Flowing Together: Addressing Social-Ecological Scale Mismatches for Estuary Watershed Restoration in the Whidbey Basin, Puget Sound, WA

by

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ABSTRACT

Landscape restoration is a global priority as evidenced by the United Nations' 2020 goal to restore 150 million hectares of land worldwide. Restoration is particularly needed in estuaries and their watersheds as society depends on these environments for numerous benefits. Estuary restoration is often undermined by social-ecological scale mismatch, the incongruence between governing units and the bio-physical resources they seek to govern. Despite growing recognition of this fact, few empirical studies focus on scale mismatches in environmental restoration work. Using a sub-basin of Puget Sound, Washington, U.S.A., I analyze scale mismatches in estuary restoration. I take a network science approach because governance networks can bridge scale mismatches. I combine quantitative social network analysis (SNA), geographic information systems (GIS), and qualitative interview analysis.

Spatial network analysis reveals several areas with weak scale mismatch bridging networks. These weak social networks are then compared to ecological restoration needs to identify coupled social-ecological restoration concerns. Subsequent study investigates jurisdictional and sectoral network integration because governance siloes contribute to scale mismatch. While the network is fairly well integrated, several sectors do not interact or interact very little. An analysis of collaboration reasons disentangles the idea of generic collaboration. Among three relationship types considered, mandated relationships contribute almost 5.5 times less to perceived collaboration productivity than shared interest relationships, highlighting the benefits of true collaborations in watershed governance. Lastly, the effects of scale mismatch on individual restoration projects and landscape level restoration planning are assessed through qualitative interview analysis. Results illustrate why human-environment processes should be included in landscape restoration planning. Social factors are not considered as constraints to restoration but rather part of the very landscape fabric to be restored. Scale mismatch is conceptualized as a complex social-ecological landscape pattern that affects the flow of financial, human, and natural capital across the landscape. This represents a new way of thinking about scale mismatch and landscape restoration in complex multi-level governance systems. In addition, the maps, network diagnostics, and narratives in this dissertation can help practitioners in Puget Sound and provide proofs of concepts that can be replicated elsewhere for restoration and broader conservation sciences.

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PREFACE

When excrement flows into your livelihood source after big rains, you become acutely aware of several things. At least I did growing up, teaching kayaking on Boston's Charles River and coastal waters. Among other problems, Boston has combined sewer and overflow pipes that discharge sewage when too much storm-water enters the system. So for one, you learn how our land-use practices combine with environmental processes to affect human wellbeing. (You also learn to keep your mouth shut when water splashes in your face or when you have to put your head underwater.) Yet, many things I did not learn until years later: for starters, why is it so hard to clean-up and restore estuarine and coastal watersheds? The collective action and coordination challenges associated with landscape restoration spanning hundreds of kilometers and encompassing dozens of local municipalities, as does the Charles River watershed, are formidable.

These challenges are even thornier in waters around the world that span local, state, federal, and tribal land jurisdictions, or cross international borders. We have parceled out the landscape with little regard for ecological processes and boundaries, a problem know as social-ecological scale mismatch or social-ecological fit. It is a fundamental and wicked sustainability problem. Fundamental because mismatches undermine our ability to provide for current and future generations while preserving earth system functions. Wicked because solutions often involve tradeoffs and there are no panaceas. Years and circumstances later, I found myself working on these problems, on the other side of the continent, in Puget Sound, Washington. Such is the subject of this dissertation.

Back in Boston, things have come a long way. In the mid-1960s, the Charles River inspired The Standells to record the hit song *Dirty Water*, the chorus declaring: "Well, I love that dirty water / Oh, Boston, you're my home." Long gone are those "dirty water" days. Since 1995, the U.S. Environmental Protection Agency (USEPA 2015) has continually raised the Charles River bacterial standards report card from Ds and Cs to B+ and A- (Fig. 1.0). While other contaminant problems, such as phosphorous, stubbornly linger (USEPA 2015), Bostonians are making progress on a wicked problem. I hope this dissertation helps our global society continue down a similar path.

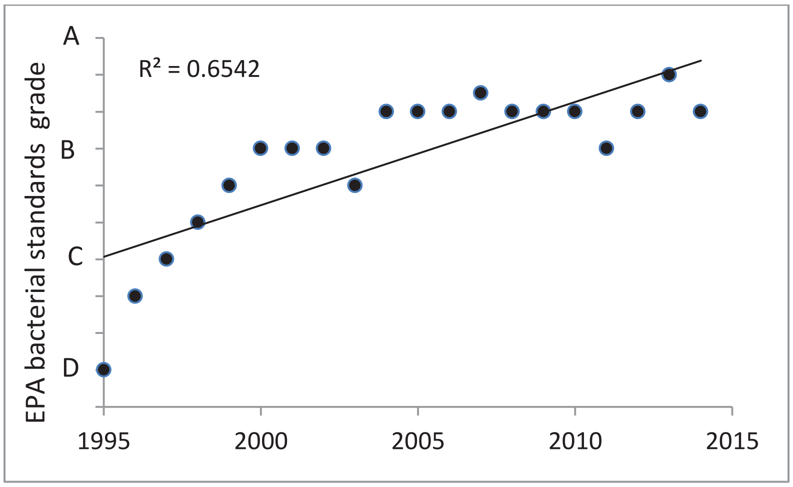

Figure 1.0. EPA report card grades for bacterial standards in the lower Charles River, MA from 1995 to 2014. Data are from USEPA (2015). Grades are reported using an ordinal letter grade scale with plusses and minuses. They have been plotted here by rank order.

Chapter 1. Introduction

1.1. Setting

The scientific community has gathered ample evidence that our development actions have fundamentally altered the Earth system in ways that threaten our own health and most life on Earth (Foley et al. 2005; MA 2005; Rockström et al. 2009). While previous phases of global change research established concerns, the next must establish solutions (Defries et al. 2012; Moss et al. 2013).

Solutions are particularly needed in estuarine environments – areas where rivers meet the sea – which are essential for human wellbeing (e.g., food, recreation, and storm protection), but degraded worldwide (Diaz and Rosenberg 2008; MA 2005; UNEP 2006). About 27% of the world's population lives within 50 kilometers of an estuary (UNEP 2006); and estuary benefits extend much farther. Estuaries are vital for world fish supplies, disease control, waste processing, biodiversity, atmospheric regulation, and tourism economies among other components of human wellbeing (UNEP 2006). Unfortunately, human activities have caused more than 400 coastal dead zones globally (Diaz and Rosenberg 2008). In the U.S. alone, roughly 37% of estuaries are in poor condition (USEPA 2007). Our global dependence on these environments, combined with global population growth (MA 2005), means that halting degradation is not enough. To provide for a growing population, we must undo some damage.

Estuary restoration usually must be coordinated among multiple government and non-government programs operating from local to larger scales and in different locations throughout a watershed (Baird 2005; Menz et al. 2013; Palmer 2009; Sabatier et al. 2005a; Schneider et al. 2003). Coordination and collaboration creates a governance network, the structure and function of which are essential for natural resource management (NRM) outcomes (Bodin and Crona 2009; Bodin and Prell 2011; Folke et al. 2005; Janssen et al. 2006). Alternatively, failure to coordinate and achieve collective support from all regions can undermine restoration efforts because all locations in a watershed are linked through biophysical processes (NRC 1992). Thus, estuary restoration is highly susceptible to social-ecological scale mismatches: the misalignment between governing units and the environmental systems they seek to govern, a fundamental sustainability problem often leading to failed or inefficient resource management (Crowder et al. 2006; Cumming et al. 2006; Folke et al. 2007; Galaz et al. 2008). While scale mismatches are frequently cited as a major challenge for landscape restoration (Baird 2005; Baker and Eckerberg 2013; Menz et al. 2013; Nilsson and Aradottir 2013; Palmer 2009), few if any empirical restoration studies explicitly address mismatch.

In this dissertation, I study scale mismatches in the context of landscape restoration in Puget Sound, Washington. Structured as three independent manuscripts (Chapter Two through Four, outlined in section 1.4), this dissertation represents a cohesive work that addresses the following question: *how does a complex spatial arrangement of organizations linked through social institutions and occupying hydrologically connected regions affect, positively or negatively, environmental restoration?*

This research is founded on the idea that restoration can help us live sustainably. Restoration can improve ecosystem processes that support human wellbeing (Suding et al. 2015) and, if balanced with societal needs for development in certain places, can improve intra- and inter-generational equity (Weinstein 2008; Weinstein et al. 2007). It is also founded on the idea that scale mismatch is a fundamental challenge to large-scale environmental management, such as landscape restoration, (Cumming et al. 2006; Folke et al. 2007; Galaz et al. 2008) and that networks can help bridge scale mismatches

(Bergsten et al. 2014; Bodin et al. 2011; Ernstson et al. 2010). Chapters Two through Four provide detailed reviews of the relevant scale mismatch and network literatures and I will avoid replicating them here. Wider reflections on environmental restoration and human-environment scholarship are provided, however.

1.2. Background

1.2.1. Environmental restoration

Environmental restoration has become a global priority as evidenced by the United Nations' goal to restore 150 million hectors of degraded land worldwide by 2020 (Menz et al. 2013). Restoring ecosystem processes to support human wellbeing (Suding et al. 2015), is a laudable goal, but must be undertaken with a specific mindset. In a world where the future will not be like the past due to climate change, sea level rise, and population growth (Baird 2005; Choi 2004; Harris et al. 2006; Jackson and Hobbs 2009), restoration may be wishful at best and foolhardy at worst. Restoration that focuses too strictly on restoring historic structure could ossify ecosystems, making them vulnerable to climate change (Harris et al. 2006). However, as Higgs (2003:270) argues: "We restore by gesturing to the past, but our interest is really in setting the draft pattern for the future."

The definition of restoration has changed over time (Clewell and Aronson 2007; Higgs 2003),[1] moving away from stark notions of virgin or indigenous ecosystems, as we have come to recognize the storied and complex history of landscapes (Denevan 1992;

[1] The Society for Ecological Restoration (SER) has continually changed the definition of restoration from strict notions of historic reference sites towards broader ideas of human-aided environmental recovery. This change is evident in the following definitions form 1990, 1996, and 2007. SER's 1990 definition reads: "Ecological restoration is the process of intentionally altering a site to establish a defined, indigenous, historic ecosystem. The goal of this process is to emulate the structure, function, diversity and dynamics of the specified ecosystem" (Higgs 2003: 107). SER's 1996 definition reads: "Ecological restoration is the process of assisting the recovery and management of ecological integrity. Ecological integrity includes a critical range of variability in biodiversity, ecological processes and structures, regional and historical context, and sustainable cultural practices" (Higgs 2003: 109). SER's 2007 definition reads: "Ecological restoration [is the] process of assisting the recovery of an impaired system" (Clewell and Aronson 2007: 192).

Higgs 2003) that have multiple stable states (Holling 1973). Restoring ecosystem processes as opposed to structures, may enhance resilience to climate and other changes (Harris et al. 2006; Palmer et al. 2014). For example, non-native wetland plants may provide wildlife habitat and nutrient filtration, while being more resilient to climate changes than native vegetation (Marris 2009). A broad definition of restoration also provides a boundary object that can unite stakeholders in a landscape (Higgs 2003; Kittinger et al. 2013; Simenstad et al. 2005).

While a broad definition of restoration is beneficial, the historic aspect of restoration remains important. Restoration requires some form of historic fidelity; we are guided by the past (Higgs et al. 2014). When we try to bring back salmon runs in an urban environment (Simenstad et al. 2005) we are creating a future informed by the past because we identify it as desirable. These actions are as much ecological restoration as they are social restoration because we mourn the loss of something (Higgs 2003). Provided that restoration does not chase fabricated or unattainable pasts, and accounts for future changes, it is a welcome concept (Higgs et al. 2014). Furthermore, as a society that has transformed the earth at an unprecedented rate (Foley et al. 2005; Turner and McCandless 2004), restoration may humble us as we reflect on the consequences of our past environmental uses while planning for the future (Higgs et al. 2014).

1.2.2. Human-environment scholarship and sustainability science

Geography has long studied the causes and consequences of earth transformation (Turner 2002). In doing so, human-environment relations are approached as a unique phenomenon of study (Turner 2002)[2] irreducible to component parts (Turner et al.

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[2] The works of Alexander von Humboldt and Friedrich Ratzel, during the European restructuring of science during the Enlightenment, represent the foundation of contemporary claims that human-environment relations are geography's focus of study (Turner 2002). Humboldt sought to study not just how the biophysical environment and humanity influenced one another, but something greater than these two parts; the unity of nature (Kates 2002; Turner 2002). Humboldt's vision was not taken up by geography as a whole and his ideas competed in the

2003). Scale-mismatch represents such a phenomenon. By definition, its drivers and consequences can only be understood by looking at how social and ecological boundaries and processes align in one or more important ways (Cumming et al. 2006; Folke et al. 2007; Galaz et al. 2008). Additionally, a study of restoration systems, i.e., interactions among the various organizations involved with restoration and their interactions with the landscape, aligns with geography's focus on the proximate and distal causes and consequences of land change (Turner et al. 2007; Turner and Robbins 2008). After all, what is restoration if not an attempt to change the landscape? While geography has an historic claim to the study of human-environment relations (Turner 2002), it is joined today by several other research traditions.[3]

One such "new" tradition is resilience (Anderies et al. 2006; Gunderson and Holling 2002; Holling 1973),[4] which focuses on a social-ecological system's ability to respond to disturbance, either by returning to a previous configuration or reorganizing into something new (Folke 2006; Holling 1973). A related concept, robustness, shifts the

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academy with spatial-chorological traditions that can be traced back to Kant (detailed in Turner (2002)). Humboldt and Ratzel influenced the geographers Davis, Sauer, and Barrows, all of whom were influential in creating contemporary human-environment geography traditions (Turner 2002). (However, contemporary geography has largely erase Davis's legacy because his geographic factor – or the control of nature over man – lead to environmental deterministic interpretations (Turner 2002).) Barrows' (1923) and Sauer's (1925) work led to subsequent development of cultural ecology and risk/hazards research that in turn led to modern day foci on land change science, human dimensions of global change, political ecology, and vulnerability (Butzar 1989; Ellen 1988; Robbins 2004; Turner 2002; Turner and Robbins 2008).

[3] While I draw primarily from human-environment geography and resilience scholarship, several other scholarly traditions have also developed around human-environment relations, such as urban ecology (Collins et al. 2011; Groffman et al. 2004; Pickett et al. 2011) and landscape ecology (which has its roots in geography) (Wu 2006; 2013). Sustainability science (Kates 2011; Kates et al. 2001) also focuses on human-environment relations, though rather than a tradition at par with the former, sustainability science may have emerged as an umbrella that can unite other traditions (Anderies et al. 2013; Bettencourt and Kaur 2011; Turner 2010; Turner and Robbins 2008).

[4] Resilience thinking has origins in complex systems and the new ecology turn (Holling 1973; Levin 1999) and is presented as a way to govern earth resources sustainably (Yorque et al. 2002) through recommendations derived from theoretical, empirical, and narrative studies (Anderies et al. 2006). Holling's (1973) seminal paper on resilience focused heavily on the implications of resilience thinking for ecosystem management. Thus, from inception, resilience has been about a new way to manage earth system resources.

focus slightly from a system's identity to its performance when perturbed or when there is uncertainty in how its internal components operate (Anderies et al. 2004). Tradeoffs usually exist between maximum system performance and robustness (Anderies et al. 2004; 2013). Performance tradeoffs may also exist among different subsystems and between the subsystems and the whole (Anderies et al. 2013; Anderies and Janssen 2011). These concepts are relevant to landscape restoration because there may be tradeoffs in how, when, and where restoration actions are carried out on the landscape (Hobbs and Cramer 2008). They are also relevant to scale mismatch bridging networks as different network configurations support different levels of efficiency, legitimacy, and robustness (Bodin et al. 2006; Bodin and Crona 2009; Janssen et al. 2006).

While founded in coupled human-environment systems, my research focuses more on natural resource governance structures and processes than it does on ecology. In doing so, it aligns with research on the human dimensions of global change (HDGC), which has a rich history in geography and resilience (Janssen 2007; Turner and Robbins 2008; Young 2008). The HDGC community remains strong and vibrant; indeed it remains a key research theme under the Future Earth program (Future Earth 2015; IHDP 2014). But human-environment scholarship may now be seen as coalescing around sustainability science, which is solutions oriented and blends scientific application and theory (Anderies et al. 2013; Bettencourt and Kaur 2011; Kates 2011; Kates et al. 2001; Liu et al. 2015; Lubchenco 1998; Turner 2010; Turner and Robbins 2008; Wu 2012). This contemporary scholarship aligns with my focus on the effects and possible solutions of scale mismatch in landscape restoration.

1.3. Study area overview

This study examines scale mismatch in landscape restoration in the Whidbey Basin (WB) in Puget Sound, Washington (Fig. 1.1). WB is one several estuarine fjord systems in Puget Sound and is bounded by the mainland to the east and Whidbey Island to the west (Cannon 1983; Yang et al. 2010). It is fed by four large rivers from the mainland that drain about 14,850km^2 (Bechie et al. 2001; PSP 2014) and account for 68% of Puget Sound's freshwater input (Yang and Khangaonkar 2010). Puget Sound is experiencing major development pressures and population growth (Grimm et al. 2008) and has been the focus of significant restoration efforts in recent decades (Bernhardt et al. 2005), which make the region, including WB, an apt case for studying human-environment relations in landscape restoration.

Key restoration foci in WB include habitat for several endangered salmonid species, shellfish beds, and marine water quality (Lyshall et al. 2008; PSP 2014; Wilhere et al. 2013). These foci are not mutually exclusive as water quality degradation from farms, cities, and rural septic systems stress both salmon and shellfish (Dethier 2006; Fresh 2006). (See Chapters Two through Four for specifics of landscape degradation and associated restoration needs.) Water quality illustrates the region's physical connections as marine waters are affected by land use in the entire basin. Salmon further illustrate biological connections as they spend their adult life at sea and return to spawn in specific rivers, but use the entire WB nearshore during their juvenile life stage (Beamer et al. 2013; PSP 2014).

While biophysically connected, WB is fragmented by numerous organizations involved in its governance, illustrating scale mismatch. Local, state, federal, and tribal jurisdictions crisscross the landscape and many nonprofit, and private organizations also work in specific regions (Lyshall et al. 2008; PSP 2014). A very small percentage of forested headwaters cross into Canada, but I focus this study on the large majority of the basin residing in WA. Land uses vary throughout the region and include urban, agricultural, and forests regions that have economic and cultural differences (Breslow

2014a; 2014b; Evans and Moore 2011; Lyshall et al. 2008; NWIFC 2012; PSP 2014). All in all, WB embodies everything that makes restoration challenging.

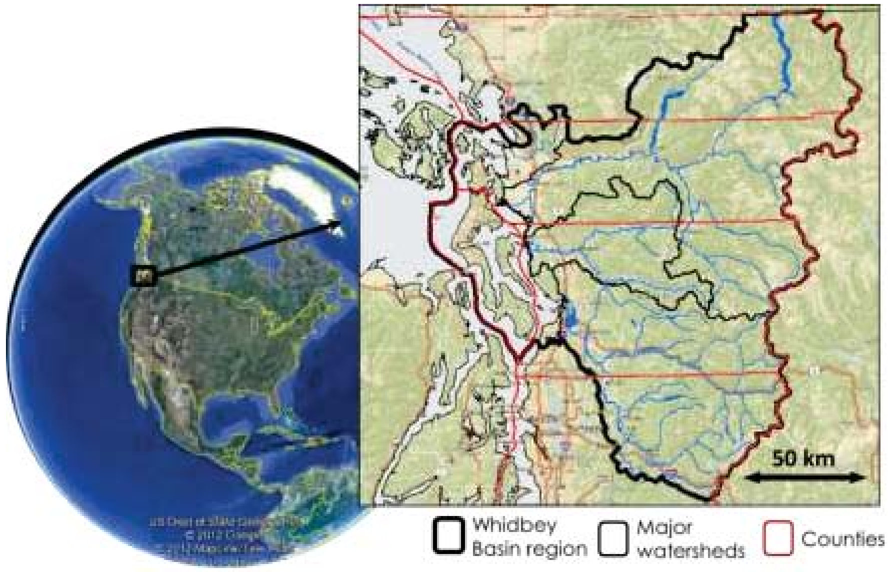

Figure 1.1. Study area map of Whidbey Basin (WB) in Puget Sound, Washington. Many local, state, federal, tribal, nonprofit, and private organizations are involved with restoration (Lyshall et al. 2008; PSP 2014). Only counties are shown in the map for visual clarity. Scale bar is approximate.

1.4. Outline of chapters

As a cohesive whole, the following three chapters argue that socio-political structures and processes should be included in landscape restoration planning in the same way that ecological structures and processes are. They also illustrate how understanding human-environment relations can improve restoration planning and practice.

Chapter Two is founded on theory that scale mismatch undermines natural resource governance (NRG) and that governance networks can help overcomes mismatches. Using social-ecological network analysis (SENA), which differs from SNA by including both social and ecological units in a single network, the chapter provides a spatially explicit and quantitative analysis of governance structures and the extent to which they align with biophysical patterns. The model considers relationships between local and regional organization (n = 210) as defined by their geographic extent. It contributes to a nascent literature on SENA that is only starting to consider multiple governance levels in spatially explicit ways. It also integrates social-ecological network patterns with an ecological habitat assessment done by WA Department of Fish and Wildlife for a coupled social-ecological restoration planning diagnostic.

During roughly twelve months of field work, I conducted participatory observations, surveys, and interviews with restoration practitioners in WB to understand and construct a spatially explicit governance network. I then modelled the biophysical network (n = 38 ecological units) using U.S. Geological Survey surface hydrology data. As a proof of concept, the analysis focuses on salmon restoration. The specific questions asked include: 1) To what extent do restoration organizations collaborate between hydrologically connected areas and thus, bridge scale mismatch?; 2) How functional is mismatch bridging in terms of organizations' self-assessed collaboration productivity?; and 3) Where do social challenges and opportunities align with ecological restoration needs?

While Chapter Two includes all organizations working in WB, it does not distinguish specific jurisdictional levels (e.g., county and state) and governance sectors (e.g., government and nonprofit). Chapter Three picks up this task, analyzing the extent to which different organizational types collaborate with one another and how these patterns vary by different collaboration reasons (i.e., mandated, funded, and shared interest relationships). The analysis combines quantitative SNA and qualitative data from interviews. It follows recent solutions oriented research that uses SNA as a diagnostic to inform targeted network interventions that aim to improve NRG. It also provides empirical findings about the correlation between productivity and different types of relationships.

Chapter Three analyzes the entre WB basin network as a whole (n = 210), but also gives specific attention to local city jurisdictions to illustrate how the analysis can aid recovery efforts. The chapter discusses how analytical unit selection and spatial relationships affect SNA for NRG research. Like the previous chapter, Chapter Three also focuses on salmon restoration. The specific questions asked include: 1) How well integrated, based on governance sector and jurisdictional level, is the salmon governance network?; 2) Why do different types of organizations collaborate, specifically considering mandated, funded, and shared interest relationships?; 3) How productive are their collaborations and how does productivity vary by collaboration reason?; and 4) How can understanding these patterns enhance restoration work in the region?

Chapter Four adds to the previous two chapters though an in-depth qualitative analysis about how scale mismatches affect restoration planning and implementation. It contributes to a growing literature on the human dimension of restoration that has yet to explicitly study the effects of scale mismatch. The chapter draws on a large set (n = 95) of semi-structured interviews conducted with a purposely selected subset of organizations in the social network. I analyze how scale mismatches affect individual restoration projects and how they affect the entire restoration system, which includes interaction between organizations inside and outside of WB. Through narrative, I illustrate how three categories of spatial arrangements affect the flow of human, financial, and natural capital and what this may mean for restoration in the region. The three spatial arrangements considered are: 1) between scalar levels (e.g., local and regional), 2) between spatial positions (e.g., up and downstream), and 3) between places of special character (e.g., urban vs rural areas). Chapter Four focuses on restoration activities broadly and is not restricted to salmon. The specific questions asked include: 1) How do scale mismatches affect estuary restoration planning and implementation in a complex, multi-level governance setting?; and 2) How can this understanding improve landscape restoration science and practice?

1.5 Significance

Social-ecological scale mismatches are a fundamental sustainability problem, often leading to failed or inefficient NRM. Estuary restoration is particularly susceptible to scale mismatches. Despite frequent citation to this fact, few empirical restoration studies specifically focus on scale mismatch. This dissertation quantitatively and qualitatively analyzes scale mismatches to improve estuary restoration planning. This includes developing a novel social-ecological network framework to analyze scale mismatch. Beyond methods, it provides evidence and argument for the inclusion of human-environment processes in landscape restoration planning. In doing so, social factors are not considered constraints to restoration, but rather part of the very landscape fabric to be restored. Scale mismatch is conceptualized as a complex social-ecological landscape pattern that affects the flow of financial, human, and natural capital across the landscape. This represents a new way of thinking about scale mismatch and landscape restoration in complex multi-level governance systems. In addition to novel ways of thinking, the resulting maps, network diagnostics, and narratives can help local practitioners in Puget Sound and provide proofs of concept that can be replicated elsewhere to support restoration and broader conservation sciences.

Chapter 2. Social-ecological network analysis of scale mismatches in estuary watershed restoration[1]

2.1. Introduction

More than a century ago, John Wesley Powell, second director of the U.S. Geological Survey, advised politicians to align political borders with watersheds for successful resource management. His advice was ignored, but continues to resonate (DeBuys 2001). Today, incongruences between governance boundaries and the natural resource systems they are meant to govern, often termed spatial scale mismatch or spatial fit, is a fundamental sustainability challenge as mismatches often lead to failed or inefficient resource management (Crowder et al. 2006; Cumming et al. 2006; Folke et al. 2007). Given this importance, mismatch was a major research theme under the International Human Dimensions Program on Global Environmental Change, now part of the Future Earth initiative (Future Earth 2015; Young 2008).

Spatial scale mismatch (scale mismatch henceforth) occurs when the geographic extent of a governing social unit is smaller or larger than, or does not align with the geographic scale at which ecological processes occur (Cumming et al. 2006; Folke et al. 2007). For example, a municipality smaller than the watershed from which it gets water may not be able to regulate upstream land-use and protect water quality (Sabatier et al. 2005a). Conversely, regional fisheries management may be too large to respond to local stock variations and local social-ecological processes (Crowder et al. 2006; Johnson et al. 2012). This is not to presume, however, a panacea prescription of local, regional, and larger governments managing ecological process at local, regional, and larger scales. Geographic size and jurisdictional level do not always equate. Some local municipalities are quite large while federal or state land holdings, such as parks or protected areas, may

[1] This chapter is co-authored with Jacopo A. Baggio, Utah State University and Center for Behavior, Institutions and the Environment at Arizona State University.

be close in size to local jurisdictions (Young 2006). An organization's resources, authority, and legitimacy play vital roles in aligning governance capacity with ecological processes and illustrates the link between spatial and functional scale mismatch (Galaz et al. 2008). Private and non-profit groups also play key roles in natural resource governance (Lemos and Agrawal 2006) and occupy, manage, or work in specific geographic spaces. Furthermore, ecosystem processes interact across spatial levels and the relative importance of ecological drivers may change over time (Galaz et al. 2008). For these reasons, scale mismatch should consider how interconnected biophysical space and associated processes are fragmented by different organizations (Crowder et al. 2006). This approach avoids trying to fit the world into a neat and nested set of Russian dolls (Galaz et al. 2008) and recognizes that governing units bisect and overlap each other and the ecological units they seek to govern in myriad ways.

