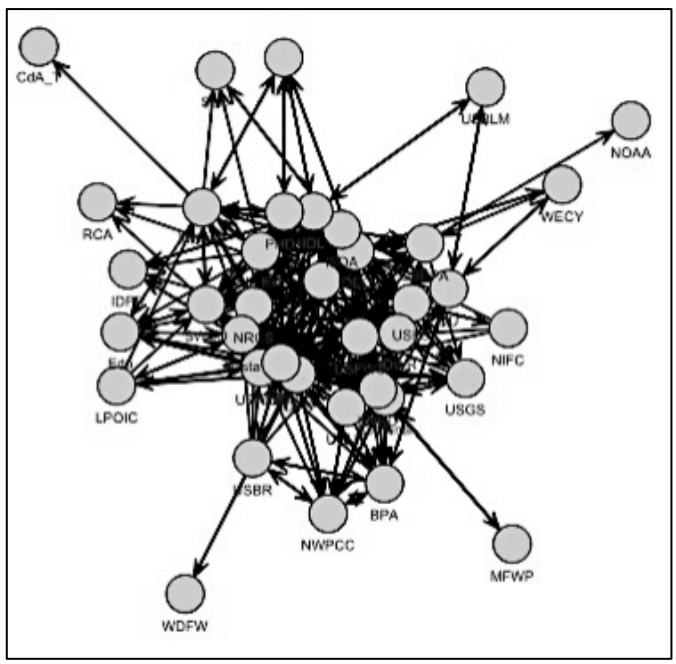

Figure 2.4. The Pend Oreille governance network

[2.4] The Idaho Lakes Commission was created by Idaho House Bill 110 in 2003

Lake Pend Oreille's location in the narrow Idaho Panhandle is evident in its governance network (Figure 2.4). The periphery of the network includes agencies from neighboring states: Washington's WDFW and WECY to the west, and Montana's Department of Fish Wildlife and Parks to the east. During my survey outreach I learned that actors in the Pend Oreille basin generally feel positive about collaborations. State and federal agencies believe they are doing a good job of managing water quality in the lake and also in giving access to quality data. Some respondents complained about litigious non-government organizations, however, and, *"an unwillingness of the other party to compromise or think creatively to solve problems."* Especially striking was the frequent complaint about lack of funds to effectively participate in basin governance, in terms of paid positions and the ability to attend meetings.

Lake Koocanusa

This lake was created in 1975 as a result of the 1961 Columbia River Treaty agreements with Canada. The actual surface area is 189 km^2 (73 mi^2), a little more than that of Lake Chelan. But as an impounded river basin, its storage capacity is only 5.8 MAF (USACE n.d.), a mere third of Chelan's volume. Operated by USACE, Libby Dam's turbines have a 600-mw-production capacity, the 2nd largest among the study sites. BPA markets the power, and part of the revenues flow back to Canada under the Columbia River Treaty agreements. The primary purposes are flood control and hydropower; the lake level fluctuates widely throughout the year, commonly up to 80 ft (USACE n.d.). Riparian zones are effectively naught, and the basin even experiences seasonal dust storms when the lake is drawn down before spring freshets. Spawning habitats for fish are generally only on river reaches and in tributaries (Leschied 2017).

Lake Koocanusa's tribal-sounding name is actually a combination of Kootenai, Canada, and USA (van Huizen 2010). Located in northwestern Montana, the Libby Dam impounds the upper Kootenai River (spelled Kootenay in Canada). After leaving Lake Koocanusa, the Kootenai River takes a long and circuitous path out of Montana, across the northern corner of Idaho's Panhandle, and back into British Columbia's Kootenay Lake before eventually joining the Columbia River in Canada. The 90-mile lake is half in Montana, and half in

British Columbia. It lies inside the relatively unpopulated Kootenai National Forest, and the nearest town is Libby. The town of Rexford, which was once in the river basin, was relocated before the basin was flooded. Ancestral lands of the Tobacco Plains Indian Band and other Ktunaxa First Nation members were inundated as well, without compensation from the Canadian government.

Recreation and sport fishing has become a secondary purpose for this Lake Koocanusa. The original fish stock in Lake Koocanusa is from an accidental release of captive-reared kokanee by the BC Kootenay Trout Hatchery. Since then, the fisheries agencies have intentionally stocked Gerrard-strain rainbow trout. Additionally, federally endangered bull trout are native to the system. Historical differences in catch limits on the two sides of the international border have made fisheries management challenging (Romans 2015). The USACE makes efforts to operate the dam for ecological flows and river temperature regulation for fish and macroinvertebrates, while fulfilling its mandates as a Columbia River Treaty dam for flood control and energy production. Spills from Libby dam are used in May for flow augmentation for native white sturgeon runs on the Kootenai River (Columbia Basin Bulletin, 2016).

Koocanusa has an issue with mine drainage, specifically selenium, from the waste piles of open pit-mines of the Elk Valley in the Kootenai River headwaters (Romans, 2015). A 2014 draft memorandum of understanding between Montana’s Department of Environmental Quality (MTDEQ) and the B.C. Ministry of the Environment established a Monitoring and Research Working Group to jointly study the lake. Recommended water quality criteria and/or objectives must

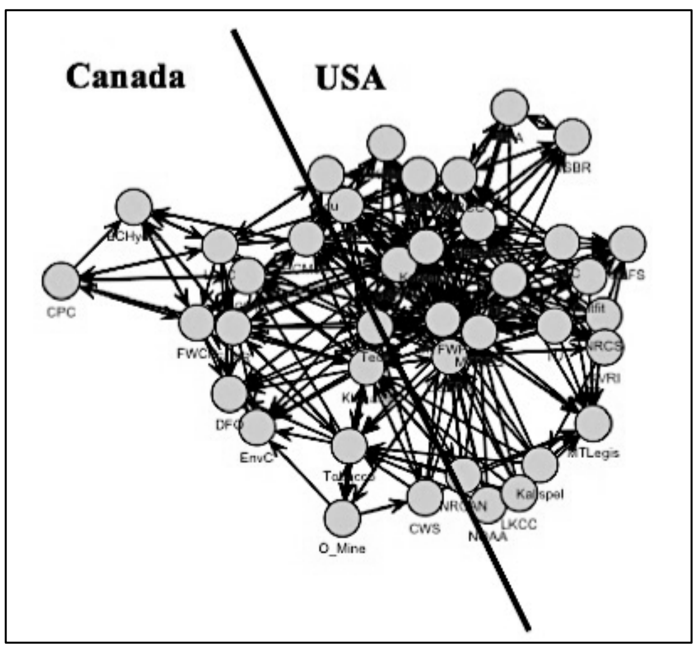

Figure 2.5. The Lake Koocanusa governance network has two distinct contingents

be submitted for approval to both Montana's Board of Environmental Review and B.C.'s Ministry of the Environment (MTDEQ n.d.). B.C.'s Ministry of the Environment monitors water quality on the Canadian side, and MTDEQ monitors the U.S. side. The USACE collaborates on research with various agencies and five Indigenous groups on both sides of the international border, and cohosts information sessions in public forums (various personal communications). Figure 2.5 shows that while the actors are densely connected, the overall network has two distinct contingents, one on the U.S. side, and the other in Canada.

In general, my informants were positive about collaborations in the basin, but outreach efforts for my study underscored Lake Koocanusa’s complex governance issues. Some survey respondents reported the difficulty with collaborations against the backdrop of cross-boundary political processes, an overpowering industry, and the challenges of implementing actions with a holistic approach under greatly differing objectives. One questioned, “the ‘teeth’ in developing a bi-national water quality standard that will be enforced by both countries.”

člq̓etkʷ (Flathead) Lake

Located in Montana on the west slope of the Continental Divide, člq̓etkʷ (Flathead) Lake’s 1284 km^2 (496 mi^2) surface area makes it the largest freshwater lake in the contiguous states west of the Mississippi, 79th in the world. The shallow Flathead Lake is the smallest basin in the study by volume at only 1.2 MAF. While the shores of Flathead are highly developed, the lake’s watershed itself is mainly in National Park, Wilderness, and managed forestlands, and has relatively low human populations. A brief foray into U.S. Indian policy is needed to place the importance of history in the basin’s context. The 1855 Hellgate Treaty [2.5] created the Flathead Reservation, placing together members of the Bitterroot Salish (Sqelixʷ), Kootenai (Ktunaxa), and Upper Kalispel Pend d’Oreille (Qæispé) Tribes in what is now known as the Confederated Salish and Kootenai Tribes (CSKT n.d.). The 1904 Flathead Allotment Act (P.L. 159) removed roughly 60 percent of the Flathead Reservation, reassigning the lands to settlers and for platting towns.

[2.5] The 1855 Hellgate Treaty is one of ten “Stevens Treaties”, in which tribes collectively ceded millions of acres of land to the U.S. An unique feature of the Stevens Treaties is the right for tribal members to hunt and fish in their “usual and accustomed places”

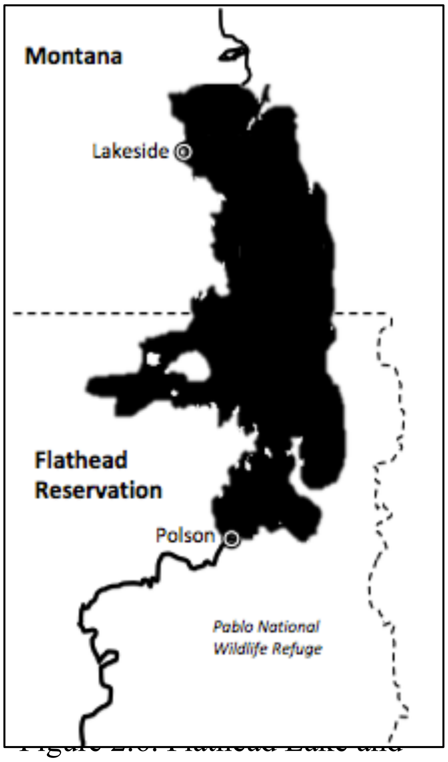

Figure 2.6: Flathead Lake and the Flathead Indian Reservation

In a reversal of longstanding U.S. policies of assimilation, the 1934 Indian Reorganization Act (P.L. 73-383) allowed Indians to create form their own governments and to form corporations outside the U.S. government. The CSKT was the first Tribe to organize under the new rules, and has carefully built its Tribal capacity and land holdings (Energy Keepers, personal communications. The Flathead Reservation (Figure 2.6) is currently home to 65 percent of CSKT enrolled members (CSKT, n.d.).

Seli'š Ksanka Qlispe' (formerly Kerr Dam) hydroelectric dam and was authorized under the Roosevelt administration, and completed in 1938. The 208 mw-capacity power generation facility was co-licensed through Montana PPL. The Dam was purchased and renamed by the CSKT in 2015, and is now operated by the tribally owned corporation, Energy Keepers, Inc. (CSKT, n.d.). Dam re-operations under the stewardship of Energy Keepers and the CSKT now consider ecological function and the importance of the lake to Tribal culture, as a popular recreation site, and as designated federal Long Term Biological Site. The dam also serves long-standing water rights for irrigation under the Federal Reserved Water Rights Compact (Energy Keepers, personal communications).

Flathead Lake's fish population and species assemblage has changed drastically since settlers arrived. Non-native fish populations, introduced (lake trout, 1905; Kokanee, 1920) flourished after the 1981 introduction of *Mysis spp* shrimp (a food species for fish) and have largely displaced the eleven native species originally found in the lake, especially the threatened westslope cutthroat trout and bull trout. Current dominant populations lake trout, lake whitefish, and yellow perch make Flathead Lake's fish community more similar to the Great Lakes than Rocky Mountain lakes (FLBS, n.d.). Montana's fisheries and recreation are managed and protected by the Montana Fish, Wildlife, and Parks (MTWFP). The agency's scope includes reviews of comprehensive water plans and projects for impacts on fish, recovering endangered fish species, and issuing permits for fishing and river recreation.

Despite being one of the cleanest lakes in the world, Flathead Lake has water quality challenges. Human causes, including increased nutrients and sediments, led state and federal agencies to classify the lake as "impaired" (FLBS, n.d.). Especially with the high value of lake and fishing recreation, the basin governance network is now highly focused on preventing invasive species, notably quagga and zebra mussels, from entering the system on the hulls of boats (FBC meeting, personal notes).

Flathead Lake has perhaps the most developed governance system of basin management in this study, as can be seen in the densely connected governance network (Figure 2.7). The CSKT has high capacity in its Department of Fish, Wildlife, Recreation, and Conservation, and is deeply engaged in basin issues. CSKT biologists assert that they have the largest and most contiguous dataset in existence for the water bodies in the basin (2016, personal communications).

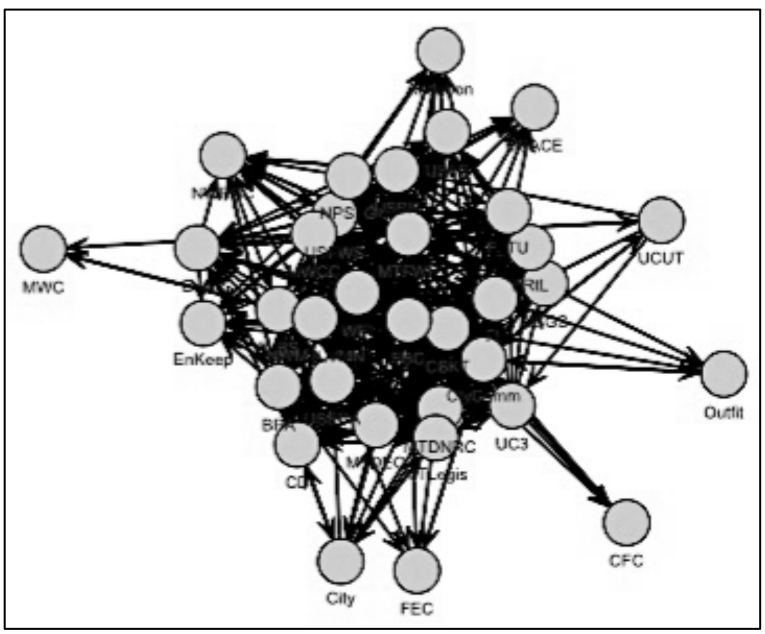

Figure 2.7. The Flathead Lake water governance network has the highest density of the five study basins

The Flathead Lake Biological Station (FLBS) has monitored water quality in the lake since it was established in 1899, and has continuous data by standardized protocols since 1977. FLBS data, along with that of MTDEQ forms the basis of Flathead Basin Commission's water management recommendations.

Montana's governor-appointed Flathead Basin Commission is a panel of collaborative partners that convenes quarterly to discuss water governance issues in the basin. Basin updates are shared with the public in the FBLS Flathead Lake Journal. Communities are actively engaged, and have contributed in actions such as fundraising for the 2013 Lake Monitoring Challenge Grant (FLBS, n.d.). The Flathead Lakers, a non-profit established in 1958, serves as a long-term champion of water quality in the lake basin.

On the surface, Flathead Lake's governance network is cohesive, but it is not without frictions either. I learned during the scoping process that *"some previous personalities made it difficult to collaborate,"* together with political stressors and apparent ulterior motives of some actors, had damaged relationships in the basin. Respondents reported position- and values-based frictions a lack of openness and good faith in negotiations, and an occasional inability to find common goals as further obstacles in joint management decisions. Funding limitations, and lack of staff time was again mentioned as an inhibitor to collaborations. Nevertheless, the overall sentiments towards Flathead's network functions were positive and forward thinking.

2.3. Overarching observations

In this chapter I presented a largely qualitative description of the basins in the study. I used literature to frame the basins in terms of geography and an historical context. Personal communications and qualitative survey responses added social context that is important also to explaining variations in quantitative results in chapter five. Several common threads emerged from my scoping interviews and from the text-entry survey responses themselves. Here I expand on legal action as a driver in the networks, the latency of actors in a network, and the seemingly ubiquitous issue of funding support. I conclude with some observations on overall network membership, and next steps for investigation.

Legal action around pollution and the impacts of dams is not uncommon. In the course of this study, I found that legal action played a shaping role in each of the study basins, often by adding actors who might not otherwise be present, or would be expected to be more peripheral in the network. The quantitative network portion of the study, however, can only be seen as a snapshot of presence or absence of actors, and says nothing about the development or devolution of the networks. It can be expected that legal obligations such as the Superfund cleanup sites such as in Chelan (Holden Mine) and Roosevelt (Midnite Mine and LeRoi smelter), add the project administrators into the active water governance conversations. In a different scenario, successful action of the Colville Indian Tribe against Teck Metals [2.5] could hold Teck in the Roosevelt network by legal obligation, though Teck is already in the center of this network by voluntary collaboration.

Legal action by non-profit citizen groups turned were more subtle drivers of network structures. In Lake Roosevelt, Citizens for a Clean Columbia (CCC) joined the original suit of the Colville Indians against Teck. One outcome from this lawsuit is that CCC is consulted for review and comment in the USEPA's Human Health Risk Assessment in a Remedial Investigation and Feasibility Study for Lake Roosevelt and the upper Columbia River (Lake Roosevelt Forum 2019; CCC personal communications). The small non-profit, which consists of members in both the U.S. and Canada, additionally actively advocates for the addition of ecosystem function in Columbia River Treaty renegotiations.

The case of Kootenai Fly Fishers also leads to an interesting observation about non-government organizations in a network system – individuals as the face of an organization, and recognition that person provides. A re-regulating dam proposed below Libby Dam (USACE 1983) was fought off by the small non-profit, and Kootenai Fly Fishers' comments are included in BPA's Final Environmental Impact Statement for its 1995 Columbia River Systems Operation Review. Kootenai Fly Fishers became, for a time, the organization that represented Trout Unlimited in Lake Koocanusa and the Kootenai River corridor (Farling 2009). After a time, however, Kootenai Fly Fishers disbanded. The former president is still an active fishing guide in the basin, attends the USACE's information forums, and participates in governance discussions. Longtime participants in the basin's governance still connect this

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[2.5] *Teck Metals Ltd. v. The Confederated Tribes of the Colville Reservation*; the petition for certiorari to the Supreme Court of the United States was denied on June 10, 2019 individual with the no longer extant organization, and therefore nominated the Kootenai Fly Fishers as an actor in the system.

In the Pend Oreille basin, virtually the opposite was true when the well-connected, long-time Idaho Fish & Game employee retired and left his position as conservation director of North Idaho Fly Casters. A legacy of connections left with him, leaving the new person struggling to rebuild the organizations conservation network (personal communications). Indeed, the organization received barely any nominations in the network section of the survey. Concerns about the longevity of non-profits that are often driven by only a few dedicated persons were voiced to me throughout the study, *"What happens to the organization when [insert name] gets old and is no longer able to do this thing?"* In chapter four I explore the impacts of informal roles like policy entrepreneurship or "rock star" networkers as an element of the 'suite of roles' fulfilled by actors in water resource governance networks.

The issue of underfunding and understaffing in conservation efforts was not limited to the non-government organizations of my study. Fourteen separate text entries in the survey speak to organizational funding needs. The funding needs for collectively managing the water resources of these basins for fisheries and water quality appear to outstrip, by far, the available monetary resources. Funding is among resource roles addressed in chapter four.

The network diagrams displayed in this chapter were produced as initial network visualizations, as a next step after processing the survey data into network matrices. The visual patterns they formed encourage me to continue my investigations into core-periphery network structure, as presented in chapters three and four. The social interactions I observed, combined with text-entry survey responses and many personal communications spurred my interest in the human dimensions I investigate in chapters four and five. The ecological concerns in all five of these reservoirs, together with the connected human dimensions of governance, underpin the investigations of basins as social-ecological systems in chapter five. The generous contributions of all my respondents and informants breathe life into the project.

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Chapter 3: Core-periphery patterns in water resource governance networks: a literature review

Abstract

Governing complex social and ecological systems in natural resources and water resources requires networking of actors at multiple levels. The resulting networks develop internal patterns or structures. In social network analysis, the core-periphery structure is characterized by a center of densely connected actors; actors in the outer regions are connected to central actors, but tied only sparsely with each other. Resource governance networks have been examined in many theoretical frameworks, including a network structure approach, social capital that is built by group interactions, and in the zoomed-out view, polycentric governance arrangements. Many describe or display patterns that resemble a core-periphery network, but it is unclear whether the core-periphery pattern is a normal characteristic in resource governance. In reviewing 30 case studies spanning over 20 years of water and natural resource governance research, I find a prevalence of the core-periphery patterns.

Key words: resource governance, social networks, core-periphery, social capital, polycentricity

3.1. Introduction

Social networks are patterns of relationships among a finite set or sets of nodes or actors. Relational ties link pairs of nodes that are related in a specified way (Wasserman and Faust 2009). Network structures or patterns emerge as a network develops and more nodes in an actor set become connected, including the relatively common [3.1] core-periphery (C-P) pattern. In the field of social network analysis, C-P network pattern is characterized by a tight center of densely connected actors. Actors on the network's outer layers are relatively close only to

[3.1] In a recent network study of 287 networks in a great variety of sizes and settings, more than 75 percent showed significantly more core-periphery structure than would be expected by chance (Katherine Faust, personal communications) the well connected, and are sparsely connected to other outer, or peripheral nodes (Borgatti & Everett 1999; Csermely *et al*. 2013).

The C-P pattern appears to be ubiquitous in natural resource governance research; however the phenomenon is often not acknowledged. C-P patterns have been explicitly observed in networks for landscape and urban planning (Enqvist *et al.* 2014), resource management (Isaac 2007), and water resource governance (Scheinert *et al*. 2015; Horning *et al*. 2017). In many research articles, however, C-P structures are visible in the network figure but are not described as such (Stein *et al*. 2011; Levesque *et al*. 2017). Still others make references to the network cores (Jasny & Lubell 2015), well connected and centrally located organizations (Scholz *et al.* 2008), or the polycentric networks (Morrison 2017; Roca et al. 2018), without connecting the concepts to the actual C-P network structure.

The sparing treatments of C-P networks in resource governance may be due to multiple frameworks that have evolved almost in parallel: Social network analysis provides a structural lens to the C-P patterns through early work of Doreian (1979) and Borgatti & Everett (1999). Polycentricity, as seen from the collective action framework, is characterized by a network center of multi-scale, independent state and non-state decision-making entities (V. Ostrom 1961; Blatter 2003; E. Ostrom 2010a; Morrison 2017). The social capital framework describes bonding ties for cohesive network centers and weak (Granovetter 1973) bridging ties that reach across structural holes (Burt 2001) to access external resources (Bodin & Crona 2009). Researchers have begun only recently to suggest that these three approaches are more closely related (Berardo & Lubell 2016; Bodin 2017; Frimpong Boamah 2017; Biesbroek & Lesnikowski 2018).

The aim of this review paper is to investigate the prevalence of the C-P pattern in natural resource governance literature. I begin by sketching these conceptually independent, but apparently overlapping approaches to describing the shape of natural resource governance networks. I then describe the methodology for sourcing and filtering documents for review.

I present results and quantify the relative prevalence of C-P patterns in the literature, as a challenge to the bold statement that the C-P pattern is ubiquitous in water resources governance cases. We finish with a discussion on gaps in natural resource governance studies.

3.2. Theories and definitions

3.2.1. Social network analysis, and types of connections

Social network analysis in not a theoretical framework; rather, it is a rigorous and computationally intensive methodology used to evaluate observed behavior among a group of people, organizations, or actors (Prell 2012). Radcliffe-Brown (1940) uses "the term 'social structure' to denote [a] network of actually existing relations" (p. 2), arguing that society could be seen as a complex network of social relations that could, in theory, be quantified and analyzed mathematically (Radcliffe-Brown 1957). Theoretical concepts of 'connectedness' and multiplex relations forwarded social network analysis both as a metaphor and as an analytical concept (Prell 2012). Important work from White *et al*. (1976) emphasize the "'knittedness' of interconnections" (p. 731) across multiple relations, and thus promote the importance of studying interactions of individuals within the overall social network structure.

Social network analyses are frequently conducted from two perspectives: The socio-centered, or overall network structure focuses on global patterns of the whole network. The ego-centered, local structure revolves around individual nodes or actors (Marsden 2002), and the relational ties among them. In real-life situations most people interact with a fairly small set or cluster of others, many of whom also know each other (Hanneman & Riddle 2005). Patterns emerge both locally and globally as actors connect and networks develop, which may contain densely connected regions (Monge 1987).