While mismatch is a recognized problem, enacting Powell's advice today is an unrealistic and potentially problematic solution. Redesigning boundaries to address mismatches can create new mismatches because existing governing bodies manage for multiple resources with processes occurring at different geographic extents (Moss 2012). Additionally, redefining institutions perceived as legitimate and linked to socio-political identity may do more harm than good (Moss 2012). This is not to say that redefining borders is never possible. But in most cases, rather than redefine borders, approaches increasingly focus on governance coordination to bridge scale mismatches and reduce associated problems (Folke et al. 2005; Galaz et al. 2008; Guerrero et al. 2013). Thus, an analytical approach that combines biophysical landscape connections and the associated governance network is an important candidate for a rigorous treatment of scale mismatch.

Social-ecological network analysis (SENA) provides this rigorous approach (Bodin et al. 2014; Bodin and Tengö 2012; Ernstson et al. 2010). SENA analyzes structural patterns of how social and ecological units are connected and relates these patterns to natural resource governance (NRG) processes and outcomes (Bodin and Crona 2009). We distinguish between SENA and social network analysis (SNA) for NRG as SENA explicitly links social and ecological units, whereas SNA only focuses on social connections in the context of NRG (Cumming et al. 2010). While a rich literature exists using SNA for NRG (Berardo and Scholz 2010; Cohen et al. 2012; Crona and Bodin 2006; Holt et al. 2012; Schneider et al. 2003; Vignola et al. 2013; Weiss et al. 2011), a SENA approach is important because it considers how social units interact with one another and the landscape in an interdependent and spatially explicit manner. Theoretical and empirical work has shown that SENA can identify scale mismatches and help managers and stakeholders address them (Bergsten et al. 2014; Ernstson et al. 2010; Rathwell and Peterson 2012; Schoon et al. 2014). Much of this empirical work incorporates a single governance level, usually local, (Bergsten et al. 2014; Bodin et al. 2014; Bodin and Tengö 2012) and has yet to address the complex, multi-level nature of most NRG systems.

We build off this growing body of SENA research to advance scale mismatch solutions in a complex, multi-level governance setting. To do so, we analyze empirical data from Puget Sound, WA, U.S.A., providing a proof of concept to advance NRG in general. Estuary restoration is an apt proof of concept as estuaries provide essential benefits for society, but are degraded worldwide (Diaz and Rosenberg 2008; UNEP 2006) making estuary restoration a vital part of sustainability planning (Weinstein et al. 2007). Restoration requires understanding both the bio-physical and socio-political landscape as conditions in one location of the estuary watershed affect other locations

(NRC 1992) making management outcomes susceptible to scale mismatch. Given that such large-scale restoration is a social-ecological problem, it requires a social-ecological solution. While restoration planning almost always involves systematic analysis of bio-physical conditions (Diefenderfer et al. 2009; Thom et al. 2011), analysis of scale mismatch patterns, a social-ecological concern, has not been addressed. Thus, our analysis not only advances SENA and scale mismatch, but also advances a social-ecological approach to restoration planning. Indeed, we link our analysis of the social governance system to existing ecological data and identify coupled social-ecological concerns that account for habitat quality and governance characteristics. This coupling can help the NRG community allocate scarce resources by identifying where social capacity is strong or needs to be enhanced in relation to ecological restoration needs. We call these social-ecological restoration low hanging fruit and hotspots, respectively. Specifically we ask: 1) to what extent do groups collaborate between hydrologically connected areas and thus, bridge scale mismatch? 2) How functional is mismatch bridging in terms of groups' self-assessed collaboration productivity? 3) Where do social challenges and opportunities align with ecological restoration needs?

2.2. Social-ecological network analysis framework

SENA uses the terms nodes and edges to denote social and ecological units and their respective relationships. The simplest social-ecological network consists of two social and two ecological nodes (Bodin and Tengö 2012). This four node structure is necessary because a network is relational and the only way to represent social-social (SS), social-ecological (SE), and ecological-ecological (EE) edges is by having two of each node type. Expanding this idea to a multi-level social-ecological governance framework, the simplest network consists of eight nodes (Fig. 2.1): two ecological nodes, two small local social nodes in each ecological node totaling four local nodes, and two larger social nodes whose spatial extent spans the two ecological nodes. To avoid confusion with other work that focuses on scale-crossing broker nodes (Ernstson et al. 2010) and bridging organization nodes (Rathwell and Peterson 2012), we call these larger social nodes regional nodes. The regional node is defined by spatial extent because it spatially overlaps two ecological nodes. Cross-scale brokers on the other hand are defined based on jurisdictional hierarchy and link organizations across the hierarchy that manage ecosystem processes at different scales (Ernstson et al. 2010). As mentioned, our framework is not based on a jurisdictional hierarchy, but rather the spatial location and extent in which organizations work. Alternatively, bridging nodes link together disconnected social nodes in general and need not be defined based on hierarchal levels of the social-ecological system (Rathwell and Peterson 2012). While some regional nodes may play scale-crossing broker or bridging roles at times, or may have the potential to play these roles, they also may exist as isolated nodes in the network, thus contributing to scale mismatch. Our conceptualization does not compete with these others. Rather it expands the notion of how different organization types interact with each other and the landscape for network approaches to scale mismatch analysis.

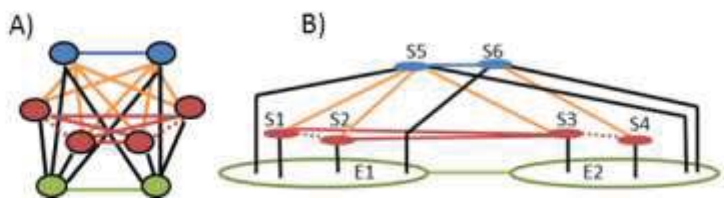

Figure 2.1. Conceptual diagram of A) the simplest multi-level social-ecological network, which consists of eight nodes as described in the text. The maximum edges possible are less than all possible edges in a regular eight node network because local social nodes only have edges to one of the two ecological nodes. B) A three-dimensional planar perspective of the network with only a few edges depicted for clarity. There are three types of social-ecological scale mismatch bridging edges: between local nodes associated with different ecological nodes (local-local (solid red)), between local and regional nodes (local-regional (orange)), and between regional nodes (regional-regional (blue)). These three can be combined for total scale mismatch bridging (SMB) edges. Edges between social nodes in the same ecological node (i.e., S1-S2 and S3-S4 (dashed red)) are not scale mismatch bridging and not included in analysis.

Within our eight node example, there are three types of social-ecological scale mismatch bridging edges: between local nodes associated with different ecological nodes (local-local), between local and regional nodes (local-regional), and between regional nodes (regional-regional). Each edge type illustrates something about if and how scale mismatch is being bridged. For example, a network with many local-local and regional-regional edges, but few local-regional edges, implies that social-ecological scale mismatch is being bridged at the local and higher level, but that these two levels are disconnected, perhaps undermining scale-mismatch bridging. Furthermore, the regional nodes would not play much of a bridging or broker role in this case. Edges may also exist between local social nodes connected to the same ecological node. While important for overall system function, these edges are not scale mismatch bridging as defined here. We thus, focus on the three scale mismatch bridging edge types (local-local, local-regional, and regional-regional) and their summation (total scale mismatch bridging (total SMB)) to analyze scale mismatch bridging (Fig. 2.1).

Our analysis utilizes a social-ecological network matrix that depicts which social nodes are connected (SS edges), what ecological nodes they work in (SE edge), and which ecological nodes are linked though ecological processes (EE edges). We restrict our analysis to the most straightforward example of scale mismatch, SS edge bridging between two connected ecological nodes. However, our framework can be expanded to include *N* ecological nodes (see Appendix A). The analysis iterates though the entire social-ecological network and assigns social nodes a local or regional membership to every pair of ecologically connected nodes based on the EE and SE edges. We then block model the social component of the network for each ecological node pair. Block modeling sorts and groups network nodes into specific roles based on block membership criteria

(Fig. 2.2). Our criteria are: attached only to ecological node one (local1), only to ecological node two (local2), and both (regional). While depicting edges in an eight node toy network is simple, real world application with hundreds of social nodes requires summary statistic of network patterns. We analyze scale mismatch bridging using two network metrics with particular implication for scale mismatch: density (D; i.e., percentage of nodes that are connected) and degree centralization (C_D; i.e., how evenly distributed network edges are) (Bodin and Crona 2009).

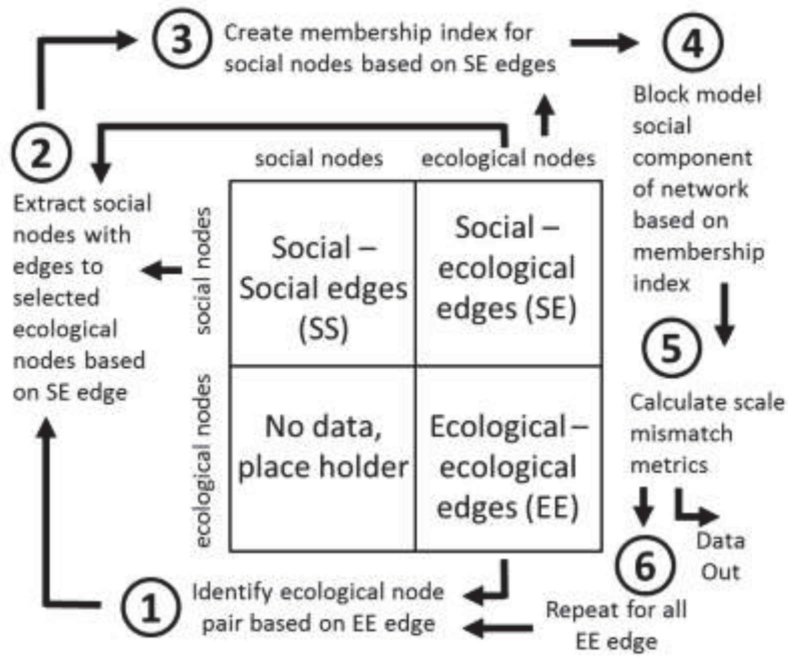

Figure 2.2. Methodological framework. Starting with a social-ecological network adjacency matrix depicting which social nodes are connected (SS edges), what ecological nodes they work in (SE edge), and what ecological nodes are linked though ecological processes (EE edges), analysis iterates though the entire social-ecological network and assigns social nodes a local or regional membership to every pair of ecologically connected nodes based on the EE and SE edges. The social component of the network for each ecological node pair is extracted and block modeled based on the SE membership. Block modeling sorts the data into membership groups and summarizes within and between group relations. Relevant portions of the blocked data are extracted to calculate scale mismatch bridging metrics.

The SS edge density between two connected ecological nodes indicates the degree to which NRG organizations are bridging the scale mismatch. Density of 0 and 1 mean none or all possible edges are present respectively. While scale mismatch bridging requires a certain level of density, too much density (hyper-connectivity) may lead to inefficient resource use (Dakos et al. 2015; Little and McDonald 2007) or poor adaptive capacity if knowledge among actors becomes homogeneous (Bodin and Norberg 2005; Crona and Bodin 2006). Optimum density is context specific, but likely lies at intermediate levels (Bodin and Crona 2009; Janssen et al. 2006).

Centralization indicates how easy it is to fragment the scale mismatch bridging network and has nuanced implications on network performance (Bodin et al. 2006; Janssen et al. 2006). Centralization ranges from 0 to 1, indicating, respectively, if edges are evenly distributed among all nodes or if a single node holds the network together. A high level of centralization can lead to efficient coordination when priorities are agreed upon (Berardo and Scholz 2010; Bodin and Crona 2009). In complex NRG situations, however, high centralization can also lead to, or stem from, asymmetric power relations, which in turn can erode legitimacy and trust between actors (Bodin and Crona 2009; Ernstson et al. 2008). Again, optimal centralization is likely context dependent, and may vary as the governance system changes and matures over time (Berardo and Scholz 2010; Bodin et al. 2006; Bodin and Crona 2009).

The structural measures of density and centralization are important considerations. However, scale mismatches can also arise even though structural bridging exists if organizations cannot work together due to a variety of problems including, but not limited to, lack of trust, insufficient resources, and illegitimacy, all making the network unproductive (Sabatier et al. 2005a). We examine organizations' self-assessed productivity to infer network performance using a productivity ratio index ranging from -1, where 100% of edges are unproductive, to 1, where 100% are productive; 0 indicates a 50% - 50% split. Lastly, we spatially integrate our network with an existing habitat integrity index (Wilhere et al. 2013) to highlight the social-ecological restoration hot-spots and low hanging fruit.

2.3. Illustrating the framework: Estuary restoration in the Whidbey Basin

Our proof of concept uses salmon habitat restoration in the Whidbey Basin (WB) in northeast Puget Sound, Washington, USA. WB is a large semi-enclosed coastal basin fed by four rivers (Fig. 2.3) that together drain roughly 14,850km^2 of land (Bechie et al. 2001; PSP 2014) and account for 68% of the freshwater input to Puget Sound (Yang and Khangaonkar 2010). Marine water quality is affected by these rivers and by surface runoff from the islands bounding WB's western side (PSP 2014) and illustrates the region's physical connections.

Salmon further illustrate biological connections as they spend their adult life at sea and return to spawn in specific rivers, but use the entire nearshore during their juvenile life stage (Beamer et al. 2013; PSP 2014). There are seven salmonid species in WB, three of which are listed as threatened under the U.S. Endangered Species Act (two listings in 1999, one 2007) and a fourth is being considered for listing (Lyshall et al. 2008; Wilhere et al. 2013). Several factors have likely led to salmonid population decline in WB including, but not limited to, water pollution and habitat losses (ranging from 7% to 64% by habitat type as compared to late 1800 baselines (Simenstad et al. 2011)) from development and farming; in particular, much of the nearshore has been diked and drained (Fresh 2006; NWIFC 2012; PSP 2014). Other restoration issues include obstructed fish passage, primarily due to culverts, and a legacy of logged upper watersheds that impact water quality (NWIFC 2012; PSP 2014).

While biophysically connected, WB is fractured by 4 counties (a fifth overlaps in northern headwaters, but lands are in federal holding, so this county is rarely, if ever, a player), 7 Native American Tribes (6 with reservation holdings), more than 30 towns and cities, federal and state agencies, and many special purpose districts (autonomous quazi-government entities with taxation authority that manage specific issues such as, but not limited to, flood control or port management (MRSC 2012)), land trusts, non-profits, and citizen groups with influences in the region (Lyshall et al. 2008; PSP 2014). Headwaters in WB are largely in federal and state holding (Lyshall et al. 2008). Some restoration and recovery efforts are state and federally led initiatives, many of which are coordinated through watershed planning bodies for each river and driven forward using competitive grant funding cycles. While the state tried for several years to advance a WB wide recovery planning and implementation effort, it was not supported by local organizations, thus leaving decisions in recovery planning and implementation to be made at smaller geographic scales. Other efforts are more grass roots (PSP 2014).

All organizations involved with salmon restoration in WB are included as social nodes in our network (n = 210; see methods for detailed listing). Ecological nodes (n = 38) are small watersheds called HUC 10s, which range from 160 to 1,010 km^2 and are commonly used in watershed restoration planning (Laitta et al. 2004; WBD 2010). SS edges constitute inter-organizational collaborations. SE edges indicate in which HUC 10s an organization works. EE edges constitute the river network in WB that connects HUC 10s as well as neighboring HUC 10s in the marine environment (details in Appendix A).

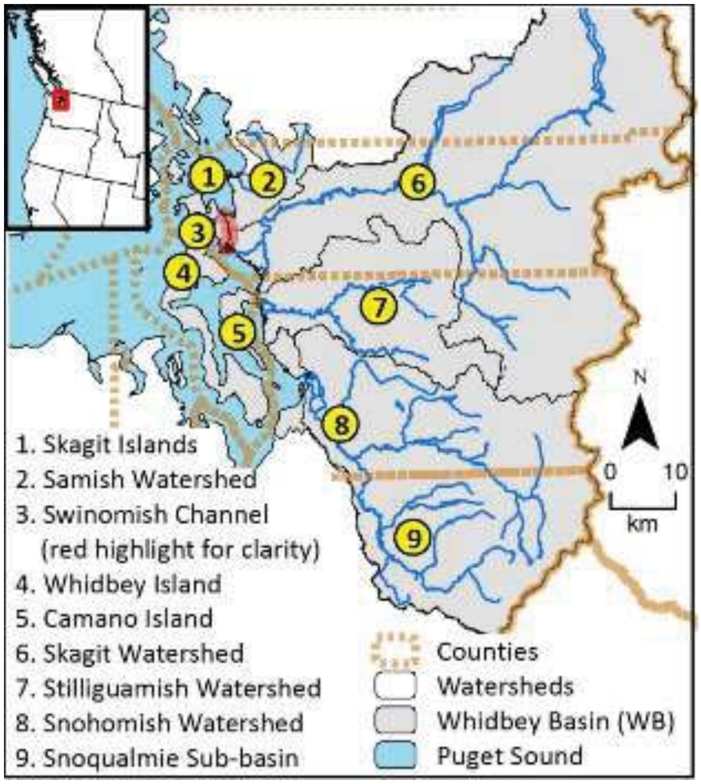

Figure 2.3. Study area map with place names used in the text. Major watersheds and counties are shown to illustrate scale mismatch. Other jurisdictions and organizations are excluded for clarity.

2.4. Methods

2.4.1 Network construction

To build WB's social-ecological network we relied on surveys, interviews, and grey literature. We recorded SS edges using an open ended recall survey that we administered online. This survey design uses a list of known network groups to illicit an initial response and solicits unknown groups via write-in responses. We asked survey participants to report who they worked with to do restoration, which we defined as directly or indirectly helping degraded ecosystems recover to support human wellbeing and local economies. Our survey was part of a larger study about restoration in WB. For this analysis, we partitioned the data to focus on salmon restoration. Within the survey, perceived partnership productivity for achieving restoration goals was measured on a five point ordinal scale (details in Appendix A). In cases where one organization said they work with another, but the other did not reciprocate or participate in the survey, we assumed there was a relationship. To account for groups reporting different interaction productivity with one another, we symmetrized the network based on maximum and then minimum values to look at the data's range. Maximum symmetrization depressed the data's range, while minimum symmetrization expanded it. There was little variation in spatial patterns and correlations with minimum and maximum symmetrization. We thus, report the minimum symmetrization in the main text as it preserves weaker edges, allowing for deeper inquiry to possible network problems and interventions. Maximum symmetrization is reported in Appendix A.

We recorded SE edges by asking groups where they worked during survey recruitment, during semi-structured interviews with a subset of participants, and grey literature for most non-participating groups (e.g., a land trust webpage describing where the trust works). From these descriptions we created a spatial database in ArcGIS using multiple data sources (details in Appendix A) and spatially joined it to the HUC 10 data using a negative half kilometer buffer to remove small overlaps. Within the HUC 10 data, Whidbey and Camano Islands are one unit. We split them to better represent local geography.

EE edges were defined by linking each HUC 10 to the one upstream and downstream of it following surface hydrology (WBD 2010), or to its adjacent coastal neighbors (details in Appendix A).

2.4.2. Recruitment and participation

We recruited 206 survey participants at 186 organizations using snowball sampling and had a 68% response rate (n = 140). We pursued multiple participants at several organizations to account for sub-programs, or staff that split geographic regions, and merged responses to form single organizational responses (details in Appendix A).

We documented 210 organizations in the salmon restoration network (41 non-profit organizations, 37 city or town departments, 24 special districts, 20 coordination or watershed groups, 14 tribal organizations/departments, 13 state departments, 13 county departments, 12 citizen groups, 12 federal departments/agencies, 11 for profit businesses, 5 educational institutions, 4 public utilities, and 4 organizations that did not fit this classification). We could not define SE edges for 17 organizations. We kept these groups in the social-ecological network, but they were effectively removed from analysis which requires a SE edge. Their prevalence in the network is low however, so their omission should not alter our results. Survey participants account for 56.67% of the total social nodes in the network.

2.4.3. *Analysis*

All network analysis was done in the R language environment with the packages network and sna (Butts et al. 2014; Butts 2013). For block modeling, SE edges were used to define block membership. We then extracted the raw, non-summarized blocked data and block edge sums and subset these to analyze scale mismatch bridging edge types (details in Appendix A). In the block model, local-local and local-regional SS edges produce a bipartite network structure meaning two sets of nodes only have inter-set edges and the total edges possible is the product of the number of nodes in each set. Regional-regional edges are not bipartite and thus, the total possible edges among *N* regional nodes is *N(N-1)* because nodes cannot have self-edges. We thus, calculated scale mismatch bridging density as follows:

$$D_{local-local} = \frac{E_p}{2(n_{l1} * n_{l2})}$$

$$D_{local-reginal} = \frac{E_p}{2(n_r(n_{l1} + n_{l2}))}$$

$$D_{regional-regional} = \frac{E_p}{n_r(n_r - 1)}$$

$$D_{tSMB} = \frac{E_p}{2\left((n_{l1} * n_{l2}) + n_r(n_{l1} + n_{l2})\right) + n_r(n_r - 1)}$$

where E_p = edges present for the relevant node sets and n_{l1}, n_{l2}, and n_r = number of node per block model membership local1, local2, and regional. Note, formulas are given for digraphs.

To control for network size effects on density, we compared observed density measures to those of 1,000 random permutations of the social-social component of the SES network (Fig. 2.2). Only rows and columns of the social-social component where simultaneously permuted; thus, spatial location (SE edge) was preserved while the probability of having a specific collaboration (SS edge) was changed. The permutation tests indicated whether or not the observed density is greater or less than expected. If less than expected, we can conclude that by pure chance, more edges should be present and that, structurally, scale mismatch bridging is weak. If greater than expected, scale mismatch bridging is strong. The permutation tests also gives the probably (p-value) of obtaining the observed density (details in Appendix A).

For degree centralization (C_D), we used Freeman's (1979) formula for regional-regional edges and Everett's and Borgatti's (2005), modified bipartite C_D for local-local and local-regional edges. Following Everett and Borgatti (2005), we ignored isolates (nodes with no SS edges) for all C_D measures, and normalized nodal centrality by the number of nodes in the opposite node set for bipartite measures. Centralization is defined as:

$$C_D = \frac{\sum_{i=1}^{n}[C_D(P^*) - C_D(P^i)]}{n^2 - 3n + 2}$$

$$C_{D\text{ bipartite}} = \frac{\sum_{i=1}^{n}[C_D(P^*) - C_D(P^i)]}{\left(\frac{(n_o * n_i - n_i - n_o + 1)(n_i + n_o)}{(n_i * n_o)}\right)}$$

where $C_D(P^*)$ = maximum degree, $C_D(P^i)$ = degree of node i, n = number of node, n_o = nodes in the bipartite set with the node of highest degree, and n_i = the other bipartite node set. We did not calculate total scale mismatch bridging centralization because of challenges combining the normal and bipartite graphs for this measure.

Lastly, PRI is defined as:

$$PRI = \frac{E_{pr}}{E_p} - \frac{E_{npr}}{E_p} \text{ if } E_p > 0 \text{ and is not defined if } E_p = 0$$

where E_{pr} and E_{npr} = number of edges perceived productive ≥ 75% of the time and ≤ 50% of the time, respectively, as recorded on the 5 point ordinal scale.

r_s values were calculated in R. To compare social-ecological network patterns with existing ecological restoration planning work, we spatially joined our ecological nodes to the Washington State Department of Fish and Wildlife's salmon habitat integrity index (Wilhere et al. 2013) in Arc GIS (details in Appendix A).

2.5. Results

2.5.1. Collaboration between hydrologically connected regions

Scale mismatch bridging edge density is generally much lower for local-local edges than other bridging edge types, notwithstanding two high density bridges in the upper Skagit watershed (Fig. 2.4). (However, where D = 1, there is only one social node in local1 and local2, so this should not be seen as extreme scale mismatch bridging. Indeed, permutation tests show that the D = 1 bridge is only significant at the $p < 0.25$ level.) There are 12 instances of complete social-ecological scale mismatch at the local-local level, where local nodes in connected ecological nodes have no SS edges (i.e., D = 0). Permutation tests support these findings (Fig. 2.5). Most local-local bridges are expected to be higher, including areas with no scale mismatch bridging. Local-local bridging between Camano Island and the lower Snohomish, lower Stillaguamish, and Whidbey Island is greater than expected by chance, but only at $p < 0.25$ and 0.50 (Fig. 2.5).

On average, local-regional and regional-regional densities are higher than local-local ones (Fig. 2.4); they are also greater than expected (Fig. 2.5; regional-regional and total SMB are excluded from the figure for clarity as all values are greater than expected at $p < 0.05$), revealing the important bridging role played by regional nodes. However, scale mismatch bridging may be particularly weak in the Swinomish Channel as both local-local and local-regional edge densities are low ($D = 0.016$ and 0.049 respectively) and less than expected by chance, but not significant at $p < 0.05$.

Many local-local and local-regional centralization scores (Fig. 2.6) are high, which means many scale mismatch bridges are governed by a small percentage of nodes, making the bridge vulnerable to targeted node removal. Low density and high centralization also implies that there are many isolated nodes. Alternatively, regional-regional centralization is somewhat lower with less variability.

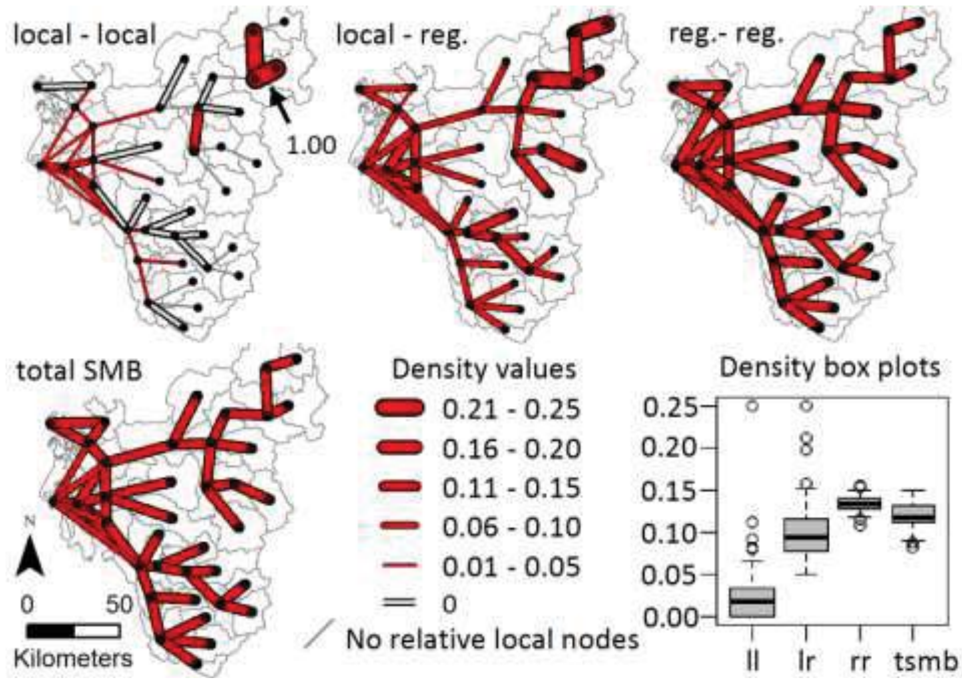

Figure 2.4. Density maps of SS edges among social nodes (n = 210) working within hydrological connected ecological nodes (n = 38). The density of social organizations spanning two or more ecologically connected regions indicates the degree to which actors are bridging scale-mismatch. Maps show that regional actors (reg.) play a large role in bridging scale mismatch and that density is lower in nearshore areas. Box plot illustrates the data's range. Axis labels are abbreviated as follows: local-local (ll), local-regional (lr), regional-regional (rr), total scale mismatch bridging (tSMB).

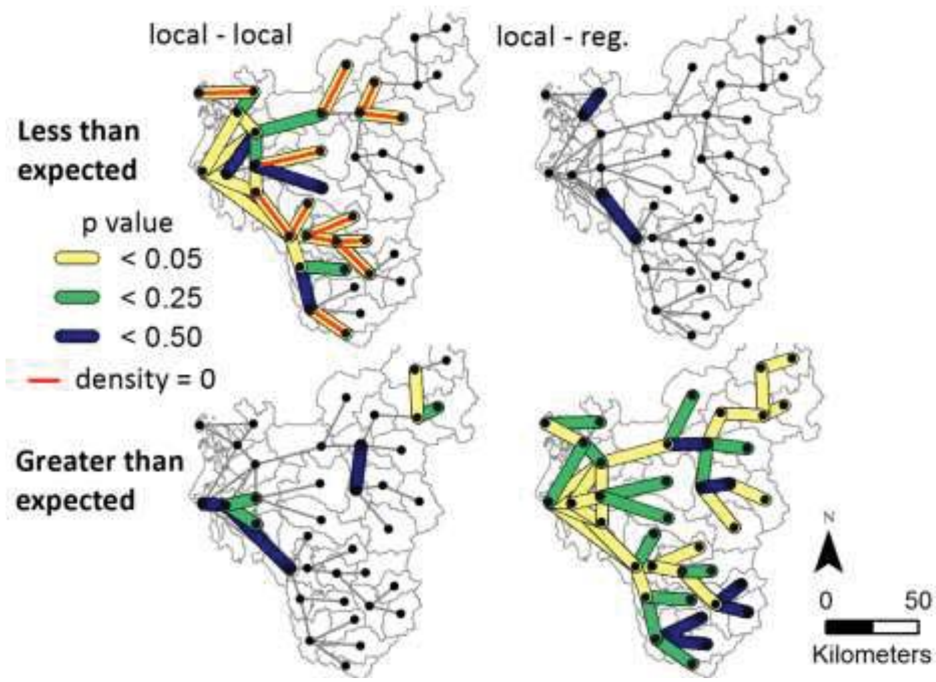

Figure 2.5. Comparison of observed densities to expected values. If density is less than expected, we can conclude that by pure chance, more edges should be present and that, structurally, scale mismatch bridging is weak. If greater than expected, scale mismatch bridging is strong. P-values indicate the probability of observing a given measure among 1,000 random permutation of the social-social component of the network. P-value cutoffs have been indicated at 0.05 (there is less than a 5% chance that the observation arose by chance), 0.25 (less than a 25% chance, or that the observation lies outside of the interquartile range of random observations), and 0.50 (less than a 50% chance, or that the observation differs from the mean in the indicated direction, either less or greater than), Regional-regional and total SMB are excluded from the figure for clarity as all values are greater than expected at $p < 0.05$.

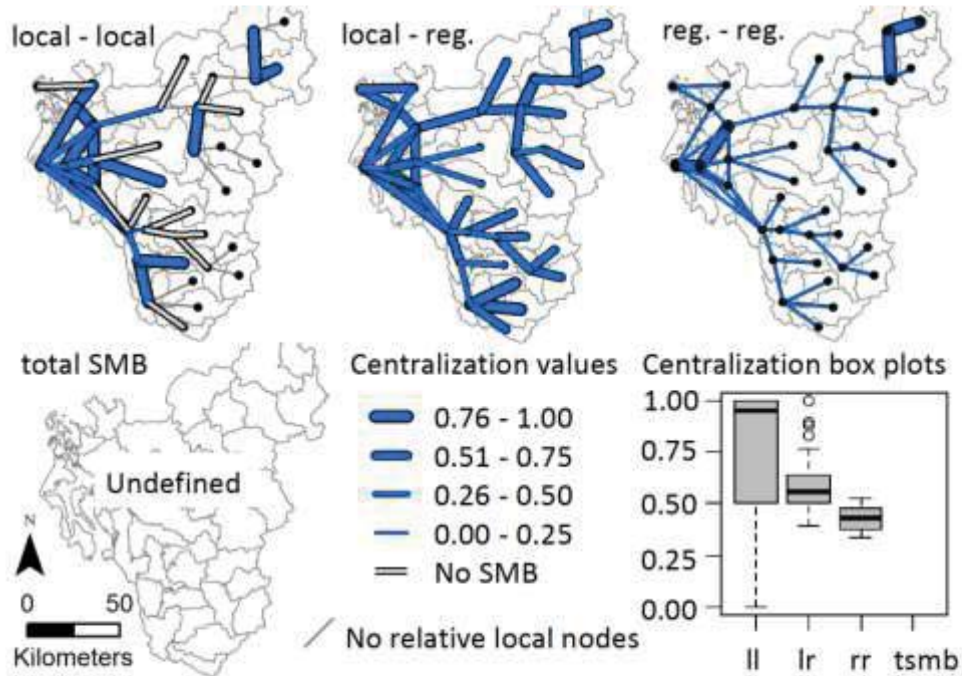

Figure 2.6. Centralization maps of SS edges among social nodes (n = 210) working within hydrological connected ecological nodes (n = 38). Centralization shows how many groups hold the social network together with implications on information flow and network robustness. High centralization is vulnerable to fragmentation. Abbreviations are the same as in Figure 2.4. Total SMB is undefined because regional-regional data structure differs from the other two. See methods.

2.5.2. Collaboration productivity across the network

While clear structural network patterns exist in WB, it is important to remember that not all collaborations within these patterns are created equal. Survey respondents ranked the majority of relationships as productive, but still many low productivity relationships exist. Within the total network, the number of edges ranked by approximate percentage of time the partnership was productive for meeting restoration goals were as follows: 17 edges at 0%, 105 at 25%, 155 at 50%, 308 at 75%, 428 at 100% and 255 edges where participants provided no response. Taken as a ratio, and spatially analyzed, the lowest PRI scores (Fig. 2.7) exist at the local-local level and thus, not only is scale mismatch bridging structurally weak (low density) at the local-local level, but in several cases, what exists has limited productivity. In general, PRI scores for local-regional, regional-regional, and total SMB are around zero or higher, though two negative local-regional scores in the upper Skagit watershed (PRI = -0.14 and -0.28) and one in the Snoqualmie sub-basin (PRI = -0.11) exist. (The two most southern Snoqualmie scores are 0.00 and 0.052 north to south, respectively.) Interestingly, there are opposite north-south gradients in PRI at the local-local and regional-regional level. At the local-local level, PRI is highest in the Skagit Islands, Skagit nearshore, and lower Skagit watershed. At the regional-regional level, the entire Skagit watershed and nearshore has a lower PRI than other locations. The local-regional and regional-regional maps also show aspects of this inverse spatial gradient, such as in the Snoqualmie sub-basin, but not as clearly. These spatial comparisons illustrates that there is either very different processes at play among local and regional collaborators, or at least restoration organizations with local and regional extents perceive their relationships to be quite different.

PRI is negatively correlated with local-regional, regional-regional, and total SMB density (r_s = -0.32, -0.64, -0.46, respectively, Fig. 2.8. Note, the outlier, D = 1 was removed from all correlation analyses because it is the only density > 0.25 and arises because local1 and local2 each have a single social node). PRI has a week positive correlation with local-local density (r_s = 0.04), but this is largely driven by a single point with 0.25 density in the upper Skagit. Given that we removed the outlier D = 1 with PRI of -1 from correlation analyses, local-local density and PRI are not correlated. Because density is theorized to be optimal at intermediate levels, we fit second order polynomials to our data. With the exception of local-local edges, the second order polynomials had a better R^2 fit illustrating non-linear relationships. Contrary to theory, local-regional PRI and density have a slightly inverted bell-shaped relationship, but this relationship is driven by two high density, high PRI values. Overall, the relationship between local-regional density and PRI is more or less negative and linear. As expected with theory, PRI was highest at intermediate density for regional-regional and total SMB densities with a robust range in the total SMB data, but perhaps a less strong fit for regional-regional data (Fig 2.8). The second order polynomials did little to improve the R^2 fit between centralization and PRI (Fig. 2.9). Overall, centralization is inversely correlated with PRI (r_s = -0.24 local-regional and -0.82 regional-regional), though not at the local-local level (r_s = 0.13).

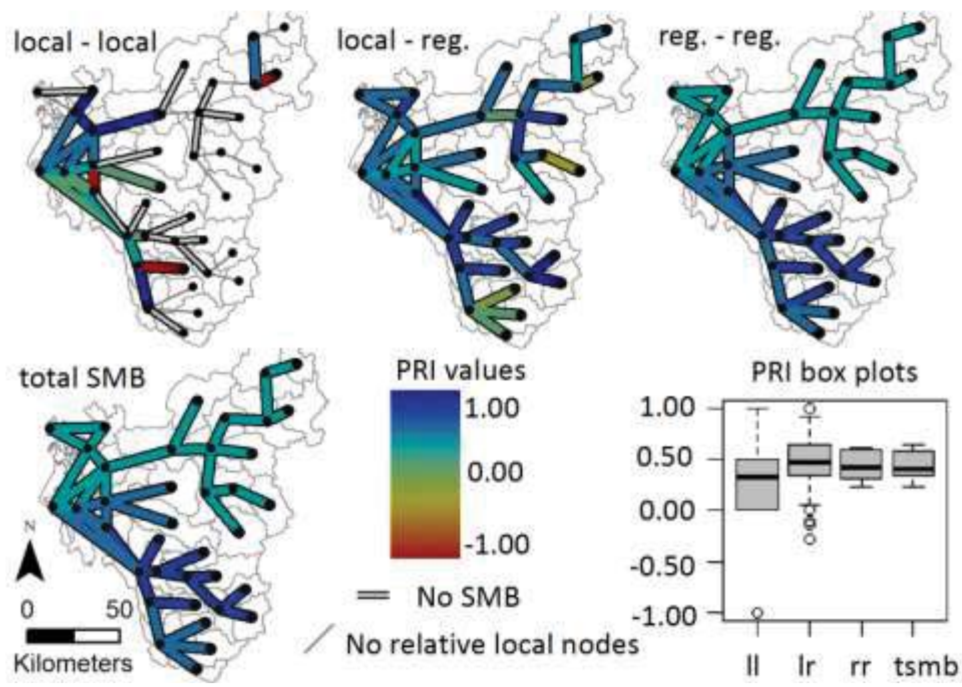

Figure 2.7. Edge productivity ratio index (PRI) map of collaborations among social nodes (n = 210) working within hydrological connected ecological nodes (n = 38). Juxtaposing the presence of low productive edges against density illustrates that edges may be present, but functioning poorly; scale mismatch may not be effectively bridged in these situations. Abbreviations are the same as in Figure 2.4.

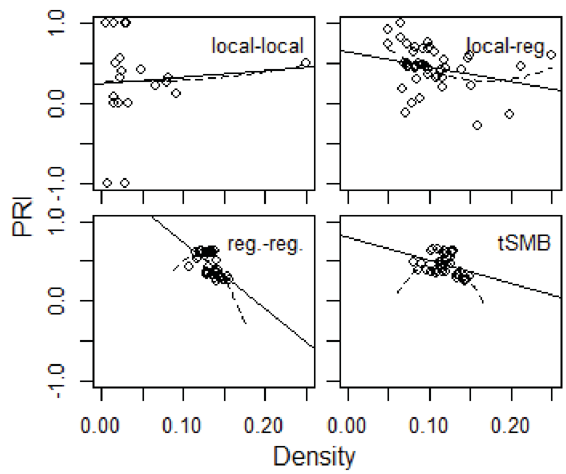

Figure 2.8. Edge productivity ratio index (PRI) vs. scale mismatch bridging edge density. Optimal density is theorized to be at intermediate levels, thus we fitted 1st and 2nd order polynomials to the data. 1st order R^2 values for local-local, local-regional, regional-regional, and total SMB are 0.0059, 0.082, 0.39, and 0.14 respectively. 2nd order R^2 values are 0.007, 0.15, 0.45, and 0.33 respectively. R_s values are 0.044, -0.32, -0.64, and -0.46 respectively. Overall, density is negatively correlated with PRI, but PRI is highest at mid-levels of density for total SMB where the 2nd order polynomial substantially improves data fit. Abbreviations are the same as in Figure 2.4.

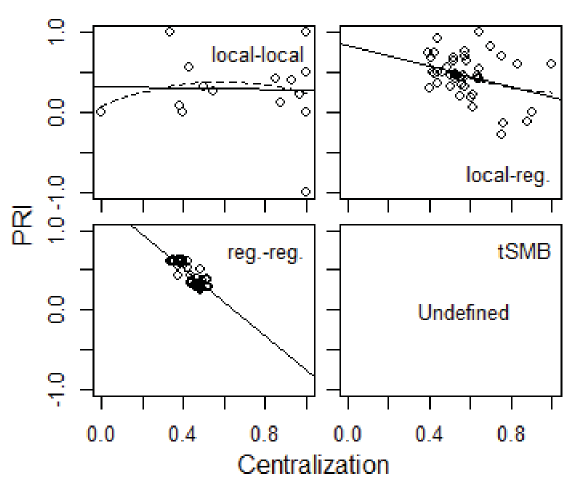

Figure 2.9. Edge productivity ratio index (PRI) vs. scale mismatch bridging edge centralization. 1st order R^2 values for local-local, local-regional, and regional-regional are 0.0008, 0.12, and 0.74 respectively. 2nd order R^2 values are 0.017, 0.12, and 0.74 respectively and do little to improve fit. R_s values are 0.13, -0.24, -0.82 respectively. Overall, PRI and centralization are inversely related. Abbreviations are the same as in figure 2.4. Total SMB is undefined as explained in Figure 2.5.

2.5.3. Alignment of social and ecological restoration challenges and opportunities

The comparison between PRI (a social concern) and salmon habitat integrity (an ecological concern) reveals both social-ecological restoration hotspots and low hanging fruit (Fig. 2.10). While we do not propose an absolute cutoff for hotspots and low hanging fruit, the local-local data show the most social-ecological restoration hotspots because the local-local data has lower PRI values. Habitat integrity and local-regional PRI are fairly well negatively correlated, with low PRI occurring in areas with high habitat integrity, and thus, there are few hotspots and more low hanging fruit in the local-regional data. Regional-regional and total SMB edges have less PRI variability and thus, the cutoff between hotspots and low hanging fruit is less clear and is subject to discussion.

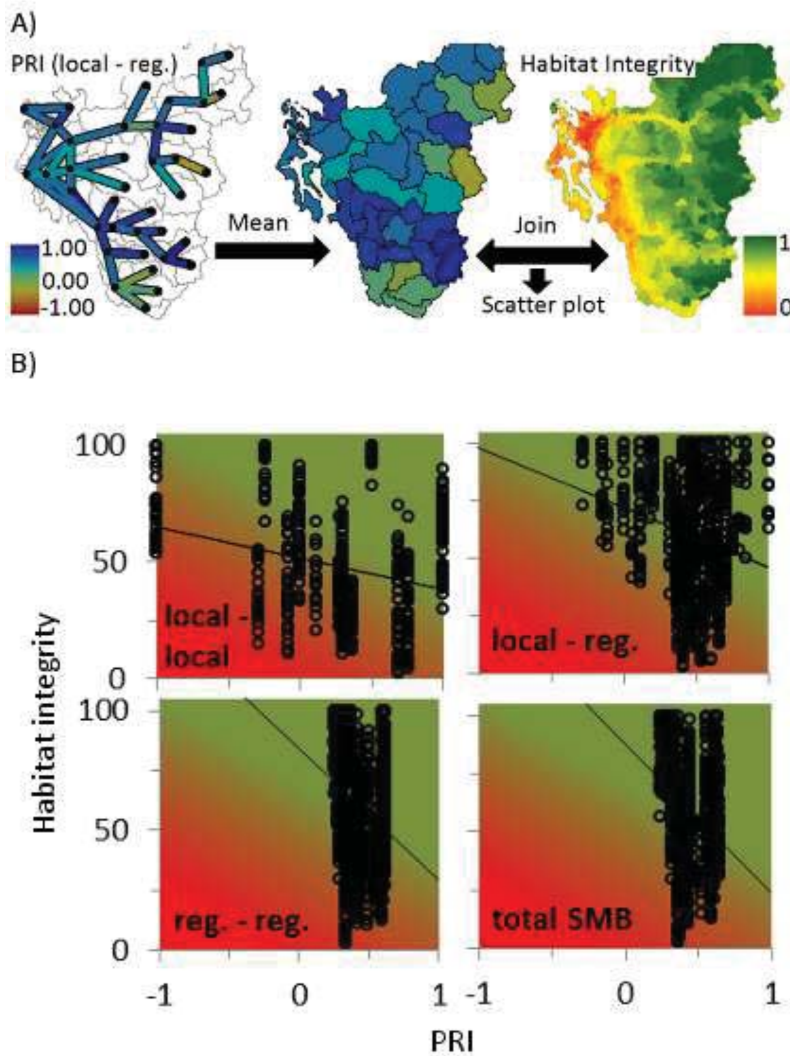

Figure 2.10. Habitat integrity index (HI) plotted against productivity ratio index (PRI). A) Average PRI edge values were calculated for each ecological node (HUC 10s). Local-regional (reg.) is shown as an example. HUC 10s and smaller HI units were spatially joined to ascribe social and ecological attributes. B) Data plotted with a stylized color ramp to illustrate social-ecological restoration hotspots (low HI, low PRI) and low hanging fruit (low HI, high PRI). R^2 values for local-local, local-regional, regional-regional, and total SMB are 0.075, 0.053, 0.073, and 0.088 respectively. See discussion in text.

2.6. Discussion

Our SENA framework identifies and quantitatively assesses scale mismatches patterns, an important undertaking as poor social collaboration in ecologically connected areas can undermine NRG success (Crowder et al. 2006; Cumming et al. 2006; Folke et al. 2007). Our density and centralization maps reveal several areas where network bridging (i.e. social edges that connect social entities working in different ecologically connected areas) is weak and easily fragmented. Additionally, low PRI scores in several locations illustrates that edges may be present, but not functioning well and thus, scale mismatch may not be effectively bridged. Linking these network patterns to key landscape restoration needs can help identify critical social-ecological scale mismatches. For example, several nearshore areas, such as the Swinomish channel, between Whidbey islands and the three major rivers, and the lower Skagit, each of which are important ecological habitat connections for salmon (Beamer et al. 2013; Khangaonkar et al. 2014), have low density, or high centralization, or both.

While recent research links high centralization to efficient problem solving in low risk settings (Berardo and Scholz 2010), the high centralization and very low density that we observed in the local-local data implies that there are many isolated nodes in the data. Thus, high centralization results from a low number of organizations collaborating at the local-local level. Centralization scores = 1 are due, in most cases, to single local nodes having edges to several other local nodes in adjacent HUC 10s. It is worth noting that survey participation may influence some results specific to the case study. While our participation rate (see methods) is certainly within the norm for SNA for NRG studies, it is possible that non-participation could create high centralization in particular, as edges could be concentrated around participating organizations. With this possibility noted, our analysis clearly shows the fragility of the local-local component of the overall scale mismatch bridging network in WB that we documented.

The inverse spatial gradients, north to south, in local-local and regional-regional PRI is somewhat puzzling. There has been some contention in the past between county and tribal groups in the Skagit watershed (Breslow 2014a; 2014b; Zafertos 2004). This historic tension may be reflected in the lower regional PRI scores in the Skagit. Additionally, the Skagit watershed is largely agricultural with many small drainage and diking districts. It may be that local actors in the Skagit prefer direct collaboration while local actors in southern watersheds do not. Future qualitative research (currently under way) about restoration collaboration dynamics in WB will further illicit explanations for these and other patterns. However, our current analysis clearly reveals important scale mismatch patterns that can be used by practitioners in WB to think about the efficacy of their scale mismatch bridging.

Indeed, we propose using our network mapping as a starting point for regional conversations about collaboration and scale mismatch bridging. Stakeholders in WB could hold focus groups to discuss our results, along with the theoretical underpinnings of density and centralization for scale mismatch, and identify where they want to build relationships. Such focus groups were used in Oregon, USA, where SNA results were presented to stakeholders and helped build needed collaborations among groups working on terrestrial and freshwater management (Vance-Borland and Holley 2011). Discussing network mapping results can clearly help practitioners. Our work takes network mapping a step farther by spatially embedding it and considering the network alongside ecological conditions.

Using our results to guide specific governance interventions is analogous to coarse grained ecological characterization for restoration planning. Ecological conditions in small hydrologic units are often assessed relative to one another and used to guide more detailed local-level analysis (Thom et al. 2011). In the same way that one might characterize ecological health to identify where restoration is needed, our analysis can help identify where governance capacity building is needed to improve scale mismatch bridging.

The bell-shaped relationship that we observed between density and PRI for total SMB supports current theories that optimal connectivity is reached at intermediate levels. Negative correlations between PRI and centralization also support theories that high centralization is undesirable. These findings may help the restoration community in WB think about how they may want to restructure their network. Our results, however, must be interpreted with caution. While PRI is a useful summary of collaboration challenges, the extent to which it represents a direct relationships or emergent property is unknown. Without further study, we cannot know, for example, if adding edges in low-density low-productivity areas, or removing them from high-density low-productivity areas, will increase perceived productivity, or foster better restoration outcomes. Our findings that highest PRI occurs at intermediate density in the total SMB data should also be interpreted with caution because local-regional and regional-regional densities are more inversely and linearly correlated with PRI. While it might be tempting to conclude that organizations should interact with fewer groups (i.e., lower density), this would be at odds with scale mismatch theory. Rather, an alternative explanation may be that many organizations are stretched thin, which several groups mentioned during field work, and these busy groups may benefit from additional resources and staff. We also did not explore temporal dynamics in the network, and it may be that some areas are going through growing pains as, for example, the state tries to implement several new regional coordinating organizations (PSP 2014). Such organizations would have many SS edges and could explain some of the observed contention at the local-regional and regional-regional level. Thus, our work lays down a foundation for longer-term time series analysis through repeated studies that can reveal these temporal dynamics and help the WB community improve governance capacity.

In addition to an explicit focus on socio-political patterns and scale mismatch, we also integrate social network concerns with ecological ones by spatially joining PRI and the salmon habitat integrity index. PRI is informative because it summarizes where people perceive strong and weak collaborations. But, density or centralization scores can also be integrated with the ecological data in the same way to show, for example, how mismatches (i.e., low density) or easily fragmented areas (e.g., high centralization) align with ecological conditions. This social-ecological join is a course level diagnostic which reveals social-ecological restoration hot-spots and low hanging fruit. These results can also help identify sites with similar ecological settings and different socio-political patterns. Such comparisons can facilitate cross-site learning to improve governance processes.

While the local-local data show clear social-ecological hotspots and low hanging fruit, the subdued variability in PRI for the regional-regional and total SMB data makes identifying these social-ecological combinations more difficult. If treated as a relative scale, which we advocate, the lower PRI scores would still be considered hot-spots. Clearly though, the most troubled social-ecological settings occur when considering local to local interactions.

Integrating the social and ecological data brings to light an interesting data comparability challenge. The base unit of our network approach is the edge, the connections among and between ecological and social nodes. We thus, look at connections between the islands and the mainland in WB. The habitat index however, is confined to the terrestrial surface as it is based on land use and terrestrial hydrology (Wilhere et al. 2013). For this reason, we took the average edge value for each HUC (ecological node) so our data's spatial structure would match the habitat integrity data's structure. In doing so, we obscure the true network. Thus, our spatial join of social and ecological criteria illustrates data comparability challenges that stem from different foci by different research traditions. As such, the productivity ratio and habitat index join should be used as one of several assessments for social-ecological restoration planning along with the more basic scale mismatch bridging network maps.

A future extension of our social-ecological overlay should be an interactive mapping tool to illustrate if a habitat unit is consistently a hot-spot or low hanging fruit in different scale mismatch bridging edge-types. Indeed, the local-local and local-regional data show fairly different distributions. An interactive mapping tool that highlights the relevant habitat unit in each edge-type scatter plot when clicking on a mapped location would provide such decision support. Still, our analysis is an important first step for social-ecological approaches to restoration planning.

Lastly, our research lays groundwork to link social-ecological network structures to ecological outcomes. Future work will need to carefully consider the proper scale for such analysis. While each river in WB hosts specific fish populations, the nearshore plays a vital role in each population's life stage; we thus, approach WB as a cohesive biophysical unit affecting salmon recovery. Alternatively, broader fisheries management networks would necessitate larger spatial scales as salmon spend their adult life stage at sea. Thus, to truly link governance networks to salmon population outcomes likely requires multiple scales of analysis.

2.7. Conclusion

Scale mismatch is a fundamental sustainability challenge that can lead to failed or inefficient NRG (Crowder et al. 2006; Cumming et al. 2006; Folke et al. 2007; Galaz et al. 2008). Our research is an important step in addressing scale mismatches. Using a SENA approach, we analyze and map if scale mismatches are bridged by governance networks and consider network strength in terms of robustness and function. We also integrate social and ecological concerns to identify social-ecological NRG hotspots and low hanging fruit. In a world where natural resource agencies, from local to national, are increasingly stretched thin, such diagnostics are essential for effective NRG to improve human wellbeing.

Future advances to our SENA approach might consider multiple social and ecological relationships. Our framework could be integrated with recent developments in multiplex network analysis and exponential random graph models to explicitly analyze multiple interdependent social and ecological networks (e.g., resource users and managers, or native and invasive species), or multiple edge types (e.g., knowledge sharing and funding, or surface and groundwater flow) (Buldyrev et al. 2010; De Domenico et al. 2014; Shrestha et al. 2014). Additionally, our research lays groundwork for comparative studies linking scale mismatches and ecological outcomes to advance NRG theory and inform how we might seek to structure governance networks to better address scale mismatch.