A common measure in social network analysis is centralization, as a measure of point-dominance, or the extent to which a few nodes dominate a network (Leavitt 1951; Freeman *et al*. 1991; Scott 2009). Among other measures, centralization can be calculated on in-degree (incoming direct ties) or popularity, out-degree (outgoing direct ties), or total 'Freeman' degree (the cumulative of incoming and outgoing ties) in a network (Freeman *et al*. 1991; Borgatti, 2005; Hanneman & Riddle, 2005). Related to centralization is network closure, or how tightly nodes are connected. In terms of social interactions, this can be thought of as the degree to which actors in a network know or communicate with each other. Coser (1975) makes the distinction between internal and external community structure of a network using the German terms of *Gemeinschaft* (the direct, close community) and *Gesellschaft* (the greater community outside of close ties). In more modern network terms, this can be described through the presence of bonding and bridging ties.

Bonding in networks is represented in the level of internal cohesion with dense or closed network ties, where no one escapes the notice of others (Coleman, 1988/2000; Burt, 2001/2017). The greatest overlap of connections occurs among friends or partners in work and is likely to be in the form of strong ties (Granovetter 1973, 1983). Clustered groups are created by linkages among individuals who have common membership in collectives (Wasserman & Faust 2009).

Bridging in networks is the conceptual counterpoint to bonding, as it provides reach to less-connected or outlying nodes or clusters via weak ties (Granovetter 1973; 1983), often while spanning structural holes in the network (Burt 20017/2011).

The social network concepts of bonding v bridging, strong and weak ties, or cohesion v reach may well constitute the critical links relating the three conceptual frameworks addressed in this review. Doreian (1979) cautions, however, that there is an important difference between structure and function:

> *We do not know if the presence of bridges was fortuitous or designed. Once there, we do not know if they were recognized or not. If recognized, we do not know if anything was done, or intended, to capitalize on their presence. In short, we know nothing about the social processes surrounding them.* (p. 250)

Keeping Doreian's words in mind, we turn first to the structural approach to describing the C-P network pattern. Here we are interested in the network itself as the outcome variable, using the structural patterns of nodes and links "as the observable empirical fingerprint" (Bodin *et al*. 2019, p.4) of the interactions.

3.2.2. Core-periphery networks: a structural approach

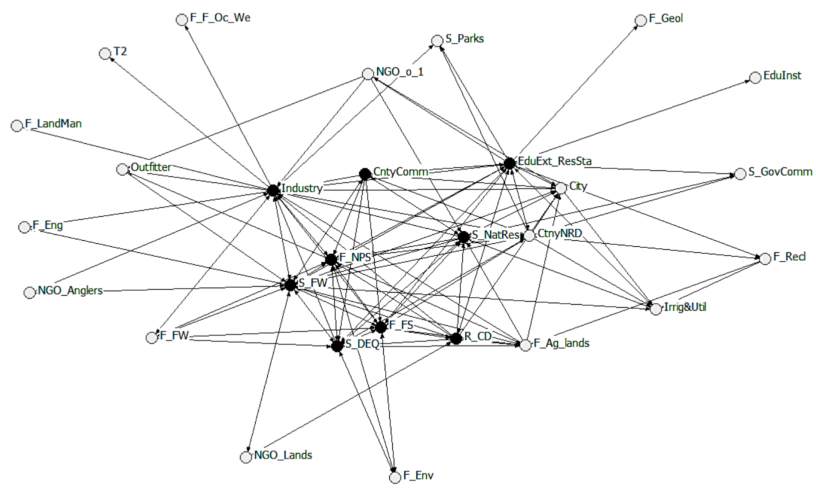

Figure 3.1. A core-periphery network structure. Source: Trebitz & Shrestha (in rev.)

It can be argued that a C-P network structure is a particular combination of bonding and bridging ties. The C-P structure is characterized by a well-connected center that cannot be easily divided into unique subgroups, surrounded by outward radiating layers of peripheral points that are relatively close only to the core actors, but have few or no connections to other nodes in the periphery (Borgatti & Everett 1999; Csermely *et al*. 2013). Figure 3.1 is an example of a C-P network. Peripheral actors (grey nodes) mostly connect directly to core actors (black nodes) of the Lake Chelan water resource governance network, whereas few actors communicate with others in the outer circles. The C-P correlation is high (fit = 0.823) when compared with an idealized C-P network where the peripheral nodes have no connections among themselves [3.2] (Trebitz & Shrestha, in rev.).

[3.2] Ucinet™ network analysis program, Borgatt & Everett 2002

3.2.3. Social capital: a framework for group function

A large body of social science literature has been developed around the idea of social capital as both a process and an outcome of collective action. 'Capital' is Marx's (1933/1849) concept of the surplus commodity value captured between production and consumption. Human capital applies the term to expected returns from such investments as education and technical skills, and the idea of cultural capital is attributed to Bourdieu, where symbols and meanings representing the dominant class are embedded in societal teachings (Lin 1999). Putnam (1993) extends the idea further, describing social capital as having "features of social organization, such as networks norms, and trust, that facilitate coordination and cooperation for mutual benefit" (p. 2), but keeps it distinct from political participation (Putnam 1995). Krishna (2002), however, finds that social capital provides the "glue and gear" that leads directly into higher political participation, as villages with high social capital are more close-knit, and better able to act together for diverse common ends" (p. 24). The idea of social capital has thus expanded to encompass all levels of collective action, and is often used in social network literature, including in natural resource management scenarios. In resource governance, social capital is often defined in terms of bonding and bridging, or cohesion and reach.

Frequent and intense interactions lead to more complex, group-specific knowledge, such as similar local ecologic knowledge in rural fishing communities (Crona & Bodin 2006). Denser networks have an advantage in building norms, trust, reciprocity, and and preserving or maintaining resources (Lin 1999/2017; Shrestha 2013). This is often referred to as bonding social capital. In contrast, bridging is the indirect reach to other communities (Shrestha 2012). In terms of governance networks, bridging ties provide access to outside resources, and provide for diversity and non-redundant information in collective actions, and increases flexibility, adaptiveness, and innovation (Hinds *et al*. 2000; Carpenter *et al.* 2004).

Better connected people enjoy higher returns in a network, Burt (2001/2017) observes, but, "what is 'better' connected?" (p. 32). Literature suggests that a balance of bridging and bonding ties are needed for successful collaborations in water resource management networks (Berardo 2009; Bodin & Crona 2009). The two are not mutually exclusive, as dense clusters can simultaneously have boundary-spanning relations (Reagans & Zuckerman 2001). A balance of cohesion and decentralization, with diverse and good brokerage for information exchange, are necessary for extensive inter-organizational and interdisciplinary collaboration (Smythe *et al*. 2014).

When the research lens is social capital, it is not unusual for researchers to display networks with C-P patterns without making express reference to the overall pattern. This is the case in Bodin *et al*.'s (2016) five information exchange networks in ecosystem-based management scenarios (Figure 3.2). The authors refer to centrally positioned actors, but do not address the apparent C-P pattern. Smythe et al. (2014), who cast their paper in the social capital framework, also display and describe an unmistakably C-P patterned network. Berardo & Lubell (2016) take a different route: they use the functions of the social capital framework to explain the shape of polycentric governance systems.

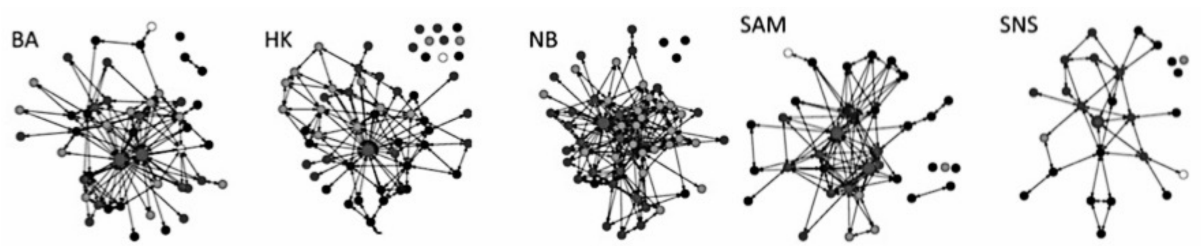

Figure 3.2. Information exchange networks in ecosystem-based management; adapted from Bodin *et al*. (2017)

3.2.4. Polycentricity: a framework of membership and influence

Collective action is seen as a potential solution to the social dilemma to managing common-pool resources (Putnam 1993; Ostrom 1998; Morçöl 2014) such as clean water or fisheries; a concept that was explored in ecologist Garrett Hardin's famous 1968 essay, the Tragedy of the Commons. These complex social-ecological systems "cannot be 'optimally' managed through top-down, command and control type of governance designs" (Zia *et al*. 2014, p. 79).

Top-down government regimes face resistance when local user groups are not taken into account (Lam, 1998), because local users, when excluded in aspects of planning, do not take ownership in its success, and might undermine the outcome (Ostrom & Cox 2010). Collective action in resource governance has evolved towards the idea of adaptive co-management, which combines regional and local participation with learning and experimentation in a local context.

Adaptive co-management styles "achieve federal goals by embracing local context" (Erickson 2015, p. 103), typically while moving governance regimes from singular government control to polycentric governance. In this model, participant organizations in management efforts may be responsible for different aspects of the projects. Participatory processes lead to greater social learning (Pahl-Wostl 2007), and thus build capacity among engaged communities towards building resilience in social-ecological systems (Olsson *et al*. 2004; Mitchell *et al*. 2014).

Ostrom (2010b) defines polycentric systems as having multiple independent decision-makers at different scales and with different levels of authority, rather than having a single (monocentric) center of authority. The core actors in Figure 1 fit this definition, as they are comprised of heterogenous independent actors—in an apparently polycentric arrangement—that include federal and state agencies, local conservation districts, and industry (Trebitz & Shrestha, in rev.).

Galaz *et al*. (2011) represent polycentricity in four network sketches (Figure 3.3), where the patterns evolve from a weakly polycentric configuration (panel a), to their idealized concept of the strongest polycentric configuration (panel c). Panel b closely resembles the C-P pattern in figure 1. The patterns in Galaz *et al*. resemble the C-P structure, with peripheral actors that tend to be connected to central actors directly or through a bridging tie, but only sparsely tied to each other.

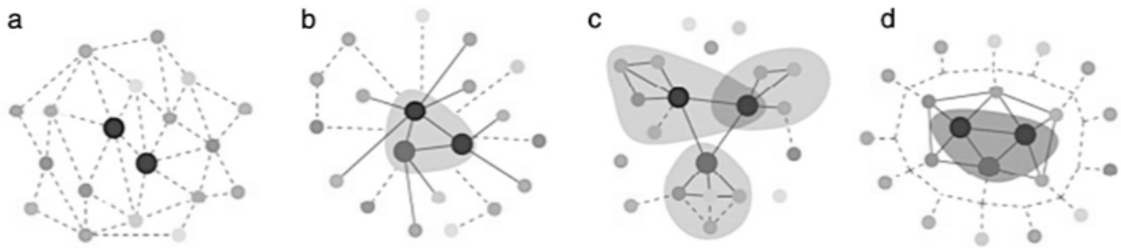

Figure 3.3. Conceptualized variations in polycentric governance patterns range from structurally weak (a) to robust (d). Adapted from Galaz *et al*. (2011).

Core-periphery network structure, collective action's polycentricity, and particular combinations of social capital's bonding and bridging social capital concepts all appear to describe a similar phenomenon: a pattern of tight relations among diverse actors in the center of a network, surrounded by less-connected actors in the outer layers of the network. If a similar C-P pattern is described in all of these approaches, then how common is it really in resource governance literature? How do authors using the different frameworks explain the pattern when they see it? I turn now to our methods for finding and evaluating literature towards answering these questions.

3.3. Methods for data collection

This review is intended to crosscut and synthesize concepts from multiple disciplines and foci, in search of the C-P pattern. I seek to capture the central themes of the disciplines and how they pertain to the phenomenon of C-P patterns in natural resources governance. As natural resource governance is a strongly applied field, not just a theoretical construct, I additionally include a few non-peer-reviewed pieces such as conference proceedings (Webster & Watson 2002) and technical reports (Levy & Ellis 2006)

I used a mixed mode approach for identifying literature to review, using a series of key words (Table 1) and combinations of the key words for an initial search through English-language electronic databases of journal publications. Some experts in the topics contributed article suggestions. Further materials were identified in reading the documents and by backtracking through reference lists (Randolph 2009). After eliminating obviously non-relevant articles, I was left with 129 pieces. I applied an internal search to the candidate documents using 19 specific key words or partial words (Table 1), and specifically in the context(s) given in table 1. Additionally I visually searched for figures that were representations of networks. In a matrix I entered a “1” if the term was a primary focus of the paper, and “2” if the term was found in the body of the paper but used in passing in the background discussion or was a secondary observation. A few studies were eliminated because they focused on two-mode (issue by actor) networks, which are not comparable to the one-mode actor networks in this investigation (e.g. Jasny & Lubell 2015). The final filtering step removed review and discussion pieces, to leave only case studies.

The final 30 case studies considered in this review include 28 peer-reviewed journal articles, two conference proceedings, one university technical publication, and one doctoral dissertation. The publishing year ranges from 1961 to 2019, with 21 publications (72.4 percent) from 2010 to present. Twenty-eight articles are specific to water resources, eight of which are in urban or rural planning for water supply in irrigation or municipal use. Nineteen case studies are in developed nations, 9 are in developing nations, and one has a global focus. There are two case studies that were published by same author or similar co-author teams, with slightly different focus questions and discussions. One is a methods paper (Das *et al*. 2019), and a comparison of structure and stakeholder vision (Horning *et al*. 2017) of the same case in British Columbia. The other explores two dimensions of social capital in planning water infrastructure projects in rural Nepali towns (Shrestha 2012; 2013). In this review I discuss such parallel articles together.

Table 3.1. Words or partial words used in internal document search

Search term	Context of search
urban	Urban planning, especially if focused on green spaces or water
regional	Regional planning, especially if focused on green spaces or water
natural	Natural resources
water	Water resources
adaptive	Adaptive governance
ecological	Social-ecological systems (SES)
governance	Governance
network	Networks in general terms
analysis	Social network analysis as a specific field of study
core	Core in terms of actor position(s) or structural characteristic
periph	Periphery or peripheral, in terms of actor position(s) or structural characteristic
periph	C-P structure is specifically identified
polycentric	Polycentric or polycentricity in terms independent central actors
bonding	Bonding ties in networks; cohesion; internal or bonding social capital
bridging	Bridging ties in networks; reach; structural holes; external or bridging social capital
trust	Trust as outcome of collaborations, bonding ties, cohesion, social capital
capital	Social capital
learning	Social learning, group learning; learning as outcome of group cohesion
collab	Collaborative, collaborations
collective	Collective action

3.4 Results

All but one case study in this review use the concept of networks explicitly. Ostrom's (1961) work predates regular applications of network concepts to governance studies, but his work otherwise fits the search critereia. I arrange the results thematically by the author(s) lenses of analyses: structural (C-P), social capital, and polycentricity. Table 2 shows authors who use the language of these three frameworks as a primary or secondary focus. Additional papers use related language or displayed networks figures and descriptions, but did not expressly address the frameworks.

Table 3.2. Distribution of papers by focus area

Framework Key points	**Concepts actively addressed in article**	**Secondary, passing reference to concepts**
Structural lens (specifically C-P) Densely connected actors at core; actors in outer layers are connected directly to core, but sparse connections to other peripheral actors; The core cannot be easily subdivided Connections are frequently referred to as bonding ties and bridging ties Filtering a larger network to issue-level or smaller geographical area often reveals C-P structure	King 2000[a] Isaac 2007[a] Ernston *et al.* 2009[a] Robins *et al.* 2011 Vance-Borland & Holley 2011[a] Scheinert *et al.* 2015[a] Horning *et al*. 2017/Das *et al*. 2019[a]	Booher & Innes 2010 Smythe *et al.* 2014[a] Hileman & Lubell 2016
Polycentricity Multiple, independent decision-makers at different scales and with different levels of authority Little is said about the structure of outer regions of the network	Ostrom 1961 Hahn *et al*. 2006 Andersson & Ostrom 2008 Galaz *et al.* 2012[a] Morrison 2017[a] Frimpong Boamah 2018 Bissonnette *et al*. 2018[a] Angst *et al*. 2018	Pahl-Wostl *et al*. 2007 Booher & Innes 2010 Hileman & Lubell 2016 Stein *et al*. 2011[a] Horning *et al*. 2017/Das *et al*. 2019[a]
Social Capital Capacities developed through interactions Internal social capital, an outcome of group cohesion, includes development of trust, social norms, and group learning External social capital, an outcome of reach to outside actors, provides information, and can lead to other capacities such as external guidance, funding, and political support	Hahn *et al*. 2006 Isaac 2007[a] Pahl-Wostl *et al*. 2007 Shrestha 2012/2013 Smythe *et al*. 2014[a] Alcañiz & Berardo 2016[a] Levesque et al. 2017[a]	Andersson & Ostrom 2008 Ernston *et al*. 2009[a] Booher & Innes 2010 Robins *et al*. 2011 Stein *et al*. 2011[a] Hileman & Lubell 2016 Bodin *et al*. 2017[a] Ulibarri 2017

Overlapping lenses		
Both C-P & Social Capital	**Polycentricity & Social Capital**	**C-P and Polycentricity**
Isaac 2007[a] Ernston *et al*. 2009[a] Robins *et al*. 2011 Smythe *et al*. 2014[a] Booher & Innes 2010 Hileman & Lubell 2016	Hahn *et al*. 2006 Pahl-Wostl *et al*. 2007 Andersson & Ostrom 2008 Booher & Innes 2010 Stein *et al*. 2011 Hileman & Lubell 2016	Booher & Innes 2010 Stein *et al*. 2011 Hileman & Lubell 2016 Horning et al. 2017/Das *et al*. 2019[a]

[a] *C-P pattern visible in a figure within the document, regardless of whether it is acknowledged by authors*

C-P pattern evident in figure in paper, but no explicit language in any of the three frameworks:
Schneider *et al*. 2003; Prell *et al*. 2009; Walters 2016;

3.4.1. Core-Periphery Structure

The structural approach to the C-P patterns comes primarily through the application of social network analysis to data sets. A network develops and network structures or patterns of ties emerge as more nodes in an actor set become connected. With differing needs or reasons to connect, the number of ties, or degrees, that actors will have with others will be different. The distribution of the number of ties (degrees) across the actors in the network is called network centralization. Centralization is a measure of point-dominance, or the extent to which a few nodes dominate a network (Leavitt, 1951; Freeman et al., 1991). Network patterns are outcomes of where, and how, clusters of centralization form. In mathematical terms, the different network patterns vary in how the degrees are distributed in a network, which is sometimes measured by geometrically weighted degree distribution.

Hileman & Lubell (2018) describe an observed C-P structure as having a highly skewed degree distribution, where a few actors have a disproportionately high number of ties. The core of the structure is characterized by locally dense connections, often referred to as closure. In contrast, the C-P structure's outer regions have very sparse, or open patterns of interconnections. On an individual actor level, a low closeness centrality score denotes that a node is connected to most others in the network, but not necessarily through direct links. Horning *et al*. (2017) use both degree distribution and closeness centrality measurements to further investigate the C-P structures they find. Das *et al*. (2019) model a study of watershed governance communities in two rural British Columbian river basins to test the application of graphlets in social network analysis; basin-level details of the C-P structures they find are explored in a separate paper (Horning *et al*. 2017).

Describing a network's topology, and various methods of measuring the closure, or openness of a network cannot "adjudicate between different types of network formation processes that lead to a skewed degree distribution" (Hileman & Lubell 2018, p. 6). C-P structures are often discussed instead in terms of underlying assumptions of the functions of ties in a network. Isaac *et al*. 2007, for example, note that 84 percent of core members sought information from external sources, which was possibly a bridging function. Indeed, most of the studies reviewed here investigate social dimensions relative to the type of network ties. Angst *et al*. (2018) directly explore role of periphery connector positions in three Swiss water supply networks. Angst and colleagues are explicit in their C-P observations, citing Ernston *et al*. 2008 and some climate change literature to support their statement that C-P structure is commonly observed in governance situations. It is not unusual, however, to find only a passing reference to C-P structure, or a network figure without mention of C-P.

The early 2000s represent an intense period of academic discussions about collective action approaches to managing common-pool resources, adaptive co-management, and resilience. Two early forays into the application of social network analysis to natural resource management are King (2000) and Schneider *et al*. (2003). King's dissertation chapter uses social network analysis to longitudinally map—in three phases—a network's evolution in conflict and problem solving actions in Kenya's coastal Biga community. Network members are blocked using core, semi-core, and peripheral positions, and displayed in obviously C-P networks. Schneider *et al*. compared networks that developed under the U.S. National Estuary Program with ones that did not. Two C-P networks are displayed in their results, though they never use the terms core or peripheral.

Social network analysis has since become a fairly common approach to mapping and evaluating the interrelations of actors in a natural resource system, and is often used as a vehicle for describing the network in general, in which the C-P structure is one of the outcomes. Isaac *et al*. (2007) evaluate the similarity among networks using degree, geodesic closeness, and betweenness measures on four farmer advice networks for transfer of knowledge in cocoa agroforestry systems in Ghana. Isaac and colleagues find C-P structures, and similar density of ties and C-P positions among three categorized networks. Ernston *et al.* (2008) find that the 49-member governance network of the Stockholm National Urban Park in Sweden is also in a C-P structure. Vance Borland & Holly (2011) use social network analysis to evaluate a conservation stakeholder in coastal Oregon. They report a C-P structure, with 104 of the 344 network actors in the core. A particularly interesting observation is that, while the 47 survey respondents constitute only 17 percent of all named participants, named non-respondents make up 60 percent of the networks' core membership.

Some other studies provide us with further evidence of C-P structure, while no elaborating deeply. Booher & Innis (2010) examine California's water planning and management process (CALFED) in terms of a complex adaptive network. They are interested primarily in the internal governance practices and—on a policy level, not a network structure level—the "distributed structure of information and decision making" (p. 1). In passing, and citing Ernston *et al*. (2008), Booher and Innes note that the resulting network resembles a C-P structure. Likewise, Smythe *et al*. notice, but do not elaborate on, the C-P structure of the Greenwich Bay (Rhode Island), and the Great South Bay (New York) marine ecosystem-based management networks.

In the course of this review, I discovered that determining a C-P structure may be a matter of scale. The C-P structure, by nature, cannot be easily subdivided (Csermely *et al*. 2013). This does not mean that the C-P network is not part of a larger patterned network. One well-known larger structure in social networks is a small-world network, which is made up of multiple clusters that are connected by weaker, bridging ties across the structural holes (Burt 2001/2017; Zhang *et al*. 2014). Like Ernstion *et al*. (2011), other authors in this review initially observe multiple clusters in the larger networks they model, only to find C-P structures in finer-grained investigations: Robins *et al*.'s (2009) full network has clusters in three issue areas in the Swan River basin of Western Australia, which reveal distinct C-P structure when filtered to the issue-level. The multi-cluster small-world network in Hileman & Lubell's (2018) investigation across five Central American nations likewise revealed country-level sub-groups with C-P structure. Scheinert *et al*.'s (2015) qualitative case study of Vermont's Lake Champlain Basin watershed governance networks finds their five functional subnetworks all have a C-P structure.

3.4.2. Social capital and network patterns

Social capital is the group capacity gained through interactions. The most-identified external capacity gained via the reach of bridging ties is information. In-group activities increase cohesion, and build norms, trust, group learning, and reciprocity (Lin 1999/2017; Shrestha 2013). Schneider *et al*. 2003 specifically emphasize trust as an outcome of consensual, collaborative institutions for resource governance:

> *We find that the networks in [National Estuary Program] areas span more levels of government, integrate more experts into policy discussions, nurture stronger interpersonal ties between stakeholders, and create greater faith in the procedural fairness of local policy, thus laying the foundation for a new form of cooperative governance* (p. 143).

An alternative conceptualization of social capital is that actors occupying structural hole-spanning positions—especially those with bridging ties that provide the advantage of brokerage to other sectors—access key information and provide the opportunity to exert influence over others (Bodin & Crona 2009). Levesque *et al*. (2017) use network density as a proxy for trust, and degree centrality for power, along with qualitative data from surveys. In a network for conservation of vernal pools in Maine, Levesque and colleagues find that power became distributed to include many non-regulatory particpants, and trust and group learning developed among the resulting dense, heterogenous network, despite deep and polarized divides at the outset of the project.