Chapter 3. Who participates and why: Assessment and diagnostic of governance network integration for salmon restoration in Whidbey Basin, Puget Sound, WA[1]

3.1. Introduction

Jurisdictional and sectoral silos represent a fundamental challenge to recovering degraded coastal environments (Crowder et al. 2006; Lubchenco and Sutley 2010) and pose problems for general environmental planning and problem solving (Lemos and Agrawal 2006; Ostrom 1990; Sabatier et al. 2005a). Alternatively, interactions among various jurisdictional and sectoral organizations create a governance network whose structure and function are integral to natural resource management (NRM) outcomes (Bodin and Crona 2009; Bodin and Prell 2011; Carlsson and Sandström 2008; Folke et al. 2005; Janssen et al. 2006). Academics and practitioners increasingly seek to understand what makes these networks thrive (Bodin and Prell 2011; Hoelting et al. 2014). For example, the Puget Sound Partnership (PSP) Science Panel, in Washington State, USA, identified analysis of governance networks as a strategic need (Hoelting et al. 2014) to improve the region's multi-billion dollar ecosystem recovery effort (Bernhardt et al. 2005; PSP 2014).

Diagnostic approaches for natural resource governance (NRG) that use social network analysis (SNA) can help fulfill the PSP's interests and those of practitioner communities elsewhere. SNA quantitatively examines structural patterns and resulting function between actors or organizations (Bodin and Prell 2011; Borgatti et al. 2009). For example, diagnostic approaches have identified social-ecological scale mismatches to better align governance collaborations with ecological patterns and processes (Bergsten et al. 2014; Ernstson et al. 2010; Kininmonth et al. 2015; Treml et al. 2015). They have

[1] This chapter is co-authored with Jacopo A. Baggio, Utah State University and Center for Behavior, Institutions and the Environment at Arizona State University.

analyzed cross-scale collaborations to improve learning and coordination (Cohen et al. 2012; Ernstson et al. 2010; Mills et al. 2014) and examined how stakeholders' future visions overlap to inform scenario planning (Munoz-Erickson 2014). Other work has compared knowledge production and legislative authority to improve communication and policy development programs (Weiss et al. 2011) and to identify stakeholders for participatory NRM (Prell et al. 2009).

Among other benefits, diagnostics can help stakeholders identify critically needed collaborations (Beilin et al. 2013; Mills et al. 2014; Vance-Borland and Holley 2011). Such network interventions, sometimes called "weaving" (Vance-Borland and Holley 2011), must be strategic however, as too many collaborations can be inefficient (Bodin and Crona 2009; Dakos et al. 2015; Little and McDonald 2007). Integrating SNA with qualitative data can enhance structural data interpretation (McAllister et al. 2013; Prell et al. 2009) for targeted weaving (Beilin et al. 2013) to increase the robustness and effectiveness of the overall governance network.

Considering the different kinds of relationships among actors is vital to understand network function (Bodin and Crona 2009; Borgatti et al. 2009). Recent work has analyzed collaborations for different NRM foci (Beilin et al. 2013; Hoelting et al. 2014; Vance-Borland and Holley 2011), rural livelihood activities (Cassidy and Barnes 2012; Crona and Bodin 2006; Rico García-Amado et al. 2012), interaction frequency, knowledge exchange, and relative influence (Cohen et al. 2012; Vignola et al. 2013; Weiss et al. 2011). Specific relationship categories such as mandated, funded, and shared interests have received less attention in SNA for NRG studies despite characterizing many NRG setting, especially in North American water governance where organizations interact through a variety of formal, informal, and financially incentivized institutional arrangements (Feiock 2013; Ostrom 1990; Sabatier et al. 2005a; Schneider et al. 2003; Shrestha et al. 2014).

Lastly, while several studies investigate network integration by considering detailed jurisdictional and sectoral categorizations (McAllister et al. 2013; Schneider et al. 2003; Vance-Borland and Holley 2011), others use broad categories such as local, regional, national, and international (Cohen et al. 2012; Vignola et al. 2013). Apt for some settings, these broader categories might not support the detailed network interventions and weaving needed by local practitioner communities (Brondizio et al. 2009). More detailed studies of NRG silos are needed.

In this paper, we use a diagnostic approach to analyze collaboration patterns among different organization types in a sub-basin of Puget Sound. We focus on salmon restoration, an important local and national topic. Salmon provide essential ecological functions, their harvest supports local economies and cultures, and their restoration is mandated under the U.S. Endangered Species Act (Bottom et al. 2009; PSP 2014). We focus on four questions. 1) How well integrated, based on governance sector and jurisdictional level, is the salmon governance network? 2) Why do different types of organizations collaborate, specifically considering mandated, funded, and shared interest relationships? 3) How productive are the aforementioned collaboration types? 4) How can understanding these patterns enhance restoration work in the region?

Following Baggio et al. (2015), we use network participation metrics, which analyze the evenness of network connections among organizations of different types as well as the relative ratio of connections within and between organization types. We ground our analysis and discussion using interview data to provide specific network weaving interventions. While we consider the dataset as a whole, we give particular attention to local city jurisdictions, as a proof of concept, to illustrate how our participation analysis can support NRG. We also compare our findings to recent analysis on Puget Sound nearshore science networks (Hoelting et al. 2014). In doing so, we discuss how geographic space may affect participation scores and how organizations and individuals shape networks (a needed and understudied research priority (Newig et al. 2010)). Our study can aid Puget Sound practitioners and informs wider SNA for NRG research.

3.2. Study Area

We focus on the Whidbey Basin (WB), a large semi-enclosed coastal basin in northeastern Puget Sound (Fig. 3.1). WB is fed by four major rivers that drain approximately 14,850km^2 of land (Bechie et al. 2001; PSP 2014) and account for 68% of Puget Sound's freshwater input (Yang and Khangaonkar 2010). Marine water quality is affected by these rivers, and by surface runoff from the islands bounding WB's western side (PSP 2014), illustrating the region's physical connections.

Salmon further illustrate biological connections. They spend their adult life at sea and return to spawn in specific rivers, but use the entire nearshore during their juvenile life stage (Beamer et al. 2013; PSP 2014). Seven salmonid species populate WB including three threatened species under the U.S. Endangered Species Act (two listings in 1999, one in 2007); a fourth is also under consideration for listing (Lyshall et al. 2008; Wilhere et al. 2013). Several factors have likely led to salmonid population decline in WB including, but not limited to, water pollution and habitat losses from development and farming (habitat losses range from 7% to 64% by habitat type as compared to late 1800 baselines (Simenstad et al. 2011)); in particular, much of the nearshore has been diked and drained (Fresh 2006; NWIFC 2012; PSP 2014). Other restoration issues include obstructed fish passage, primarily due to culverts, and a legacy of logged upper watersheds that impact water quality (NWIFC 2012; PSP 2014).

WB's biophysical connections illustrate the importance of an integrated governance network. Major jurisdictions in WB include four counties (a fifth overlaps in northern headwaters, but lands are in federal holding, so this county is rarely, if ever, a player), seven Native American Tribes (six with reservation holdings), more than 30 towns and cities, federal and state agencies, and many special purpose districts, i.e., autonomous quasi-government entities with taxation authority that manage specific issues such as flood control or port management (Lyshall et al. 2008; MRSC 2012; PSP 2014). Several land trusts, numerous non-profits, and citizen groups are also involved in salmon restoration (Lyshall et al. 2008; PSP 2014). Headwaters in WB lie predominantly in federal lands (Lyshall et al. 2008). A very small percentage of forested headwaters cross into Canada, but we focus this study on the vast majority of the basin residing in WA. Some restoration and recovery efforts are state and federally promoted initiatives, many of which are coordinated through watershed planning bodies and driven forward using competitive grant funding cycles. While the state tried for several years to advance a WB-wide recovery planning and implementation effort, it was not supported by local organizations, leaving decisions in recovery planning and implementation to be made at smaller geographic scales (PSP 2014). Other efforts are more grassroots (PSP 2014).

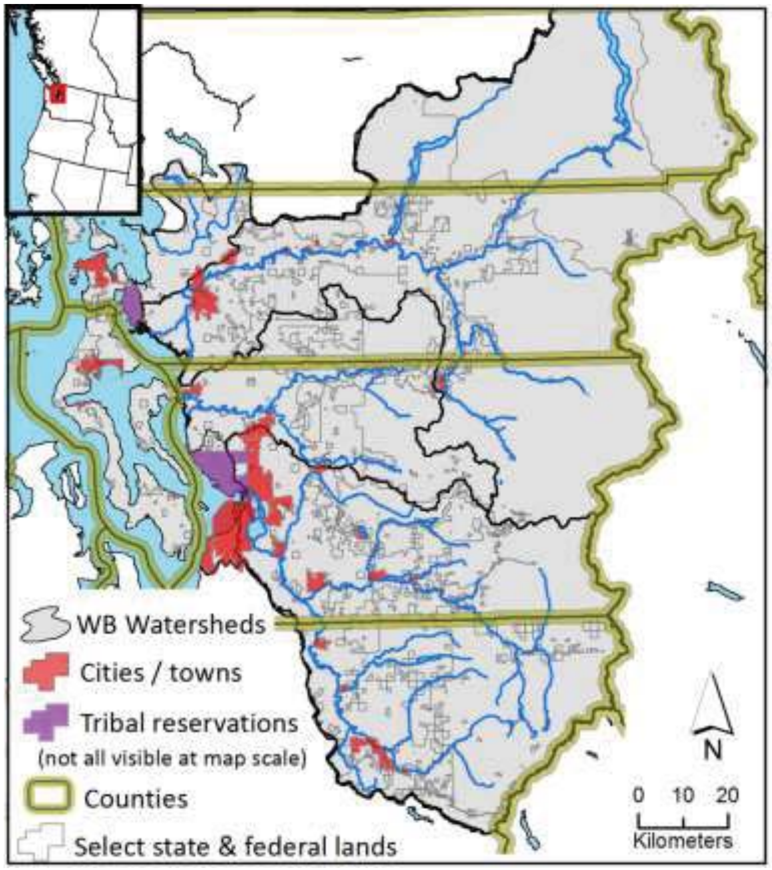

Figure 3.1. Study area map. Several jurisdictional units are depicted to illustrate scale mismatch. Only two of the six tribal reservations are visible at this map scale. Land holdings by select state and federal organizations are depicted for reference, but this is not an exhaustive portrayal. Other governing organizations have been excluded for clarity.

3.3. Methods

We conducted interviews and surveys with restoration practitioners in the region to understand the WB salmon restoration network. The survey and interview guide were developed based on four months of ethnographic research in WB during 2011, refined during pilot runs in summer 2012, and applied between August 2012 and April 2013.

3.3.1. Social network survey

Organizations were sampled using an open-ended recall method common to SNA, in which a list of groups working in the region was compiled and blank spaces were included for additional write-in responses. Write-ins were also contacted to participate.

We partitioned the recall list into a simple a-priori typology to reflect major jurisdictional and sectoral categories (Table 3.1). The list was compiled from 1) attendance at a 2011 WB science symposium, which brought together regional stakeholders to communicate the current state of knowledge about the region, 2) participant observations in 2011, and 3) pilot runs.

We recruited 206 survey participants at 186 organizations using snowball sampling and had a 68% response rate (n = 140). We used targeted phone and email recruitment (with a minimum of three contact attempts), which involved contacting organizations, explaining the research, and asking to speak to the person(s) best able to participate on behalf of the organization. We had multiple participants at several organizations to account for sub-programs, or staff that split geographic regions. We merged responses to form single organizational responses (Table 3.1). Survey participants reported who they worked with to do restoration, defined as directly or indirectly helping degraded ecosystems recover to support human wellbeing and local economies (language we adopted from state planning documents (PSP 2008)). In cases where one organization said they work with another, but the other did not reciprocate or participate in the survey, we assumed there was a relationship (i.e., weak symmetrization). Survey participants account for 56.67% of the total documented salmon network.

Participants were asked to indicate why they worked with each organization (i.e., mandated, because of funding, and shared interests). They were also asked to report the percentage of time they perceived a collaboration to be productive for meeting their organization's restoration goals. Responses were recorded on a five point ordinal scale and included the following: approximately 0%, approximately 25%, approximately 50%, approximately 75%, approximately 100%, don't know, and no response. This question had an 80.35% response rate. Non-responses include blank responses as well selection of "don't know" and "no response" options.

Table 3.1. Organizations in network and survey responses by individuals and organizations

Organization type	Nodes (organizations)	Responses by individual	Responses by organization
City & Town	37	25	24
Citizen Group	12	7	7
Coordinating & watershed groups	20	7	7
County	13	13	10
Federal	12	12	8
Nonprofit	41	22	22
Other	4	0	0
Public utility	4	3	3
Business	11	6	6
Special districts	24	13	13
State	13	25	12
Tribe	14	7	7
Education	5	0	0
All	**210**	**140**	**119**

3.3.2. Network Analysis

A network consists of an ensemble of nodes connected by an ensemble of edges. Nodes in our network were organizations involved in restoration. In different analyses, edges denote collaboration presence/absence, reasons, or productivity. We grouped nodes into categories, called network modules, based on major jurisdictional and sectoral divisions (Table 3.1). Following Baggio et al. (2015), we calculated each node's network participation score (P_i) to understand the extent to which nodes of one module collaborated with other modules. P_i measures a node's overall position in the network. P_i = 1 when a node has an equal number of edges to each network module and 0 when it has no edges to other modules (Guimerà and Amaral 2005).

$$P_i = \sum_{S=1}^{N_M} \left(\frac{k_{iS}}{k_i}\right)^2$$

where P_i is the participation coefficient of node i, k_{iS} is the number of edges from node i to nodes in module S, k_i is node i's total edges, and N_M is the number of network modules.

We also calculated specific module-to-module participation (*PM*), which is the proportion of a node's total edges to nodes in a specific module (Baggio et al. 2015).

$$PM_{i,m} = \frac{k_{i.m}}{k_i}$$

where $PM_{i,m}$ is node i's participation score to module m, and $k_{i.m}$ and k_i are the module specific and total edges of node i, respectively.

We summarized *PM* scores as quartiles and created module-to-module participation matrices to compare intra- and inter-module collaborations. Because *PM* scores are assessed as a relative edge ratio for each node, we also calculated each node's total edges (Freeman's degree centrality, C_D) and the percentage of funding, mandated, and shared interest edges between each module.

Finally, we assessed productivity of different collaboration reasons in two ways. First, using a 1-5 ordinal scale for edge productivity (where 1 is approx. 0% and 5 is approx. 100%), we created boxplots of the raw, un-merged survey responses as merging and symmetrizing the data obscures the direct responses. We only considered complete cases (both productivity and collaboration type) and stratified them by the different permutations of combined collaboration types. Then, to control for structural autocorrelation in the data and assess how productivity varied by collaboration reason, we used Quadratic Assignment Procedure (QAP) Pearson's correlations and multiple linear regression (MRQAP) (Dekker et al. 2007). QAP simultaneously permutes the rows and columns of the dependent variable data matrix and computes the probability of obtaining the observed statistic to chance based on *N* permutations. This is a common and necessary statistical approach for network analysis because network data do not fit classical statistical assumptions, including independence of observations (Borgattii et al. 2013; Dekker et al. 2007). QAP tests were calculated in UCINET 6.509 (Borgatti et al. 2002), used 5,000 permutations, and unsymmetrized directed networks to preserve survey responses. Non-responses were coded as zero. Because we merged responses to the organization level, we considered two models, one based on merging by maximum productivity, the other by minimum, to see if this decision affected results. We merged data prior to recoding non-responses as zero to prevent overwriting the productivity score when merging by minimum.

3.3.3. Interviews

We used qualitative interviews to ground and complement our network analysis. Semi-structured interviews were conducted with a subset of 95 participants, purposefully selected to represent the most prominent groups in the network, but also its organizational diversity and different geographic regions. Interview questions were open-ended and addressed a number of themes relating to restoration planning and implementation and inter-organizational collaborations.

All interviews were conducted by the primary author and used an interview guide for consistency. Interviews were done in person or over the phone based on the participant's preference and ranged from 0.5 to 2.5 hours. Interviews were voice recorded, transcribed, and coded using Max QDA 10 based on a-priori themes (i.e., deductively). For this study, quotes from two of several coding themes are used: 1) challenges and limits to doing restoration work, and 2) the role of individuals and an organization's culture in shaping collaborations.

3.4. Results

3.4.1. How well integrated is the WB salmon governance network?

The WB salmon restoration network consists of a diverse array of organizations. Several are highly central in the network (large circles signifying high degree centrality, Fig. 3.2, and maximum degree scores, Table 3.2), including a few state and federal organizations. Several tribal organizations also have high centrality. While a few organizations are more central, the mean and median centrality scores (Table 3.2) are similar for most organization types indicating a rather integrated network overall.

Participation scores show that the majority of organizations have even collaborations with nodes of other organization types (i.e., median > 0.6, Fig. 3.3), with the exception of most business and other organizations. While most P_i scores are high, max $P_i < 1$ indicating that no organization has a perfectly even collaboration across organization types. Interestingly, while federal, state, and tribal organizations were more central in the network (high C_D, Fig. 3.2, Table 3.2), counties, public utilities, and tribes play more of an integrating role as they have the highest participation scores, even slightly higher than coordinating and watershed groups, which often play integrating roles (Fig. 3.3).

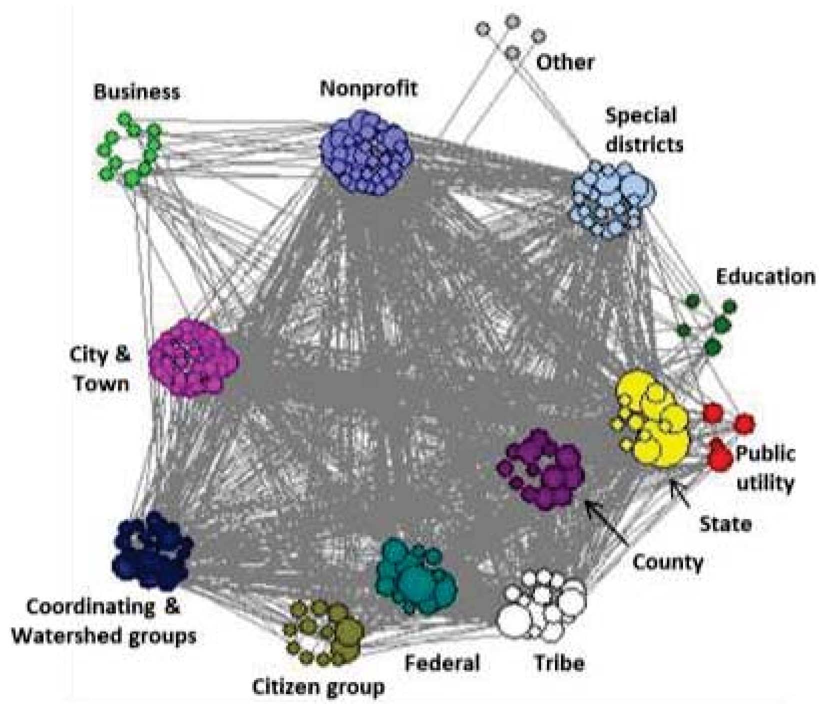

Figure 3.2. Salmon restoration network diagram (n = 210). Nodes are grouped and colored by organization type. Node size is proportional to the node's degree centrality.

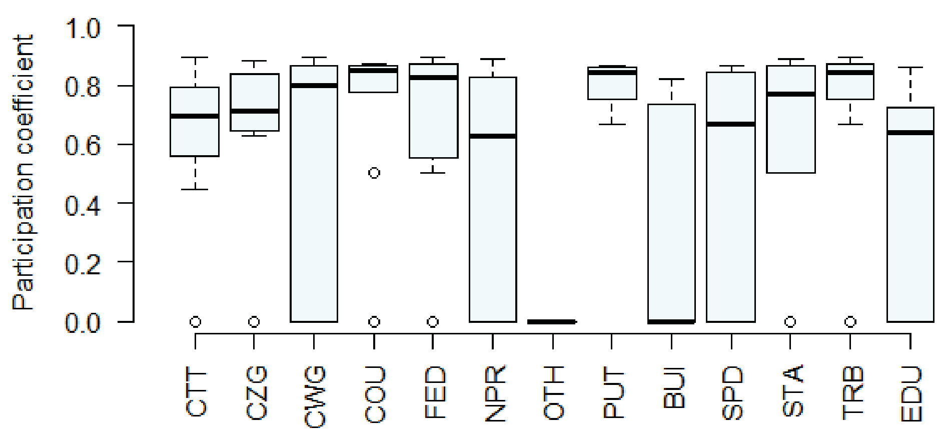

Figure 3.3. Box plot of participation scores (P_i) by organization type. Abbreviations listed in Table 3.2.

Table 3.2. Descriptive statistics of degree centrality (C_D) by organization type. Abbreviations used in the text and figures are given to the right of organization names.

Organization type		N	min	max	mean	sd	median	25th%	75th%
City & Town	(CTT)	37	1	35	6.32	6.22	4.00	3.00	8.00
Citizen Group	(CZG)	12	1	37	10.25	12.37	5.00	3.00	11.00
Coordinating & watershed groups	(CWG)	20	1	39	12.15	11.98	8.00	1.00	21.50
County	(COU)	13	1	35	16.00	11.05	14.00	8.00	25.00
Federal	(FED)	12	1	60	22.00	21.07	19.50	2.75	30.25
Nonprofit	(NPR)	41	1	53	10.22	12.49	4.00	1.00	16.00
Other	(OTH)	4	1	1	1.00	0.00	1.00	1.00	1.00
Public utility	(PUT)	4	3	25	16.00	9.59	18.00	12.00	22.00
Business	(BUI)	11	1	10	2.82	2.82	1.00	1.00	4.00
Special districts	(SPD)	24	1	41	9.79	12.88	4.00	1.00	10.00
State	(STA)	13	1	93	25.31	30.60	13.00	2.00	35.00
Tribe	(TRB)	14	1	72	21.29	20.37	13.50	8.25	28.00
Education	(EDU)	5	1	11	4.80	4.15	5.00	1.00	6.00
All		**210**	**1**	**93**	**11.79**	**15.06**	**5.50**	**2.000**	**15.75**

Figure 3.4 and Table 3.3 further illustrate that the governance network is fairly well integrated. The median, upper, and lower quartile *PM* scores are relatively homogenous for all module to module combinations. Had the network been overtly siloed, *PM* scores to one's own module (i.e., the diagonal in Fig. 3.4, Table 3.3) would be much higher than other module to module combinations. Additionally, an integrated network should not have an extremely low diagonal in the *PM* matrix (Fig. 3.4, Table 3.3), as this would indicate a paucity of collaboration within sectors. Educational and other organizations have no within module participation due to their non-participation in the survey. Thus, WB does not appear to suffer from within sectoral isolation based on our results.

While the overall network is fairly well integrated, some organization types play a bigger role than others. Most organizations have a high *PM* scores with nonprofit, state, and to a slightly lesser extent, federal and special district organizations (i.e., high scores relative to row, Fig. 3.4, Table 3.3). *PM* scores to public utilities, businesses, and educational organizations are much lower for most organization types (i.e., low scores relative to row, Fig. 3.4, Table 3.3). This pattern is partly a function of module size, but not entirely and illustrates an important characteristic of the network. For example, nonprofits are the largest group in the network (Table 3.2), so it not surprising that an organization has many nonprofits partners. Conversely, the possible collaborations to educational organizations may always be low; there are only five education nodes. An organization can clearly have more nonprofit partners than educational ones. Yet the mean, median, and even upper quartile centralities in the network are not that high (Table 3.2). It is entirely possible for the median organization to have almost all of its edges with educational organizations. *PM* values could be close to 0.30 for an organization in the upper quartile C_D. Yet *PM* scores from any group to education are a magnitude smaller (i.e., 0.03 to 0.06, Table 3.3). While module size may alter the range of possible *PM* scores, the *PM* values we observed represent the reality of the WB network. Continuing with the original example of nonprofits, they play a big role in the network, both in number and with whom organizations engage as partners.

Finally, several organization types do not collaborate with each other (i.e., several *PM* scores = 0). Particular noteworthy, is an absence of collaboration between businesses and cities/towns and between educational and state organizations. These are major gaps between key sectors in WB.

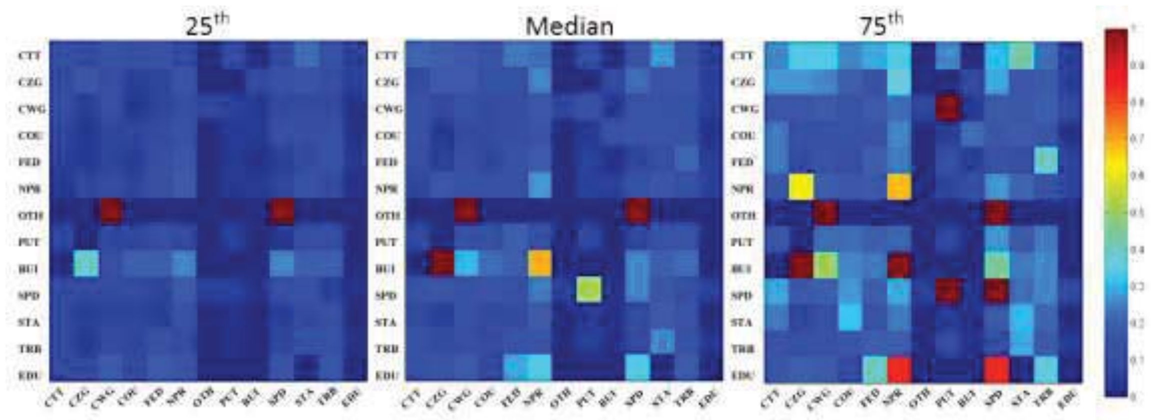

Figure 3.4. Median, 25th, and 75th percentile module to module participation (*PM*) scores between different group types in the salmon restoration network (n = 210). Colors indicate *PM* score. Data should be read across in rows; for example, top row represents *PM* scores from cities/towns (CTT) to other organization types. Abbreviations listed in Table 3.2.

	CTT	CZG	CWG	COU	FED	NPR	OTH	PUT	BUI	SPD	STA	TRB	EDU
CTT	0.218 (0.12 - 0.25)	0.196 (0.09 - 0.33)	0.174 (0.13 - 0.33)	0.143 (0.12 - 0.25)	0.235 (0.13 - 0.29)	0.225 (0.08 - 0.33)	0.000 (0.00 - 0.00)	0.101 (0.08 - 0.25)	0.000 (0.00 - 0.00)	0.143 (0.09 - 0.31)	0.268 (0.22 - 0.43)	0.143 (0.13 - 0.23)	0.057 (0.06 - 0.06)
CZG	0.088 (0.08 - 0.27)	0.183 (0.16 - 0.27)	0.186 (0.10 - 0.25)	0.118 (0.06 - 0.19)	0.112 (0.07 - 0.15)	0.250 (0.14 - 0.38)	0.000 (0.00 - 0.00)	0.000 (0.00 - 0.00)	0.081 (0.08 - 0.08)	0.232 (0.11 - 0.29)	0.155 (0.14 - 0.17)	0.167 (0.10 - 0.18)	0.054 (0.05 - 0.05)
CWG	0.133 (0.10 - 0.17)	0.088 (0.06 - 0.17)	0.122 (0.10 - 0.18)	0.083 (0.04 - 0.14)	0.100 (0.07 - 0.18)	0.167 (0.10 - 0.23)	0.069 (0.07 - 0.07)	0.125 (0.06 - 1.00)	0.038 (0.03 - 0.04)	0.130 (0.08 - 0.17)	0.130 (0.09 - 0.16)	0.121 (0.08 - 0.20)	0.054 (0.03 - 0.08)
COU	0.125 (0.07 - 0.24)	0.039 (0.03 - 0.12)	0.080 (0.07 - 0.12)	0.091 (0.07 - 0.13)	0.103 (0.08 - 0.14)	0.143 (0.13 - 0.25)	0.000 (0.00 - 0.00)	0.042 (0.04 - 0.06)	0.128 (0.03 - 0.22)	0.143 (0.10 - 0.17)	0.143 (0.10 - 0.19)	0.138 (0.12 - 0.17)	0.029 (0.03 - 0.03)
FED	0.100 (0.05 - 0.25)	0.050 (0.04 - 0.09)	0.101 (0.06 - 0.15)	0.071 (0.05 - 0.10)	0.136 (0.10 - 0.20)	0.181 (0.16 - 0.25)	0.000 (0.00 - 0.00)	0.047 (0.03 - 0.10)	0.017 (0.02 - 0.05)	0.071 (0.06 - 0.13)	0.100 (0.08 - 0.10)	0.211 (0.14 - 0.40)	0.052 (0.03 - 0.07)
NPR	0.077 (0.04 - 0.16)	0.167 (0.07 - 0.63)	0.125 (0.09 - 0.20)	0.111 (0.08 - 0.16)	0.132 (0.10 - 0.18)	0.269 (0.19 - 0.69)	0.000 (0.00 - 0.00)	0.061 (0.03 - 0.08)	0.061 (0.05 - 0.10)	0.111 (0.07 - 0.28)	0.163 (0.12 - 0.22)	0.116 (0.09 - 0.15)	0.059 (0.03 - 0.07)
OTH	0.000 (0.00 - 0.00)	0.000 (0.00 - 0.00	1.000 (1.00 - 1.00)	0.000 (0.00 - 0.00	0.000 (0.00 - 0.00	0.000 (0.00 - 0.00	No data	0.000 (0.00 - 0.00	0.000 (0.00 - 0.00	1.000 (1.00 - 1.00)	0.000 (0.00 - 0.00	0.000 (0.00 - 0.00	0.000 (0.00 - 0.00
PUT	0.080 (0.07 - 0.16)	0.000 (0.00 - 0.00	0.120 (0.07 - 0.23)	0.107 (0.06 - 0.23)	0.190 (0.10 - 0.20)	0.120 (0.08 - 0.21)	0.000 (0.00 - 0.00	0.067 (0.05 - 0.08)	0.000 (0.00 - 0.00	0.067 (0.05 - 0.27)	0.133 (0.10 - 0.18)	0.138 (0.11 - 0.24)	0.000 (0.00 - 0.00
BUI	0.000 (0.00 - 0.00	1.000 (0.40 - 1.00)	0.300 (0.10 - 0.50)	0.225 (0.20 - 0.25)	0.200 (0.20 - 0.24)	0.700 (0.25 - 1.00)	0.000 (0.00 - 0.00	0.000 (0.00 - 0.00	0.000 (0.00 - 0.00	0.250 (0.25 - 0.44)	0.200 (0.20 - 0.24)	0.225 (0.20 - 0.25)	0.000 (0.00 - 0.00
SPD	0.145 (0.09 - 0.29)	0.160 (0.08 - 0.18)	0.127 (0.08 - 0.20)	0.154 (0.09 - 0.27)	0.123 (0.08 - 0.20)	0.236 (0.18 - 0.29)	0.059 (0.06 - 0.06)	0.530 (0.06 - 1.00)	0.029 (0.03 - 0.03)	0.250 (0.10 - 1.00)	0.167 (0.13 - 0.22)	0.094 (0.06 - 0.25)	0.059 (0.03 - 0.09)
STA	0.093 (0.09 - 0.24)	0.058 (0.06 - 0.06)	0.114 (0.08 - 0.14)	0.086 (0.07 - 0.32)	0.093 (0.06 - 0.14)	0.181 (0.14 - 0.25)	0.000 (0.00 - 0.00	0.032 (0.03 - 0.04)	0.021 (0.01 - 0.03)	0.088 (0.05 - 0.18)	0.174 (0.09 - 0.31)	0.148 (0.09 - 0.21)	0.000 (0.00 - 0.00
TRB	0.111 (0.09 - 0.14)	0.091 (0.04 - 0.12)	0.109 (0.09 - 0.14)	0.091 (0.07 - 0.17)	0.153 (0.13 - 0.19)	0.144 (0.09 - 0.19)	0.000 (0.00 - 0.00	0.057 (0.03 - 0.09)	0.018 (0.01 - 0.03)	0.091 (0.07 - 0.11)	0.250 (0.12 - 0.28)	0.125 (0.12 - 0.17)	0.032 (0.02 - 0.04)
EDU	0.129 (0.09 - 0.17)	0.145 (0.09 - 0.20)	0.182 (0.18 - 0.18)	0.091 (0.09 - 0.09)	0.291 (0.18 - 0.40)	0.333 (0.15 - 0.83)	0.000 (0.00 - 0.00	0.000 (0.00 - 0.00	0.000 (0.00 - 0.00	0.333 (0.15 - 0.83)	0.000 (0.00 - 0.00	0.182 (0.17 - 0.35)	No data

Table 3.3. Median, 25th, and 75th percentile module to module participation (*PM*) scores between different group types in the salmon restoration network (n = 210). Data should be read across in rows; for example, top row represents *PM* scores from cities/towns (CTT) to other organization types. Median scores are listed on top with the 25th and 75th percentiles in brackets below. Within each row, high (> 75th% in row) and low (< 25th% in row) median *PM* scores are colored red and blue, respectively, for descriptive purposes. Zeros (colored in brown) were excluded when calculating row quantiles. Abbreviations listed in Table 3.2.

3.4.2. Why do different organization types work together?

Figure 3.5 illustrates that focusing on specific collaborations reveals different patterns between organization types. For example, the median participation between cities and most other organizations is high for funded relationship and lower for shared interests. Cities also have high participation with federal and state organizations for mandated relationships. As might be expected, few organization types collaborate with nonprofits and businesses because of mandates.

Figure 3.6 accounts for all module to module edges and shows the proportion of edges between modules by collaboration reason. For this reason, the data are symmetrical, and only the upper half of the matrix is shown for clarity. Collaboration reasons are not mutually exclusive; funding, mandates, and shared interests can each be 100% (i.e., top of box, Fig. 3.6). Shared interests characterize most edges followed by funding. The high role of mandated edges between cities/towns and federal and state organizations is clearly visible (top row Fig. 3.5 and 3.6).

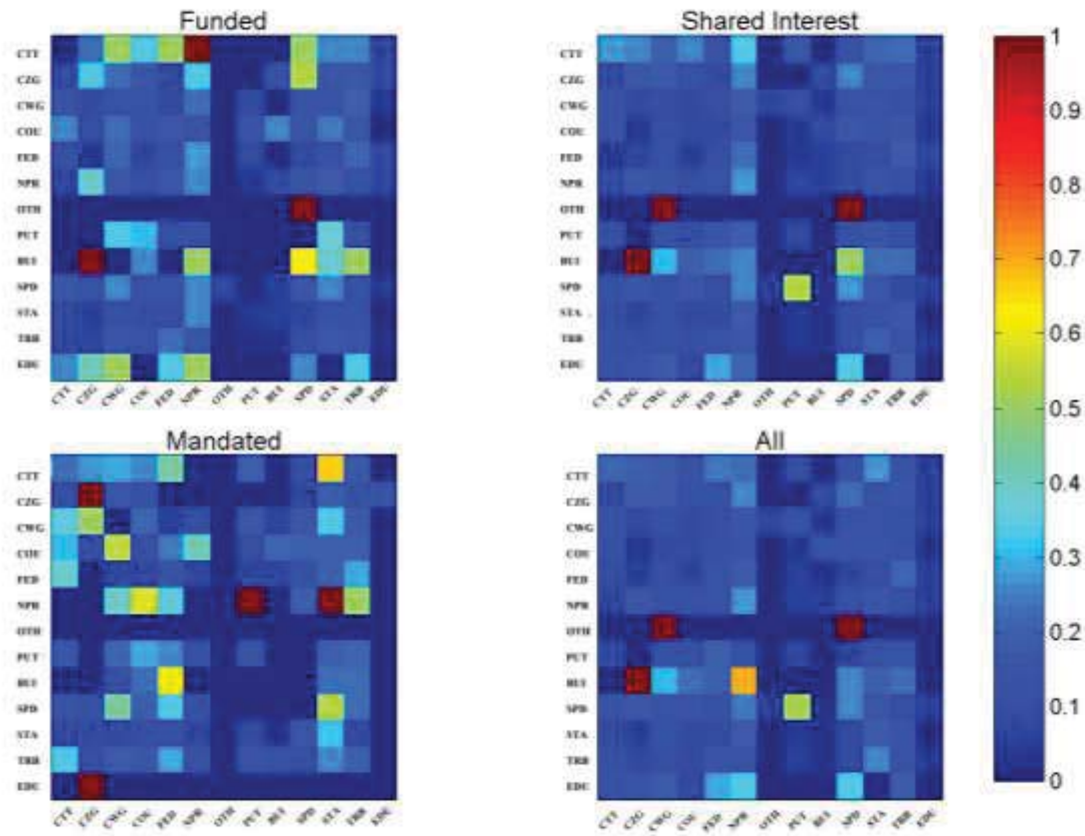

Figure 3.5. Median module to module participation (*PM*) scores between different group types for different collaboration reasons. Colors indicate *PM* score. Data should be read across in rows; for example, top row represents *PM* scores from cities/towns (CTT) to other organization types. When analyzing different relationships types, isolates where removed. *N* = 151, 119, 200, and 210 for funded, mandated, shared interest, and all respectively. Results for lower and upper quartiles are presented in Appendix B. Abbreviations listed in Table 3.2.

Figure 3.6. Percent edge type between modules for all organizations in the network (n = 210). Bars depict the percentage of edges that are because of funding, mandated, or shared interest (left to right, and in dark, medium, and light grey, respectively). Bar height represents percentage of total edges. Each bar can reach 100% (top of box). Y-axis of each box has been ticked at 25, 50, and 75%. Abbreviations listed in Table 3.2.

3.4.3. How productive are different collaboration types?

Figure 3.7 provides simple descriptive statistics about the productivity of different collaboration reasons. While there is no difference in median productivity, the presence of mandated relationships increases the interquartile range of collaboration productivity and negatively skews the distribution. Mandated collaborations have a lower productivity, while collaborations based on mutual interest and funding are perceived to be more productive.

QAP results confirm these patterns (Tables 3.4 and 3.5). Shared interest relationships have a stronger correlation with productivity and explain the majority of variance (correlations in Table 3.4, standardized coefficients in Table 3.5, $p < 0.001$). While all three edge types are positive and significant in the MRQAP, the positive effect of shared interest relationships on productivity is almost 5.5 times higher than mandated relationships. These findings illustrate that mandated collaborations are less likely to be productive for achieving collaborative governance objectives (i.e. salmon restoration in our specific case).

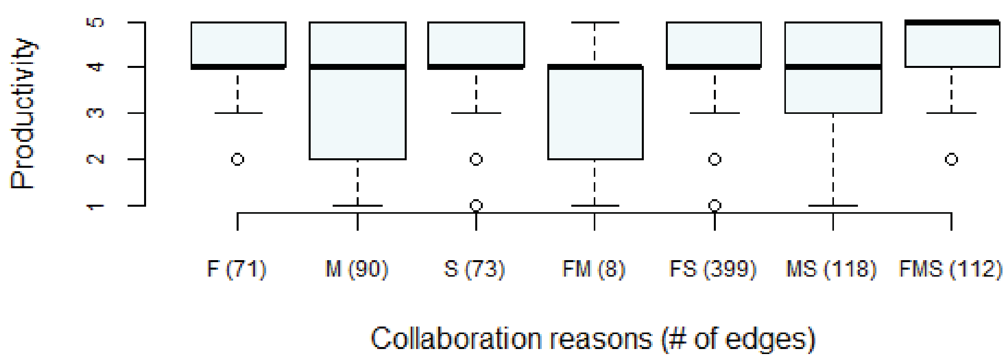

Figure 3.7. Box plots of collaborations reasons and their productivity. F, M, and S refer to funded, mandated, and shared interest relationships, respectively. More than one letter indicates more than one reason for the collaboration. The number of edges by type is in parentheses. Productivity measures the percentage of time collaborations are perceived productive for meeting an organization's restoration goals. 1 = approx. 0%, 2= approx. 25%, 3 = approx. 50%, 4 = approx. 75%, and 5 = approx. 100%.

Table 3.4. QAP correlations between collaboration reasons and productivity. All p-values < 0.001. Max and min merge refer to merging survey responses to the organizational level (n = 210) by maximum and minimum reported productivity, respectively.

	Funding	Mandated	Shared	Productivity (max merge)	Productivity (min merge)
Funding	1.000	0.293	0.626	0.629	0.623
Mandated	-	1.000	0.372	0.416	0.407
Shared	-	-	1.000	0.812	0.809

Table 3.5. MRQAP regression models between collaboration reasons and productivity (n = 210). There was little variation between the maximum and minimum merge models, so only maximum is displayed in the table. The difference in adjusted R^2 between the two models was only 0.008 (maximum model was higher). The absolute difference between standardized coefficients in the minimum model was slightly larger. Details in Appendix B.

Model: max merge	**R^2 = 0.695**	**Adj. R^2 = 0.695**	**p < 0.001**	
	Unstandardized coefficient	Standardized coefficient	p-value	Standardized error
Funding	1.082	0.188	< 0.001	0.023
Mandated	0.915	0.120	< 0.001	0.026
Shared	2.691	0.650	< 0.001	0.025
Intercept	0.011	0.000	0.000	0.000

3.4.4. How can understanding these patterns enhance restoration work in WB? An example with cities and towns

During phone recruitment and interviews, many city and town participants described how their jurisdictions lacked capacity to do restoration work. The following quotes illustrate some of these challenges:

> The city is in transition right now. … We just did a bunch of layoffs [and my job description changed]. … Even though the community and other [City] Council members want me to keep doing natural resources, I don't know if I will be able to or not to be honest. … [Restoration] is not necessarily the highest priority. There are other priorities to the city … health and safety is more important.
>
> (City/town participant 1)

> Money! I mean, it is really a matter of funding … To do restoration projects you know, you got to have the money not just for the initial planning, but you got to have at least five years of maintenance and monitoring. And that is very vigorous for the first two years if you're gonna end up with a restoration site that is worth two hoots. … We got the sites; we just don't have the funding.
>
> (City/town participant 3)

> Politics – I mean that's the main thing. If we had a different political tone, we would, the city would probably be pursuing restoration projects more aggressively. And then money is obviously a factor. … And then, the third thing, … there isn't leadership on that issue. So there isn't … a discussion happening about the benefits of restoration to people and to the city generally … It's not part of the culture and discussion that happens around other issues like economic development. … It's viewed myopically. … The case just hasn't been historically made here that restoration has these greater benefit than just the restoration project itself.
>
> (City/town participant 17)

> We are by necessity and purpose involved in environmental management; we are not by mandate, necessity, or purpose, involved in environmental restoration. We don't have the budget to do anything that we are not mandated to do …. We are not a restoration agency; and we are nevertheless, happy to cooperate as we did with [that group on those] projects.
>
> (City/town participant 22)

Cities and towns face several challenges; but, interview results also illustrate opportunities to overcome them. Quote four, for example, outlines enthusiasm for collaborating with partners. Cities and towns are one of the few organizations that have a slightly lower participation with nonprofits as compared to other organization types (i.e., median values in row CTT < 75^{th}%, Table 3.3). Nonprofit collaborations with cities/towns are also low, only 0.004 above the nonprofit row lower quartile *(PM* = 0.077, 25^{th}% = 0.073). Furthermore, cities/towns do not collaborate with businesses. They predominantly collaborate with federal and state organizations (Fig. 3.4, Table 3.3), but these collaborations are largely mandated relationships (Fig. 3.6) and may be of low productivity (Fig. 3.7, Tables 3.4 and 3.5). Indeed, one participant felt that cities and towns “are regulated to death,” indicating that they thought poorly of these mandated relationships. Based on the above network structures, restoration capacity might be enhanced by promoting partnerships with nonprofits or businesses.

Such network interventions, or weaving, should be targeted, however. A blanket push for nonprofit and business partnership may yield undesirable results. As one city participant said:

> You kind of start to know who’s got the right technical background and who’s just maybe a nonprofit group that is trying to do the right thing but maybe does not have enough knowledge and shouldn’t totally be doing the project.

Network weaving should strategically match groups based on needs and capacities. However, the above quote should not overshadow the benefits of nonprofit partnerships. As one city/town participant said:

> If we didn’t have these nonprofit groups stepping up to the plate, and they are really good at getting grant funding. … If it wasn’t for those groups we would have nothing going on here. … Nonprofits … have taken the lead, not the county.

While some smaller nonprofits may lack the technical capacity for large restoration project, they could be instrumental in helping cities/town overcome stagnant political will. Partnerships with smaller nonprofits could be instrumental in education and outreach campaigns and citizen monitoring, which might address concerns voiced by the city/town participants above. Collaborating with businesses might improve the link between restoration and development as discussed by city/town participant 17. While, network weaving should be guided by local knowledge of individual stakeholder needs, our participation analysis provides a coarse grained diagnostic that helps focus where more detailed study is needed for targeted interventions.

3.5. Discussion

Our results indicate that the WB governance network is overall fairly well integrated. Specific sectoral collaborations, however, warrant refining to enhance restoration capacity, as in the case of cities and towns. Our study provides empirical evidence about why different types of organizations collaborate and the importance of disentangling the broad notion of "network collaboration" to consider the actual types of collaboration. Indeed, while we cannot infer causality, mandated relationships often have lower perceived productivity based on practitioners' self-assessments.

It is possible that mandated relationships were established (and enforced) to create collaboration among organizations that did not want to work together. That is, mandated relationships could be an attempt to deal with perceptions that a partnership was not worthwhile, which might explain their lower reported productivity. However, as presented in section 3.4.4, discussing possible holistic benefits of restoration (such as green infrastructure that can reduced the risk of flooding, or ecotourism that can boost local economies (Suding et al. 2015)) could help stakeholders unite around shared interests, which contribute significantly more to partnership productivity. Thus, even if mandates are not causing lower productivity, but rather, are put in place where low productivity already existed, network weaving to help stakeholders see shared interests could still lead to more productive relationships.

In addition to case study specifics, various insights about the application of network diagnostics and environmental governance more broadly are also apparent. We constructed the network using the highest organizational level as our unit of analysis, such as the state department of ecology, or county public works. This was necessary for a consistent node unit based on the data we obtained in the survey. This network construction, however, may have the effect of reducing participation values to modules containing large organizations and increasing participation values to those containing small ones. Rather than a node having several edges to each sub-unit or program of a large organization, these multiple edges get reduced to one. Such effects may be more acute at the state or federal level, or for populated and wealthy municipalities, where organizations often consist of several units with varying degrees of interaction. For example, one interview participant said they rarely interacted with another division of the state department that they worked for. They described it as “kind of a program unto itself.” Alternatively, a participant at a different state department described their program as “intertwined” with another. “We all work as a team,” this participant said. Thus, aggregation may be more or less logical in different situations and poses a real challenge to SNA diagnostics.

The question of appropriate unit extends beyond programmatic level to the very notion of whether or not organizations or individuals should be the unit of network studies for NRG (Newig et al. 2010). Organizations are frequently the units of analysis (Bergsten et al. 2014; Kininmonth et al. 2015; Rathwell and Peterson 2012; Treml et al. 2015); but, as interviews (and a review by Newig et al. (2010)) illustrate, the role of individuals versus organizations in networks is fertile ground for future research. The right or wrong individuals can play a decisive role in networks creation:

> You could spend a life just learning how to navigate it [government bureaucracy], and he has done an excellent job at doing that. And he has built relationships. … It has kind of been one of the cornerstones of how we approach restoration and it is one of the reasons I value staff who have been with us for a while. … I don’t go [into a] project without my guy who knows the [jurisdiction in question].
>
> (Tribal participant)

> We’ve had turnover …, complete turnover of our staff. Our old partners are kind of walking away from some of the new staff we have; they’re saying [to me], if you come work with us I will stay in this, but I am not working with that guy. He is just a pain in the butt.
>
> (Federal participant)

> [Those two people] have worked together quite a bit and it's amazing how, I think, how far we have come in the last five years .... So sometimes, you know, it's just getting the right individuals in the right spots from the right organizations, that can really; you got to get trust, right? And then pretty soon you're working together. … I know these things are cliché, but it's so true.
>
> (Drainage, diking, or irrigation district participant)

> Over the past year or so, we've had a major breakthrough with [that city]. … It is amazing what personnel changes can do for partnerships. The previous staff were very, sort of fearful of what that could mean for them, and the new folks are really committed to partnering. It has just completely transformed our relationship and what seems possible now.
>
> (County participant)

Individuals are also fluid, moving from one organization to another, and take relationships with them.

> People move around, too, from one organization to another, so we have this giant interconnected network of resource people .... That's how we learn about a willing landowner or learn about a particular problem on a particular [river] reach. It's that larger experience pool.
>
> (County participant)

> Even though we just [hired people], there is so much work to be done. And [several nonprofits are having] financial issues. And so they have seen their restoration staffs decline, whereas ours increased, but we cannot make up for all the other stuff. So really, there has been no net increase in the number of people who are able to do restoration work in the basin.
>
> (Conservation district participant)

> I worked with [the tribes] for [many years] before I came [here]. And so some of what we have done there is related to either the work we were doing there before, or just continued on because we have working relationships with people there.
>
> (Federal participant)

Additionally, while individuals may change, relationships may still be maintained between organizations.

> We've been successful because we developed a really good partnership .... The tribe has been great to work with. ... Unfortunately, their lead restoration planner ... left. And that took some wind out of our sails .... But we have adjusted to that.
>
> (State participant)

Lastly, while individuals clearly play an important role, organizations also have a character of their own that affects how individuals from different organizations interact.

> The political reality [is that our city] is a more property rights oriented place. And its leadership, Mayors and city council in the past, and I would say it's still true, haven't focused a whole lot on environmental issues generally, and so that has filtered down ... to the staff level, ... that's created some tension at times between us and other cities and the county.
>
> (City/town participant)

> Every director has a focus, an interest. And you know, my background, my education is in natural resources or environmental studies. ... I think country wide, the consciousness is growing ..., but I think I brought in a natural resource kind of bend, I guess, to what we do.
>
> (County participant)

> We try, at least at my level, to get along really well with the tribal biologists, and doing [restoration] projects like that. But it is the upper, you know, management that are sometimes butting heads on issues. ... So, there is a somewhat lack of consistency on where the county should be on some of these restoration issues. .... So, at our level, it's just, you know, chug-along and try and get things when you can.
>
> (County participant)

These quotes illustrate that both individuals and organizations affect network structure and function. This is perhaps an intuitive conclusion, but also something that creates a challenge for SNA for NRG research (Newig et al. 2010).

Unit selection may explain certain differences in our findings as compared to other recent Puget Sound network analysis, though only in part. Hoelting et al. (2014) studied collaborations amongst individuals conducting research on a variety of Puget Sound nearshore restoration and recovery issues. Among other findings, academics made up the largest part of the network, at 34% (Hoelting et al. 2014, further discussion in Appendix B). We found educational organizations made up a small part, both in number (2.4% of the network) and in terms of whom other organizations collaborated with. Certainly some of the difference in these two studies is due to units of analysis. Hoelting et al. (2014) recorded individuals and many individual academics work at a few universities. However, as noted earlier, comparing median C_D and *PM* scores illustrates that participation with educational organizations could have been higher. Additionally, one community college was nominated as a write in response in our study, but there are others in the region. So, the number of educational organization could have been higher. While academics at community colleges may be less involved in research than their university counterparts, teaching could be integrated with activities such as citizen monitoring, which could help address some of the challenges voiced by city/town participants in section 3.4.4.

It is possible that we documented more of a practitioner network and Hoelting et al. (2014) document more of a research one. Hoelting et al. (2014) reported numerous collaboration challenges between the applied and academic sector and several of our interview participants commented on this as well. For example, one said:

> [That academic] speaks a language that is really difficult to translate on the ground. That's a huge impediment …; you can be all published and everything, but if it doesn't result in a change on the ground it's [participant pauses], you know what I mean? … There is a big disconnect between the academic community and the people that are doing the work.
>
> (State participant)

Others commented that the universities were vital to the work they do.

> [We are] trying to think a lot about and work with meteorologists and folks in the climate impacts group and others [at the University of Washington] for what [climate change] means for hydrology and the available supply of water. … We partner quite a lot with scientists from the "U-dub."
>
> (Public utility participant)

If in fact, universities play a vital role, one possible explanation for their low prevalence in our data could be that people use academic research outputs (i.e., data, models, research reports, and articles) while not considering the actual academic organizations producing these documents to be direct collaborators. Alternatively, there may be a genuine disconnect due to communication challenges and cultural differences between academics and practitioners as stated by the first participant. In that case, WB and Puget Sound may benefit from a more focused study on boundary organizations to enhance network weaving.

A final consideration to properly interpret our data is the spatial arrangements of the organizations in the network. Our participation analysis does not account for space, but space likely affects collaboration patterns, especially at the local level. For example, *PM* scores from city/town to county are lower than those from county to city/town (Fig. 3.3, Table 3.3). Both cities/town and counties are independent local jurisdictions. A city or town is likely to collaborate only with the county organizations of the county in which it resides, as well as those of a neighboring county in cases where a watershed is bisected by county lines. Collaborating with a neighboring county in the same watershed is important because an ecosystem based management approach requires collaborations to be organized around biophysical boundaries, not jurisdictional ones. Alternatively, a county organization would interact with the many cities within its borders and those of a neighboring county if they share a watershed. While the *PM* scores provide insight about sector and jurisdictional integration, future work must incorporate spatial arrangements. Indeed, Cassidy and Barnes (2012) note a similar research limitations and future need in their analysis of households networks in rural Botswana. True spatial arrangements, beyond reference to local and larger scales, have rarely been incorporated into SNA for NRG studies. However, several recent studies are either explicitly spatial or include spatial proximity as an independent variable[2] (Bergsten et al. 2014; Bodin et al. 2014; Bodin and Tengö 2012; Gallemore and Munroe 2013; Lubell et al. 2014; Treml et al. 2015). The future direction of spatial SNA for NRG is promising.

3.6. Conclusion

Effective coastal management and restoration are often hampered by sectoral and jurisdictional siloes. Based on our participation analysis, the WB network is fairly well integrated, but we identify several concerning gaps in the network between businesses and cities/towns as well as educational and state organizations. The WB analysis shows how specific network interventions might enhance restoration capacity in the basin, such as between cities/towns and nonprofits and businesses. We show that collaboration patterns change with different collaboration reasons such as funding, mandates, or shared interest relationships. Overall, mandated relationships were associated with lower productivity than funded or shared interest relationships, highlighting the benefit of true collaboration in collaborative watershed governance. Lastly, our quantitative and qualitative data comparisons strengthen recent calls to better incorporate geographic space and the role of individual actors versus organizational culture into SNA for NRG.