In the vein of positions of importance, two of our social capital-focused studies concentrate on a central actor as the driver of network formation. In Hahn *et al*. (2006) an ecomuseum is cast as an innovative policy entrepreneur that provides considerable bridging capacities in an ecosystem management network in Kristianstadt, Sweden. Outcomes include a conceptual diagram showing cross-level collaborations that involve actors from citizen level to national and even international partnerships. Actors in the study employ communications strategies ranging from informal contacts to formalized contracts. Hahn *et al*. write that the networks underlying dynamics include variables “like trust building, social capital, strategic collaboration in ad hoc projects/networks, knowledge generation, sense-making, identification of win-win situations, preference formation, conflict resolution, etc." (p. 576). Bodin et al. (2017) compare the effectiveness of networks developed under five different ecosystem-based management plans under a Swedish Environmental Protection Agency pilot program that explicitly mandated a multi-actor collaborative approach. Bodin and colleagues find that the centrally managed networks (Figure 3) vary considerably in internal structure, but produce similar management results. They suggest that a manager can choose to weave connections specifically to maximize towards needed social capital capacities.

Successful collaborations in water resource management networks require a balance of capacities built by bonding and bridging (Berardo 2009; Bodin & Crona 2009). In a comparative study of ecosystem-based marine management networks, Smythe *et al*. (2014) find that a balance of cohesion and decentralization, with diverse and good brokerage for information exchange, are necessary for extensive inter-organizational and interdisciplinary collaboration. Shrestha (2012 & 2013) calculates the balance of internal (cohesion) and external (reach) social capital in networks for rural water supply projects in Nepal. He finds that, "more partners, more indirect reach, and more subgroup cohesion among partners significantly increase the communities' chance of being funded"(Shrestha 2012, p. 321).

Furthermore, an unbalanced trade-off exists between internal and external capacities: a project network with a lack of cohesion, especially in terms of internal conflict, requires relatively more external capital for project success (Shrestha 2012). Alcañiz & Berardo (2016) examine the network structure to analyze the transboundary water cooperation of five South American countries. In contrast to Shrestha, however, Alcañiz and Berardo's networks are, "characterized by a considerable level of bridging capital, rather than bonding capital, with a small group of organizations capturing most of the present links in the network" (p. 1120). Ulibarri & Scott (2017) operationalize social capital concepts of trust, efficiency, and co-creation into measures that link network structure to the collaborative process of relicensing three U.S. dams. The authors find that the high-collaboration case has more concentrated, two-way communications, and a lower tendency for a few actors to dominate. In the low-collaboration case, while two-way communication was lower, the overall involvement was higher. Taken together, the varied study outcomes suggest that different equilibria of cohesion and reach can be effective for outcome success.

3.4.3 Polycentricity

Victor Ostrom's (1961) theoretical inquiry into polycentric governmental organization entered through the case of Los Angeles metropolitan water management makes some bold assertions that could be viewed as background to social network analysis approaches in natural resource governance: "The performance of a polycentric political system can only be understood and evaluated by reference to the patterns of cooperation, competition and conflict that may exist among its various units" (p. 838). With this seminal paper, Ostrom illustrates that governing a region's water resources can occur only with cooperation with a diverse and autonomous mix of organizations and agencies from local citizens to national government agencies, because no single entity can faithfully represent every interest in an issue. Ostrom adds a challenge: that it needs to be shown empirically if centers of decision-making actually function independently or constitute an interdependent system of relations.

Many theoretical papers have been written to build on Ostrom's work, but few use case studies directly apply the polycentric framework to real-world outcomes. Andersson and E. Ostrom (2008) use a comparison of 'decentralized' forestry networks in Bolivia, Guatemala, and Peru to continue the discussion. Anderson and Ostrom suggest that relationships among actors who have a stake in the governance of the resource are the key to effective governance, and call for empirical studies that quantify outcome success. Galaz *et al*. (2012) then use multiple examples from the Global Partnership on Climate, Fisheries and Aquaculture (PaCFA) initiative to propose versions of what they call polycentric order, in degrees, from weak coordination to strong order (Figure 3.2 in introduction). Galaz and his co-authors also call for empirical case studies to test polycentricity theories.

Morrison (2017) takes up the challenge in her longitudinal study of multi-actor and multi-level, polycentric arrangements in governance across the Great Barrier Reef of Australia. Her conceptual representations of the polycentric structure (Figure 3.4) show how regime realignment and a mass coral bleaching event-triggered changes in size, membership, and bonding patterns across three time steps and 35 years. In Baldwin *et al*.'s (2018) examination of the polycentric governance idea in small-scale irrigation systems in rural Kenya they unfortunately use polycentricity as a qualitative independent variable, and do not model the shape of the network.

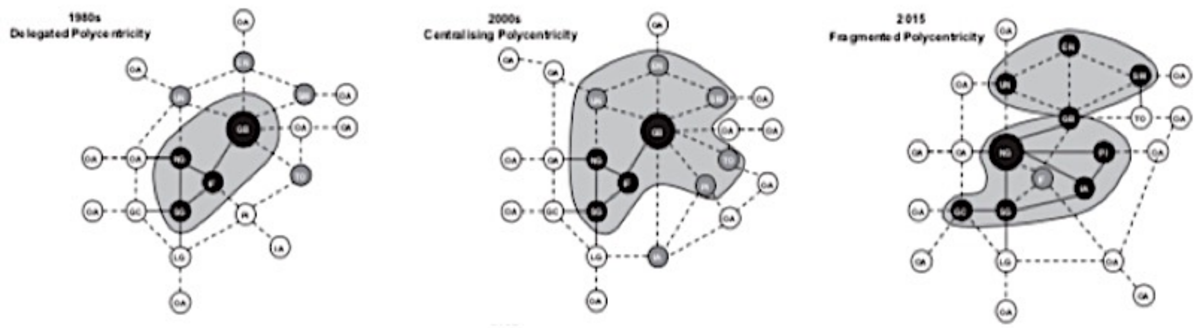

Figure 3.4. A polycentric network in three periods of evolution; adapted from Morrison *et al*. (2017)

Frimpong Boamah (2018) examines the polycentricity of an urban watershed in the Middle Rio Grande using a social-ecological network analysis for identifying scale mismatches between governance and the natural resource system. Centralization indices are used to capture actors' connectedness within islands of polycentric order. In his conclusion, Frimpong Boamah characterizes the area's watershed governance as largely monocentric with only small elements of polycentricity.

In their comparison of two community forest initiatives in the U.S. (New Hampshire) and Canada (Ontario), Bissonette *et al*. (2018) do not break the trend of using a conceptual model of a polycentric governance structure. Their model, however, is a representation of a network of interactions, using weighted arrows to demonstrate the relationships between individual actor types in the configuration (Figure 3.5). Bissonette *et al*. observe that in the New Hampshire case, federal, state and municipal bodies are central actors, but that there is constant interplay with the community forest initiative and recreational interests. In the Canadian case, the involvement of provincial and federal governing bodies appears to limited by mechanisms that favor the forestry, recreation, and education sectors.

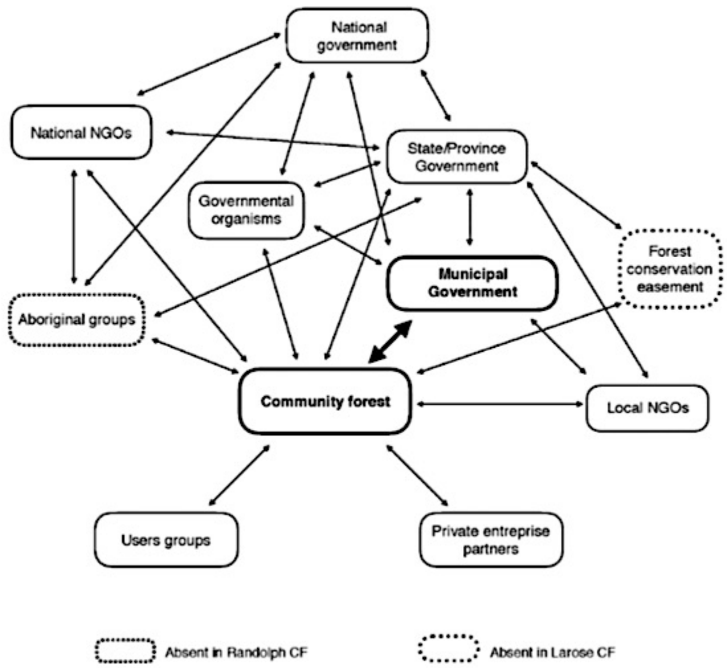

Figure 3.5. A polycentric network representation of two community forest initiatives. Source: Bissonette *et al*. 2018

3.4.3 Overlapping lenses

I began by presenting papers as they fit neatly into one lens of analysis or another. Many of the papers could be re-classified, however, into other frameworks (see Table 3.2), based on the word and figure content alone. To finish this section I examine overlaps in analyses that underscore the fuzzy boundaries between concepts and frameworks.

The assumption that resource governance occurs in the form of a network was almost universal in our study, but different attention was given to network structure. Thirty papers presented the governance interactions as networks, and 24 used some form of social network analysis. Thirteen describe their networks as having cores, and 15 write about actors on the peripheries. Eleven specifically refer to C-P structure, three of which do not accompany their work with a visualization of the network. C-P patterns are visible in fifteen of the 17 case studies distributed throughout this review that include network representation.

In our introduction I sketched the importance of bonding and bridging ties, and similar use of these terms in bonding or bridging social capital. I applied "bridging" in our internal searches, expecting to find applied context in both the typology of connections and the social capital framework. Thirteen of 20 papers that mention social capital, learning, or trust, also use the word "bridging". Bridging was used in 19 papers total. With the exception of Hahn (2006) and Alcañiz & Berardo (2016), I was surprised to find that authors in this study uniformly use bridging only to denote structural attributes, even when they are investigating human dimensions of interactions.

I also introduced polycentricity as an outgrowth term of collective action, but found that the two can by no means be thought of synonymously. Polycentricity has been championed as an ideal (normative) governance outcome of collective action (Ostrom 2010a; 2010b; Baldwin *et al*. 2018). A polycentric structure does not necessarily arise from collective action, however, as we see from the varied use of the two terms. Seventeen studies approach collective action and eleven papers discuss polycentricity in some way, but only seven use the terms together. Galaz *et al*. (2012) pointedly avoid defining features that drive governance along their scale of polycentric order. Morrison (2017) describes the beginning network in the Great Barrier Reef case (Figure 4) as 'delegated', and Hahn *et al.* (2006) note that, "successful collaboration often requires a legal polycentric arrangement" (p. 589).

Pahl-Wostl *et al*. (2007) take aim at the social learning dimension of social capital, as envisioned in the European project HarmoniCOP. But their results fit also with polycentricity, as outcomes support the development of nonhierarchical governance institutions with collaborations of multi-level participants, including government bodies, companies, interest groups, and individuals. Stein *et al*.'s (2011) conceptual model of multi-scale interactions in the Mkindo catchment of Tanzania likewise could fit in polycentricity literature, rather than in the social capital network where they cast it. Their network analysis images (generated in Ucinet) that follow are all clearly C-P structures, and the authors describe the relative position of 16 community groups that low centrality scores and few links to others.

Prell *et al*. 2009, who conduct a stakeholder analysis and social network analysis of a national park in the United Kingdom, present a table of network structure concepts with the social effects in resource management groups. They use tie strength and betweeness scores to determine central and peripheral actors in their system. The network of 147 actors from eight different focus categories shows a C-P pattern, without being subdivided into its constituent pieces. Das *et al*. (2019), who discuss C-P structure, and Schneider *et al*. 2003, who fit in the social capital framework both use language suggesting their work could as easily be placed in a polycentricity framework.

3.5. Discussion

Reviewing the 29 case studies from the lenses of analysis supports our statement that similar patterns appear to exist across the resource governance literature. To what extent, however, can they truly be equated?

Social network analysis is frequently used to evaluate dimensions of social capital in governance scenarios, and several studies display the resulting C-P networks (e.g. Figure 3.2 from Bodin *et al*. 2017). The same cannot be said for polycentricity literature. Galaz *et al*. (2012) and Morrison (2017) present their networks as stylized sketches (Figures 3.3 and 3.4). While the middles of polycentric networks look remarkably like the cores of a C-P structure, little is said about the outer regions of these networks. If, for example, the outer areas of a strong polycentric system truly connect as per Galaz *et al*.'s drawing (Figure 3, panel d), then the C-P structural rules of sparsely interconnected peripheral actors is violated. Unfortunately, polycentricity papers in this review present organizations in conceptual diagrams, and on general, actor-type levels (Morrison 2017; Bissonnette *et al*. 2018), rather than via social network analyses.

Observing the phenomenon of apparent C-P patterns from the structural perspective does not get us closer to an answer. The cores of C-P structures are known to be densely connected, but its structural rules say nothing about the composition or diversity of core actors. However, "[w]ithin a given system of rules, polycentric governance is less about connecting to multiple actors and more about connecting to heterogeneous actors (across multiple sectors and governing scales)." (Frompong Boamah 2018, p.16). In short, a polycentric government arrangement can have a C-P structure, and a C-P network can be polycentric, but the one does not necessitate the other. Echoing V. Ostrom (1961) and Galaz (2012), I conclude that more empirical network studies are in order.

I noted during the review that the study scale, in terms of network size, issue foci, and geographical coverage may play a role in the identification of C-P patterns. Vance-Borland & Holley's (2011) large C-P structured network has 344 actors, whom they further categorize into five focal ecosystem groups: freshwater, terrestrial, estuary, marine, and 'multiple'. While they calculate bridging scores of focus-group actors within the larger system, they unfortunately do not model these sub-networks individually. Given the evidence from other authors (Isaac *et al*. 2007; Robins *et al*. 2009; Scheinert *et al*. 2015; Hileman & Lubell's 2018), it could be expected Vance-Borland and Holley's subnetworks would also have strong C-P scores. On the other hand, the methods that Frimpong Boamah (2018) applies to his study fragments the components into groups of people rather than issue networks, making this comparison impossible. I would like to see a representation or description of the full network.

Our review is limited to case studies because I was interested in how often analyses of natural resource and water governance research discover and describe C-P patterns. I have shown that the C-P pattern is, indeed, prevalent in these resource governance cases. I am also not first in suggesting that a focused synthesis of overlapping terms may be in order, as several of our cases suggest that very idea (e.g. Berardo & Lubell 2016; Bodin 2017; Frimpong Boamah 2017). By reviewing only case studies, I also drop from consideration the many valuable and insightful foundation articles, literature reviews, and discussion papers across the disciplinary fields that inform these very studies.

One call for further synthesis comes from a literature review on adaptive management by Biesbroek & Lesnikowski (2018). They find that adaptive co-management also relies on the collaboration of a diverse set of actors, operating at different levels, through networks from local users to municipalities, to regional and national organizations, and also to international bodies. The sharing of management power and responsibility can involve multiple institutional linkages across user groups or communities, government agencies, and non-government entities. Further, they note:

> *We have demonstrated that whilst adaptation scholarship does not necessarily use polycentric governance theory, but rather adaptive governance, network governance and multilevel governance, the key characteristics of polycentric governance are nonetheless visible in the many cases from across the globe we discussed. Does this mean that adaptation mirrors the polycentric governance model that Ostrom proposed?* (p. 309)

With this in mind, I observe that the community of published studies in this review is, in itself, a small community. It could be sketched as a polycentric, core-periphery network, with many bonding ties that strengthen the collective knowledge and understanding (social capital) of authors in this literature review. Besides forming a tight core of shared knowledge, these authors also bridge to other disciplinary foci through varied co-authorship outside the narrow scope of water and natural resource governance. I illustrate this with an example of a co-authored paper in our review. Galaz *et al*. (2011) is focused on polycentricity: co-author Beatrice Crona is known for her social capital and networks publications with Örjan Bodin, and for work on adaptive co-management with other authors. In other work, Henrik Österblom models social-ecological scenarios in marine systems, and Per Olsson and Carl Folke are known for work in social-ecological systems, sustainability, and resilience literature. Indeed, Nobel Prize winning Elinor Ostrom was married to Victor Ostrom, whose concepts on polycentricity she championed throughout her career. Elinor partnered on various publications with Galaz, Olsson, Folke, and others in this literature review. Except for V. Ostrom (1961), the papers of all three lenses are in similar temporal distributions (Table 3.2), further supporting the idea of co-evolving concepts and theoretical foundations, with extensive cross-pollination among authors.

3.6. Conclusions

With this review I thus fill an important gap in our understanding of resource governance networks. I conclude that C-P patterns do indeed occur frequently in natural resource and water resource governance scenarios. While the C-P pattern is apparently common, it seems that it has escaped notice as a regular feature of these governance networks. As a result, there has been little study of C-P networks as they pertain to resource governance. One problem may be that there is paucity in comparative studies (Jasny and Steven Scheinert, separate personal communications). With the exception of V. Ostrom's 1961 paper, my review encompasses two decades of research from around the world, and finds less than thirty case studies that address the research questions.

I looked at case studies in natural resource and water resource governance that were analyzed from the lenses of core-periphery network structure, social capital, and polycentricity. While I determined that these are distinct and separate frameworks, I find considerable overlap in concepts, analysis, and outcomes. Further studies could address the fuzzy boundaries of terms, and perhaps synthesize where they are, in fact, the same.

Acknowledging the C-P pattern allows future research to ask and empirically examine some key questions: In what ways are the C-P networks similar? What properties cause actors to be in the core of a network? What, if any, differences within C-P networks result in different governance outcomes? Do social interactions among members of similar network structure mean more than the structure itself?

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Chapter 4: 'Suite of roles' as a driver of core-periphery patterns in water resource governance networks [4.1]

Abstract

Reaching out to others in social networks is fundamental to developing communications needed for sustainable water resource governance. We examine governance networks involving water quality and fisheries management within five reservoirs of the Columbia River Basin along the US-Canada border, using a mixed-methods, survey based approach to data collection. Each network exhibits a core-periphery pattern, with a center of multiple, densely connected actors. In a stepwise analysis process, we test the proposition that actor centrality in these networks is driven not by who an actor is, but by what an actor does in a suite of resources, formal, and informal roles.

4.1. Introduction

Water basins are complex social-ecological systems, spanning political, legal, jurisdictional, socio- economic, geographic and biophysical boundaries (Bodin & Ramirez-Sanchez, Prell, 2011). No single player has sole authority in water governance. Rather, it involves a wide variety of organizational players with different organizational agendas (not necessarily conflictual), resources, expertise, and authority. Further, water resource governance requires an adaptive process that addresses both place-based needs of water users and ecological challenges in such complex systems (Folke, Hahn, Olsson, & Norberg, 2005). Network-weaving (Krebs & Holley 2006), or reaching out to others to build and maintain networks of relationships and collaborations, is fundamental to the solving the "perpetual crisis," of water policy (Scholz and Stiftel 2005, p. ix).

Social networks are patterns of relationships among a finite set or sets of actors, which can be presented graphically and are evaluated empirically. Networks for natural resource governance generally self-organize as actors choose to connect or maintain a relationship based on the utility of the contact (Ostrom 2009). Network structures or patterns of ties

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emerge as a network develops and more nodes in an actor set become connected. Collective actions in resource governance result in polycentric collections of independent agencies and organizations from all levels of government and the public that work towards common goals for the good of all (Ostrom 2010).

A core-periphery network structure has high network centrality, with tight centers of densely connected actors or tightly overlapped layers of communities (Yang & Leskovec 2014). Actors in the peripheries are relatively close only to the well connected, and are sparsely connected to other peripheral nodes (Borgatti & Everett 2000; Csermely *et al*. 2013). Network centralization measures the extent to which a few actors dominate, based on individual centrality scores for each node in the network (Scott 2009). Core periphery patterns are not uncommon, and have been observed in collaborative water resource management situations, such as in the St. Joe/St. Maries River sub-basin of Idaho's Lake Coeur d'Alene (Trebitz & Shrestha, unpublished), and all the watershed governance sub-networks studied in Vermont's Lake Champlain Basin (Scheinert *et al*. 2015).

Little research has been done, however, to examine the drivers of core-periphery structures observed in resource governance networks (Smedstad & Gosnell 2013; Kapucu, Hu, & Khosa 2014; Scheinert *et al*. 2015; Jasny & Lubell 2015). Comparative studies of social networks across multiple settings have been rare—due, in part, to a paucity of data sets (Steven Scheinert; Lorien Jasny, personal communications). In this study we focus on drivers of the core-periphery structures observed in 18 networks related to fisheries and/or water quality in the water governance networks of five large reservoir basins of the greater Columbia River Basin. Focus questions in this paper are: *What actor attributes lead to similar core-periphery structure across the five lake basins? By implication, what attributes lead actors to be central in the network?*

Resource dependence theory posits that actions of organizations revolve around important resources (Pfeffer & Salancik 1978/2003). Actor-organizations in water governance seek services or capacities that further their goals in the basin. We propose that centrality of an actor in a network is not based on *who an actor is* in terms of a formal entity or mission, but is a function of how many capacities or roles an actor fulfills in a given network—*what an actor does*. We develop a panel of actor capacities as a *suite of roles* in three sub-categories: *resources*, consisting of data, expertise, funding, political support; *formal*, consisting of dam & resource tenure, regulatory jurisdiction, legal precedent; and *informal* collaborations, communications, and policy entrepreneurship.

We use a mixed-methods approach for concurrent collection of quantitative and qualitative data (Onwuegbuzie & Collins, 2007), in both fisheries and water quality issues across the five reservoir basins. Integrating the results of multiple analysis techniques can result in more complete findings than the individual methods can provide (Haunss, Schmidtke, & Biegoń, 2017). We evaluate our proposition by combining methods in conventional statistics and social network analysis in a stepwise process. We begin with scoping to develop possible actor lists for water resource governance involvement in each basin. We develop and distribute surveys to representatives of actor-organizations in the identified lists. Survey data are used to populate network matrices and to construct elements of the proposed suite of roles. After visualizing the network graphs, we test our assumptions statistically. We test for core-periphery in the Ucinet (Borgatti *et al*. 2002) social network analysis platform. We use the "statnet" package in R for quadratic assignment procedure (QAP) to compare network patterns between and within basins. Finally, we evaluate the suite of roles with Pearson's correlations and Poisson regressions.

4.2. The study – setting and data collection

4.2.1. Study setting

In this study we focus on five large reservoir basins of the greater Columbia River Basin (Figure 1). From its headwaters in the Rocky Mountains of British Columbia, Idaho, and Montana, the Columbia River's mainstem flows nearly 2,000 km before emptying into the Pacific Ocean along the border between Oregon and Washington.

Various stems of the Columbia River system cross, and in some cases, re-cross the U.S.-Canada border. Lakes Chelan, Franklin D. Roosevelt, Pend Oreille, and čłq̓etkw (Flathead) are entirely in three US states, Washington, Idaho, and Montana. Lake Koocanusa extends north from Montana into Canada, with nearly half of its length in British Columbia. Each reservoir in this study is created by or enhanced by a hydroelectric dam. Factors such as major land tenure, dam ownership, water user needs, and water quality and fisheries issues, however, vary between basins. Governance styles range from top-down co-management by dam owners and government agencies to fuller collaborations by a broad variety of actors.