[2] Including Chapter Two

Chapter 4. Effects of social-ecological scale mismatches on estuary restoration at the project and landscape level in Puget Sound, WA with specific focus on spatial subsidies

4.1. Introduction

A single coastline or estuary may be governed by dozens to hundreds of organizations that overlay the landscape in myriad ways (Crowder et al. 2006). Indeed, Lubell et al. (2014) documented 387 organizations operating in one coastal bay of the US Pacific Northwest. Such fragmentation creates complex patterns of social-ecological scale mismatches, where governing units do not align in one or more important ways with the environmental systems they seek to govern, often leading to failed or inefficient resource management (Crowder et al. 2006; Cumming et al. 2006; Folke et al. 2007; Galaz et al. 2008). In most cases, governing organizations operate at different spatial extents, represent different societal sectors, and often have different missions or goals (Cash et al. 2006; Lemos and Agrawal 2006), further complicating scale mismatch problems. These problems are particularly serious for estuaries.

Estuaries are vital to human wellbeing (UNEP 2006) but degraded worldwide (Diaz and Rosenberg 2008; UNEP 2006). Their restoration is an essential component of sustainability planning to balance healthy productive ecosystems and development needs (Weinstein et al. 2007). Restoration is not just about ecological outcomes but can and should help educate the public about the environment, create jobs, and restore or enhance environmental services that benefit people (Higgs 2003; Kittinger et al. 2013; Suding et al. 2015). To restore estuaries, practitioners must understand both the bio-physical and socio-political landscape. Conditions in one location of an estuary's watershed affect other locations (NRC 1992), so restoration must be coordinated among the many governing organizations working in different locations (Sabatier et al. 2005b).

Scale mismatches are frequently cited as a major challenge for large-scale restoration (Baird 2005; Baker and Eckerberg 2013; Menz et al. 2013; Nilsson and Aradottir 2013; Palmer 2009). While Hagen et al. (2013) show restoration practices vary by country, few if any empirical studies explicitly analyze how scale mismatch affects restoration.

In this paper, I elucidate these effect for the Whidbey Basin (WB) in Puget Sound, an estuary that hundreds of organizations are working to restore (PSP 2014; Wellman et al. 2014). I qualitatively analyze a large set of semi-structured interviews with participants from governing organizations to understand how scale mismatches affect restoration projects and landscape level restoration planning and implementation.

Scale mismatches are often classified as spatial, temporal, or functional (Cumming et al. 2006; Galaz et al. 2008) and defined as follows: *spatial*, where governance boundaries are too big, too small, or misaligned with natural resource extents; *temporal*, where governance arrangements are created at inopportune times, or operate at different cycles (e.g., political elections) than relevant ecological process; *functional*, where governance arrangements lack capacity or ability to operate in response to ecosystem dynamics. These types are not mutually exclusive (Galaz et al. 2008); however, spatial mismatches are my primary focus, while recognizing that temporal and functional mismatches often play a role in the manifestation of spatial scale mismatches (Moss and Newig 2010). Indeed, an organization's resources, authority, and legitimacy affect how it works on the landscape, illustrating the strong link between spatial and functional mismatches (Galaz et al. 2008).

Governance networks are frequently promoted to address scale mismatches (Bergsten et al. 2014; Bodin et al. 2014; Ernstson et al. 2010). Networks may be preferable to other options such as redefining spatial governance boundaries, which can create new mismatches or undermine management when existing institutions are considered legitimate (Moss 2012). To collaborate, organizations often must reconcile different goals and objectives (McManus 2006; Pahl-Wostl 2006), a process affected by their relative authority (Lebel et al. 2005; Swyngedouw 2004). Central concerns for collaborative water management include harmonizing strengths and weaknesses of bottom-up and top-down management (Moss and Newig 2010) and addressing collective action problems (Ostrom 1990; Sabatier et al. 2005a). Resource competition between up and downstream users is a common collective action problem (Janssen et al. 2011), sometimes addressed by compensating upstream users to forgo resource uses ensuring that usable water is delivered downstream (Zheng et al. 2013). In sum, scale mismatch is clearly a social-ecological landscape pattern affecting decision making and the flow of resources, called spatial subsidies, across the landscape.

To understand patterns and processes in scale mismatched systems, I integrate heuristics from the politics of space (Lebel et al. 2005) and spatial resilience (Cumming 2011a; 2011b) (Fig. 4.1). Both identify three categories of spatial arrangements as particularly useful for understanding governance dynamics across the landscape: 1) between scalar levels (e.g., local and regional), 2) between spatial positions (e.g., up and downstream), and 3) between places of special character (e.g., urban vs rural areas). Spatial resilience provides further insight into interactions including feedbacks, network connections, and material and non-material spatial subsidies (e.g., water and knowledge) (Cumming 2011a; 2011b).

I use this conceptual approach to answer the following questions: 1) how do scale mismatches affect estuary restoration planning and implementation in a complex, multi-level governance setting? 2) How can this understanding improve landscape restoration science and practice?

This research fits into a growing literature on the human dimensions of restoration in which previous studies have critically evaluated restoration science itself (Baker and Eckerberg 2013; Eden and Tunstall 2006) and studied how social values, public participation, communication, and governance affect restoration processes and outcomes (Barthélémy and Armani 2015; Breslow 2014a; 2014b; Druschke and Hychka 2015; Flitcroft et al. 2009; Franklin et al. 2014; Hagen et al. 2013; McManus 2006; Petursdottir et al. 2013). Previous studies have also documented public perceptions of restoration targets (Safford et al. 2014) and evaluated social outcomes, including ecosystems services (De Groot et al. 2013; Kittinger et al. 2013; Simenstad et al. 2005). Landscape restoration has also been planned using stakeholder consensus (Sisk et al. 2006), economic optimization (Fullerton et al. 2010; Wilson et al. 2011), and information about landscape managers (Curran et al. 2012). This study also contributes to natural resource governance more broadly as Folke et al. (2007) note a dearth of research on scale mismatch in multi-level governance settings.

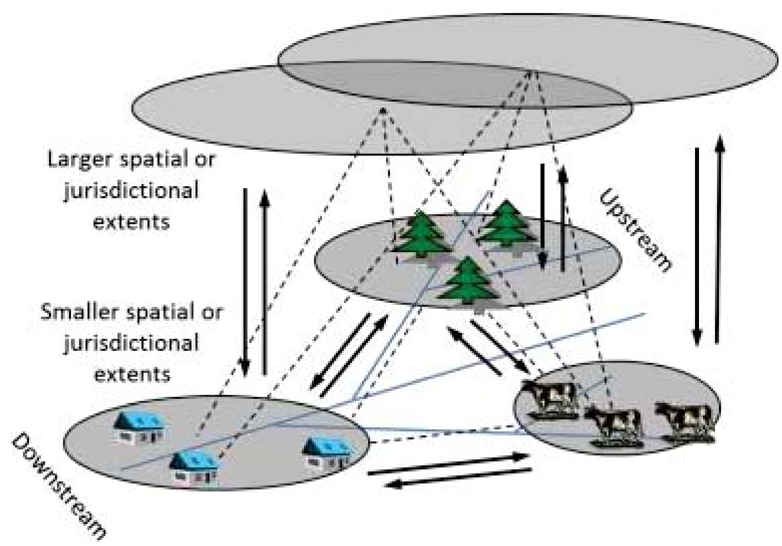

Figure 4.1. Conceptual diagram depicting spatial arrangements of governing units (grey circles) in a watershed (blue lines), their relationships (dashed lines), and resulting spatial subsidies (black arrows). Spatial arrangements are broken into three types: 1) between scalar extents or levels (e.g., local and regional), 2) between spatial positions (e.g., up and downstream), and 3) between places of special character (e.g., urban vs

rural areas). I do not draw a strict distinction between spatial and jurisdictional extents because local jurisdictions may cover large spatial extents and some state or national jurisdictions may work in small areas (i.e., parks or protected areas) (Young 2006). Rather, spatial nesting between governing organizations is the critical consideration for scalar interactions. Relationship between spatial units may be structural (e.g., presence/absence or strong/weak connections) or functional (e.g., collaborative or confrontational). Spatial subsidies may be material (e.g., water, fish, money, resource managers) or non-material (e.g., knowledge, political influence).

4.2. Study Area

WB is a large semi-enclosed coastal basin in northeastern Puget Sound (Fig. 4.2). Fed by four major rivers, WB drains roughly 14,850km^2 of land (Bechie et al. 2001; PSP 2014) that accounts for 68% of Puget Sound's freshwater input (Yang and Khangaonkar 2010). Puget Sound is experiencing major development pressures and population growth (Grimm et al. 2008) and has been the focus of significant restoration efforts in recent decades (Bernhardt et al. 2005). Key restoration foci in WB include habitat for several endangered salmonid species, shellfish beds, and marine water quality (Lyshall et al. 2008; PSP 2014; Wilhere et al. 2013). These foci are not mutually exclusive as water quality degradation from farms, cities, and rural septic systems stress both salmon and shellfish (Dethier 2006; Fresh 2006). Nearshore habitat losses in WB range from 7% to 64% by habitat type as compared to late 1800 baselines (Simenstad et al. 2011). In particular, much of the nearshore has been diked and drained (Fresh 2006; NWIFC 2012; PSP 2014). Other restoration issues include obstructed fish passage, primarily due to culverts, and a legacy of logged upper watersheds that impacts water quality (NWIFC 2012; PSP 2014). Water quality illustrates the region's physical connections as marine waters are affected by land use in the entire basin. Salmon further illustrate biological connections as they spend their adult life at sea and return to spawn in specific rivers, but use the entire WB nearshore during their juvenile life stage (Beamer et al. 2013; PSP 2014).

While biophysically connected, WB is fragmented by numerous organizations involved in its governance. These include four counties (a fifth overlaps in northern headwaters, but lands are in federal holding, so this county is rarely, if ever, a player), seven Native American Tribes (six with reservation holdings), more than 30 towns and cities, federal and state agencies, many special purpose districts (autonomous quasi-government entities with taxation authority that manage specific issues such as flood control or port management (MRSC 2012)), land trusts, non-profits, and citizen groups (Lyshall et al. 2008; PSP 2014). Headwaters in WB lie predominantly in federal lands (Lyshall et al. 2008). A very small percentage of forested headwaters cross into Canada, but I focus this study on the vast majority of the basin residing in WA. Some restoration and recovery efforts are state and federally promoted initiatives, many of which are coordinated through watershed planning bodies and driven forward using competitive grant funding cycles. While the state tried for several years to advance a WB-wide recovery planning and implementation effort, it was not supported by local organizations, leaving decisions in recovery planning and implementation to be made at smaller geographic scales (PSP 2014). Other efforts are more grass roots (PSP 2014).

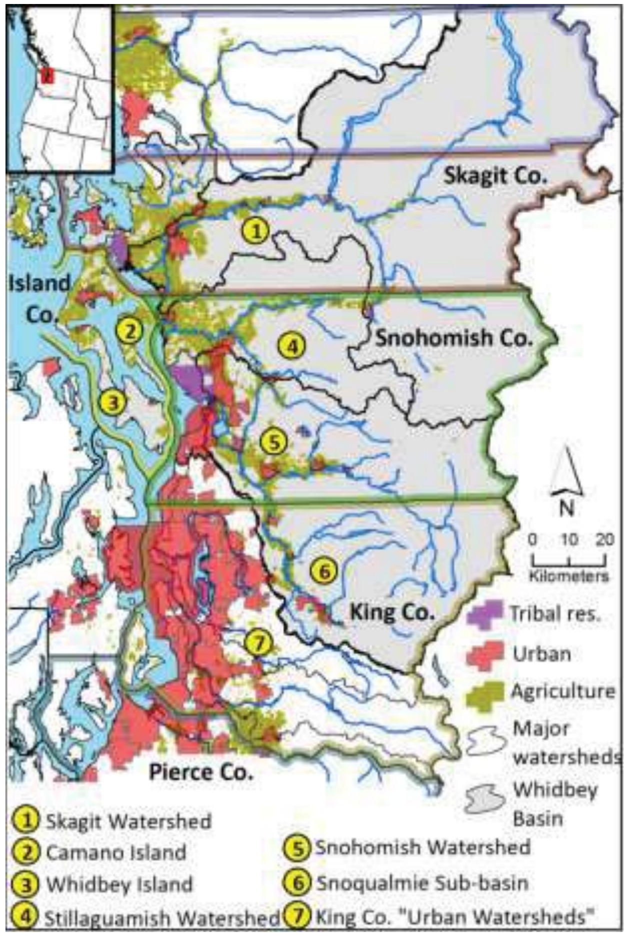

Figure 4.2. Map of Whidbey Basin (WB) depicting place names used in the text. Only two of the six tribal reservations are visible at the given map scale. Urban areas and counties (colored borders in the map) are depicted for reference. Other governing units, e.g., state and federal lands, or regions where nonprofits work, are excluded for clarity.

4.3. Data and Methods

To understand how scale mismatches affect restoration, I conducted 95 semi-structured interviews with purposely selected participants from 306 organizations identified in a parallel social network analysis (SNA) survey reported elsewhere (Sayles in prep).[1] For the survey, I sampled organizations using an open-ended recall method common to SNA. This uses a list of groups and includes blank spaces for additional

[1] The number of organizations in the SNA reported here is greater than that reported in Chapters Two and Three because Chapters Two and Three focuses on salmon, a subset of that original survey data (details in Appendix A). Alternatively, this chapter focuses on all restoration activities documented in the survey and interviews (see discussion in text).

write-ins that are also contacted to participate. I compiled the list from 1) attendance at a 2011 WB science symposium, which brought regional stakeholders together, 2) four months of participant observations at local and regional planning meetings in 2011, and 3) survey pilot runs in 2012.

Participants were selected to represent prominent restoration organizations in WB restoration network, but also its organizational and geographic diversity. I recruited survey and interview participants by phone and email and made a minimum of three contact attempts. I explained my research and asked to speak with the best person or persons who could participate on the organization's behalf. The 95 informants represent 80 organizations as I was sometimes directed to multiple participants, covering different geographic areas or resource topic, in one organization (Table 4.1). For analysis, I treated each interview as a case and considered inter- and intra-organizational connections among participants.

I used an interview guide to ensure consistency across interviews. It was piloted and refined through practice interviews with peers and a subset of ten interview participants. Follow-up interviews were conducted with seven pilot participants after making minor revision to the guide. The other pilot participants were unavailable for follow-ups. Interviews covered a range of themes, but gave specific attention to how jurisdictional borders affected restoration and inter-organization collaboration dynamics. I interviewed informants from July 2012 until April 2013 in person or over the phone based on their preference. Interviews ranged from 0.5 to 2.5 hours, were voice recorded, and transcribed. Transcripts were then coded in Max QDA 10 using the themes listed in Table 4.2 (i.e., deductively).

For recruitment and interviews, restoration was defined using phrasing adopted from state planning documents (PSP 2008): restoration is directly or indirectly helping degraded ecosystems recover to support human wellbeing and local economies. This open definition allowed me to engage a diverse stakeholder group identified by the WB community as directly involved with WB restoration. Most participants (77%) worked as restoration scientists or practitioners, planners, or in public works/health. Others (23%) represented a variety of interests related to the primary sector and development (Table 4.3). Rather than a skewed sample, this illustrates a healthy diversity in the WB restoration network, which logically consists primarily of restoration and natural resource management professionals.

Table 4.1. Interview participants by organizational type. Both the number of informants and organizations are listed because it was necessary to speak to more than one person at several organizations. While the total number of participants is 95, Table 4.1 depicts 97 because two participants were the points of contact for two organizations.

Organization type	No. participants	No. organizations
Federal	8	5
Tribal	7	7
State	20	11
County (planning, public works, health)	11	8
City / town	7	7
Public utility	3	3
Special purpose districts		
Conservation	2	2
Port	5	5
Diking, drainage, flood, and/or irrigation	4	4
Other (health, transportation)	2	2
Nonprofit	10	10
Coordinating organizations	13	11
Citizen groups	4	4
Business	1	1

Table 4.2. Deductive coding themes

Deductive coding themes
Restoration targets / how organizations relates to restoration
The role played by an informant's organization for restoration
How the informant's organization relates to WB wide restoration efforts
Geographic scope of work
Reasons why restoration is done in specific locations
Ways that borders affects where restoration is done
Ways that borders affects how restoration is done
Examples about relationships to other groups, the WB system, or the wider restoration network
Examples of scale, position, and place
Examples of spatial subsidies

Table 4.3. Interview participants by primary objective of their organization. Both the number of informants and organizations are listed because it was necessary to speak to more than one person at several organizations. In row one, restoration includes science and practice. General natural resource management (NRM) includes planning and public works/health. The majority of participants fall into the restoration or general NRM category. Rather than a skewed sample, this list of objectives illustrates a healthy diversity in the WB restoration network, which logically consists primarily of restoration and natural resource management professionals.

Primary objective of organization	No. participants	No. organizations
Restoration or general NRM that also addresses restoration	73	59
Agriculture	2	2
Aquaculture	1	1
Fisheries	2	2
Forestry	2	1
Education and outreach	3	3
Transportation	2	2
Flooding, drainage, and irrigation infrastructure	4	4
Dual mission of economic development/job creation and environmental stewardship	6	6

4.4. Results

To understand how scale mismatches affect restoration in WB I first describe where restoration organizations work, then individual projects, and lastly landscape planning and implementation. Results combine direct quotes with summarized information across interviews. Superscripts indicate the number of interviews behind summarized statements.

4.4.1. Where restoration organization work

Understanding where and how organizations work is a prerequisite for understanding scale mismatch. County and city governments work within their political border,[11] or are further restricted to service areas in which taxes or fees are collected, or to department owned properties like parks.[4] Similarly, special purpose districts (i.e., autonomous quasi-government entities) have clearly defined services areas. Most dike, drainage, and irrigation districts are quite small.[4] Port authorities have larger districts, but restrict their restoration activities to port owned lands, which are much smaller than the district.[5] Health and conservation districts borders usually align with counties, the exception being that Camano Island, which is part of Island County, is served by the Snohomish County conservation district, preventing the separation of Port Susan along county lines.[3] However, several informants discussed that Camano Island had little interaction with the rest of Island County.[6] So, in reducing one scale mismatch, another may have been created. While WB is encapsulated by state and federal boundaries, some state and federal organizations restrict or focus their work to priority regions or agency owned lands,[7] which adds to WB's social-ecological fragmentation.

Native American tribal boundaries are more complicated. Tribes work in usual and accustomed areas (U&A), which reflect historic resource harvesting ranges.[7] U&A boundaries are often fuzzy in demarcation and may overlap one another.[7] Most U&A are large, incorporating one or more watersheds and adjacent coastal waters (NWIFC 2012).[7] Tribes in WB have different legal authority over natural resource management (NRM). Five tribes have resource harvesting and co-management rights under the 1976 Boldt Decision, a landmark U.S. supreme court case between WA tribes and the state

(Breslow 2014a). Two other WB tribes did not gain co-management statutes under this decision. One has reservation land, while the other lacks even reservation status (WADFW 2015a; 2015b).(3) Regardless, all tribes have U&A. When U&A overlap, specific NRM locations are often part of political and collegial negotiations over rights and status.(3) At least one tribal restoration practitioner said they preferred to work on reservation land as opposed to the wider U&A; the work is easier as it does not involve additional partners and permitting.(1) Alternatively, tribes with small or no reservations must work off reservation land.(2)

Where nonprofit organizations work also varies. Some map onto one or more political jurisdictions, watersheds, or bio-regions.(8) Other nonprofits define themselves based on the geographic locations of their constituents.(2) The working boundary between some nonprofits can be fuzzy, such as a soft flexible boundary with a sister organization in a neighboring location.(1) Lastly, some coordinating organizations are based on watershed boundaries and seek to unite organizations within the watershed for planning.(7) Other coordinating groups operate along county boundaries(4) as do several citizen-based organizations.(4) In sum, organizations are bound to the landscape in varying ways, creating a complex pattern of scale mismatches.

While organizations fragment the landscape, they rarely work in isolation. Almost all participants said inter-organizational collaborations were fundamental for restoration work. Collaborations helped them access funding, draw on other organizations' strengths, and plan at a watershed level. Many participants said coordination was relatively strong within watersheds, but weak at the WB scale.(15) Some felt WB-wide coordination was unnecessary.(4) Others felt it would enable knowledge sharing, help leveraging funds, and pool money for large regional priority projects.(14) Several groups said restoration focused too much on salmon and was disconnected from other targets.[8] Comments like the following where not uncommon:

> These cities, towns, and counties are constantly competing for the same pots of money to do restoration. They sometimes do partner, but they are also competing, and so I think that sort of crates an atmosphere of contention in some ways, sort of [Puget] Sound wide as well as [locally around here].

Another participant said:

> We are all aware of what the priorities are, and we go to all these meetings and we try and coordinate, but in the end, what we need to do is have a more strategic discussion about what are the actual goals, are we meeting them, and what are we not meeting and who needs to do what. Because we each just go take these documents off on our own and decide to do things and try and get funding.

WB organizations from local to federal and government to non-profit are working hard to understand how best to collaborate and restore WB and wider Puget Sound. However, scale mismatches still exist and affect restoration.

4.4.2. How scale mismatches affect restoration projects

Informants provided several examples where scale mismatches directly affected project design or implementation. For example, one city informant discussed some collaborative projects between the city and county that fizzled because of different perceptions about the necessary permitting studies.[1] This informant also described a proposal for a collaborative project that could not be funded because the county was unwilling to sign on as an official sponsor, a requirement for the application. Floodplain restoration had become too politically sensitive in the county, so the county walked away.[1] In another city, a project was expanded onto county land, but only because a federal agency required it.[2] In this case, cross-border collaboration proved quite difficult:

> Any time it is a project in the county, the permitting is just really difficult and the reason is that they had to lay off permitting staff because of the economic downturn, which affects the projects. So it took several years to get amendments through … because they just have such a backlog of projects to look at. Whereas when it is in our jurisdiction, you can walk over and talk to the people and explain it better and say, hey, how's it going? And the managers can come talk to each other and say, well, we believe this is a priority, and bump it up. … You have very little sway over another jurisdiction. … Land use and zoning is different as well. … Our planners are advocates for restoration.

Another informant described the effects of scale mismatch as follows:

> We have a really good partnership with Sate Parks […], and we also have a team built in terms of getting permitting done and working with regulators and funders [and over there] are some restoration areas within the park, that we would be ideal project managers and applicants for but they are not in our county and so, jurisdictionally that is simply not something we can pursue, even though, to the fish, they don't see the political boundary and you wouldn't recognize it as a scientist. But unfortunately that's the reality. And even when we try to work across county boundaries, well I have learned in the last five years, we just don't really live together, we don't have meetings together, and even if we meet and try and have it on the agenda, we work for different elected officials.

Scale mismatch can create challenges at the project level, but it is possible to overcome them. Informants in two different cities described how their jurisdictions provided site opportunities for tribes, non-profits, conservation districts, and public utilities (though not between cities and counties), to do restoration work.(2) In these cases, inter-organizational collaborations were necessary because the cities lacked funds to do restoration.

In addition to jurisdictional borders, the boundaries of private land also affect restoration and were frequently cited as a major restoration challenge.(14) For example, a county parks' project had to be limited in size because of neighboring private land. According to the department head, if they "owned more of the land … the project could be much larger in scale and be more effective." However, the parks department only works on lands they own.[1]

Sticking to public land may not be enough to prevent private land conflicts because hydrology has its own boundaries. One coastal wetland restoration project led to unintentional flooding of neighboring farmland, becoming a liability issue for the restoration project sponsors. This event raised concerns about property damage liability throughout the restoration community, adding another layer of complications to large-scale restoration projects.[6]

Of course, restoration does happen on private land, but not without challenges. One participant described a large floodplain restoration project where a farmer owns much of the land in question. According to this participant, the farmer has a "strong sense of place." He wanted to see the property restored to floodplain when he retired, provided he could retain a small section to farm. The project team originally sought to relocate a section of dike to preserve some farmland. They soon realized, however, that they would have to spend millions of dollars on a pumping station to pump water out of a creek at high tide. According to the participant:

> It would have killed the project … It would have required maintenance and monitoring forever. And that goes against the grain of restoration planning, which is you undo, you know, you don't end up with a contrived hydrologic system that requires money and time to maintain.

So the team negotiated with the farmer and agreed to fill in a small area of floodplain for him to farm. What made this project work? "It is all people, relationships, listening to people," said the participant. "It's developing trusts. It is all of these intangibles that go into successful restoration planning."

Working with private land sometimes necessitates creative solutions. In this case, filling a small part of floodplain to create a larger self-sustaining project met the needs of the restoration community and property owner. While this project is going ahead, governance fragmentation, either by jurisdiction or ownership, can affect if, where, and how restoration projects are done.

4.4.3. How issues of scale affect landscape level planning and implementation

Scale mismatches not only affect individual projects, but also how restoration is planned and carried out across the landscape. Some examples might be considered classic politics of scale where local and larger organizations have different goals as in the case of state and federal agencies,(1) cities and counties,(4) a port district and surrounding county,(1) and local diking districts and wider restoration community.(1) Several participants commented that the Puget Sound Partnership, the state agency tasked with coordinating Puget Sound recovery, was too top-down and did not help them carry out projects locally, but acknowledged that it helped them identify state and federal funding.(7) More germane to restoration outcomes, several informants working at local levels discussed how their priorities did not match state priorities, which prevented them from access funds. However, they sometimes deviated from local priorities(3), pursuing the funder's priorities instead, illustrating how cross-scaler interactions influence what happens at the local level.

While higher level organizations may influence lower level organizations, the reverse is also true. Larger entities often navigate or operate though spatially nested local jurisdictions because of collaborative program designs. Informants from six of the 13 different state organizations interviewed discussed how they work directly through local level groups and that local politics and funding affected their ability to contribute to on the ground restoration work.(8) As one state participant working on water quality said:

> We all work as a team ..., our two state programs and local … programs. … The players behind those [local] boundaries, ..., their policies do, I think, lead to variation in how management plans are designed and

> implemented. The management plans are approved by the local [groups] …. That group of people, depending on their interest in working with these programs, does play a factor in how they all play out.

This vertical interplay can be quite nuanced though. Three other state level participants said that they worked with local watershed groups that appreciated different levels of state involvement.(3) Each noted that local groups sometimes avoided conflict with each other as they live and work together. Accordingly, local groups appreciated when state staff provided a critical voice on certain projects. While I was unable to corroborate this dynamic with local groups, the fact that all three state participants observed it is noteworthy.

In addition to working through local organizations, five other participants from three state programs commented that local borders added complexity to restoration work, but that it was just part of the job.(5) One participant put it this way:

> Those [political] boundaries are just an obstacle to sound watershed management. … Because I have to deal with two counties and a whole bunch of different cities that dot the way. … I mean you could get all academic about it, and discuss it, but really it gets down to people, the difficulty of getting people to sit at the table and think about what is good for the watershed and not think about just protecting their little piece of the watershed.

Taken together, what these examples show is that even if organizations span all of WB, they still may be affected by scale mismatch through vertical governance and scalar interactions.

4.4.4. How issues of scale and subsidies affect landscape level planning and implementation

Scaler interactions also create spatial subsidies that affect how and where restoration is done. Participants discussed several examples in which state wide resources are pushed and pulled to certain regions of WB. State and federal programs often require local partners to provide a funding match for restoration work.[3] This can make it harder for less wealthy local groups to access services and resources. While some government funds are allocated uniformly to all relevant local regions,[2] others may be distributed on a competitive basis. Not all local organizations have the staff and resources to compete successfully, illustrating the link between functional and spatial scale mismatch. One state level participant discussed this problem for water quality restoration funding:

> We do try to steer some financial resources to local governments, but it doesn't come automatically .... So, to some extent, a local jurisdiction has to take it upon themselves to find the resources to get the actions done. But we do encourage them to apply for [our annual grants]. But they are competitive, so it can be hard for a small municipality .... We have meetings to educate them on the process. But it is a competitive grant process, so their application has to be well written and address the elements we ask for.

Local groups also acknowledged this challenge. "Everyone goes to [WA State Department of] Ecology every year for grants," said one participant from a county based conservation district. "There is a lot of work that goes into planning [for grants] and putting the application together." This participant said their organization was limited by staff and time. They were concerned about being able to compete for grants as more steps were being added to the application process. Similarly, a natural resource manager at the county said, "what we consider to be unfair or unjust is that we are pretty small as far as a county goes, so when we have to [compete with larger counties] we almost always lose." "Small" here refers to a small population and small revenue base. Like the conservation district, this organization does not have the staff or resources to compete for grants. Certain local groups are better able to attract resources, and restoration will be done in those locations.

Interview participants often spoke of resource allocation in terms of fairness as in the above case. Some felt that restoration funds should be somewhat equally distributed across the region and among organizations, while others believed some regions deserved more funding based on ecological criteria, or that organizations capable of doing the biggest projects should get more funds.(5) This analysis does not present a comprehensive treatment of what is ethical, but such issues affect restoration patterns across the landscape.

Resource allocation likely impacts the sum total capacity for restoration work in a landscape, an idea clearly articulated by one state level participant:

> There's pressure to keep [all the organizations] working. So, even if [a location] was your priority and you wanted to take the whole thing [i.e., use all available state funds], you'd lose an implementation team [in other areas] if you directed all the money to one project.

Another participant from the same organization expressed the same concern:

> We have created a salmon market where a lot of these non-profits, their organizations, need continual grant money, not just from us, but from other funding sources, to stay afloat and keep them implementing projects. So, if you dedicated [all the state program money in one year] to one huge project ..., it would really hamper future restoration; you couldn't do that, the capacity would get killed [i.e., people and organizations available to do restoration]. Even if you did it one year, let alone tried it two or three years in a row.

In addition to affecting general restoration capacity, there can be a spatial tradeoff in resource flow from regional to local groups. Only in these cases, the flow is human as opposed to financial capital. Regionally focused agencies (e.g., state and federal) often divide work among their staff by watersheds or counties. Individuals are often responsible for more than one watershed or county. Several participants described how their obligations in one location sometimes prevented them from working in another location.(4) One participant, who covers two counties, one inside and one outside of WB, said:

> I think there is a lot going on, but gosh, it is a bit scattered at the moment …. And we are all so busy. And so one thing takes us in one direction; we are going in that direction and forgetting about this other stuff that we are working on because it is sort of being handled.

When asked if they had been pulled off of projects in WB recently, this participant replied: "Oh yeah, definitely; I have not been working on the Whidbey restoration stuff lately." This push and pull of human capital is not limited to federal and state organizations. One tribal natural resource manager with a large U&A felt "spread fairly thin" and said:

> It is not knowing what to do. It's the funding and time to coordinate with other partners. I've got four or five no brainers that I would like to do to fix the nearshore, but …, I have to pass on things that I know are good because we don't [have the capacity].

This participant later described a specific project, saying, "I missed out with a whole summer of cooperating and collaborating with these guys because we don't have the manpower to do it."

This tribal example differs slightly from the previous one. In this case, there is no one specific local jurisdiction gaining the regional practitioner's focus at the cost of another jurisdiction. Rather, responsibility for a large geographic space can pull people away from specific projects and specific collaborations with adjoining jurisdictions. A participant from one such jurisdiction commented on this saying:

> I feel that [our jurisdiction and the tax payers] are making a major contribution to [something], which is primarily a tribal interest. … I know their … manager has [their] hands full; [their manager is] very busy. [They've] got a huge U-and-A area that [they're] responsible for …. At the same time, I feel like [the tribe has] not adequately provided the resources

> to enable their active involvement in our [recovery and protection] program. ... I think that creates kind of a legitimacy issue for [what we are doing].

This participant clearly recognizes and respects that their colleague has a large area to manage. Still, spatial subsidies, or the flow of human capital from one place to another, can lead to missed opportunities and undermine collaborative cross-border approaches to NRM.

Working in a large geographic region can stretch some practitioners thin. However, it also facilitates knowledge transfer from one location to another, as discussed by two participants.(2) Therefore, scale mismatches lead to both positive and negative spatial subsidies.

4.4.5. How issues of position and subsidies affect landscape level planning and implementation

The distribution of restoration activities are also influenced by location and spatial subsidies. Several participants described the effects of classic up and downstream dynamics. One drainage and diking district that incurs substantial storm water discharge from upstream county land receives restoration funds from the county through a formal agreement to address water quality and flow problems.(1) In another county, a flood control district is in a similar situation; however, it lacks a funding agreement, but feels it should have one.(1) The county cannot allocate funds to this district because it falls outside the service area from where the county collects water quality improvement fees.(2) While the county is trying to remedy this situation by applying for grants to assist the district,(1) scale mismatches create problems of location and spatial subsidies (water and funding) that affect restoration capacity.

Inter-local agreements may allow groups to spend money outside their jurisdiction, but more often than not, money does not transcend borders.(4) According to one county staff:

> We don't typically go beyond the juridical boundaries to partner with other forms of government. All grants require the assignment of a contract and a fiduciary agent. So, counties aren't set up to share money very well. Counties and cities are probably more adept at doing that, especially when they reside in … the same county. But, absolutely, what we invest in is affected by those boundaries.

While politically sensible, the hurdles to spending money across jurisdictional borders may represent a lost opportunity for a spatial subsidy. Previous examples show that different cities and counties have different capacities to do restoration work. Allowing funds to follow a species like salmon, which uses fluvial and marine habitats that span jurisdictional borders, could change restoration patterns resulting from scale mismatches. Restoration in a neighboring jurisdiction would still benefit the efforts of the other jurisdiction because a degraded river up or downstream may harm fish as they migrate, negating the original restoration efforts.

4.4.6. How issues of place and subsidies affect landscape level planning and implementation

Place specific attributes also orchestrate restoration patterns in WB. One state level participant commented that urban areas have a lot of "political power … in Olympia," the State's capital. This participant discussed how urban restoration work was expensive; you could restore more habitat per dollar in rural areas. Additionally, restoration success in the urban environment may be limited for a species like salmon, due to wider land use/cover alterations, an assessment confirmed by local ecologists who have eloquently said: "Restoration in urban estuaries such as the Duwamish [in urban Seattle] may need to address a somewhat higher order: If you build it, will [salmon] come and not suffer for it?" (Simenstad et al. 2005: 19). However, according to the aforementioned participant, and confirmed by a second participant at the same organization, it was important to continue restoration work in urban areas because it helps garner legislative support for restoration statewide, due to urbanites' political influence.(2)

At a smaller geographic scale, however, the asymmetric power relations between urban and rural areas may hamper local restoration efforts. For example, the rural Snoqualmie watershed in southern WB covers about 40% of King County, but only receives 20% of county restoration funds.(2) The other 80% go towards two urban watersheds that drain the remaining 60% of the county and are not part of WB.(2) Participants working in the Snoqualmie watershed,(2) plus a resource manager from one of the urban watersheds in question (personal communication), confirmed that the urban areas felt entitled to more money because they contribute more taxes. As discussed by one participant, this politics of place has significant implications for landscape scale restoration and human wellbeing:

> The [County] Council members don't always behave as if they understand this is one county, and that the natural resources we have, which in some ways are more ample out in the rural areas, [are] owned and shared and are the responsibility of all of us. Instead, they talk about how … most of the taxes are paid in Seattle, so shouldn't most of the money be spent over [there]? And, you know, that's true for some things; it's not true when you're talking about natural resources. … And what's kind of ironic is in the State of Washington, we have what's called the Growth Management Act and … one of the goals of that was to preserve rural areas and natural resources and to concentrate growth in urban areas. Makes sense. And the result is we have this amazing beautiful rural area 20 minutes away [with recreation opportunities, salmon bearing rivers, and working farms]. But, … is the growth management model sustainable if we're not willing to sort of, you know, pay for it in a sense? … I think it is only effective if we are all willing to kind of carry the weight of funding that reality.

The concern is that small cities and towns in the rural Snoqualmie watershed lack the financial and human resources to undertake major restoration activities. "They don't have the tax base to pay for that stuff," said the participant. And while independent local jurisdictions, their development activities are partly subject to collective decision making by elected officials in the County Council.

> These small cities that we have out in the valley, they don't just get to grow. The county Council has to approve it. … And it is not just about the county council, but the [urban] cities [around Seattle] have a tremendous influence on the Council. … The whole urban area's political machine can really kind of run the county.

This example illustrates the layered reality of scale mismatch. Activities in WB are influenced by county level institutional arrangements that extend beyond WB's geographic boundaries. While separate hydrologic regions, urban and rural King County are connected politically and jurisdictionally. Therefore, the participant asks a valid question: if rural areas provide subsidies to urbanites in the form of recreation and other services, should funds flow in the opposite direction to support these services? Thus, natural resource managers(2) and elected officials working in the Snoqualmie Watershed (personal observations and communications) have argued for a more equal allocation of King County funds among the three King County watersheds.

Place specific attributes can also affect where organizations work. For example, one state program that unites job training and restoration had been working intermittently in Island County for years, but only recently started a fulltime program in the County. However, as a fee for service program, they are hiring young people from neighboring urban counties with higher tax revenues because Island County, according to the participant, cannot support their program.

> We're based, normally, in population areas, to hire. So, … we tend to go, I hate to sound like this, we go where the money is because that's what pays for our program and that's where we can hire people. … Even the work we are doing now in Island County, we bring crews form King County and Pierce County into Island County on a daily bases to do the work because there is not a big enough population base to hire out of [in Island County].

However, bringing in people from outside as opposed to hiring locally may be a missed opportunity. According to one local Whidbey Island participant, "restoration seems to be severely disconnected with the need to have a sustainable community." This participant, who is part of the development community, cited "a 12% unemployment among the people between 20 to 30 years old on [Whidbey] Island." While a different structure than fee for service would be needed, a local restoration program that hired young people might be welcome. It might also enhance local capacity for restoration.

Compared to other counties in WB, Island County has fewer resources and professionals, a sentiment confirmed by several participants both in and outside the County.(7) One local participant said:

> People look to us to do a lot, and they think that we are doing a lot. And the reality is that we don't do nearly what people think we … do. … There is so little money or effort or people, just raw people on the ground doing stuff on the Island. … It's not like we are making ourselves look big; there's nobody else.

To overcome capacity problems, this participant said they build geographically and politically strategic partnerships:

> Partnerships are essential to everything we do. … Particularly out here on Whidbey Island [because] we don't have Tribal headquarters; we don't have any large restoration outfits. It's really vital for us to bring larger outfits out here to help do a lot of stuff.

According to this participant, these larger organizations had teams of biologists and grant writers and access to technologies like GIS. Important partners included those who were “playing in the larger restoration community,” and knew what was going on Puget Sound-wide. Larger groups often understood what “the funders [were] interested in [more so] than people … working on a very localized level.”

By collaborating with these larger groups from more populated areas and knowledge centers, this participant has established subsidies of knowledge, skills, and funding. This participant did caution about some negative experiences where “[groups] sort of collaborate[d], but not a complete collaboration.” This participant could “think of a half dozen of examples where a Tribe or an NGO came out, did a restoration project, or participated in part of one, and didn’t collaborate with local groups.” However, they considered their recent collaborations to be genuine and positive.

4.5. Discussion

The WB case study shows how scale mismatch patterns affect individual restoration projects and landscape levels planning and implementation. These cases help explain observed patterns whereby restoration project locations sometimes map on to jurisdictional borders better than ecological priorities (Palmer 2009).

At the project level, both jurisdictional and private land borders affect how and where restoration is done. In jurisdictional cases, projects were hampered or altered by permitting, political sensitivity about restoration activities, and a culture of working within jurisdictions. Private land presents further challenges, including dealing with land owners’ sense of place, liability, and project size restrictions. Some people might find creative solutions to work on private land, such as filling in a small section of wetland to gain permission to restore a larger section, troubling. They may be concerned about spending limited funds on anything but habitat creation. However, such solutions highlight that restoration is a coupled social-ecological activity requiring coupled social-ecological solutions. While interdisciplinary collaborations are needed, previous analysis of 522 researchers working on Puget Sound nearshore recovery found lower than expected collaborations among natural and social scientists (Hoelting et al. 2014). Focusing on scale mismatch problems, however, could provide a bridging concept to promote interdisciplinary collaborations because scale mismatches inherently involve both social and ecological processes. To do so, regional planning authorities might sponsor participatory research processes for overcoming scale mismatch challenges.

At the landscape level, the WB case shows how scale mismatches unfold in a multi-level governance setting. Figure 4.3 and Table 4.4 summarize the main landscape level processes and outcomes associated with scale mismatch. Germane to this picture, is the flow and distribution of financial and human resources. While a certain amount of resource allocation is undoubtedly linked to detailed ecological restoration planning in WB and wider Puget Sound (PSP 2014), this study clearly illustrates that scale mismatches also affect resource distribution. Future restoration planning should consider scale mismatches as part of a holistic social-ecological perspective on landscape restoration that seeks to minimize negative spatial subsidies and maximize positive ones.

Many of the WB examples illustrate the strong link between spatial and functional mismatch. Limited staff, time, and expertise hampered both cross-border collaborations and affected resource allocation. Adding staff could help alleviate problems with functional capacity. However, additional staff or organizations may also increase transaction costs in scale mismatch bridging networks (Bodin and Crona 2009; Ernstson et al. 2010). Further research on how to improve scale mismatch bridging should be a fundamental part of restoration planning research. While knowledge networks among scientist has been identified as a local priority in Puget Sound (Hoelting et al. 2014), scale mismatch bridging networks are not considered in local social and social-ecological science planning documents (PSP Science Panel 2014; PSP Social

Science Advisory Committee 2011; Wellman et al. 2014). Failure to consider scale mismatches is concerning as they clearly impact landscape restoration.

Conceptualizing landscape restoration as a social-ecological process extends the goals of restoration beyond ecological outcomes to human wellbeing, job creation, and environmental education (Higgs 2003; Kittinger et al. 2013; Suding 2011). Indeed, job creation was addressed by several WB interview participants. A social-ecological focus raises questions about where to do restoration. While maximizing ecological gain for a given restoration target may makes sense at times, lower ecological priorities may also make sense if they yield desired social benefits. A focus on scale mismatch highlights these tradeoffs by revealing spatial subsidies of resources that impact human wellbeing as in the case of employment.

Urban – rural subsidies are particularly interesting in the WB case. While restoration in urban settings is costly and often produces fewer ecological gains (Simenstad et al. 2005), urban work may help garner political support for restoration state wide as discussed by several participants. Thus, what happens outside of WB affects what goes on in WB and perhaps alters how costs and returns on restoration investments should be calculated. There may be situations where the cost of urban restoration is offset by heightened political support for restoration in other locations, a form of spatial subsidy. Such a social-ecological perspective, gives pause to the notion that some places are too far gone to restore (Hobbs and Cramer 2008). Rather, we need to ask questions not about specific places, but how financial and social capital flow among interlinked biophysical and jurisdictional units. A detailed analysis of tradeoffs between local costs and system wide political support would be a logical extension of the dynamics I have documented. It would also help answer questions about cross-scale tradeoffs in complex system (Anderies and Janssen 2011).

Taken as a whole, the WB case shows how scale mismatches affect restoration at the project and landscape level. Nevertheless, several limitations to this study are worth noting. Not all instances of scale mismatch should be seen as implicit problems. WB stakeholders have done substantial ecological restoration planning (PSP 2014) and I have not attempted to directly compare outcomes of these plans against the scale mismatch challenges I documented. Still, scale mismatches do affect restoration and must become part of regional conversations and planning efforts. Additionally, the above examples tend to document interactions among only a small number of organizations, often two or three. Future work should strive for a full understanding of how all organizations interact and how action by one organization feeds through any number of linkages to other organizations. How does the sum total of scale mismatches and associated spatial subsidies affect landscape restoration? The research presented here is a first step towards understanding such patterns and processes.

4.6. Conclusion

Scale mismatches are frequently cited as a major challenge for estuary and other forms of large-scale restoration. Few, if any, empirical studies address the complex forms that scale mismatches take and their immediate impacts as viewed from the practitioners in question. This study demonstrates how different scale mismatches arrangements, related to scalar level, spatial position, and place-based attributes, affect individual restoration projects and landscape level planning and implementation. These spatial arrangements lead to spatial subsidies that affect resource distribution, local and regional capacities, and scale mismatch bridging collaborations. Only by understanding these patterns and processes, can we approach landscape restoration as a social-ecological undertaking that can help create sustainable landscapes and communities.

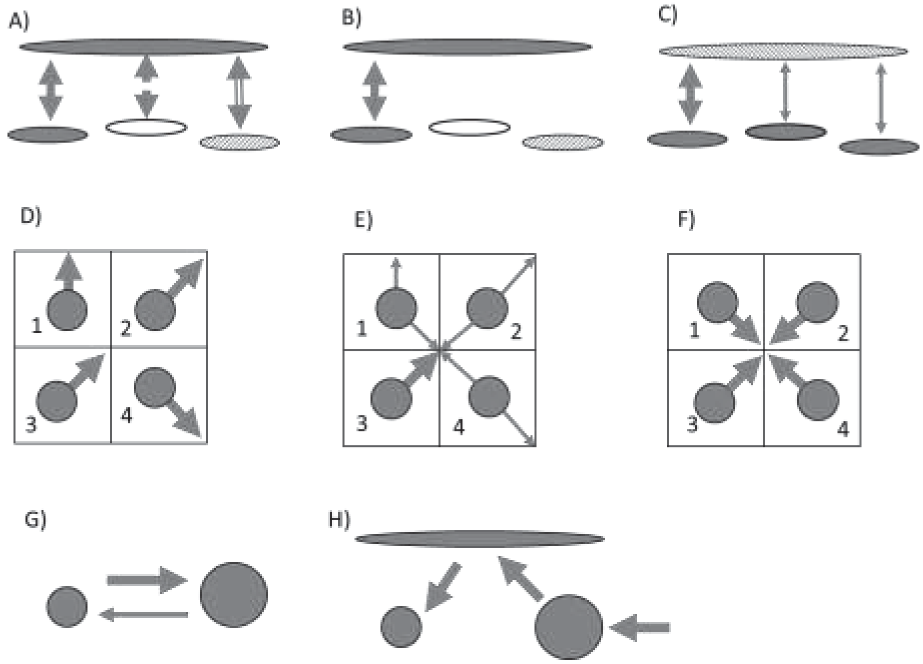

Figure 4.3. Schematic diagrams depicting some of the major scale mismatch dynamics in WB. Large and small ovals represent regional and local organizations respectively. Circles indicate organization independent of their spatial or jurisdictional extent. Different circle sizes (G and H only) indicate political power (large = more). Arrows indicate flows, or spatial subsidies, of financial, social, or natural resources. Arrow thickness indicates relative amount (i.e., more or less). Arrow fill indicates a change in quality of flow. A) In collaborative governance settings, local politics or capacities can alter if, how, and where regional efforts translate into on the ground actions. B) Local groups may have different capacities to access regional resources (i.e., interplay between spatial and functional mismatch). This has possible environmental justice implications if, for example, wealthy groups are better able to compete for grants. C) In collaborative governance settings, regional organizations may be pulled to work with one local partner at the cost of working with others. D) Organizations may have limited capacity to work in all locations of their jurisdiction (or "home range" in the case of nonprofits). In Figure D, only organization three is working on the cross border issue, which may lead to collective actions problems or concerns of legitimacy where three feels they are addressing a common problem without help from partners. E) Organizations one, two, and four help three by spreading efforts over multiple locations in their jurisdiction. This could hypothetically create a situation where outcomes are sub-optimal in all locations because efforts are stretched thin. F) Alternatively, all organizations could address the cross border issue at the costs of addressing issues elsewhere. G) Rural areas feel they provide ecosystem services for urban areas, while urban areas feel less restoration funding should go to rural areas because fewer taxes are generated there. Study participants questions if this was ethical or sustainable. H) However, because urban areas are politically powerful, urban restoration (right-hand most arrow), which often has lower ecological returns for financial cost, may garner support for state wide restoration at the legislative level.

Table 4.4. Summary of major scale mismatch drivers and effects presented in results

How scale mismatches affect restoration projects

- Challenges associated with jurisdictional borders include permitting, political sensitivity in different jurisdictions, a culture of not working together, and working for different elected officials.
- Challenges associated with private land borders include sense of place, liability (flooding), and restriction of project size.

How issues of scale affect landscape level planning and implementation

- Groups working at different spatial extents had different values/foci which can influence who can apply for funds. Or, to access funds local groups may change their restoration foci.
- Local politics also affect how some regionally focused actors, like the state, translate their efforts to on the ground work. Thus, even if boundaries span all of WB, they still might be affected by scale mismatches.

How issues scale and subsidies affect landscape level planning and implementation

- Push and pull of state wide resources to certain areas. 1) Certain local groups are better able to compete for regional funds illustrating interplay between scale and functional mismatches. 2) Questions arose about what constitutes equitable distribution of funding. The restoration system had resulted in a restoration market. Spatial allocation of funds may affect the long term viability of some organizations and hence restoration capacity in different regions of the landscape.
- Regional capacities impact where state resources go to at a local level. 1) Staff may get pushed and pulled to different regions within their geographic scope of work. 2) Not being able to collaborate can raise concerns of legitimacy. 3) Regional entities working in multiple locations allows for knowledge transfer.

How issues of position and subsidies affect landscape level planning and implementation

- Downstream entities may be burdened by upstream lands uses. Financial agreements to alleviate burden reached in one case, but not in another due to service fee restrictions. In the latter case, the upstream jurisdiction working in good faith to get grants to support the downstream jurisdiction.
- Spending money outside jurisdictional borders is challenging and is potentially a lost opportunity for a spatial subsidy.

How issues of place and subsidies affect landscape level planning and implementation

- Because urban areas are politically powerful, urban restoration, which often has lower ecological returns for financial cost, can garner support for state wide restoration at legislative level.
- County overlaps rural WB and urban areas outside of WB. Urban areas generate more taxes and use political power so that less county money is spent in WB than in urban areas. However, WB provides ecosystem services to urban area. Leads to questions of equity and sustainability.
- Need for job creation linked to restoration in rural areas. Rural areas have less capacity (personnel, technical expertise, and political connections) to do restoration. Partnerships with larger organizations based elsewhere can help. However, there are concerns about groups coming into rural area and taking over and not truly collaborating with local groups.

Chapter 5. Conclusion

Scale mismatch is an enduring human-environment problem, one that John Wesley Powell warned Congress about more than a century ago (DeBuys 2001) and one on which academic and applied communities continue to grapple. In an excellent review, Moss (2012) traces early academic treatments of scale mismatch back to policy research in the 1960s and how this was reflected in Ostrom's (1990) pioneering work on common pool resource management. Scale mismatch continued to be a major research theme of the International Human Dimensions Program on Global Environmental Change (IHDP) during the 1990s and 2000s (Folke et al. 2007; Young 2008) and has been the subject (or at least significant focus) of several recent special journal features (Cash et al. 2006; Farrell and Thiel 2013; Moss 2014; Moss and Newig 2010).

Recent work has dispelled simplistic notions of an optimal alignment between social and ecological units. Governance arrangements invariably face tradeoffs because different ecological processes operate at different spatial extents, interact across scalar levels, and change over time (Cash et al. 2006; Galaz et al. 2008). Additionally, governance framed solely on natural resource systems may not align with important social or cultural landscape dimensions (Mitchell 2005; Moss 2012). For these reasons, governance networks are seen as a desirable way to overcome scale mismatch. By developing the right kinds of networks, stakeholders can work across scale mismatches and adapt to coupled human-environment changes (Bodin et al. 2011; Ernstson et al. 2010). My findings contribute to this evolving scholarly corpus.

Chapter Two analyzed the alignment between governance collaborations and ecological patterns for an assessment of scale mismatch bridging strength. It also spatially compared potentially weak networks and ecological restoration needs to identify coupled social-ecological restoration concerns. Chapter Two identifies several weak areas in the scale mismatch bridging network based on density, centralization, and participants' perceptions of productivity. In general, local to local collaborations (as defined by geographic extent, not jurisdiction) occurred less than expected, while local to regional and regional to regional occur more than expected. This illustrates that regional organizations play a large role in scale mismatch bridging by uniting local and other regional organizations together.

Overall, network density was negatively correlated with perceived network productivity, which does not support the contention of complex systems theory that networks perform best at intermediate densities (Bodin and Crona 2009; Janssen et al. 2006). Rather than challenge this theory, one possible explanation for the observed relationships is that many groups are stretched thin, as discussed in Chapters Three and Four, making collaborations with many organizations difficult. In such cases, restoration organization would benefit from additional staff and resources, recommendations supported by findings in Chapters Three and Four. Centralization was also negatively correlated with productivity, which supports theories for decentralized governance (Bodin and Crona 2009; Ernstson et al. 2008; Ostrom 1990; 2010). Lastly, several areas with governance and ecological problem were identified and designated social-ecological restoration hotspots. These stand in contrast to social-ecological low hanging fruit, which are areas in need of restoration and that have productive scale mismatch bridging networks. To improve ecological conditions in social-ecological hotspots, investments must be made in both social and ecological capital. Identifying hotspots and low hanging fruit can help practitioners think about how to allocate resources.

Chapter Three analyzed jurisdictional and sectoral network integration and provided specific examples showing how social network diagnostics can aid NRG. Results show that the WB network is fairly well integrated, but several sectors did not collaborate at all (e.g., between businesses and cities/towns and between educational and state organizations). Cities and towns provided a specific proof of concept that demonstrated how network interventions might enhance restoration capacity. Chapter Three provides empirical evidence about why different types of organizations collaborate and the importance of disentangling the broad notion of “network collaboration” to consider the actual types of collaboration. Indeed, mandated relationships often had lower productivity (based on practitioners’ self-assessments) than funded and shared interest collaborations. While we cannot infer causality, this highlights the potential benefits of true collaborations in collaborative watershed governance. Lastly, the quantitative and qualitative data comparisons highlight the need to incorporate geographic space and the role of individual actors versus organizational culture into SNA for NRG studies.