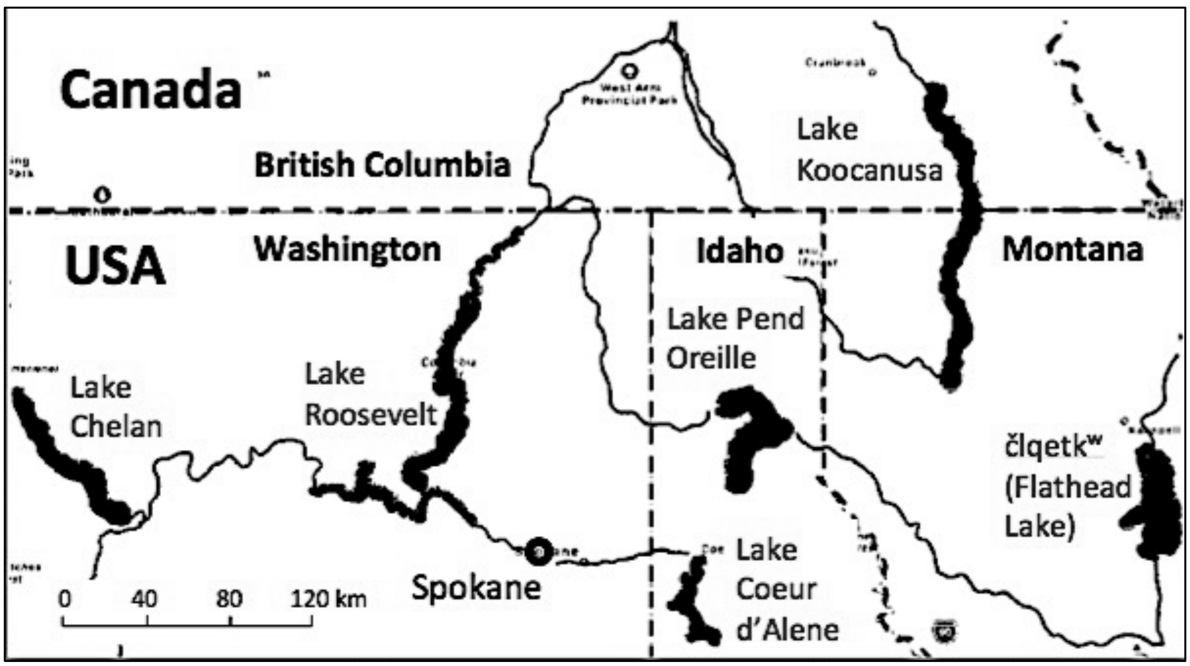

Figure 4.1. Locations of the reservoir basins in this study, from west to east: Lakes Chelan, Roosevelt, Pend Oreille, Koocanusa, and čłqetk^{w} (Flathead). Lake Coeur d'Alene (bottom center) was the setting for the pilot study in this research.

4.2.2. Obtaining network data

Our research used online surveys to collect data in the five Columbia River Basin reservoirs. Following the whole-network study approach, we defined the network boundaries to include all actors who participate in the water governance issues in the five basins, rather than by the basins' watershed delineation. For this research, water governance includes organizations involved in fisheries and water quality management. In our preliminary scoping we used resource management documents (Scheinert *et al.* 2015), website searches, meeting minutes, to identify organizations that are likely to play a role in the basin (Lubell & Lippert (2011).

We first developed a name list of organizations for the five basins. This list included organizations involved in fisheries and water quality management. Study basins are located in different political units such as state or federal (e.g., part of Koocanusa basin falls in Canada). The name list of organizations was standardized by actor type, such as "state-DEQ", to encompass different state departments of environmental quality operating in the five different basins. We identified 59 actor type across the basins, including federal, tribe, state, regional, county, and city government agencies, educational and research institutions, irrigation and utilities, industry, and non-profit organizations.

We reached out to each actor in each basin using a mixed-mode approach (Vaske 2011) of email, phone, in person contacts, and via public forums. Organizations themselves designated the person best qualified to fill our survey. Respondents further identified a few actors that were not included in the original list; adding to it in a form of snowball sampling (Schneider *et al*. 2003). The number of organizations, corresponding to the original actor-types in the list, varied by basin: 38 actor type organizations in Pend Oreille, 35 in Koocanusa, 32 in Flathead, 39 in Roosevelt, and 35 in Chelan.

A total of 75 surveys were filled of 179 across all five basins. An additional 18 actors asserted they have no active involvement in water governance, though some received numerous incoming ties. The response rate, by basin, was: Pend Oreille 51.3 percent, Koocanusa 48.7 percent, Flathead 61.8 percent, Roosevelt 46.3 percent, and Chelan 37.8 percent.

4.2.3. Constructing and visualizing matrices

We used the contacts identified in surveys to construct directed adjacency matrices of basin networks (A reaches out to B, but B does not necessarily contact A). For each basin, we created the combined water governance network matrix first (relating to both fisheries and water quality), as many respondents, marked connections for both networks. Actors indicated whether contacts were for fisheries, water quality, or both. We could therefore also filter each basin matrix to a fisheries-focused network and another focusing on water quality.

Lake Koocanusa presented a unique challenge, as it straddles an international boundary. We created a matrix for Koocanusa once from a Canada/ British Columbia (KBC) perspective, with the Canadian agencies coded as primary federal and state actors, and U.S. agencies as "federal-other" or "state-other". We constructed Koocanusa's basin matrices again with a U.S./ Montana (KMT) perspective, reversing these regulatory actor positions.

Non-responses are highly problematic in network analysis, as they result in missing ties and errors in centrality measures. Imputing missing contacts using the median of 3-nearest neighbors technique, which is based on the smallest calculated (Euclidian) distance of incoming ties to the actors, produces the most reliable results with up to 50 percent missing values (Žnidaršič *et al*. 2017). Following recommendations of Žnidaršič and her co-author Patrick Doreian (separate personal communications), we first reconstructed missing contacts, where possible, using information from archival data and personal communications, before imputing the remaining missing ties. The reconstruction method is supported by data experiments in the pilot study (unpublished) showing strong correlations of the survey-based network and its parallel archive-based network.

The survey showed that some basin networks were comprised largely of government agencies. Both the U.S. and Canada have strong environmental quality laws and standards at national and state or provincial levels for water quality, fisheries, and endangered species, which affect the Pacific Northwest [4.2]. Many U.S. resource laws, such as the Northwest Power

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[4.2] Environmental legislation includes: [U.S.] Clean Water Act (33 U.S.C §§ 1251 et seq.); Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. §§ 1801 et seq.); Endangered Species Act (16 U.S.C. §§1531-1544)**;** Canada Water Act (R.S.C., 1985, c. C-11); Fisheries Act (R.S.C. 1985, c F-14); and [Can.] Endangered Species Act (S.O. 2007, c 6).

Act of 2010 [4.3], require collaborative co-management of resources. Canadian laws are sparse in such requirements, which is reflected in lower diversity of central actors in governance networks (Horning *et al*. 2017). Tribes and First Nations, as sovereigns, operate their own natural resource departments. Regulatory structure coupled with centralized management could lead to dominance of tribal and government agencies in water governance networks. Thus, we first compare the patterns in each reservoir basin based on actor type—*who an actor is*.

4.2.4. Constructing the suite of roles

The main premise of this paper is that central actors in the basin network fulfill multiple services or functions in a suite of roles—*what an actor does*. An actor's suite of roles is defined as having three separate types of roles: resource roles, formal roles, and informal roles. The four *resource* roles are providing data and information, expertise, funding support, and/or political support. The seven *Formal* roles are set by legal framework, including dam, land and resource tenure, regulatory oversight, regulatory obligation, treaty rights, formal agreements and court decisions. Four *Informal* roles of organizations are social dimensions, including technical collaborations, hosting public forums for information exchange, publishing newsletters (print or email) or providing good online information and resources. Expressive leadership (Johnson *et al*. 2003) is defined as the degree to which another organization (or a key person within it) is considered by others to be a policy entrepreneur or "rock star" actor. Each role activity in the categories was assigned a 1 when the activity is present (otherwise 0) in a matrix of actors by roles. This was performed for all basins using data from surveys, archives, and interviews. The sum of the 1s of each actor for each type of role determines the level of each actor's engagement. Counts for roles are: resources roles, maximum = 4, average = 2.8, mode = 4; formal roles, maximum=6, average=0.6, mode=0; informal roles, maximum=4, average=1.3, mode=1.

[4.3] 16. U.S.C., Ch. 12H: Pacific Northwest Electric Power Planning and Conservation Act 838(2) - 838(3)(B), *94 Stat. 2698*

4.3. Analysis

4.3.1. Network visualization

We visualized the 18 network matrices in the UCINET platform for social network analysis (Borgatti *et al*. 2002). We expected to see core-periphery structures across all basins. Visualization of networks reveals differences in the densities and distributions of interactions both between and within basins. Central actors in Figure 4.2 are colored solid black, as blocked by Ucinet's core-periphery test. Chelan and Roosevelt differ in both density and pattern (Fig. 4.2, A and B). Fisheries and water quality networks vary even within basins, as seen in Chelan (Fig. 4.2, C and D). All 18 matrices, however, demonstrate core-periphery patterns.

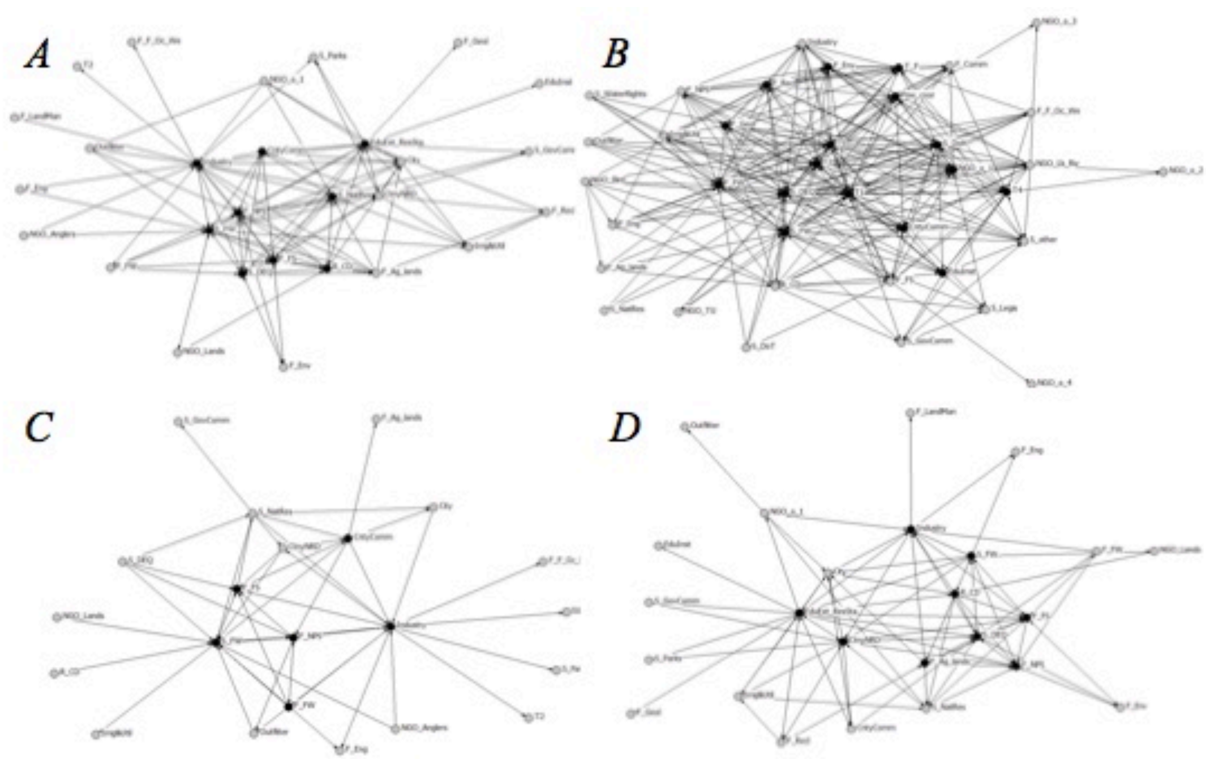

Fig. 4.2. Visualization of select basin matrices shows core-periphery patterns: Chelan's combined focus of fisheries and water quality (A), with the lowest network density (0.040) and Roosevelt (B) with the highest density (0.108). Chelan's fisheries-only network (C) (density = 0.016), and Chelan's water quality only network (D), density = 0.031).

4.3.2. Core-periphery tests

Network centralization measures how much a network is dominated by a few actors (Scott 2009), as can be seen in the core-periphery pattern. Core-periphery tests in UCINET were used to confirm the visual perceptions of the 18 matrices. The categorical core-periphery function in Ucinet uses a generic algorithm to divide actors into core and peripheral membership classes. Ucinet simultaneously fits a model to the network data, blocking the member classes into a 2x2 contact matrix. Networks are correlated relative to an idealized core-periphery structure, where the core-core region is a "perfect" 1-block (all connected), the two core-periphery regions are 1-blocks, and the periphery-periphery region is a 0-block (no contacts)(Borgatti *et al*. 2000) [4.3]. A resulting fit score that approaches 1 corresponds to a strong core-periphery structure (Table 4.1).

Table 4.1. Core-periphery fit (correlation) scores of basin networks. Core-periphery tests consistently confirm visual observations. Chelan's network shows the highest core-periphery correlations; Pend Oreille tends towards the lowest fit.

Network	**PO**	**KBC**	**KMT**	**F**	**R**	**C**
Full (Fisheries & WQ)	0.623	0.696	0.674	0.678	0.688	0.823
Fisheries	0.646	0.651	0.630	0.651	0.714	0.791
Water Quality	0.546	0.725	0.699	0.722	0.644	0.750

4.3.3. QAP correlation of network patterns on actor types

We used the quadratic assignment procedure (QAP) in R to assess correlations between network structures across the basins, as given by actor type. QAP unstrings network matrices into vectors for pairwise matrix correlations. QAP has been used to evaluate watershed governance networks (see Scheinert *et al*. 2015). We used 1,000 permutations to determine statistical significance (Butts 2008).

The QAP correlation results do not support similarity in network structure based on actor types. The highest correlations occur between Koocanusa, Canadian perspective (KBC) and

[4.3] Ucinet provides no p-value for fit scores, and does not always partition networks into the most optimal core-periphery structure; resulting correlations are found to be accurate in some cases, low in others (Boyd *et al.* (2006).

Koocanusa U.S. perspective (KMT) 0.275 (fisheries), 0.287 (water quality). The lowest correlations are KBC with Flathead 0.001 (fisheries) and 0.043 (water quality). Both network visualizations and Ucinet's core-periphery block models show different actors in the network cores.

4.3.4. Poisson regressions on the suite of roles

In testing the suite of roles argument we are interested in how well individual categories of roles, and the entire suite of roles explain high indegree centrality scores of core actors in the core-periphery structures of the five basin's water governance networks.

Prior to conducting Poisson regressions, we ran Pearson's correlation coefficient between actor indegrees and the roles categories (resources, formal, informal). Correlation values range from moderate to strong on combined networks (fisheries plus water quality networks), but are more variable in the issues networks: The resource category correlates weakly with indegree in Flathead's fisheries network (0.396) and well in Chelan (0.751, also fisheries). The formal roles category has its minimum in Pend Oreille (0.513, water quality) and maximum in Koocanusa (0.799, fisheries). For informal roles, the range is 0.465 (Chelan, fisheries) to 0.736 (Chelan, water quality).

As the final test, we used Poisson regressions to examine effects of the suite of roles on centrality of actors. For the dependent variable we used the measure of "indegree", or actors with the most incoming ties (receiving a message or inquiry), as a proxy for being more central in the network. Indegree is a count measure, satisfying the first assumption of Poisson regressions models (Legler & Roback 2015). Possible indegree in each basin is N-1 contacts. For the independent variables we used the three role types (resources, formal, informal). In our case, high indegree (popular) actors are often highly active communicators, thus also having high outdegrees. Since popularity and activity are different phenomena, yet correlated, we included outdegree of actors as a control in our model. We also tested for potential multicollinearity of the independent variables.

Table 4.2 presents the regression results for effects of the suite of roles on indegree centrality on the aggregate of all five basins types on both fisheries and water quality, while controlling for outdegree. All three roles demonstrate positive effects on indegree, with statistical significance. Outdegree is also related, but with small effect sizes.

Table 4.2. Poisson regression estimates explaining indegree centrality in aggregate across all basins. R-square is Nagelkerke

Variable	**Fisheries all basins**	**Water quality all basins**
(Intercept)	-0.37 (0.15)*	-0.02 (0.13)
Resource	0.43 (0.05)***	0.37 (0.04)***
Formal	0.22 (0.03)***	0.22 (0.02)***
Informal	0.12 (0.04)**	0.18 (0.03)***
Outdeg	0.04 (0.01)***	0.03 (0)***
R-square	0.98	0.98
N	179	179

*Sig. codes: 0.00 '***', 0.001 '**', 0.01 '*' 0.05*

The tendency for the role category variables to be important factors remains across all reservoir basins, even when separated by basin. The effects sizes and significance levels vary by basin and network focus, however. In the fisheries-focused networks (Table 4.3), the resource roles are important factors in all but Flathead basin. Formal roles affect all networks except Chelan. Informal roles are especially important in Flathead basin, but not in the other four. The control variable, outdegree, has small effects in Roosevelt and Chelan.

In the water quality-focused networks (Table 4.4), resource roles affect the indegree in all networks. Formal roles, again, are important in all basins except Chelan. Informal roles are the most highly variable factors in the networks with effects in Pend Oreille and Roosevelt. We removed informal roles from the model for just the Flathead water quality network because of multicollinearity of the informal with the formal roles variable. Modeling either without the other produces similar, highly significant results. Outdegree again has very small, but significant effects.

Table 4.3. Poisson regression estimates explaining indegree centrality, by basin, for fisheries networks; *R-square is Nagelkerke*

Variable	**Pend Oreille**	**Koocanusa**	**Flathead**	**Roosevelt**	**Chelan**
(Intercept)	-0.84 (0.33)*	0.00 (0.29)	0.17 (0.62)	0.24 (0.31)	-1.32 (0.47)*
Resource	0.52 (0.1)***	0.4 (0.09)***	0.27 (0.18)	0.33 (0.09)***	0.47 (0.16)***
Formal	0.4 (0.08)***	0.25 (0.1)*	0.16 (0.05)***	0.22 (0.05)***	0.53 (0.24)
Informal	0.16 (0.09)	0.14 (0.09)	0.25 (0.08)**	0 (0.1)	-0.29 (0.21)
Outdeg	0.03 (0.01)	0.02 (0.02)	0.02 (0.01)	0.04 (0.01)***	0.17 (0.05)***
R-square	0.99	0.98	0.88	0.98	0.916
N	38	35	32	39	35

*Sig. codes: 0.00 '***', 0.001 '**', 0.01 '*' 0.05*

Table 4.4. Regression estimates explaining indegree centrality, by basin, for water quality networks; *R-square is Nagelkerke*

Variable	**Pend Oreille**	**Koocanusa**	**Flathead**	**Roosevelt**	**Chelan**
(Intercept)	-0.1 (0.25)	0.17 (0.29)	0.76 (0.47)	0.02 (0.31)	-0.73 (0.33)*
Resource	0.42 (0.08)***	0.31 (0.09)***	0.25 (0.13)*	0.35 (0.09)***	0.4 (0.11)***
Formal	0.23 (0.07)***	0.24 (0.09)*	0.22 (0.04)***	0.23 (0.05)***	0.27 (0.16)
Informal	0.31 (0.08)***	0.13 (0.08)	†	0.2 (0.09)*	0.08 (0.1)
Outdeg	0.01 (0.01)	0.05 (0.02)**	0.04 (0.01)***	0.03 (0.01)**	0.1 (0.03)***
R-square	0.97	0.98	0.9	0.97	0.969
N	38	35	32	39	35

*Sig. codes: 0.00 '***', 0.001 '**', 0.01 '*' 0.05*
† variable dropped due to multicollinearity issues

4.4. Discussion

Both network visualization and core-periphery analyses found the presence of core-periphery governance network structure in all five basins. It is notable that no single actor is central, rather a group of core actors, is in the apex of the basin governance. The core actors are diverse organizations acting collaboratively for collective wellbeing, reflecting a Ostrom's (2010) polycentric system of governance. Densely connected core groups create a condition for the core actors to regularly consult when making decisions. The mechanism also allows them to build social capital as information flows quickly through overlapping ties among the core actors. Links between the peripheral and core actors create governance systems that provide opportunities for peripheral actors not only to participate but also to voice their interests or concerns via core actors.

As to what drives basin actors to be at the core of the network, a very low correlation observed between structurally similar core-periphery networks across all basins shows that the actor type—who an actor is—has less to do with it. Since all five basins have core-periphery network structures, significance of actor type defining network of ties would reflect in high correlation across the basin networks. However, that was not the case.

Analysis results support our premise that the emergence of core actors in the networks of the study basins is driven by filling multiple roles—what an actor does. A generally high correlation between the suite of roles and indegree centrality of actors suggests that, when making the choice of partners, actors care deeply what those partners have to offer to meet the governing challenges of the basin. Actors tend to rely on organizations that play multiple roles, have greater capacity, or can shoulder more responsibility. This mechanism can lead to a highly centralized network with a dominant central actor, but in this study, basin networks are characterized by the presence of multiple central (core) actors. This implies that actors in the basins favor a group of core (central) actors that encourages greater consultation and collaboration in the network.

4.5. Conclusion

Our research shows that lake basin governance in the Columbia River Basin is characterized by core-periphery network structure, and the centrality of actors in the network is driven by what actors do rather than what actors are. In this research, we examined three types of roles – resource roles, formal roles, and informal roles. We used social network analysis and conventional statistical analysis in a stepwise manner to examine our proposition that roles matter. The significance of each type of roles varies across the basins. While more study is needed for better understanding, part of the variability appears to be associated with the size and composition of the core actors and how roles are distributed across these actors. Variability in actor composition and network evolution appears to stem also from geographic, cultural, and historical contexts of each basin. Further, even within the fisheries or water quality networks, multiple sub-issues are specifically addressed by smaller sets of specialized actors.

Core-periphery structure in collaborative water governance is not uncommon; yet, the literature is scant, or limited to a single basin. This research contributes to this literature by highlighting the presence and importance of core-periphery network structures in multiple lake basins. We were able to observe the network governance structure in the basins at one point in time. Variability in actor composition and network evolution could stem in part also from geographic, cultural, and historical contexts of each basin. It is possible that the governance structure changes with time, requiring the study of basin networks over time. In addition, five basins still are a small number study limiting the generalizability of the results. Future research should address these limitations. Adding other basins to the study may reveal similarities in network characteristics of central actors, such as organization size, or defining features that are individual, and distinctly different between the basins.

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Chapter 5: Relating social networks, ecological health, and reservoir basin governance [5.1]

Abstract

The Columbia River Basin is a complex social-ecological system, spanning political, legal, socio-economic, geographic and biophysical boundaries. Outreach to others in social networks develops fundamental communications needed for sustainable collaborations in adaptive management. However, operationalizing and comparing measures of social processes and outcome success in biophysical indicators remains challenging for resource managers. Using survey-based research, we examined the interactions for water resource governance of five Columbia River reservoir basins in the northwestern US and Canada: Lakes Chelan, Roosevelt, Pend Oreille, Koocanusa, and čłq̓etkw (Flathead). Respondents included: water resource professionals working for Tribes/First Nations, federal, state, or provincial departments in water quality and/or fisheries, and people who engage in the networks on behalf of area businesses, government offices, public services, non-profit organizations, and other entities. Perceived social process metrics in these governance networks included the levels of collaboration and inclusiveness, common goals, common strategies, identifying issues, implementing action, and the adequacy of available scientific data. We evaluated social measures relative to participant-reported changes in physical lake health indicators. Qualitative data enhanced understanding of basin-specific differences. Correlations of social by ecological measures varied widely between basins. Even moderate to strong functionality parameters did not scale well from individual to cross-basin levels, as many correlations vanished with data aggregated. However, data analysis at the basin scale revealed important variability across the region in scope and governance functionality. Process indicators such as identifying issues and implementing action yielded stronger relationships for 10-year horizons than for two years, reflecting the lag-time in resource action.

[5.1] Co-authors: Karen I. Trebitz & J.D. Wulfhorst. This article was recommended for publication, with minor edits, at the time of dissertation submission, in *River Research and Applications*.

Key words, search terms etc.: Lake basin governance, social-ecological systems, collaboration, adaptive co-management, performance indicators, governance scale

5.1. Introduction

In 1996, C. S. Holling advocated designing resource management models focusing on the interrelationships between people and resources rather than yield productivity. Berkes and Folke (1998) used the term "social-ecological systems," to stress the integration of humans and nature (Folke *et al*. 2006) in an effort to better capture relationship dynamics between these often compartmentalized domains. Elinor Ostrom (2007, 2009) introduced the Social-Ecological Systems framework as a complex, multi-level hierarchy of interacting variables of human and environmental systems. In this model, resource users behave within governance systems that define the rules to compose the social system, and its many interactions with the ecological health of natural resources in question, including both positive and negative feedback loops (Binder *et al*. 2013). Specifically, in water management regimes, governance constitutes a key structural dimension to manifest decision-making institutions and actors for (Pahl-Wostl 2007).

Yet, governance and governance efficacy remain bounded by the resilience of rarely-measured and often unaccounted-for social networks coupled to resource distribution and ecological management needs. Calls for adaptive governance approaches to watershed management emphasize transparency, participation, and accountability—all dimensions embedded in the social networks of the systems (Akamani & Wilson 2011). Multiple studies demonstrate water resources governance in the context of adaptive co-management, especially in terms of social dynamics (Chaffin *et al*. 2012; Blackstock *et al*. 2012). Operationalizing social measures with physical outcome measures has proven challenging (Leslie *et al*. 2015). Comparative studies of social networks across multiple network settings remain rare (Smedstad & Gosnell 2013; Kapucu *et al.* 2014; Jasny & Lubell 2015; Leslie *et al*. 2015). This manuscript analyzes the role of social networks specific to water resource governance within multiple water basins at a regional scale as a basis for evaluating governance scenarios within social-ecological systems.

In this context, our fundamental research focus queries: how do governance networks measure social dimensions of their effectiveness to enhance normative values of ecological health, operationalized in this case as fisheries and water quality? The study correlates measures of the perceived internal dynamics of water governance networks in implementing water resource policy with perceived outcome variables of lake health indicators in the management of five Columbia River reservoir basins. The analytical results demonstrate that nuances of cross-scale variability matter significantly to governance design and implementation for water resources management, and more generally, ecological systems.

5.2. Setting

A complex international social-ecological system, the Columbia River Basin overlaps the U.S. and British Columbia and contains the lands of 15 aboriginal Canadian First Nations. The Basin additionally encompasses portions of seven US states and 15 US Tribal Nations. During the twentieth century, engineering projects substantively modified the Columbia River Basin's ecosystem. The resulting infrastructure put the basin's waters to use by generating electrical power, enhancing navigation, developing expansive irrigation, and controlling floods, but also notably led to the virtual extirpation of the historically vast salmon runs.

Five sub-basins of the Columbia system inhabit a geographic transect along the US-Canada border, and share similar ecology, climate, and human demographics. Each contains a hydroelectric dam and a resultant reservoir. These basins (Figure 5.1) provide the opportunity for a unique cross-basin study of water resource governance.

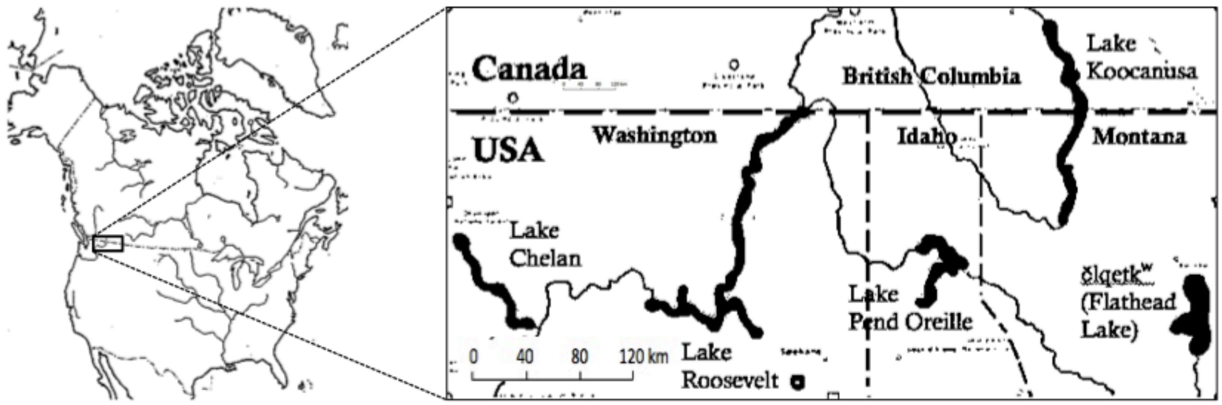

Figure 5.1. Locations of the five reservoirs in the study area, and relevant inter-connecting river sections of the upper Columbia River Basin.

5.3. Methodology

5.3.1. The study

In a review of 120 articles reporting empirical results on social-ecological systems, Rissman & Gillan (2016) found that only 8 percent of these manuscripts rely on quantitative correlations to link social and ecological variables. Following Rissman & Gillan's suggested use of methodological pluralism, this study is rooted in a mixed-methods approach to social science research (Creswell & Piano Clark, 2017). The analysis includes quantitative survey data and qualitative key-informant data collected concurrently during scoping meetings for survey recruitment, analyzed, and synthesized for a more integrated set of results and findings.

We surveyed representative actors who collectively constitute the governance networks for the five reservoir basins. Communication linkages to accomplish water resource governance define the networks boundaries, rather than using the basin's physical boundaries. Scoping to find network actors used: resource management documents, website searches, published minutes from meetings, and extensive personal outreach for identifying organizations that play a role in the governance of each reservoir basin (Lubell & Lippert 2011; Scheinert *et al*.

2015). Following Kapucu *et al*. (2014), the actor-list in each basin included: agencies, organizations, government entities, and local and regional businesses, as well as indigenous tribes and non-governmental organizations.

5.3.2. Survey design & key-informant meetings

We administered the online surveys via the Qualtrics™ platform. We adapted questions from a pilot study conducted in the Coeur d'Alene Basin in Idaho (Trebitz & Shrestha, unpublished) and Lubell's (2014) California Delta Water Management Survey. Survey content remained identical for all lake basins, except for the available actor list in the network section. Question design oriented responses to ordinal Likert scales, the most commonly used psychometric measurement for self-reporting (Wakita *et al*. 2012).

Five general sections comprised the survey instrument ranging from organizational and individual biographical information to public engagement. This manuscript focuses analytically on portions of select sections: measuring physical indicators, and metrics of network function and success (see selected survey instrument items in Appendix E).

Each organization identified a qualified representative—with a focus in fisheries or water quality—to complete the survey in the context of their basin. Multiple email reminders prompted non-respondents for completion of the surveys.

Information gained from personal outreach to selected actors in each initial network list augmented the network roster and enabled the start of a key-informant list for scoping meetings and survey respondent recruitment. Within the survey, many within the basins elaborated their responses with invaluable place-based context and supplemental networking suggestions to further the research. A series of 30 scoping meetings supplemented the survey data in order to recruit respondents and enrich survey results through contextual interpretation (Creswell & Piano Clark 2017).

Lake health indicators

This survey block targeted indicators of fishery and water quality health most commonly used by members of governance networks and enabled local variability. Inconsistencies often exist in measurements, quality control, and reporting for ecological indicators data such as water quality measurement records (Sprague *et al*. 2017). Due to the variable access participants have to physical data, we asked about individuals' perceived measures of lake health.

Measuring ecosystem well being in a social-ecological system has challenges to cut across cultures and disciplines. The *Mauri* Meter (see Morgan 2006; Sterling *et al.* 2017) provides a metric to capture elements of those dynamics, and we adapted it here to measure ecosystem indicators on a zero-center, five-point Likert scale. Using *Mauri* Meter assessment, the scale of an ecosystem's health ranges from -2 (totally denigrated) to +2 (fully restored). This scale has an advantage by allowing for inclusivity and applying the same metric to measure all indicators, whether physical or perceived (Sterling *et al.* 2017). See the survey instrument items in the Appendix E for operationalization of key indicator variables.

The network, or "who interacts with whom"

Each survey tailored the network section to customize the list of actors by basin, in which respondents identified whom they interacted with in the past two years. The survey organized participant lists into tables of actor types: agencies, organizations, indigenous tribal and government entities, as well as local and regional businesses, and non-governmental organizations. Write-in options provided the opportunity to add to the network lists.

Measures of governance network function

As an alternative to an exclusive reliance on quantitative methods, analysts of watershed governance frequently use perceived success as a proxy for measuring outcomes of collaborations (Dakins *et al*. 2005; Chaffin *et al*. 2011). The network process section of the survey used Likert scale questions to assess individual respondents' perceived effectiveness of their particular governance networks to meet water quality enhancement and fisheries health goals. Given lag-time between planning, implementation, and ecological responses, we asked for perceptions on both 2-year and 10-year horizons.

We also measured social dimensions of group processes as fundamental to decision-making and governance effectiveness. We asked respondents' perceptions about the group's level of collaboration, as "adaptive management without collaboration lacks legitimacy" (Berkes 2009, p. 1698), and to what extent groups could find common goals and employ common strategies especially in contexts of change and uncertainty (Whaley & Weatherhead 2016). Most collaborative groups maintain political inclusivity to explore value and position differences of demographics, scales, and knowledge bases (Smedstad & Gosnell 2013, Blackstock *et al*. 2012). We asked respondents to rate 'helpfulness' of currently available scientific knowledge and data, as weakness in information (e.g., insufficient data) can hinder exchange in collaborative action (Genskow & Wood 2011), as well as confound self-organizing and coordinating capabilities needed in complex cross-scale governance scenarios (Karpouzoglou *et al*. 2016). Water resource managers contacted during the scoping phase of this research additionally emphasized the need to first identify issues, and subsequently, to implement action.

5.3.3. Data analysis

We evaluated survey responses both as aggregated data added together from all respondents from all five basins, and filtered by individual basin. Of 190 identified "possible" actors across all five networks, 39.5 percent (n = 75) completed the survey. An additional 18 (9.5 percent) claimed inactivity in the basin, which does not preclude receiving ties from other actors. We included actors with no contacts in the networks (isolates) in the total count response summary for all basins (Table 5.1), though they may not all be part of the active basin governance networks.

Table 5.1. Response rates by basin. Inactive organizations assert that they have no active, outgoing ties, but they may nevertheless receive communications form others.

	Network size	Surveys filled		Stated "not active"		Responses overall (surveys + "not active")	
	N =	n =	rate (%)	n =	rate (%)	n =	rate (%)
Pend Oreille	39	17	43.6	3	7.7	20	51.3
Koocanusa	39	16	41.0	3	7.7	19	48.7
Flathead	34	18	52.9	3	8.8	21	61.8
Roosevelt	41	16	39.0	3	7.3	19	46.3
Chelan	37	8	21.6	6	16.2	14	37.8
Actors all basins	190	Ave:	39.5		9.5		48.9
Total surveys filled	75						

Pearson's correlation tables provided a basis to evaluate the interrelations of physical and social metrics. The three groups tested included: (i) measures within the social dynamics set; (ii) physical indicators of lake health; and, (iii) physical indicators by social measures. While all social measures received enough responses to determine statistical significance, not all physical indicators did. In filtering to basin-level analyses, we dropped metrics receiving fewer than four responses in a basin from evaluations in that particular basin (see Onwuegbuzie & Collins 2007). Data for all calculations in are contained Appendix F.

5.4. Results

Results report a synthesis of findings from the combined survey data analyses and supplementary outcomes noted via the key-informant scoping meetings.

5.4.1. Communication networks

Communication networks are defined as a set of actors (nodes) connected by their interactions (ties). We constructed networks for each basin, using frequency measures from survey responses to weight contact ties. Networks ranged from 27-41 potential actors. The networks in all five basins demonstrate a core-periphery pattern, with a group of densely connected actors at the center of the system. Other actors generally communicate directly with the central actors, but with lower frequency. These peripheral actors, on average, maintain fewer communications with each other.

In addition to sharing a network structure, all but one network in this study have approximately the same number of connected actors and density of connections (ranging from 0.22 to 0.36 on a scale of zero to one). Lake Chelan's network showed sparse connectivity (density = 0.09), with seven actors left without connections to the network. This likely reflects Lake Chelan's physical position away from the main stems of the Columbia River, and a public utility district that has delivered power to the community since 1947 (Chelan PUD 2014), independent of the system of federal dams.

5.4.2. Social indicators and their interrelations

Measurements of perceived social variables showed interrelation, though only the ability to identify issues and to implement actions were highly correlated (0.79 on a 2-year and 0.83 on the 10-year planning horizon). Responses in surveys on individual questions varied substantively within the 10-point Likert scales. For example, perception of the helpfulness of available scientific data, despite positive correlation with all the process variables, had a varied distribution. This finding emphasizes the importance of data accessibility impacts—and in some cases, more importantly than data quality—on collaborative governance and network cohesion. As one participant noted:

> *In a few situations, data is not willingly shared between agencies or tribal parties. In those situations, it can be incredibly frustrating to provide the best collaboration and doesn't build trust between the groups.*

In-group dynamics results, higher inclusiveness in the network related to greater collaboration, issue identification, and action implementation. The perceived level of collaboration in the network correlated positively with all other group process measures. Results showed that having common goals and employing common governance strategies is not synonymous. Similarly, the ability to implement action does not necessarily follow from the ability to identify issues; an especially apparent disconnect in results for Lakes Pend Oreille and Flathead.

5.4.3. Physical indicators

Most respondents completed filled the network dynamics section, yet showed selectivity about marking physical indicators. This reflected organizations' types and missions, individual disciplinary backgrounds, and direct knowledge of the system. Response numbers additionally varied due to conditions and management needs in individual reservoir basins. Response counts on individual physical indicators in the aggregate data set ranged from 8 to 43; we thus report trends rather than statistical significance for the paired correlation calculations.

Scores varied on physical indicators even within individual basins. Both positive and negative responses occurred for perceptions of change on an indicator in a particular basin. The correlations on conceptually interrelated ecological indicators showed similar patterns *within individual basins* despite some individual respondent variability, and much stronger than those correlations identified in the aggregated data. This suggests consistency in how respondents perceive various dimensions of fisheries and water quality indicators within the context of their own basin.

5.4.4. Correlating physical indicators with the social dynamics

Correlating lake health indicators with social process measures in the aggregated data set remained inconclusive (Figure 5.2, panel A), especially given the literature supporting the use of social process as a proxy for measuring outcome success. Many relations, though only weakly correlated, moved in the opposite direction from perceptions of network processes. The ability to control turbidity, nutrient levels, algal blooms, and the inflow of toxins from human industry such as mining showed linkages to conflicting relations. Also addressed within the scoping meetings, one respondent noted:

> *It's very difficult to collaborate when industry wants a green light to compromise water quality and potentially the health of the fishery.*

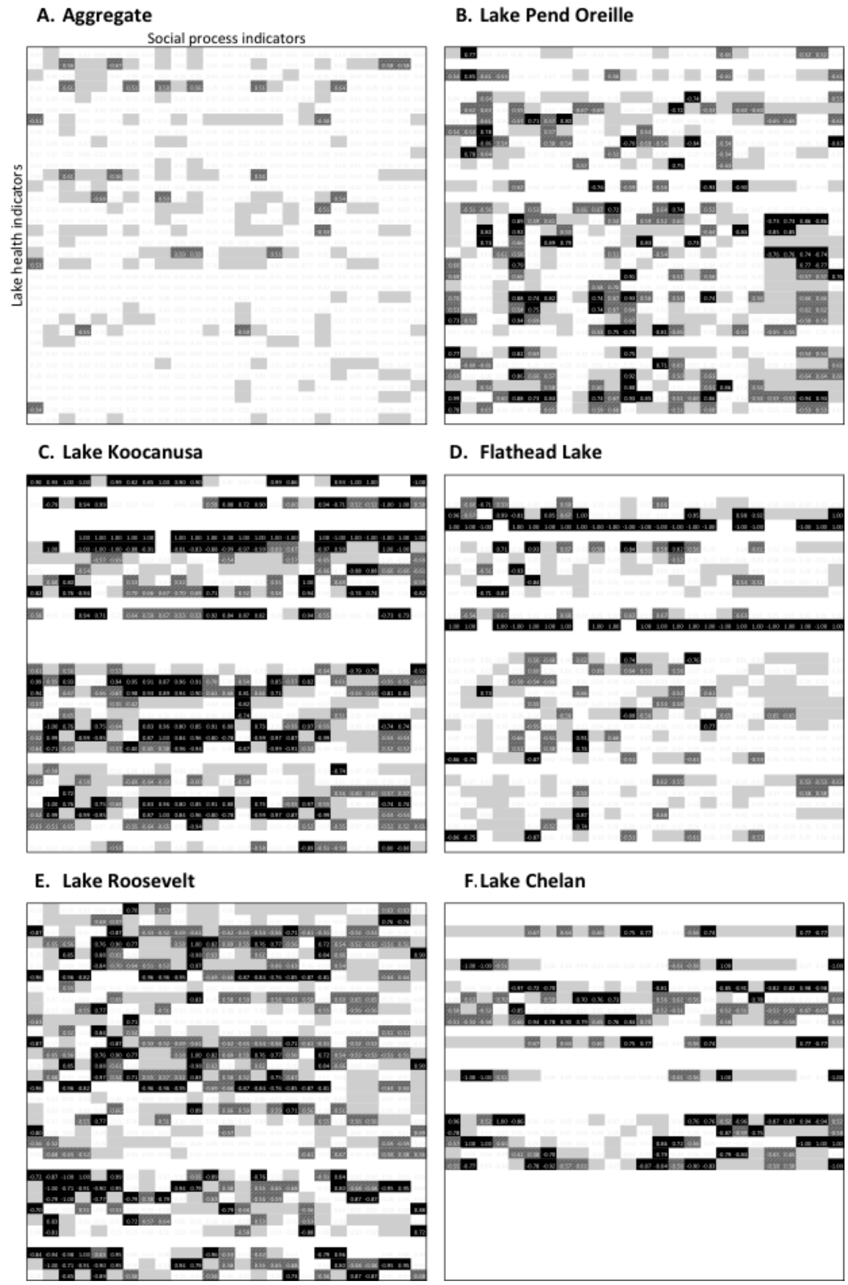

Figure 5.2. Correlations of lake health indicators (x-axis) and social process indicators (y-axis) for aggregate data (A) and individual reservoir basins (B-F). Correlations: light grey = weak (+/- 0.30 – 0.49), dark grey = medium (+/- 0.50 – 0.69), black = strong (≤ -0.70; ≥ 0.70). Data removed for indicators with fewer than four responses in basin.

The complexity of watershed planning became especially evident in relating responses on governance action on fisheries indicators across the aggregated data. While the ability to identify issues in a two-year window had little relation with any of the fisheries indicators, action implemented in the same period correlated positively with improved spawning habitat and riparian zones. The fish size and weight measure, concerns also noted in Columbia River Basin reports, exhibited negative correlation with many social process indicators.

In contrast to the remarkably flat correlations in the aggregated data, filtering the data to individual reservoirs delivered robust results. Moderate to strong relations emerged, even after eliminating variables with low response numbers in given basins (Figure 5.2, panels B-F). Closer inspection revealed that these correlations varied substantively by basin and focus area, and in cases, relationships in opposite directions.

We reduced data analysis further, narrowing to the seven social variables of group processes discussed in the methods section: (i) adequacy of scientific data; the level of (ii) collaboration; (iii) common goals; (iv) common strategies; and, (v) inclusiveness. Both water quality and fisheries have considerable lag time in management actions versus system responses. Thus, the ability for the network to (vi) identify issues and to (vii) implement action were assessed on both 2-year and 10-year spans (Figure 5.3, panels A-F).

We selected physical indicators by the criteria of having response data in at least three of the five reservoir basins. This filtering reduced the physical measures to five fisheries indicators and five water quality measures. Eight of these indicators have commonality throughout the US and Canada, and are addressed in the USEPA's *Rapid Bioassessment Protocols* for wadeable streams and rivers (Barbour *et al.*1999). Fish quotas operate as a function of the numbers of fish available for catch in a sustainable fishery. Stabilizing lake levels has special concern in reservoirs, where fluctuating lake levels from dams operations can greatly impact riparian zones and spawning habitats.

A. Aggregate

	Resp. $\bar{x}$	Scientific data	Collaboration	Common goals	Common strategies	Inclusiveness	Identify issues_2-yr	Identify issues_10-yr	Implement action_2-yr	Implement action_10-yr
Available food	0.0	-0.34	0.20	-0.10	-0.16	-0.13	0.05	-0.18	0.02	0.11
Fish quotas	0.4	-0.08	-0.01	0.28	0.06	0.17	0.21	0.13	0.23	0.12
Control invasives	0.2	0.24	0.04	0.02	0.19	0.09	0.14	0.13	-0.02	-0.04
Riparian zones	0.6	0.11	-0.03	0.23	0.28	0.06	0.08	0.33	0.32	0.30
Ecological flows	0.2	0.27	0.09	-0.07	-0.12	0.01	0.08	0.17	0.07	0.21
Lake levels	0.0	0.01	-0.04	-0.18	0.05	-0.06	-0.17	-0.02	0.02	0.02
Temperature	-0.2	0.13	-0.04	-0.12	0.16	0.06	-0.07	0.09	0.08	0.09
Turbidity	0.0	0.07	-0.33	-0.33	0.01	-0.22	-0.25	-0.05	0.19	0.09
Nutrient levels	0.0	-0.03	-0.41	-0.34	-0.18	-0.18	-0.31	-0.15	0.03	-0.03
Control algae	0.0	-0.06	-0.16	-0.50	-0.34	-0.28	-0.22	0.21	-0.14	0.26

B. Pend Oreille

	Resp. $\bar{x}$	Scientific data	Collaboration	Common goals	Common strategies	Inclusiveness	Identify issues_2-yr	Identify issues_10-yr	Implement action_2-yr	Implement action_10-yr
Available food	0.3	0.54	0.13	-0.32	-0.18	0.29	0.02	0.06	0.36	0.56
Fish quotas	0.0	-0.14	0.18	-0.47	-0.72	0.20	0.06	-0.69	-0.67	-0.43
Control invasives	0.7	0.54	0.57	0.13	0.16	0.64	0.49	-0.10	0.27	0.35
Riparian zones	0.4	-0.39	-0.58	-0.54	-0.32	-0.69	-0.54	0.28	0.15	0.11
Ecological flows	0.8	0.47	0.18	-0.24	-0.15	0.33	0.03	0.05	0.28	0.52
Lake levels	0.0	0.35	0.13	0.00	0.05	0.25	-0.20	0.58	-0.09	0.70
Temperature	-0.2	0.70	0.82	-0.15	0.53	0.56	0.04	0.74	0.45	0.67
Turbidity	-0.1	0.53	0.42	-0.21	0.50	0.27	-0.12	0.74	0.17	0.67
Nutrient levels	0.2	0.73	0.46	-0.26	0.38	0.38	-0.36	0.28	0.24	0.46
Control algae	0.1	-0.17	-0.20	-0.81	-0.65	-0.48	-0.33	0.53	-0.13	0.75

C. Koocanusa

	Resp. $\bar{x}$	Scientific data	Collaboration	Common goals	Common strategies	Inclusiveness	Identify issues_2-yr	Identify issues_10-yr	Implement action_2-yr	Implement action_10-yr
Available food	-0.5	-0.05	0.17	0.72	0.90	0.88	0.14	0.01		0.02
Fish quotas	NA									
Control invasives	0.0	0.44	0.36	-0.32	-0.46	-0.54	0.23	0.39	0.22	0.29
Riparian zones	1.0	-0.05	-0.28	-0.41	-0.46	-0.45	-0.37	-0.29	-0.39	-0.33
Ecological flows	0.0	0.39	0.53	0.20	-0.17	-0.20	0.39	0.52	0.19	0.40
Lake levels	-0.2	-0.28	-0.47	-0.74	-0.29	-0.02	-0.22	-0.23	-0.21	-0.22
Temperature	0.3	0.23	0.40	0.47	0.73	0.80	0.83	0.80	0.96	0.85
Turbidity	NA									
Nutrient levels	-0.6	-0.64	-0.80	-0.87	-0.43	0.01	-0.65	-0.96	-0.58	-0.94
Control algae	NA									

D. Flathead

	Resp. $\bar{x}$	Scientific data	Collaboration	Common goals	Common strategies	Inclusiveness	Identify issues_2-yr	Identify issues_10-yr	Implement action_2-yr	Implement action_10-yr
Available food	0.0	-0.20	0.25	0.66	0.17	0.07	0.68	-0.10	0.04	-0.23
Fish quotas	NA									
Control invasives	0.8	-0.01	-0.34	0.31	0.52	0.27	0.08	0.42	-0.23	0.17
Riparian zones	0.5	0.44	-0.43	0.00	0.11	-0.33	-0.02	0.00	-0.44	-0.08
Ecological flows	-0.1	-0.15	-0.41	-0.07	0.34	-0.25	-0.42	0.15	-0.34	0.12
Lake levels	-0.1	-0.18	-0.48	-0.37	-0.25	-0.56	-0.56	-0.48		-0.36
Temperature	-0.1	-0.37	-0.02	-0.21	0.11	-0.01	-0.36	0.04	0.15	0.25
Turbidity	0.0	-0.28	-0.51	-0.45	0.20	0.19	-0.42	0.46	0.91	0.66
Nutrient levels	0.0	-0.14	-0.58	-0.09	0.14	0.00	-0.10	0.22	0.74	0.38
Control algae	0.2	-0.86	-0.02	-0.31	-0.38		0.16	-0.16	0.38	0.10

E. Roosevelt

	Resp. $\bar{x}$	Scientific data	Collaboration	Common goals	Common strategies	Inclusiveness	Identify issues_2-yr	Identify issues_10-yr	Implement action_2-yr	Implement action_10-yr
Available food	0.6	-0.87	0.33	-0.65	-0.54	-0.62	-0.53	-0.69	-0.52	-0.61
Fish quotas	0.4	0.22	0.64	0.44	0.32	0.47	0.51	0.44	0.52	0.97
Control invasives	-0.5	-0.11	0.06	0.05	0.24	-0.16	0.05	-0.04	0.14	-0.47
Riparian zones	0.4	0.44	0.32	0.59	0.37	0.58	0.50	0.47	0.49	0.83
Ecological flows	0.2	0.33	-0.20	0.12	0.19	0.28	-0.48	-0.24	-0.51	-0.01
Lake levels	0.0	-0.56	0.48	-0.09	0.14	-0.23	0.40	-0.12	0.46	-0.15
Temperature	-0.6	0.04	-0.04	-0.29	-0.16	-0.18	0.06	0.39	-0.06	0.22
Turbidity	0.0									
Nutrient levels	0.0	-0.72	0.19	0.00	-0.76	-0.36	0.37	-0.17	0.27	0.55
Control algae	-0.5	0.41	0.28	0.38	0.53	0.58	0.38	0.94	0.16	0.79

F. Chelan

	Resp. $\bar{x}$	Scientific data	Collaboration	Common goals	Common strategies	Inclusiveness	Identify issues_2-yr	Identify issues_10-yr	Implement action_2-yr	Implement action_10-yr
Available food	0.3	0.38	0.38	-0.24	0.01	0.77	0.64	0.60	0.47	0.45
Fish quotas	0.8	-0.48	-0.06	-0.24	-0.61	-0.05	0.19	-0.21	-0.04	-0.10
Control invasives	0.0	0.40	-0.70	-0.81	-0.20	-0.33	-0.34	-0.27	-0.45	-0.50
Riparian zones	0.6	-0.08	0.50	0.56	0.62	0.40	0.49	0.76	0.70	0.73
Ecological flows	0.8	0.58	-0.17	-0.52	-0.51	0.13	0.05	0.15	-0.01	0.01
Lake levels	0.5	0.57	0.38	0.86	0.72	0.13	-0.09	0.30	0.22	0.31
Temperature	0.0	0.40	-0.70	-0.79	-0.20	-0.25	-0.32	-0.24	-0.44	-0.42
Turbidity	0.5	-0.55	-0.92	-0.84	-0.59	-0.87	-0.57	-0.33	-0.61	-0.27
Nutrient levels	NA									
Control algae	NA									

Figure 5.3. Correlations, by basin, of selected ecological indicators on a 2-year horizon, with social process measures. Response mean on physical indicators with a scale of -2 (deteriorated) to +2 (improved). Correlations: light grey = weak (+/- 0.30 – 0.49), dark grey = medium (+/- 0.50 – 0.69), black = strong (≤ -0.70; ≥ 0.70).

The aggregated data (Figure 5.3, panel A) again showed no discernible trends across the five lake basins. Correlations within individual basins, however, demonstrated the complexity of interactions between the physical indicators and social factors under varied local conditions. As Friemel (2008) writes, context matters in applications of social network analyses, and for using a mixture of methods for analyses (Creswell & Piano Clark, 2017). Qualitative information from the surveys, archival documents, and scoping meetings supplemented to add interpretive explanation to quantitative outcomes for individual basins.

Lake Pend Oreille

Lake Pend Oreille's Albeni Falls Dam was authorized under the Flood Control Act of 1950. The USACE owns and operates the dam, with regional headquarters far away in Seattle. Idaho's governor-appointed Pend Oreille Lakes Commission was formed, to create some (limited) level of state oversight on federal dam operations, largely in response to lake level fluctuations and native fisheries issues (personal communications). The Idaho Department of Environmental Quality, and more recently, the non-profit Lake Pend Oreille Waterkeeper monitor water quality in the basin, filling a gap left by the defunct regional Tri-State Water Quality Council. Contentious plans to open a silicon smelter just below the dam in Newport, WA, have recently spurred public participation in Lake Pend Oreille's water quality issues.

Write-in responses to barriers to collaborations added richness to the quantifiable group process data correlations in the Lake Pend Oreille basin. Respondents reported litigious non-profits, unwillingness by others to work creatively, and disconnects in collaborations and communications. In light of the basin's history, collaboration, inclusiveness, common goals and strategies, and the ability to identify issues understandably included both positive and negative correlations with physical outcomes (Figure 3, panel B). Not surprisingly, Likert responses about the adequacy of available scientific data varied widely, ranging from 2.6 to 10 (of possible 10). Nevertheless, the perceived ability to implement action on a 2-year, and especially 10-year horizon, correlated positively with all physical indicators, except fish quotas.

Lake Koocanusa

The USACE owns and operates Libby Dam, which was built under the Columbia River Treaty [5.2] to create the trans-boundary Lake Koocanusa. The dam backs up the Kootenai River (spelled Kootenay in Canada) for roughly 145 km, with just over half of the basin in Montana, the remaining 68 km in British Columbia. Riparian zones are effectively naught and the basin experiences seasonal dust storms during lake drawn-downs of up to 30 m before spring freshets. The basin additionally suffers from toxic levels of selenium leachates from the coalmines in the Elk Valley, a part of the Kootenay River's drainage above Lake Koocanusa. The USACE strives to operate the dam for ecological flows and river temperature regulation for fish and macroinvertebrates while fulfilling its mandates as a Columbia River Treaty dam for flood control and energy production.

Qualitative survey data reflected Lake Koocanusa's complex governance issues, as respondents reported the difficulty to collaborate against the backdrop of cross-boundary political processes, an overpowering industry, and lack of progress in implementing actions with a holistic approach under greatly differing objectives. Dissatisfaction remained with the management of lake levels and nutrients (Figure 3, panel C), which correlated negatively with the social processes in the governance network. Temperature correlated strongly and consistently with all social measures, which suggests functional collaboration with USACE's dam operations for water temperature.

Flathead Lake

Člq̓etkw (Flathead Lake) is the largest natural lake by surface area in the western states. The Confederated and Salish and Kootenai Tribes (CSKT) purchased Kerr Dam (renamed Se¿lis¿ Ksanka Ql¿ispe¿) and assumed operations in 2018. Flathead has the most developed basin in the study, in terms of population demographics and research capacity. Flathead Lake Biological Station, established in 1899, and the CSKT both provide long-term water quality

[5.2] Treaty Between the United States of America and Canada Relating to Cooperative Development of the Water Resources of The Columbia River Basin, US-Can., Jan. 17, 1961, 15.2 UST 1555. This international treaty entered into force in 1964; current processes have the US and Canada renegotiating Treaty terms.

data. The Flathead Lakers, a non-profit established in 1958, champions water quality in the lake basin. Montana's governor-appointed Flathead Basin Commission (FBC) comprises a panel of collaborative partners that convenes quarterly. The basin governance network is vigilant about preventing invasive species, notably quagga and zebra mussels.

The Flathead governance network is the most densely connected of the five study basins, but it had the lowest incidences in strong correlations of physical indicators with social measures among the five basins (Figure 3, panel D). The levels of collaboration and the ability to come to common goals showed negative relation to almost all physical indicators, and the ability to identify issues on a 2-year horizon. Qualitative responses included a need to build stronger relationships with partners and the occasional inability to find common goals, which hampered collaboration. Respondents reported position- and values-based frictions and a lack of openness and good faith in negotiations, including inadequacy of scientific data, and that [governance] outcomes should be "based on rational and well-informed decisions." The ability to implement action correlated overall positively in water quality but negatively with fisheries indicators, suggesting that actors view these two governance themes separately in this very large basin.

Lake Roosevelt

Grand Coulee Dam impounds the main stem of the Columbia River for over 200 km to create Lake Roosevelt. Irrigation for the Columbia Basin Project drove establishment of Grand Coulee. Completed in 1941, the colossal structure blocks all anadromous fish passage to points upriver and caused ongoing conflict over species conservation issues. A 1990 cooperative agreement, of the USBR, the National Park Service, the Confederated Tribes of the Colville Indian Reservation, the Spokane Tribe of Indians, and the Bureau of Indian Affairs, provides management structure. Toxics issues on Lake Roosevelt include a former uranium mine on Spokane Tribal lands and a decommissioned smelter that are now Superfund sites [5.3], and an active zinc smelter still operating just upriver in Canada.

Qualitative data for Lake Roosevelt included complaints about non-scientific decision-making, a lack of willingness by others to share data, poor or even combative communication, insufficient funding, and frustrations with differing goals. No pattern emerged in which actor types (e.g. federal, tribal, state, non-profit) responded high or low on the social processes. Social measures reflected discord, tending towards a mean of only between four and six on a 10-pt. Likert scale, with variation from one to nine. Moderate to strong positive correlations of fish quotas (Figure 3, panel E) with social variables relate to collaborations on sturgeon conservation regulations. Correlations around nutrients, algae, and variations in other measures in the lake lacked triangulation from qualitative data.

Lake Chelan

Often overlooked in the Columbia River Basin, the 80-km long Lake Chelan has a unique status as the longest and deepest natural lake in Washington, and the third deepest lake in United States. Its privately owned hydroelectric dam does not connect to the federal power grid coordinated through Bonneville Power Administration. The dam's owner, Chelan County Public Utility District (Chelan PUD), performs most lake management functions. The lake has high legacy DDT and PCB levels in fish tissue and sediments (WECY 2008). Despite those concerns, and a long-term monitoring plan written in 2008, water quality data for the lake remains sparse. The Lake Chelan Institute (LCI), a water quality focused non-profit formed in 2016, has begun collecting baseline data and monitoring data from its probes in the lake (LCI personal communications).

While in-person communications in survey outreach pointed to overall positive relations, results suggested otherwise. The collaboration score averaged only 6.4, with individual ratings from 0.9 to 10, a trend corroborated by other social process categories. Qualitative

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[5.3] Hazardous waste cleanup sites authorized under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or Superfund Act, 42 U.S.C §9601 *et seq*. (1980)

survey responses revealed that litigious action has historically hampered collaborations, and some suggested that the "watershed governance group should be facilitated by a neutral leader". Indeed, collaboration, common goals, and common strategies (Figure 3, panel F) correlated negatively with most physical indicators. The lack of nutrient and algae responses reflected the paucity of general water quality data.

5.5. Discussion and conclusions

5.5.1 Scale & Scope

Measures of resilience do not always scale well, meaning that tracking functionality parameters within a system may not transfer up or down in geographic space and time (Carpenter *et al*. 2001). This study demonstrates a similar issue. Analyzing the aggregated data, and isolating either the physical or the social dimensions, we revealed consistent cross-basin patterns that became far more robust within individual basins. Relating the social with the physical indicators within the aggregated data revealed no apparent patterns. In contrast, stronger correlations show up within the individual basins, and had triangulation from other supporting sources within the study (e.g., archival literature, qualitative responses, and field notes from scoping meetings). This pattern suggests issues vary widely at the cross-basin scale and confound layers of governance analysis, whereas the basin-specific scale allows elaboration of the local issues and dynamics on the question of how governance networks behave to measure their effectiveness on topics such as fisheries and water quality.

With a narrower scope of issues affecting the basin, and a relatively small group of actors in the system, Lake Chelan shows clear and strong network relations. In contrast, geographic size of Lake Roosevelt's system suggests its scale operates at a level challenging to network ties and efficiencies. In other words, a geographically larger scale basin (similar to confounding effects from the overall 5-basin scale), may yield more constraining and less flexible outcomes in relation to democratization, participation, transparency, and needed accountability. Such effects become reminiscent of more centralized command and control water management regimes (Engle *et al*. 2011) often criticized for governance structure issues.

Related, measuring indicator precision exists as an ongoing challenge. Several participants wished for more issue-specific or location-specific questions, claiming the cross-basin scale as too vague (participant feedback, personal communications). One major actor in Lake Roosevelt basin declined to participate because they interpreted the *Mauri* Meter as too non-specific for reporting the physical indicators.

5.5.2. Temporal issues

Constraints on availability of funding and resources, lag time of pollutant responses, and other environmental factors in watersheds, contribute to researchers' inability to attribute water quality improvements to specific entities or actions (Dakins *et al*. 2005; Chaffin *et al*. 2011; Genskow & Wood 2011). A related outcome suggested that the ability to identify issues and implement action on a 10-year horizon yielded stronger markers than for 2-years.

In particular, the "ability to control invasive species" and varied responses over timing and time lag for management showed network level disagreement. While collaborative efforts to contain invasive species may have positive outcomes, the presence of invasive species is considered a negative change. In Lake Roosevelt, for example, agencies have removed over 10,000 pike since 2015 as part of a collaborative effort to control the fish, but fisheries managers fear that the voracious fish will expand its territory (Columbia Basin Bulletin 2019).

5.5.3. Social motives for water governance

Social networks, where different actors come together to deal with natural resource problems and dilemmas "can be more important than the existence of formal institutions for the effective enforcement and compliance with environmental regulations" (Bodin & Crona 2009, 367). Koontz (2014, p 1574) focuses on six basic factors for social learning in collaborative groups: inclusiveness, extended engagement, information exchange, opportunities for interaction, process control (democratic structure and ability to set agenda and procedures), and process equity (individual efficacy and being taken seriously by others). Although participants reflect on water governance challenges, a dominant theme indicated a commitment to ongoing collaboration and high value placed on group process for the networks. One basin actor described the following:

> *We collaborate well on water quality, [aquatic invasive species] prevention, and dam operations. Some previous personalities made it difficult to collaborate on fisheries management.*

This pattern advances one of the critical elements of adaptive water governance – further integration of social and human dimensions as systems experience increased complexities, uncertainty, and coordination challenges (Akamani 2016) – by illustrating the scale of variability and spatial contexts for decision-making.

Related, respondents actively expressed the need for infusion of expanded social science efforts within water governance at basin scales. The core-periphery model resonated strongly in conversations, and participants seized on the concept in describing their interactions with others in the basin. Respondents collectively spent more than 70 percent of their time in physical sciences (as opposed to than social sciences) related to resource management, but quickly pointed out the need for strong interactive skills. One even quipped that,

> *[No] one told me when I got my degree in fisheries that I would have to deal with the public, but it has become an important part of my job.*

Many outcomes link to the process of adaptive co-management, including ecological sustainability (Plummer *et al.* 2013). These results attest to the interactive effects between governance structure and ecological health outcomes because natural resource management occurs as a series of social decisions, negotiations, and degrees of coordination. Thus, perceived success of governance as measured here, serves as an indicator of governance efficacy and capacity of groups and organizations committing to co-management and collective determination of outcomes.

Our research explored group processes relative to management success in terms of changes in physical lake health indicators. Highly variable correlations among parameters illustrate the uniqueness of each basin, and the need for collaborative, place-based governance. The motive for collective action in water governance may not originate from exactness in change or outcomes, however, but rather a shared understanding about a common pool resource and needs spread across user groups, geography, and time.

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Chapter 6. Discussions and conclusions

> *To come to terms with the Columbia, we need to come to terms with it as a whole, as an organic machine, not only as a reflection of our own social divisions but as the site in which these divisions play out. If the conversation is not about fish and justice, about electricity and ways of life, about production and nature, about beauty as well as efficiency, and about how these things are inseparable in our own tangled lives, then we have not come to terms with our history on this river* (White 1995, p. 113).

6.1. Research summary

The title of this dissertation refers to the shapes of water governance networks in the Columbia River Basin, and how those networks function. I began by presenting methodology aimed at discerning the patterns and dynamics of those networks in the five study basins. The survey, in five sections, collected information in each basin on: respondents' actor-organizations; changes in lake health indicators over two and ten years; the organization's network contacts in the basin; perceived dynamics of the network; and perception of public engagement. I described data preparations and what types of methods are applied for the analytical chapters. Extensive in-person communications during the scoping and development phases as well as in soliciting survey responses brought descriptive context to the basin shapes.

Different governance network arrangements between the lakes were already evident in the study in the basin descriptions (chapter two). Lake Chelan's sparse network of mostly regional actors reflected its private dam ownership, and its location away from the main stems of the Columbia River. While Flathead's Seli'š Ksanka Qlispe' Dam is also privately owned, the basin is located below an important federally operated dam (Hungry Horse). Multiple overlapping commissions and management partnerships create a dense, polycentric governance network for Flathead Lake. In contrast, Koocanusa's network interactions remain somewhat polarized across the U.S. and Canadian organizations. The Idaho Panhandle's Lake Pend Oreille network includes members from its near neighbors, Washington and Montana. Lake Roosevelt has the most actors in its network, which is partly due to multiple toxic waste cleanup sites, and extensive efforts to control non-native pike, restore native sturgeon fisheries, and to reintroduce salmon above Grand Coulee Dam.

Chapter three examined the prevalence of specifically the core-periphery pattern in the literature of water and natural governance networks cases. Networks in the 30 case studies are generally approached from one of three analytical lenses: In analyzing social network structure, the focus is on the quality of ties, in terms of bonding actors tightly together, or bridging across structural holes in the network, to outer actors. Social capital is developed by network interactions within a central group or by reaching out for capacities or resources outside the core group. Polycentric governance systems are characterized by independent multi-level actors who govern collectively. I observed similarities, overlaps, and differences in how the disciplinary lenses approach the evaluation of collaborative governance networks, but academic debate is still needed about how closely these concepts are related. Regardless of the academic approach used for analysis, however, the core-periphery pattern makes a regular appearance in resource governance network literature.

In chapter four we analyzed the data from this five-basin study in a stepwise methodology. Beginning with network visualization and mathematical core-periphery tests, we find that core-periphery structures are present in all of the networks, whether or not they are filtered to focus areas in fisheries or water quality. Comparing the networks of the five basins with one another using quadratic assignment procedure shows that actor type, or who an actor is, does not significantly influence the actor's position in the network. Using Poisson regressions, we find that the number of roles an actor fulfills in a 'suite of roles' explains actor positions within the specific networks of this study. Roles are divided into three general categories: resource roles (data, expertise, funding and political support); formal (land, dam, and resource tenure, regulatory and planning, juridical); and informal or social roles (collaboration, news and public forums, policy entrepreneurs or “rock star” networkers). Some variability exists in the importance of the role categories in the different basin settings.

The fifth chapter delved into the interaction dynamics of the networks vis-à-vis changes in physical lake health indicators. Few relations were evident with data from all five basins aggregated into a single general data set. Patterns emerged, however when data were filtered by basin, albeit with variability among basins. We conclude that issues vary widely at cross-basin scales, confounding layers of government analysis. At basin-specific scales, local issues and dynamics are additionally reflected in the local contexts of the governance settings. Scale was also important temporally, as data markers for some relations were stronger on ten-year than on two year time horizons. Qualitative responses did more than help explain the quantitative findings in the basins; they revealed social motives in the generally held conviction that shared understanding and collaborative governance is needed to successfully manage water resources.

6.2. Theoretical applications: future research and synthesis

The concept of adaptive governance, or adaptive co-management was mentioned several times throughout this dissertation; adaptive was one of the search words I used in the literature review (chapter three). Adaptive, ecosystem-based co-management is a more experimental approach to addressing resource issues on a regional or local scale (Olsson *et al*. 2004; Smedstad & Gosnell 2013). In this model, water users, tribes, researchers, agencies, and other actors in a water basin can knit together diverse views, expertise, and resource bases to collectively and sustainably govern the commons of water resources (McGreavy *et al*. 2015).

References to adaptive co-management are evenly applied in literature of all three disciplinary lenses, core-periphery structure (55 percent), social capital (55 percent), and polycentricity (56 percent), suggesting that this question merits further investigation. Four of the five articles that addressed both social capital and polycentricity also discussed adaptive management.

Could this be a unifying concept among the frameworks? It is furthermore unclear, whether the governance networks actually achieve their co-management goals.

Many books written about the Columbia River Basin in the 1990s, including Richard White's (1995) Organic Machine, call for adaptive co-management approaches. Furthermore, tenets of participatory, adaptive co-management processes are expressly stated in some major U.S. planning documents, such as the 1980 Northwest Power Act [6.1]:

> *... to assure the Pacific Northwest of an adequate, efficient, economical, and reliable power supply; to provide for the participation and consultation of the Pacific Northwest States, local governments, consumers, customers, users of the Columbia River System (including Federal and State fish and wildlife agencies and appropriate Indian tribes), and the public at large within the region in the development of regional plans and programs related to energy conservation, renewable resources, other resources, and protecting, mitigating, and enhancing fish and wildlife resources.* (Northwest Power Act, 838(2) - 838(3)(B), *94 Stat. 2698)*

In an information page about the The Northwest Power Planning and Conservation Council lauds the Northwest Power Act's focus on adaptive management (NWPCC 2010). Yet, how many organizations in the governance networks include "collaborative processes" in their mission statement? Are governance network functionally achieving these goals?

In the same spirit of questioning would be a reexamination of existing case data, to ask to what extent described networks approach the tenets of polycentricity. Victor Ostrom (1961) writes of the "the patterns of cooperation, competition and conflict that may concept as polycentric governance arrangements" (p.35), which is championed by Elinor Ostrom (2010).

[6.1] Pacific Northwest Electric Power Planning and Conservation Act, 16 U.S. Code, Chapter 12H (1994 & Supp. I 1995). Act of Dec. 5, 1980, 94 Stat. 2697. Public Law No. 96-501, S. 885.

Aligica & Tarko (2012) suggest using three basic features to analyze the presence or strength of polycentricity in a system: First, whether actors implement their different methods into practice, in terms of autonomous decision-making layers, and in the presence of a set of common or shared goals. Secondly, if the institutional and cultural frameworks provide an overarching system of rules, whether territory based or superimposing, are various actors involved in making the rules, how are the rules formed (market, consensus, or majority rule), and does the decision-making center find them useful? Aligica and Tarko call the third criteria 'spontaneous order', in which a decision center can freely decide to enter (or exit) the polycentric system.

6.3. Practical applications

*6.3.1. Networks as boundary object*s

The term "boundary object" is used to describe a concept that is, "both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (Star & Griesmer 1989, p. 393). In this study, I found that the hydrologic or geographical boundaries of a basin, sub-basin, or watershed, do not adequately capture which actors should be included or excluded from consideration. Informants and potential respondents, likewise, often doubted whether they should be part of my study. Upstream users still impact the basin. A reservoir or dam's management impacts the river reaches below the dam, and onward to the next catchment.

Instead I used the network itself as the study's boundaries. If an actor was involved in communications for governing the basin—regardless of the location of an actor's office, be it far removed from the basin (e.g.: Seattle, Denver, Vancouver), or on the shoreline (Flathead Lake Biological Station)—then that actor was part of the network. "A boundary object is any object that is part of multiple social worlds and facilitates communication between them; it has a different identity in each social world that it inhabits" (Star & Griesmer 1989, p. 409). The social worlds of my study included sovereign aboriginal interests, federal agencies implementing regulations, biologists, geologists, farm programs, local government, politicians, attorneys, industry, environmental activists, and more. I used 'who talks to whom' in governing fisheries or water quality as the criteria for participation in the network. For some, this was in how they directly could or could not manage the fisheries. For others, it was about rights to the resources, or the ecological impacts of decision-making. My respondents sometimes doubted whether they were the "right person" to answer my survey, but were all clear about whether they were involved in basin governance conversations to begin with. Regardless of actor's focus or background, people I spoke with immediately identified with the concept of a network of communications for water resource governance.

6.3.2. Network application as a watershed governance tool

Using the governance network as a boundary object leads to distinct applied value. Organizations in a water governance network can use network concepts to determine if outreach for collaborative participation is truly including all representative actor-organizations of a basin. Survey results in the present study showed that the average perceived level of inclusion was among the lowest of the network dynamics measures, only 5.9 on a 10-point Likert scale (n responses = 68). Survey text entries for barriers to collaborations and many additional personal communications revealed that lack of inclusion occurred on two levels: non-acceptance of diverse values and perspectives, and insufficient inclusion of diverse actors/organizations, especially non-profits and citizen groups. The latter suggests that certain actors who should be in the network are being missed or marginalized.

Especially for non-government organizations, a network map might be used to identify actors relevant to their goal. One informant in this study noted that, "*it would be nice to have a central website of all government agencies that are involved in basin management."* As we demonstrated in chapter four, however, the mere presence of a government agency in the basin says nothing about its relative position of influence in a network.

In a 1996 book about risk and informing decisions in a democratic society, the National Research Council (NRC) stresses the importance of, "getting the right participation", and "getting the participation right" (p. 132), when integrating analysis and deliberation in decisions. According to the NRC guide, participation means that, "[t]he analytic-deliberative process has had sufficiently broad participation to ensure that the important, decision-relevant information enters the process…" (p. 132). In the course of the present research I found that federal and state/ provincial agencies broadly recognize the importance of collaborations and open communications across their basins. Yet I also heard from agency employees themselves that they were sometimes accused of "just checking off the boxes" on their public engagement requirements. Potentially valuable resources and social capital could be missed by not bridging across the structural holes in the networks to more peripheral actors. A network analysis could be used as a mapping tool in the basin, and to see which actors are (or are not) connected.

Experiments with the 2015 St. Joe/ St. Maries pilot study data (Trebitz, unpublished) suggest that useful network analyses can be constructed by lay practitioners, using only archival data and linkages found on the Internet. The pilot study asked survey respondents about which other actors they communicated with for water resource issues in the past two years (2013-2015). I used archived documents and Internet hyperlinks to other actors' websites to construct a network in the St. Joe/ St. Maries sub-basin that was focused specifically on transmission of data and information from 2010 - 2015. Both matrices consisted only of unweighted, directional contacts (1 = contact, 0 = no contact). All but one actor identified by survey respondents was also present in the Internet search network. I made no attempt to reconstruct or impute missing data (NAs) in the survey-based network before comparing the two networks. Despite the slight mismatch of network focus (water resource governance in general from the survey vs. specific to data/ information exchange from the web), the networks correlated moderately on centralization scores: Spearman's rho on in-degree = 0.67, total degree rho = 0.69, both with $p < 0.0001$. Visualization of the two networks revealed similar core membership and structures, albeit with visible differences in the peripheral regions. These test results further support the 'suite of roles' premise (chapter four), where data and technical information—together with other resources roles—correlated moderately to strongly with actor centrality in the basin networks.

Analytical results throughout this dissertation show place-based differences of networks by basin and disciplinary focus. Using the network itself as the boundary object helps delimit the basin. A practitioner can additionally specify the boundaries of the networks, in terms of scale, focus, and time. In the pilot study test case, I included all possible actors at the organizational level (a universal sample), who provide or exchange data and technical information that relates to water resources in the study area in a five-year period. While an in-depth network analysis would be the better approach, test results support the idea of an Internet-sourced network as a useful working model to examine the membership and structure of a basin's governance network membership.

6.4. Limitations in the study

In future research one could substitute real fisheries and water quality data for the survey respondents' perceived changes in lake health indicators. Such efforts could demonstrate whether real and perceived changes in indicators actually track together in a basin. Considerable work would be necessary to source and assemble representative longitudinal data for these same indicators, especially given the scattered nature of data collection and repositories (Sprague 2017; Trebitz 2017). Conversations with non-profits in the basins show, however, that data access issues underlie processes of collaborations. One respondent noted in the survey, that:

> *In a few situations, data is not willingly shared between agencies or tribal parties. In those situations, it can be incredibly frustrating to provide the best collaboration and doesn't build trust between the groups.*

It is evident that the various actors in the systems are operating with imperfect information. Using the *Mauri* Meter assessment in this study had the advantage that respondents could root their answers in known data if they have access to it, or still make an answer given no physical data. I contend that, for many less central actors who may have limited access to data, perceived changes in basin health indicators are likely greater motivators in collaborations and negotiations than actual measurements. While using real lake health data would no doubt give a more accurate picture of real basin conditions, perceived conditions may produce stronger correlations with social network dynamics in this type of analysis.

In the methods section (chapter one) I discussed some data limitations, which stem in part from the interrelation nature of fisheries and water quality issues. Expanding the survey to be more precise in either the fisheries or the water quality network sections would lengthen the survey by an unacceptable amount. The survey took, on average, 20 minutes to complete, which my respondents and informants felt was appropriate. Respondents appreciated the ability to skip questions that were not relevant to their organizations (many personal communications). Cross-checking responses with research notes suggested that most respondents took care to give accurate responses.

In terms of a cross-basin study, improvements could be made on a sample of just five basins. A bold approach to future research is to apply this study to other areas of the Columbia River Basins. While the current study was intentionally focused on basins in a fairly tight geographical transect, and mostly on the U.S. side of the international border, it could be expanded to include other regions. In the U.S., the research approach could be applied to Rufus Woods Lake (Chief Joseph Dam), which is downriver from Lake Roosevelt on the Mainstem Columbia River, to Dworshak Dam and Reservoir in Orofino, Idaho and the Hells Canyon Dam system that blocks the Snake River as it comes north from Boise on the Idaho-Oregon border. Dworshak and Chief Joseph Dams are both federally owned and operated, the Hells Canyon Dams are privately owned; all three completely block fish passage. On the Canadian side, the study could be repeated also in Kinnebasket Reservoir (Mica Dam), Arrow Lake (Hugh Keenleyside Dam), Duncan Reservoir and Dam, Revelstoke Lake and Dam, and Kootenay Lake (Corra Lin Dam). Duncan, Mica, and Keenleyside Dams, like Koocanusa's Libby Dam, were all constructed under the Columbia River Treaty. A study of the Similkameen and Kettle River basins in British Columbia suggest that adaptive processes and polycentric governance are less developed (Horning *et al*. 2017) than on the U.S. side. Adding some or all of the listed reservoirs to this multi-basin study would allow more thorough comparison across basins, and also of management differences between the U.S. and Canada.

6.5. Conclusions

The outcomes of this research further theoretical work on multiple fronts. First, paucity in comparable data sets makes evaluating water and natural resource governance networks difficult. The present study is unusual, in that it applies the same survey instrument across five large reservoir basins. The literature review reveals that core-periphery patterns are common, but under-recognized in network studies of natural resource and water resource governance. By acknowledging the core-periphery pattern as a common phenomenon, we can begin to examine the drivers of the structure's formation, what grants membership into these governance networks, and what attributes place an actor into various positions in the network.

Chapter four results support the 'suite of roles' approach as an explanation of attributes that contribute to an organizational actor's centralized position in core of water resource governance networks. Operationalizing dynamics of the governance networks with physical indicators of lake health address the difficulties of relating social factors to physical outcomes in complex social-ecological systems. Results suggest that researchers should carefully consider physical scale, temporal scales, and social motivations in collective governance of the water commons.

I conclude with a personal observation about this five-basin research project. The outreach for this research was in itself a networking exercise. I conducted early scoping via contacts that were already in my university-based network: colleagues, faculty, and friends who are active in Pacific Northwest water resources issues. The water resource community itself is a small family in a very large geographic area. I met some people in one basin, and then encountered them at a forum in another, or at the transboundary 2019 conference in Kimberly, B.C. My informants made recommendations for whom to talk to in other organizations, and often made introductions to facilitate my progress. For others I was able to furnish information they were seeking about their own basin. I was invited to attend public forums, in the basins, and many have additionally extended personal invitations for me to return to present my results to the public. Within a short time, I found myself a part of the very networks I was studying. The experience underscores the value of networks and collaborations across these water resource governance scenarios.

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Appendix A. Institutional Review Board approval for survey used in the five-basin study

University of Idaho
Office of Research Assurances

Institutional Review Board
875 Perimeter Drive, MS 3010
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To:	Manoj K Shrestha
Cc:	J.D. Wulfhorst, Karen Ingeborg Trebitz
From:	Jennifer Walker, IRB Coordinator
Approval Date:	February 25, 2019
Title:	Management Regime, Governance Networks and Social-Ecological Resilience in Columbia River Headwaters Lake Basins
Project:	19-055
Certified:	Certified as exempt under category 2 at 45 CFR 46.104(d)(2).

On behalf of the Institutional Review Board at the University of Idaho, I am pleased to inform you that the protocol for this research project has been certified as exempt under the category listed above.

This certification is valid only for the study protocol as it was submitted. Studies certified as Exempt are not subject to continuing review and this certification does not expire. However, if changes are made to the study protocol, you must submit the changes through VERAS for review before implementing the changes. Amendments may include but are not limited to, changes in study population, study personnel, study instruments, consent documents, recruitment materials, sites of research, etc.

As Principal Investigator, you are responsible for ensuring compliance with all applicable FERPA regulations, University of Idaho policies, state and federal regulations. Every effort should be made to ensure that the project is conducted in a manner consistent with the three fundamental principles identified in the Belmont Report: respect for persons; beneficence; and justice. The Principal Investigator is responsible for ensuring that all study personnel have completed the online human subjects training requirement. Please complete the *Study Status Check and Closure Form* in VERAS when the project is completed.

You are required to timely notify the IRB if any unanticipated or adverse events occur during the study, if you experience and increased risk to the participants, or if you have participants withdraw or register complaints about the study.

Appendix B: The survey instrument

University of Idaho

Water Resource Management
Five-Basin Network Survey, 2019
[XXX Basin]

Consent page

Introduction to the study and consent statement

The purpose of this study is to measure communication networks and interactions associated with water quality and fisheries management in five different Columbia River headwaters lake basins. The five basins are (from west to east): Chelan Lake and Lake Roosevelt in Washington, Lake Pend Oreille in Idaho, Lake Koocanusa in Montana and BC, Canada, and čłq̓etkʷ (Flathead) Lake in Montana. The survey will gather input from participants with fisheries and/or water quality management experience in the five lake basins. *This study is designed to identify trends that strengthen collaborations in the lake management networks. Results will be shared with the participants, if requested.*

You are receiving this survey because you or your organization have been identified as participating in water resources management of the [XXX basin], in either fisheries or water quality management. *We are interested in your experiences regarding your direct contacts in water resource management in the [XXX basin]. Your opinion is very important for us, whether you are a water resource professional working for a Tribal/First Nation, federal, state, or educational institutions, or other entities. Your responses will help us understand patterns of contact among network participants, and the flow of information about water quality and fisheries related issues in the [XXX basin].*

The completion of this survey should take approximately 20 minutes. Your participation is voluntary. *There is no payment or direct benefit to you for participating other than helping to further this research. There is no cost or risk to you beyond the time needed to complete the survey. You can opt out of this study at any time by not starting the survey or by requesting that your responses be removed from data collections. There are no penalties associated with your withdrawal. Starting this survey will be considered informed consent in that you are confirming that you are 18 years old or older, and have reviewed this consent form and agree to its contents.*

All information you provide will be kept confidential to the extent allowed by University of Idaho policies. *Data will be stored in a secure computer file, or placed in a locked file cabinet with access only by Karen Trebitz, the student investigator, and principal investigators Manoj Shrestha and J.D. Wulfhorst. Individual identifiers will be removed from all published data. The University of Idaho Institutional Review Board has certified this project as "Exempt". A summary of survey results will be available, if you are interested.*

Thank you in advance. *Please feel free to contact one of us with any questions or concerns.*

Karen Trebitz
PhD candidate, University of Idaho/Water Resources; IGERT Program
Moscow, ID 83844-1234
Ph. 570-688-8703
treb6275@vandals.uidaho.edu

Background info -- organization and/or individual

Please provide information about the organization or group you are representing in this survey

Your organization's name:

Your program or sub-unit (if applicable):

The city and state where your regional office is located:

Your years of service for this organization:

Would you consider yourself and your work mostly:

- **In the social sciences (e.g.: cultural anthropology, social psychology, political science, economics)?**
- **In physical sciences (e.g.: biology, chemistry, geology, hydrology)?**

○ Mostly social science
○ More social than physical sciences
○ Both social and physical sciences
○ More physical than social sciences
○ Mostly physical science

Within your organization, how is your time divided between fisheries and water quality management?

	Primarily fisheries				Equal time fisheries & water quality				Primarily water quality	
0	10	20	30	40	50	60	70	80	90	100

Division of time:

In your work, you may interact with managers of more than one basin in this study.
Please click all the lake basins in which **<u>you personally</u>** **actively communicate:**

☐ Lake Chelan
☐ Lake Roosevelt
☐ Lake Pend Oreille
☐ Lake Koocanusa
☐ čłq̓etkʷ (Flathead) Lake

General and SES indicator questions

The remainder of this survey is specific to the [XXX basin].

Lake health can be measured in many different ways. The following two tables list common fisheries and water quality indicators, some of which may not apply to the [XXX basin]

Please tell us which of following indicators are used for evaluating the health of the fisheries in the [XXX basin]. Also, please indicate whether there have been changes (positive or negative) in the past two (2) years and the past ten (10) years, and if measurement records exist for those changes. You may skip indicators that do not apply to your basin.

Table 1. Fisheries indicators

	Measured?	**Change in past 2 years**					**Change in past 10 years**				
	Mark if YES	Large negative change		No change		Large positive change	Large negative change		No change		Large positive change
Available spawning and rearing habitat for **resident fish**	○	○	○	○	○	○	○	○	○	○	○
Available spawning and rearing habitat for **anadromous fish**	○	○	○	○	○	○	○	○	○	○	○
Returning numbers of spawning anadromous adults	○	○	○	○	○	○	○	○	○	○	○
Success of **fish passage and fish ladders**	○	○	○	○	○	○	○	○	○	○	○
Available numbers of **adult fish for fishing quotas**	○	○	○	○	○	○	○	○	○	○	○
Increased **average size or weight** of adult fish caught	○	○	○	○	○	○	○	○	○	○	○
Success in preventing, controlling, or reducing **invasive species**	○	○	○	○	○	○	○	○	○	○	○
Success in stabilizing and/or restoring **riparian zones**	○	○	○	○	○	○	○	○	○	○	○
Improved **ecological flows** in river reaches and related lake levels	○	○	○	○	○	○	○	○	○	○	○

Please tell us which of following indicators are used for evaluating water quality and related factors in the [XXX basin]. Also, please indicate whether there have been changes (positive or negative) in the past two (2) years and the past ten (10) years, and if measurement records exist for those changes. You may skip indicators that do not apply to your basin.

Table 2. Water Quality indicators

	Measured?	**Change in past 2 years**					**Change in past 10 years**				
	Mark if YES	Large neg. change		No change		Large pos. change	Large neg. change		No change		Large pos. change
Meeting water quality mandates (e.g. TMDLs) in lake basin or tributary streams	☐	○	○	○	○	○	○	○	○	○	○
Stabilizing lake levels	☐	○	○	○	○	○	○	○	○	○	○
Keeping or lowering **temperatures** in lakes or streams	☐	○	○	○	○	○	○	○	○	○	○
Lowering **turbidity** in lakes or streams	☐	○	○	○	○	○	○	○	○	○	○
Lowering **nutrient levels** in lakes or streams	☐	○	○	○	○	○	○	○	○	○	○
Success in controlling **toxic algae blooms** and dead zones	☐	○	○	○	○	○	○	○	○	○	○
Reduction of **toxic inflows** (e.g. from mine seepage)	☐	○	○	○	○	○	○	○	○	○	○
Did we miss an important one? Please fill in: ______	☐	○	○	○	○	○	○	○	○	○	○

In your opinion, how helpful are the currently available scientific knowledge and data to understand future impacts of water management decisions in the [XXX basin]?

	Not helpful at all		Somewhat helpful		Moderately helpful		Extremely helpful				
	0	1	2	3	4	5	6	7	8	9	10
Helpfulness of scientific knowledge:											

In your opinion, how important is it to include local and traditional knowledge of the [XXX basin] system into water management decisions?

	Not at all important		Slightly important		Moderately important		Very important				
	0	1	2	3	4	5	6	7	8	9	10
Importance of local & traditional knowledge:											

Does your organization consider local and/or traditional ecological knowledge in weighing management decisions?

- ○ Never
- ○ Sometimes
- ○ About half the time
- ○ Most of the time
- ○ Always

Network section

Communication networks and collaborations are important for water resource management. This section will enable us to map the network of communications among participants in managing fisheries or water quality in the [XXX basin] in the past two years. We would also like to learn to what extent you feel those collaborations have led to an improvement in lake conditions.

The following tables contain lists of common participating organizations that were identified in the [XXX basin] for fisheries or water quality management interactions. They are sorted by level of organization (federal & tribe, state, regional, special districts, industry, etc.).

Please check all organizations that you have contacted in the context of fisheries or water quality during the past two years. Indicate if the contacts are in Fisheries, Water Quality, or both. Please also note the the purpose of the contacts and the contact frequency.

Network contacts in the past two years
Federal agency or Tribe/First Nations

	Click all that apply		Purpose for contact					Average contact frequency		
	Fisheries	Water Quality	Inform-ation or data	Exper-tise or advise	Tech-nical colla-boration	Fund-ing support	Political support	Several times per month	Every few months	Once per year
EPA U.S. Environmental Protection Agency	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
USACE U.S. Army Corps of Engineers	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
⋮										
CWS Canadian Wildlife Service	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DFO Fisheries and Oceans Canada	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
NRCAN Natural Resources Canada	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Tribe/First Nation (1)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Tribe/First Nation (2)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Tribe/First Nation (3)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Missed one? Please fill: ______	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

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Network contacts in the past two years

U.S. State or B.C Provincial agencies:

	Click all that apply		Purpose for contact					Average contact frequency		
	Fisheries	Water Quality	Infor-mation or data	Exper-tise or advise	Tech-nical colla-boration	Fund-ing support	Poli-tical support	Several times per month	Every few months	Once per year
State level Dept. of Environmental Quality	☐	☐	☐	☐	☐	☐	☐	○	○	○
State level Fish & Game	☐	☐	☐	☐	☐	☐	☐	○	○	○

Network contacts in the past two years

Special Districts, Local Government offices, and Research Institutes:

	Click all that apply		Purpose for contact					Average contact frequency		
	Fisheries	Water Quality	Infor-mation or data	Exper-tise or advise	Tech-nical colla-boration	Fund-ing support	Political support	Several times per month	Every few months	Once per year
Regional SWCD Soil & Water Conservation Dist. (might be multiple)	☐	☐	☐	☐	☐	☐	☐	○	○	○

Network contacts in the past two years

Industry and Non-government 0rganizations:

	Click all that apply		Purpose for contact					Average contact frequency		
	Fisheries	Water Quality	Infor-mation or data	Exper-tise or advise	Tech-nical colla-boration	Fund-ing support	Political support	Several times per month	Every few months	Once per year
Industry (1) Major area mining (e.g. Teck)	☐	☐	☐	☐	☐	☐	☐	○	○	○
Industry (2) Major area logging	☐	☐	☐	☐	☐	☐	☐	○	○	○
Industry (3)	☐	☐	☐	☐	☐	☐	☐	○	○	○

Communications and collaborations

Successful collective action groups often exhibit particular strengths in their interactions. In contrast, progress in collaborative management can be hampered by both the regulatory framework in which you must operate, and frictions that arise among management participants. Please help us understand the factors in collaborations among the network members you identified in the [XXX basin].

Are your organization's participation in this communications network mostly voluntary or mostly mandated?

Primarily voluntary — Primarily mandated

0 10 20 30 40 50 60 70 80 90 100

Scale of voluntary vs. mandated participation

How much authority does this network have to produce and implement binding management decisions in the [XXX basin]?

No authority — Some authority — Complete authority

0 1 2 3 4 5 6 7 8 9 10

Level of authority:

How much input from this network is non-binding, yet valuable in assisting management efforts in the [XXX basin]?

No input — Some input — High input

0 1 2 3 4 5 6 7 8 9 10

Amount of non-binding input:

How would you describe the level of collaboration among your network contacts in the [XXX basin]?

No collaboration — Moderate collaboration — We collaborate on everything

0 1 2 3 4 5 6 7 8 9 10

Level of collaboration:

<u>In the past two (2) years</u>, how effective has the network been at helping to solve management issues in the [XXX basin]?

Not at all effective — Moderately effective — Very effective

0 1 2 3 4 5 6 7 8 9 10

Identifying issues and planning actions **2 years:**

Implementing planned actions **2 years:**

<u>In the past ten (10) years</u>, how effective has the network been at helping to solve management issues in the [XXX basin]?

	Not at all effective				Moderately effective				Very effective	
0	1	2	3	4	5	6	7	8	9	10

Identifying issues and planning actions **10 years:**

Implementing planned actions **10 years:**

How much influence do you feel your organization has in management outcomes in the [XXX basin]?

	No influence				Some influence				A high level of influence	
0	1	2	3	4	5	6	7	8	9	10

Level of influence:

How inclusive would you say the process of reaching policy decisions has been for management in the [XXX basin]?

	Not inclusive				Moderately inclusive				Highly inclusive	
0	1	2	3	4	5	6	7	8	9	10

Level of inclusiveness:

To what extent do you feel that network participants share common goals for management?

	No common goals				Some common goals				Many common goals	
0	1	2	3	4	5	6	7	8	9	10

Level of common goals:

Can you share a specific situation that decreases your willingness to collaborate?

What might increase your willingness to collaborate in the future?

Public outreach

Please tell us about public participation in management processes in the [XXX basin].

To what extent is the public encouraged to participate in the management network via active outreach, forums, and media outlets?

	No public outreach				Some sharing and outreach				Lots of public outreach		
	0	1	2	3	4	5	6	7	8	9	10
Level outreach											

Is there adequate public participation in the lake management processes (e.g. attendance at forums, and public meetings; participation in conservation and restoration efforts)?

	No public participation				Some public participation				Highly engaged public		
	0	1	2	3	4	5	6	7	8	9	10
Level of public participation											

Can you name a particular forum, community round table, or annual workshop that is instrumental in communication of water management issues in the [XXX basin]?

In the past, have you participated in this event?

- ☐ Yes -- attended only
- ☐ Yes -- I presented information about basin issues
- ☐ No

Receive summary report?

This concludes the survey.

Please indicate if you would like to receive a summary report of the study.

- ○ Yes
- ○ No thank you

Appendix C: Actor-types and corresponding actor lists by basins

	PendOreille	KoocanusaMT	KoocanusaBC	Flathead	Roosevelt	Chelan
F_Env	USEPA	USEPA	EnvC	USEPA	USEPA	USEPA
F_Eng	USACE	USACE	NA	USACE	USACE	USACE
F_FW	USFWS	USFWS	CWS	USFWS	USFWS	USFWS
F_Recl	USBR	USBR	NA	USBR	USBR	USBR
F_LandMan	USBLM	NA	NA	NA	NA	USBLM
F_Geol	USGS	USGS	NRCAN	USGS	USGS	USGS
F_FS	USFS	USFS	NA	USFS	USFS	USFS
F_NPS	NA	NA	NA	NPS_G	NPS	NPS
F_Ag_lands	NRCS	NRCS	NA	NA	NRCS	NRCS
Pow_coor	BPA	BPA	BCHydro_CPC	BPA	BPA	BPA
F_Comm	NWPCC	NWPCC	FWCP_CBT	NWPCC	NWPCC	NWPCC
F_Weather	NOAA	NOAA	DFO	NA	NOAA	NOAA
T_F	NA	NA	NA	NA	BIA	NA
T1	Kalispel	Kootenai	Ktunaxa_Tobacco	CSKT	Spokane	Colvile
T2	Kootenai	CSKT	Kootenai	NA	Colville	Yakama
T3	CdA_T	Ktunaxa_Tobacco	CSKT	NA	NA	NA
T4	NA	Kalispel	Kalispel	NA	CRITFC	CRITFC
T5	UCUT	UCUT	UCUT	UCUT	UCUT	NA
S_DEQ	IDEQ	MTDEQ	BCMoE	MTDEQ	WECY	WECY
S_FW	IDFG	MTFWP	FLNRO	MTFWP	WDFW	WDFW
S_WaterRights	IDWR	NA	NA	NA	WSWRA	NA
S_Ag_Soil	ISDA	NA	NA	NA	NA	NA
S_Parks	IDL	NA	NA	NA	NA	WParks
S_NatRes	IDPR	NA	NA	MTDNRC	WDNR	WDNR
S_GovComm	ILComm	NA	NA	FBC	WRCO	WRCO
S_Legis	NA	MTLegis	NA	MTLegis	WLegis	WLegis
S_DoH	PHD1	NA	NA	NA	WDoH	NA
S_DoT	NA	NA	NA	NA	WDOT	NA
S_other	NA	NA	NA	UC3	WGov	WGov
S_o_DEQ_1	WECY	BCMoE	MTDEQ	NA	NA	NA

	PendOreille	**KoocanusaMT**	**KoocanusaBC**	**Flathead**	**Roosevelt**	**Chelan**
S_o_FW_1	WDFW_MFWP	FLNRO	MTFWP	NA	NA	NA
S_o_L&W_1	NA	BCHydro_CPC	BPA	NA	NA	NA
S_F_o_Env_1	NA	EnvC	USEPA	NA	NA	NA
S_o_DEQ_2	NA	NA	USACE	NA	NA	NA
S_o_FW_2	NA	CWS	USFWS	NA	NA	NA
S_o_L&W_2	NA	DFO	NOAA	NA	NA	NA
S_F_o_Env_2	NA	NRCAN	USGS	NA	NA	NA
F_o_Geol	NA	FWCP_CBT	NWPCC	NA	NA	NA
F_o_1	NA	NA	USFS	NA	NA	NA
F_o_2	NA	NA	USBR	NA	NA	NA
R_CD	SWCD	NA	NA	CD	CntyCD	CascCD
CntyComm	NA	NA	NA	CtyComm	CntyComm	CntyComm
CtnyNRD	NA	NA	NA	NA	NA	CCtyNRD
City	NA	NA	NA	City	NA	CCityC
EduExt_ResSta	UI_Ext	NA	NA	FLBS_WFI	NA	LCRI_WSUExt
EduInst	Edu	Edu	Edu	Edu	Edu	Edu
IND	Avista	Teck	Teck	NA	TeckAm	C_PUD
Irrig&Util	NA	NA	NA	EnKeep_FEC	IrrigDist_PUD	LCReclDist
NGO_Lk_Riv	WKeep	LL_C	LL_C	FL	CCC	NA
NGO_Lk_Riv_o	RCA	LKCC	LKCC	NWMTLVMN	CRKeep	NA
NGO_Lands	LPOIC	NA	NA	NA	NA	CDLndTr
NGO_o_1	ICL	KVRI	KVRI	MWC	LRF	CBCons
NGO_o_2	SLC	KRN	KRN	FRtL	CRndTbl	NA
NGO_o_3	NA	NA	NA	MWCC	Sierra	NA
NGO_o_4	NA	NA	NA	CFC	NWFCC	NA
NGO_TU	TU	TU	TU	F_TU	TU	NA
NGO_Anglers	NIFC	LRGC	LRGC	NA	NA	WSA
Outfitter	Outfit	Outfit	Outfit	Outfit	Outfit	Outfit
NGO_DU	DU	NA	NA	NA	DU	NA
NGO_Audubon	NA	NA	NA	Audubon	NA	NCWAud

Appendix D: Five-basin communications network study – Frequently asked Questions

What is this research about?

The purpose of this study is to understand the communication networks and interactions between participants in water resource management. This dissertation research compares the communication network patterns of five Columbia River headwaters reservoirs: Lakes Chelan, Roosevelt, Pend Oreille, Koocanusa, and čłq̓etkʷ (Flathead). At its center is the "who talks to who" in a basin, and how effective organizations or actors feel their collaborations are in managing the basin. The specific focus is on networks for managing water quality and fisheries, which may have some overlap, but do not necessarily involve the same people or entities.

Primary research questions are:

1. Which network patterns and/or actor attributes affect the creation or maintenance of communication ties among the actors in the lake basins?
2. Do different management regimes lead to different communication network structures? If so, why?
3. Which network attributes and networking processes effect changes in the identified ecological indicators?

What is a network?

Communications networks are like a spiders web of interlinked ties of people and their interactions. In social network analysis we are interested in the patterns and linkages of the actors. Figure 1 shows relations in a simple playground scenario. Larger circles or "nodes" denote more involved actors in the system. Arrows or "edges" show the direction of contacts, and the weights of the arrows denote the frequency of contact. Julia (bottom center) is the rock star, who is central to network interactions. Sally (top right) in this scenario is called an "isolate" because she has no connection to the core network. Lauren (lower left) might be a valuable resource to which stronger connections could be built.

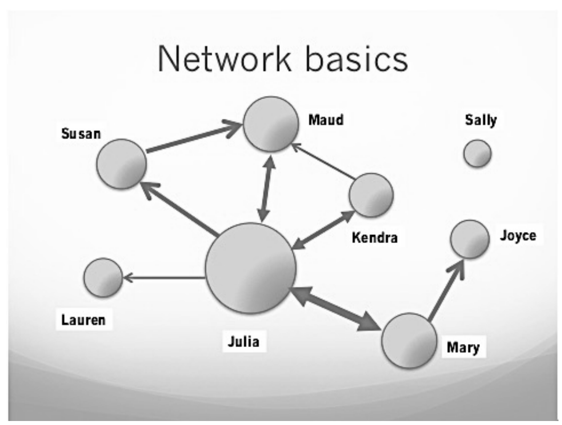

Figure 1. A simple network schematic. Larger nodes denote more active actors. Arrows show direction of contact, and weights of the arrows show frequency of contact.

Figure 2 shows a network resulting from the pilot study for this research, in the St. Joe/St. Maries River subbasins of the Lake Coeur D'Alene basin system (Trebitz & Shrestha, 2015). The actors are coded by letter and number, e.g., F-1 (Federal), S-1 (State), etc. To be a truly useful networking aid for resource managers, however, it is better to identify actors by acronym (e.g. USACE, USGS, MTDEQ, CSKT, DU, etc.). This way it becomes evident whether potentially valuable connections are being missed. A further advantage of using acronyms to label the actors in the current five-basin study is that the network of each basin can be displayed individually, or all can be combined into a regional network, showing where actors overlap across the basins.

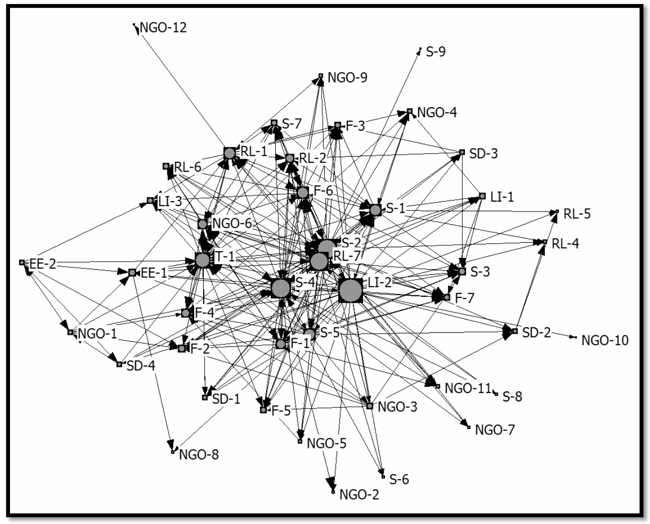

Figure 2. The St. Joe/St. Maries River subbasin network (pilot study, Trebitz & Shrestha, 2015).

How will survey responses be used?
Survey responses will be used in three principal ways:

1. To determine which indicators are used to measure lake/reservoir basin health in both fisheries and water quality issues
2. To develop the communication networks, including direction of ties and strength of ties among the actors
3. To develop statistical trends of how communications are perceived to function in the networks

How will information be protected?
University of Idaho's Institutional Review Board (IRB) has approved the research protocol for this study (IRB project 19-055, "exempt"; link to IRB here: Uidaho IRB). Only the student investigator has access to the survey response masters, which are kept on a pass-worded computer. Organizations will be identified by acronym only, without any mention of regional jurisdiction. All individual information will be removed from data sets before any statistical analysis is performed on the survey results. Individual responses are thus kept entirely confidential. As per University protocol, respondents have the right, at any time, to withdraw from the study.

Where will results be published?
Research results will be published in academic journal articles, and presented in professional conferences, and as a doctoral dissertation. Additionally, summary reports will be supplied to survey respondents and other interested parties. More targeted discussion will be available within the basins, as appropriate, to apply research results in the water resources communication networks.

Whom to contact for more information about this study?

Karen Trebitz treb6275@vandals.uidaho.edu 570-688-8703

Appendix E: Selected survey questions for chapter 5

Five general sections comprised the survey instrument ranging from organizational and individual biographical information to public engagement. The manuscript focuses analytically on portions of select sections: measuring physical indicators, and metrics of network function and success. Here we present the questions from survey instrument that are directly relevant to this study.

1. Lake health indicators

Questions about fisheries and water quality were identical across all basins. The introductory language was as follows, with the exception that "[XXX basin]" was replaced by the basin's actual name:

> *Lake health can be measured in many different ways. The following two tables list common fisheries and water quality indicators, some of which may not apply to the [XXX basin].*
>
> *Please tell us which of following indicators are used for evaluating the health of the fisheries in the [XXX basin]. Also, please indicate whether there have been changes (positive or negative) in the past two (2) years and the past ten (10) years, and if measurement records exist for those changes. You may skip indicators that do not apply to your basin.*

Respondents were asked to mark one bubble based on the direction and magnitude of change, for both 2-yr. and 10-yr. horizon (Figure 1) on the following indicators.

	Change in past 2 years				
	Large negative change		No change		Large positive change
Available spawning and rearing habitat for resident fish	○	○	○	○	○

Figure 1. Excerpt of lake health indicator questions in survey tool

The indicators that are included in the final analysis (Chapter 5, Figure 5.3) have key words bolded:

1.1. Fisheries indicators

1. Available spawning and rearing habitat for resident fish
2. Available spawning and rearing habitat for anadromous fish
3. **Availability of food** for juvenile fish (e.g. macroinvertebrates)
4. Returning numbers of spawning anadromous adults
5. Success of fish passage and fish ladders
6. Available numbers of adult fish for **fishing quotas**
7. Increased average size or weight of adult fish caught
8. Success in preventing, **controlling**, or reducing **invasive** species
9. Success in stabilizing and/or restoring **riparian zones**
10. Improved **ecological flows** in river reaches and related lake levels
11. Did we miss an important one? Please fill in: ________________

1.2. Water Quality indicators

12. Meeting water quality mandates (e.g. TMDLs)[1] in lake basin or tributary streams
13. Stabilizing **lake levels**
14. Keeping or lowering **temperatures** in lakes or streams
15. Lowering **turbidity** in lakes or streams
16. Lowering **nutrient levels** in lakes or streams
17. Success in **controll**ing toxic **algae** blooms and dead zones
18. Reduction of toxic inflows (e.g. from mine seepage)
19. Did we miss an important one? Please fill in: ________________

---

[1] TMDL (Total Maximum Daily Load) is a common acronym in U.S. water quality management, for allowable levels of certain pollutants

2. Measures of governance process function

We asked respondents about perceived successes of the governance processes within their basin's network. The introductory wording to this section is as follows, again with the basin name inserted for "[XXX basin]":

> *Successful collective action groups often exhibit particular strengths in their interactions. In contrast, progress in collaborative management can be hampered by both the regulatory framework in which you must operate, and frictions that arise among management participants. Please help us understand the factors in collaborations among the network members you identified in the [XXX basin].*

Questions were presented with sliders on a 10-point Likert scale, from low to high in importance, efficacy, etc. Responses to the following questions were used in this statistical evaluation, arranged here in the order found in Figure 5.3 of the article:

1. How helpful are the currently available scientific knowledge and **data** to understand future impacts of water management decisions in the [XXX basin]?

2. How would you describe the level of **collaboration** among your network contacts in the [XXX basin]?

3. To what extent do you feel that network participants share **common goals** for management?

4. To what extent do you feel that network participants share **common strategies** or approaches for improved for management of the lake basin?

5. How **inclusive** would you say the process of reaching policy decisions has been for management in the [XXX basin]?

6. In the past two (2) years, how effective has the network been at helping to solve management issues in the [XXX basin]?

    A. **Identifying issues** and planning actions

    B. **Implementing** planned **actions**

7. In the past ten (10) years, how effective has the network been at helping to solve management issues in the [XXX basin]?

    A. **Identifying issues** and planning actions

    B. **Implementing** planned **actions**

The Likert scale questions were followed by two write-in responses, from which we draw some of the direct quotes in the manuscript:

8. Can you share a specific situation that decreases your willingness to collaborate?
9. What might increase your willingness to collaborate in the future?

Appendix F: Data supplement for chapter 5

BasinID	Spwn_hab_res_2	Spwn_hab_an_2	Macros_avail_2	Return_an_2	Success_pass_2	Fish_quota_2	Fish_sz_wght_2	Contr_inv_2	Riparian_2	Ec_Flow_2	Spwn_hab_res_10	Spwn_hab_an_10	Macros_avail_10	Return_an_10	Success_pass_10	Fish_quota_10	Fish_sz_wght_10	Contr_inv_10	Riparian_10	Eco_flow_10	WQ_man_2	Lake_lev_2	Temp_2
1=PO,	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n
1	1		0		2	0	0	-1	2		0		0		2	1	0	-1	1		0	0	
1																							
1	0				0			1	0	0	1				1			2	1	0			
1																							
1	0		0		1	0	1	1	1	0	2		0		2	2	1	2	1	0	0	0	0
1																					-1		-1
1	0		0		0	1		0		0	-1		0		0	1		2		0		0	0
1	1				1			1			1				0			1					
1					0	1	0	1	0	0					1	2	1	2	1	1	1	0	0
1	1		1			1	1	2	1	1	1		1			2	2	2	2	1	0	1	0
1																							
1	-1		-1					-1		-1											0	0	0
1	0		0		0	1	1	0	1	0	1		1		0	1	2	1	1	-1		-2	
1																						1	
1																							
1											-1		0					2					
1																							
2			0			0	0	0	0	0	-1		-1			0	0	-1	1	1	0	-1	0
2	-1		0					-1	1	-1	-1		-1					-1	-1	-1	0	0	
2																							
2	0		0				0	0	1	1	2		1				0	1	2	2	-1		2
2																							
2								0										0			0		
2										1										0			
2	0		-2			-1	1	1	1	0	0		-2			0		1	1	0	1	1	0
2										0										2		0	
2																					-1	-1	-1
2								1	1									1	1	1	0	0	
2																							
2																							
2																							
2																							
2																							
3	0		-1			0	-1	0			-1		-2			0	-1	-1			0		0
3			0					0					0					0			0	0	0
3	0							0	0	0	0							0	0	1	0	0	0
3										0										2		0	
3	0		-1			0	0	2			-1		-1			0	0	2			0		
3	0		0	0	1	0		-1	1	0	1		0		1	0		-2	2	0	0	0	0
3																							
3								1	1									2	1		0	0	-1
3			-1										-1								1	0	0
3	0			-1				1	0	0	-1			-2			2	2	1	1			0
3																							
3	0		0				0	2	1	0	0		0				0	1	1	0	1	0	-1
3	0		0	0		0	0	0	0	0	0		0	-1		0	0		0	0	0	-1	0
3								1										1			1		0
3	0						0	1	0	0	0						0	1	0	0	0		0
3								2															
3																							
3	0		0		0			1	1	1	1		0		1			1	2	1		0	1
4																							
4	0	0	0			0	0	0			0	0	0			0	0	0				0	
4	2	0	0		0	2		-2	2	0	2	0	0		0	2		-2	2	0	0	0	0
4								0	0														
4	2	2	2		1			2	0	0	2	2	2		1			2	0	0	1	1	-1
4								1															
4	0	0	0			1	0	-1			1	0	0			2	0	-2			-1	0	-1
4	0	0	1	0			0	-1	0	0	1	0	1	0			0	-1	0	0	0	0	0
4																							
4	0	0	0	1	1		0	1	0		1	1	0	1	1		0	1	0			0	0
4								-1										-1			0		-1
4																							
4									0	0									1	0	-2		-1
4		0		0								0		0									
4	0	0	2	0	0	0	2	-2	0		2	0	2	0	0	0	2	-1	0				
4	0		0			-1	0	-2	1	1	0		0			-1	0	-2	1	1	-1	-1	-1
5	0		0		0	1	1	0	-1	1	0		0		0	1	1	0	-1	1	0	0	0
5	0		0			1	0	-1	1	0	1		0			1	0	-1	1	0			-1
5	0	2	0	2	0	0	0	0	2		0	2	0	2	0	0	0	0	2	2	0	2	0
5																							
5									0	0													
5																					0		0
5								1	1												1	0	1
5	0		1	2		1				2	1		1	2		1				2		0	

BasinID	Turb_2	Nutr_2	Algae_2	Toxins_2	WQ_man_10	Lake_lev_10	Temp_10	Turb_10	Nutr_10	Algae_10	Toxins_10	Sci_Data	Lvl_Collab	Id_Iss_2	Impl_Act_2	Id_Iss10	Impl_Act_10	Lvl_Infl	Lvl_Incl	Com_Goal	Com_Strat
												Likert	Likert	Likert	Likert	Likert	Likert	Likert	Likert	Likert	Likert
1=PO,	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	1=lrg n	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10	0-10
1					0	0						7	1	1	7.1	8.1	7.2	4	1	6.1	6.1
1													7.6	6.8	4.5	6.2	4.8	5.4	3.6	8.1	7.6
1												10	7.5	8.9	9	8.1	8.1	10	9	8.1	8
1												6.5	4	3	3			1	3	6.1	3.1
1	0	0	0		0	0	0	0	1	0		8.1	8.1	9	9.1	9	9	4.9	8.1	8.1	8.1
1	-1	-1			-1		-2	-1	-2			2.7	2.9	6.1	4.1	5	5.1	0.7	4.2	7	3.9
1	0	0	0			-1	0	1	1	1		9	7	6	4.9	8	6.9	6	8	6	3.9
1				0							0	7	5	5.1	5.2	4.9	5	4.9	5	5.1	5
1	0	1	0		1	1	1	0	1	0		8	5	4	4	6	6	5.9	6	7.6	6.1
1	0	1	1		1		0	0	1	1		8.1	7.1	6.2	8	7.6	9	4	6.9	5.1	5.5
1			-1							-1		7	5	4.9	4.9	4.9	4.9	7	9	10	10
1	0		0		0	1	0	1		-1		3.5	6	6		7.4		5	4.1	6.2	6.3
1			0			-2				-1		2.6	2.9	5.1	5.1	5.6	5.7	3.1	2.1	5.1	5.1
1	0		1									3.1	1	0.2	0.7			1	2	5.1	5.1
1												7.1	5	7.1	5	8.1	2.9	8	5	6.1	5
1						-2						5.1	8	8.2		8		9.1	5	5.2	3.9
1												7.1	6.4	3.1	3.2	3.2	3.3	1.2	5.9	5.1	4.1
2		-1	0	-1	-1	-1	0		-1	0	-2	7	8.1	7.7	7.7	7.7	7.8	7.6	8.6	8.7	8.6
2		0		0	1	0			0		-1	3.1	3	2.4	2.5	0.9	0.9	6.1	7.1	6.1	7.2
2												9.2	5.1								
2		-1		0	-1		2		-1		-2	10	10	9.2	9.2	10	10	9.2	9.2	10	9.1
2												5	7	3.9		6.1	7.1	8.1	8.1	5	5.1
2		0		0	-2				-2		0	8.2	7.2	7	7.2	1.9		8.1	7.1	7.1	5
2				-2							-1	4.2	5.2	4.1	2	4.3	2.9	5.1	3.1	5.1	3.8
2	0			-1	1	1	0	0			-1	7	6	5.6		6.1	6.1	5.8	5.1	4.9	4.9
2						2						10	9.1	10	10	10	10	6.1	10	9.2	9.2
2	0	-1	0	0	-1	-1	-1	0	-1	0	1	10	9.1	6.2	5.7	7.3	6.9	4	3.4	8.2	5.1
2	-1			0	-1	0		-1			1	6.9	7	5	4.2	5.1	4	7	6.1	6.1	6
2												6.1	1.9	6.1	1.7	6.2	3.1	1.9	5.1	8.3	5
2												9.2	10	9.3	9.2	9.8	9.6	5.2	10	9.7	9.2
2																				8.2	
2											1	8.2	10					10	9.2		
2												4.9	5	2	3.9	0.9	0.9	7.1	7.1	4.5	5.1
3					0		-1					8.5	7.4	3	3.2	4.5	4.7	1.4	5.1	3.4	3.7
3		0	1		1	0	0		0	1		6.5	6.8	7.1	7	7	7.2	5.1		6.1	6.1
3	0	0			0	1	0	0	0			9.1	8.1	4	5.9	4	1.9	6	4	5	5
3						2						8.6	9.5	8.2	8.8	8	8.5	6.1	9.4	9.2	8.1
3		-1			-1				-1			10	8.1	5.1	3.1	8.1	7.1	7.1	6.1	4	6.1
3	0	0			-1	0	0	1	1			10	7.1	6	6	5.1	5.1	5	5	3.9	3.9
3												5.1	7.1	8.2	7.2	6.1	5.2	5	5.1	7.1	6.1
3	0	1	0	0	0	0	-1	0	1	0	0	10	6	7.1	5.1	7.2	6.2	6	5	6.1	6.1
3	1	1	0		1	0	0	1	1	0		8.1	4	3	8.2	9.1	9.1	6.1	7.1	5	7
3							-1					7.1	5.1	5.1	5.1	7.1	6.2	9.2	7	6.1	5.1
3												5	5	5.1	5.2			9.1	5		
3	-1	-1	0		1	0	-1	-1	-1	0		9.1	7.1	6.1	2.9	6	3	6.1	6	8.1	6
3	0	0	0	0	0	-1	0	0	0	0	0	9.2	9.3	9.2		9.2	8.6	9.2	9.1	8.1	7.1
3	0	0	0		1		0	0	0	0			8.1	6.2	4.9	6.2	6.3	9.2	5.9	9.2	8.1
3					0		0					3	8.1	5.1	5.2	5.1	5.1	5	5	5	5
3												9.3	4.1	8.1	8.2	8.5	8.6	8.1	8.3	6.4	7.6
3												10									
3	0	0				0	1	0	0			7.1	6	4	4	7.1	6.3	7	5.1	6.1	7.1
4													7.1					0.1			
4						0						9.1	6.1	6.1		6.1		2	1.9	5	5
4	0	1	0		0	0	0		1	0	1	7.6	8.1	9.1	9	9.1	9.1	8.1	9.1	9.1	7.6
4												6.2	5.1	5.2	5.2	5.1	5.2	8	7.2	5.1	5.4
4			-1	-1	1	1	-1			-1	-1	4	9	8	8.2	6.7	6.8	9.2	5	6.9	8
4				0							1	3.5	5	1.5	3.7	1.7	4	1.9	1.9	5	3
4	0	-1			-1	0	-1	0	-2			9.1	8	8.2	8.2	9.3	8.1	10	10	9.1	8
4				0	1	-1	1				0	7	6	6	6.1	7.3	6.1	5	4	5	3.9
4												10	0.9	0.9	0.8	1	1.1				
4	0	0	0	0		0	0	0	0	0	0	7.1	7.6	6.7	6.1	8.2	7.3	8.2	7.5	7.2	8.1
4			-1		0		-1			-1		8.1	5.1	6	6.1	6	6	5	8.1	8.1	5
4												5	5.1	2	2.1	5.1	5	0.8	5.1	4.1	4.1
4	0	0			-2		-1														
4												5.5	3	6.3	4.7			1.8	5.4	6.1	5.1
4												0		0	0	0		0	0	0	0
4	0				-1	-1	-1	0				7.3	7.2	6.3	6.3	7.2	7.3	8.2	7.3	7.4	7.2
5	1	1	0	1	0	0	0	1	1	0	0	7.1	0.9	1.9	1.9	0.9	0.9	0.9	0	5	3
5				1			-1				1	2.5	10	8	9.1	6.8	9.1	7	5	8.2	7.2
5	0				2	2	2	0				8.6	7.2	5.1	7	7.1	7.2	5	5.1	7.1	8.2
5												4	7	9.2		8.2	4.2	8	8.2	8.2	9.2
5												7.7	8.4	7.3	7	6.8	6.5	8.9	8.2	6.3	9
5	0			1	0							6.4	5.5	7.1	5.3	1.9	1.3	7.2	7.3	5.8	5.3
5	1			1								5.1	2.9	5.9	5.8	4.9	4.8	6.9	3.1	5.1	6.1
5						1						8.2	9.2	9.2	9.2	9.2	9.3	10	9.2	6.1	6.2