Chapter Four took a narrative approach to analyze how scale mismatch patterns affect individual restoration projects and landscape levels planning and implementation. At the project level, scale mismatches affected where and how restoration project were done. Specific drivers included permitting, political sensitivity about restoration activities, a culture of working within jurisdictions, land owners’ sense of place, liability, and available property size. At the landscape level, results illustrate how scale mismatch patterns affect the distribution of financial and social capital, which in turn influence the capacity to do restoration in one location as compared to another. Results show strong links between spatial and functional mismatch as constraints on staff, time, and expertise hampered cross border collaborations and affected resource allocation. Several examples in Chapter Four, as well as in Chapter Three, also showed how trust and personal relationships where vital to overcoming scale mismatch problems. The case study examples raise important questions about calculating costs and returns on restoration investments. For example, there may be situations where the cost of urban restoration is offset by heightened political support for restoration in other locations, a form of spatial subsidy. Such a social-ecological perspective gives pause to the notion that some places are too far gone to restore (Hobbs and Cramer 2008). Rather, than ask question about specific places, restoration planning should ask how financial and social capital flow among interlinked biophysical and jurisdictional units in a landscape.

Together, the research in these chapters provides strong evidence and arguments for why socio-political structures and processes should be included in landscape restoration planning in the same way that ecological structures and processes are. The restoration and conservation sciences have long focused on systematic analysis of bio-physical conditions to inform action. Much less frequently included, if at all, is comparable treatments of socio-political and human-environment structures and processes. Indeed, Curran et al. (2012) claim to publish "the first spatial restoration prioritization incorporating human and social factors defining the effective implementation of restoration activities." This dissertation goes beyond thinking about social factors as elements to define successful restoration, a notion common in the ecological sciences, which often conceptualizes humans as constraints to environmental management. (However, several groups within the ecological sciences are working on this issue, among them urban (Collins et al. 2011; Pickett et al. 2011) and landscape (Wu 2006; 2013) ecologies.) This dissertation considers socio-political and human-environment processes as part of the very landscape fabric that is being restored. Of course, at times it does make sense to approach a socio-political or governance problem as a constraint, if for example, all other factors are equal and funds are limited. The social-ecological low-hanging fruit identified in Chapter Two support such decision making. At other times, however, important ecosystem recovery may require building social capital, or enhancing governance networks as demonstrated throughout this dissertation. Restoration, and NRM in general, deal with human-environment problems that necessitates human-environment solutions.

The diagnostics presented in this dissertation should not be confused with technocratic solutions. If the human-environment sciences, especially that devoted to governance and institutions, have taught us anything, it is that there are no panaceas (Ostrom 2007). Thus, while Chapters Two and Three provided systematic analyses of scale-mismatch bridging and governance network integration, they should be treated as coarse grained diagnostics that can inform more local study and intervention. Such a treatment is analogous to biophysical landscape restoration planning (Diefenderfer et al. 2009; Stanley et al. 2012; Thom et al. 2011; Wilhere et al. 2013).

Chapters Two and Four treat scale mismatch as a complex pattern of organizations that operate at different spatial extents and in different locations within a landscape. This advances how scale mismatch is approached in multi-level governance settings (Folke et al. 2007). As demonstrated in Chapter Four, organizations that span the entirety of a region, even if they map onto it perfectly, may still experience scale mismatches through collaborative governance arrangements with organizations operating at smaller or larger extents. The complex social-ecological patterns created by scale mismatch push and pull financial and human resources to various locations, sometimes at the costs of other locations. Chapter Four provides a unique perspective about how scale mismatches produce spatial subsidies, which can affect restoration capacity across the landscape. Whether through quantitative or qualitative methods, documenting and mapping such processes may help regional practitioners enhance positive NRG interactions and reduce negative ones.

Chapter Four also begins to unpack how spatial overlaps among groups affect restoration both positively and negatively. Several research questions remain, however. For example, future research might try to understand how the density of individuals and organizations in a specific place, or the degree of overlap among groups affects restoration outcomes. Chapter Four documented several unique challenges for practitioners on Whidbey Island, which is somewhat remote from the mainland. Extending form these funding, future research might also try to understand how physical distance and environmental context amplify or dampen scale mismatch effects or scale mismatch bridging. Lastly, as discussed in chapter Four, interactions were often analyzed among only two or three organizations. Future work should strive for a full understanding of how all organizations interact and how action by one organization feeds through any number of linkages to other organizations. How does the sum total of scale mismatches and associated spatial subsidies affect landscape restoration?

Beyond contributing to the restoration and conservation sciences, this dissertation is in tune with contemporary concerns for solutions oriented research (Defries et al. 2012; Kates et al. 2001; Lubchenco 1998; Moss et al. 2013). While drawing from several disciplinary traditions, geography's human-environment legacy is central to my treatment of scale mismatch and landscape restoration. Geography has, at times, not fully aligned itself with the sustainability umbrella (Turner 2002; 2010). Yet, the solutions blood runs deep within some veins of the discipline. Over 40 years ago, Gilbert White (1972:103) cautioned:

> Let it not be said that geographers have become so habituated to talking about the world that they are reluctant to make themselves a vital instrument for changing the world. This position will no longer do for research, [or] teaching ... . It can survive only at the peril of the society which permits its comfortable and encapsulated existence.

Understanding and addressing scale mismatches to support estuary restoration is fundamental for sustainability: for ensuring that current and future generations can meet their needs without damaging earth system functions. “We restore by gesturing to the past, but our interest is [to create] the draft pattern for the future” (Higgs 2003:270). I hope this dissertation can be an instrument for changing the world and drafting that future.

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APPENDIX A

SUPPLEMENTARY INFORMATION FOR CHAPTER TWO

A.1. Data and code structure for expanding analysis to *N* ecological nodes

Our framework is based on a social-ecological network adjacency matrix (main text, Fig. 2.2) depicting which social nodes are connected (SS edges), what ecological nodes they work in (SE edge), and what ecological nodes are linked though ecological processes (EE edges). The analysis iterates though the entire social-ecological network and assigns social nodes a social-ecological membership index (MBI) based on the EE and SE edges. MBI is calculated by taking the Boolean SE edge of two connected ecological nodes and adding the SE edge value for ecological node 1 (e1), ecological node 2 (e2), and then e2 again. Since the edge values are Boolean, this produces MBIs of 1, 2, and 3 for each social node associated with e1, e2, and both, respectively (i.e., local1, local2, and regional in the main text).

We then extract the social component of the network for each ecological node pair and block model the data using the MBI. Block modeling sorts and groups network nodes into specific roles based on block membership criteria, i.e., the MBI. We use these sorted groups, or blocks (Table A.1), to calculate density, degree centralization, and productivity ratio index. (PRI uses valued data in the SS part of the social-ecological adjacency matrix). As noted in the main text, the diagonal blocks in the model (i.e., blocks (1,1), (2,2), and (3,3)) are regular graphs and all others are bipartite. Local-local metrics are derived from block (1,2) or (2,1) if the data are undirected and from both if the data are directed. Local-regional metrics are derived from blocks (3,1) and (3,2), or (1,3) and (2,3) if undirected and all if directed. Regional-regional metrics are derived from block (3,3). Total scale mismatch bridging (SMB) is derived from the total combination of the aforementioned blocks. Lastly, while not the focus of our analysis, metrics for SS edges within e1 or e2 can be derived from blocks (1,1) and (2,2) respectively. Thus, all multi-level governance edge types can be understood from the block model.

Table A.1. Illustration of a block model. Blocks are ordered based on the MBI index. The numbers in each block illustrate how to reference a block. The block summarizing SS edges from e1 to e1 (SS edges between nodes that only have an SE edge to e1) is referenced as "block (1,1)." The block summarizing SS edges from e1 to e2 is referenced as "block (1,2)." Note that for a symmetrical graph (where ij = ji), block (1,2) = block (2,1).

Ecol node		e1	e2	e1&2
	MBI	1	2	3
e1	1	(1,1)	(1,2)	(1,3)
e2	2	(2,1)	(2,2)	(2,3)
e1&2	3	(3,1)	(3,2)	(3,3)

Table A.2 depicts an example of the MBI calculation and block model using a simple 8 x 8 social-ecological multi-scale governance network. Nodes "a" through "f" are social nodes; "y" and "z" are ecological nodes. Note that all EE edges are recoded to 0. This is strictly for computational purposes as explained below. Because the number of nodes in table A.2 are small, and because the data are organized based on MBI (though not in ascending order) it is easy to see the blocks. Table A.3 shows the same data once sorted in the block model. Tables A.4 and A.5 illustrate the block modeling with a more complicated example of randomly generated data for a 20 x 20 node matrix, with 16 social nodes and 4 ecological nodes. Block modeling is done for the ecological node pair X and Z (i.e., 18 and 20), because in this example, they would share an EE edge.

Table A.2. Adjacency matrix of a basic 8 x 8 social–ecological multi-level governance network. Social nodes = a:f. Ecological nodes = y and z. MBI = membership index. Local-local edges are red, local-regional edges are orange, and regional-regional edges are blue.

MBI		1	1	3	3	2	2			MBI
		a	b	c	d	e	f	y	z	
1	a	0	1	0	1	0	1	1	0	1
1	b	1	0	1	1	0	1	1	0	1
3	c	0	1	0	1	1	0	1	1	3
3	d	1	1	1	0	1	1	1	1	3
2	e	0	0	1	1	0	0	0	1	2
2	f	1	1	0	1	0	0	0	1	2
na	y	0	0	0	0	0	0	0	0	na
na	z	0	0	0	0	0	0	0	0	na

Table A3. Sorted blocked data from Table A2 based on the MBI

MBI		1	1	2	2	3	3
		a	b	e	f	c	d
1	a	0	1	0	1	0	1
1	b	1	0	0	1	1	1
2	e	0	0	0	0	1	1
2	f	1	1	0	0	0	1
3	c	0	1	1	0	0	1
3	d	1	1	1	1	1	0

Table A.4. 20 x 20 randomly generated adjacency matrix, with 16 social nodes (a through p) and 4 ecological nodes (W thorough Z). The two highlighted columns, with headings e1 and e2, are the two ecological nodes for which MBI (last column) has been calculated. In this example, the ecological nodes X and Z share an EE edge, however, for computational purposes, all EE edges have been recoded to zero as explained in the text. Highlighted rows are social nodes that have an SE edge with ecological nodes X, or Z, or both.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
																		e1		e2	MBI
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	W	X	Y	Z	
a	0	1	1	1	1	0	1	0	1	0	1	0	0	0	1	1	1	0	1	1	2
b	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	0	0	0	0
c	1	1	0	1	1	1	1	0	1	1	1	0	1	0	1	1	1	0	1	0	0
d	1	1	1	0	1	1	1	0	1	1	1	0	1	1	0	1	0	1	1	1	3
e	1	1	1	1	0	0	1	1	1	0	1	1	0	1	1	1	1	1	0	1	3
f	0	1	1	1	0	0	1	1	1	1	1	1	1	0	1	1	1	1	0	1	3
g	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	0	1	1	1	1	3
h	0	0	0	0	1	1	1	0	1	1	1	1	1	0	1	1	1	0	1	1	2
i	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	1	0	1	1	1	3
j	0	1	1	1	0	1	1	1	0	0	1	1	1	1	0	1	1	1	0	0	1
k	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	1	1	1	3
l	0	1	0	0	1	1	1	1	0	1	1	0	1	0	1	1	1	1	0	1	3
m	0	1	1	1	0	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	3
n	0	1	0	1	1	0	1	0	1	1	1	0	1	0	1	1	1	0	0	1	2
o	1	1	1	0	1	1	1	1	1	0	1	1	1	1	0	0	1	0	1	0	0
p	1	0	1	1	1	1	0	1	1	1	0	1	1	1	0	0	1	1	1	1	3
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	na
X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	na
Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	na
Z	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	na

Table A5. Sorted blocked data for data in Table A.4 based on MBI to nodes X and Z. Local-local edges are in red, local-regional edges are in orange, and regional-regional edges are in blue.

MBI		1	2	2	2	3	3	3	3	3	3	3	3	3
		j	a	h	n	d	e	f	g	i	k	l	m	p
1	j	0	0	1	1	1	0	1	1	0	1	1	1	1
2	a	0	0	0	0	1	1	0	1	1	1	0	0	1
2	h	1	0	0	0	0	1	1	1	1	1	1	1	1
2	n	1	0	0	0	1	1	0	1	1	1	0	1	1
3	d	1	1	0	1	0	1	1	1	1	1	0	1	1
3	e	0	1	1	1	1	0	0	1	1	1	1	0	1
3	f	1	0	1	0	1	0	0	1	1	1	1	1	1
3	g	1	1	1	1	1	1	1	0	1	1	1	0	0
3	i	0	1	1	1	1	1	1	1	0	1	0	1	1
3	k	1	1	1	1	1	1	1	1	1	0	1	1	0
3	l	1	0	1	0	0	1	1	1	0	1	0	1	1
3	m	1	0	1	1	1	0	1	0	1	1	1	0	1
3	p	1	1	1	1	1	1	1	0	1	0	1	1	0

The basic code structure of our framework extracts social nodes by calling out ecological nodes and then taking the union of those networks. To do this, we set up a list of vectors representing EE edges and use it to get a subgraph. To avoid extracting ecological connected ecological nodes when extracting subgraphs, we recoded all EE edges as zero. Thus, for analysis, the EE edges are represented in a list of vectors. At the end of this appendix is an example of our code, written in the R language environment (using the packages network and sna (Butts et al. 2014; Butts 2013)). The code illustrates subgraph extraction, MBI calculation, block modeling, blocked data subsetting, and calculation of density, centralization, and PRI.

As mentioned, we restricted our analysis to first degree of separation ecological nodes (i.e., neighboring pairs), but *N* nodes are possible. To expand this approach to *N* nodes requires an expansion of the number of get.neighborhood() function in the code *N* times. Expanding to *N* nodes requires careful consideration about how local and regional are defined; and this consideration should be based on relevant theory. For example, if considering ecological triplets, one would need to decide how to treat social nodes with edges to two versus three of the ecological nodes. Should there be two types of regional nodes (i.e., connected to two or three ecological nodes) or one type (i.e., simply connected to more than one ecological node)? While this may seem trivial for ecological triplets, both data processing and the interpretation of results may rapidly become unruly as the number of ecological nodes increases. Thus, the analyst will need to developed a clear rational based on theory, or specific end user needs, on how to deal with the possible spatial permutations as data analysis should provide understanding and clarity about the world (Pickett et al. 2007).

A.2. Surveys and interviews

We conducted interviews and surveys with restoration practitioners in the region to understand who works with whom. We developed the survey and interview guide based on four months of ethnographic research in the Whidbey Basin (WB) during 2011, and refined them through pilot runs in 2012. For the survey, we sampled organizations using an open-ended recall method common to SNA, in which a list of groups working in the region was compiled and blank spaces were included for study participants to write-in additional groups. Write-ins were contacted to participate. We compiled the recall list from 1) attendance at a 2011 Whidbey Basin science symposium, which brought regional stakeholders together to communicate the current state of knowledge about the region, 2) participant observations in 2011, and 3) pilot runs. We recruited participants by phone, or email, or both, and made a minimum of three contact attempts.

Our survey was administered online. It asked participants to identify the groups they worked with and several attributes about their relationships. We report only two of these attributes here: (1) the restoration goals that the survey respondent and partner organization worked towards (e.g., salmon, shellfish, or write-in response) and extracted only the salmon collaborations for this study; and (2) the percentage of time participants perceived the collaboration to be productive for meeting their organization's restoration goals with selection options being approximately 0%, approximately 25%, approximately 50%, approximately 75%, approximately 100%, don't know, and no response. The productivity questions had a 80.35% response rate within the salmon network. Non-reposes include blank responses as well selection of "don't know" and "no response" options.

In addition to the survey, we also conducted interviews with a subset of survey participants to better understand how restoration was coordinated and implemented in the region. We covered a range of themes, but gave specific attention to how jurisdictional boarders affected group's abilities to do restoration and inter-organization collaboration dynamics. All interviews were conducted by the primary author for consistency and were done in person or over the phone based on the participant's preference. Interviews ranged from 25 minutes to 2.5 hours, were voice recorded, and transcribed. Questions were open-ended, read from a script to insure consistency, and addressed 1) restoration goals, 2) regional collaborations, 3) challenges and opportunities for doing restoration, and 4) locations where groups worked. The interview results are not analyzed in this paper, but rather used to help guide network creation. In total, we had 140 survey participants and conducted interviews with 95 people, purposefully selected to represent the most prominent groups in the network, but also its organizational diversity and different geographic regions.

A.3. GIS data and methods

We established the geographic locations of each organization's work during interviews, during survey recruitment for those groups not interviewed, and from grey literature for most non-participating groups. From location data, we created a spatial database in Arc GIS using existing data such as city, Indian reservation, or county borders obtained from relevant local authorities, or by selecting National Watershed Boundary (WBD 2010) hydrologic unites 12 and 10 (unit 12 is nested in 10 and is smaller) to represent the area described when, for example, a citizen group said they work in "x" watershed between the towns of "A" and "B." While delineating work areas using different data sources introduces some resolution differences, a more precise or consistent approach, such as participant mapping, was not possible given the time constraints of the participants and emphasis in this study on the survey. To prevent resolution differences from influencing our results, we defined the SE edge by spatially joining work areas (i.e., social nodes) to the WBD unit 10 data (i.e., ecological nodes). This aggregates all data to a common currency. We were conservative and used a negative half kilometer buffer during the join to remove small overlaps. Within the WBD 10 data, Whidbey and Camano Islands are one unit. However, we split them, as many groups work on one island, but not the other.

We also constructed EE edges using the WBD. Our EE edges represent surface water hydrology between HUC 10s. EE edges were assigned if surface waters flowed from one HUC 10 to another, or if HUC 10s were neighbors in the coastal environment with no other unit in between them. Again, we restricted our analysis to first degree of separation ecological nodes (i.e., neighboring pairs) and thus, only defined EE edges for neighbors. Our EE network is undirected, meaning we do not distinguish upstream versus downstream flows because we were concerned with both water quality and anadromous fish movement. Since our analysis is meant as a coarse grained diagnostic, we do not account for natural fish barriers in our EE network. Analysts wishing to apply our framework and approach at finer grains may wish to consider surface flow direction, nearshore drift cells, and fish passage when constructing the EE network. For visualization, we created spatially referenced straight lines connecting HUC 10 centroids.

To compare our network data with existing ecological restoration planning work, we spatially joined the HUC 10s to Washington State Department of Fish and Wildlife's (DFW) salmon habitat integrity index (Wilhere et al. 2013). The habitat integrity index is one parameter used by DFW to develop an overall freshwater habitat conservation index to aid land use and conservation planning. Wilhere et al. (2013) used salmonid species as an umbrella species, assuming the sensitive nature of salmonids will confer conservation value for other aquatic species. We did not use the final conservation index because it is calibrated for conservation value, not restoration needs. The habitat integrity index however, which is calculated from upstream and local land use/covers, is a good indicator for degradation and thus, possible restoration needs.

The spatial unit for the habitat integrity data is small hydrologically delineated polygons. The spatial unit of our network analysis is lines (EE edges) connecting HUC 10s (ecological nodes) as explained above. The different geometries make it impossible to directly attribute EE edge values to the habitat polygons as there is no meaningful way to ascribe edge values. Any join method such as "nearest," or "intersects with a buffer," would reflect more the choice to depict our EE edges as straight lines than any meaningful social-ecological spatial relations. Therefore, we first spatially joined the EE edges to points representing the centroid of each HUC 10 by intersection with a 0.5km buffer to overcome small gaps in shapefile geometry and took the mean EE edge value. Several EE edges had no data value for PRI at the local-local level. We manually corrected these cases, adding edge values only for edges with data and dividing by *N* edges with data. We then spatially joined these points to the HUC 10 polygons by intersection. Finally, we spatially joined the HUC 10s to the salmon habitat integrity polygons by centroid (smaller being located in the larger). Twelve habitat index units did not align with the HUC 10s, so we joined these based on closeness and merged them into our dataset.

A.4. PRI symmetrization by maximum values

To account for groups reporting different interaction productivity with one another, we symmetrized the network based on maximum and then minimum values to look at the data's range. Maximum symmetrization depressed the data's range, while minimum symmetrization expanded it. There was little variation in spatial patterns and correlations when considering minimum and maximum symmetrization. We thus, report the minimum symmetrization in the main text as it preserves weaker edges, allowing for deeper inquiry into possible network problems and interventions. Within the total network, the number of edges, based on maximum symmetrization, ranked by approximate percentage of time the partnership was productive for meeting restoration goals were as follows: 12 edges at 0%, 90 at 25%, 125 at 50%, 270 at 75%, 516 at 100% and 225 edges where participants provided no response. Figures A.1, A.2, A.3, and A.4 and Table A.6 show additional maximum symmetrization results.

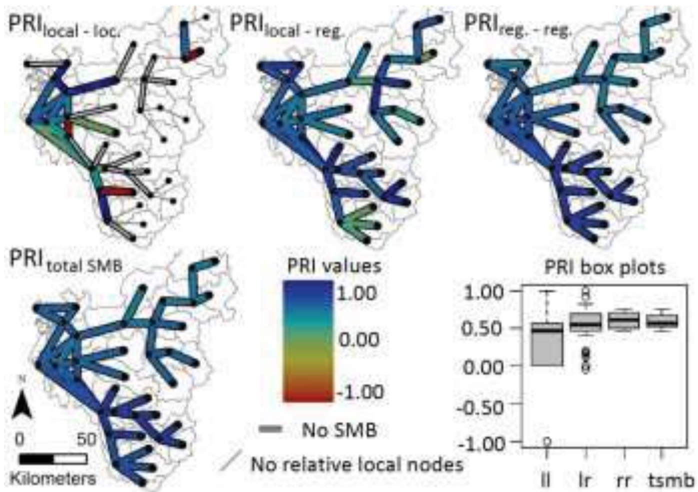

Figure A.1. Edge productivity ratio index (PRI) map using maximum symmetrization (minimum is used in the main text) of collaborations among social nodes (n = 210) working within hydrological connected ecological nodes (n = 38). Juxtaposing the presence of low productive edges against density illustrates that edges may be present, but functioning poorly; scale mismatch may not be effectively bridged in these situations. Abbreviations are the same as in Figure 2.4, main text.

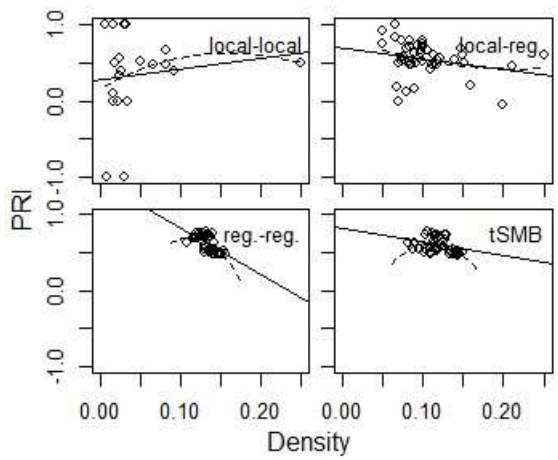

Figure A2. Edge productivity ratio index (PRI) using maximum symmetrization (minimum is used in the main text) vs. scale mismatch bridging edge density. Optimal density is theorized to be at intermediate levels, thus we fitted 1st and 2nd order polynomials to the data. 1st order R^2 values for lcoal-loal, local-regional, regional-regional, and total SMB are 0.019, 0.069, 0.39, and 0.09 respectivly. 2nd order R^2 values are 0.037, 0.079, 0.43, and 0.24 respectivly. R_s values are 0.16, -0.27, -0.60, and -0.34 respectivly. Overall, density is negatively correlated with PRI, but PRI is highest at mid-levels of density for total SMB where the 2nd order polynomial substantially improves data fit. Abbreviations are the same as in Figure 2.4, main text.

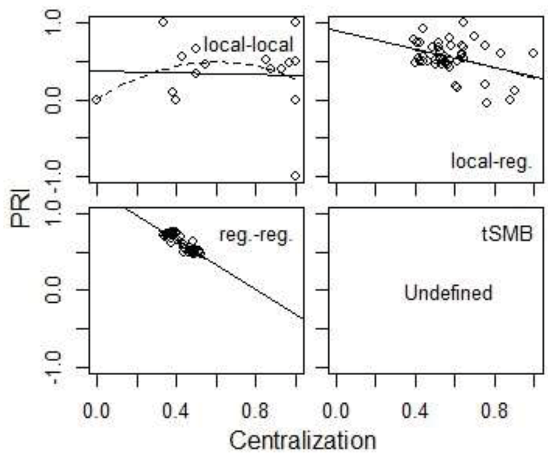

Figure A.3. Edge productivity ratio index (PRI) using maximum symmetrization (minimum is used in the main text) vs. scale mismatch bridging edge centralization. 1st order R^2 values for lcoal-loal, local-regional, and regional-regional are 0.00091, 0.14, and 0.77 respectivly. 2nd order R^2 values are 0.039, 0.14, and 0.78 respectivly and do little to imporve fit. R_s values are 0.086, -0.15, -0.83 respectivly. Overall, PRI and centraliation are inversly related. Abbreviations are the same as in Figure 2.4, main text. Total SMB is undefined as explained in Figure 2.5, main text.

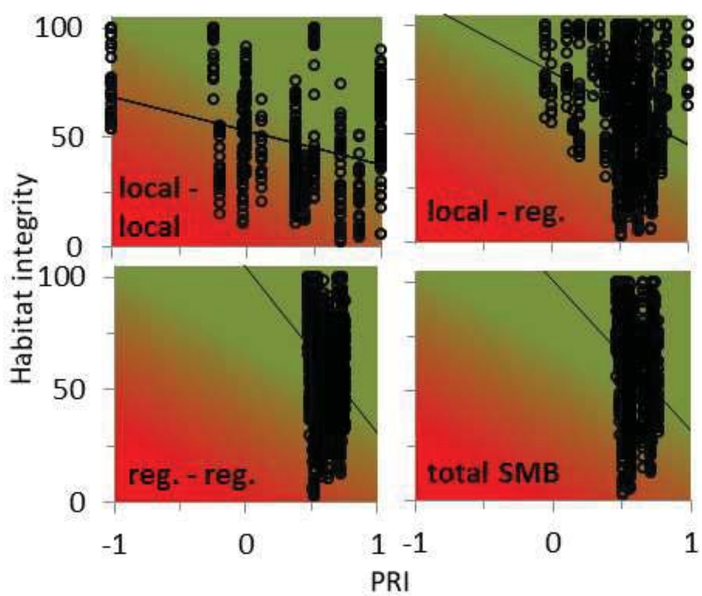

Figure A4. Habitat integrity index (HI) plotted against productivity ratio index (PRI) using maximum symmetrization (minimum is used in the main text). Average PRI edge values were calculated for each ecological node (HUC 10s). HUC 10s were then spatially joined to smaller salmon habitat index units to ascribe social and ecological attributes. Data are plotted with a stylized color ramp to illustrate social-ecological restoration hotspots (low HI, low PRI) and low hanging fruit (low HI, high PRI). R^2 values for local-local, local-regional, regional-regional, and total SMB are 0.10, 0.063, 0.069, and 0.054 respectively.

Table A.6. Summary of R^2 and R_s values for select scatter plots in the main text and appendix. D = density, C_D = degree centralization, PRI = productivity ratio index, 1st and 2nd denote polynomial order, respectively, min and max denote minimum and maximum symmetrization for edge productivity.

Scatter plot	ll	lr	rr	tSMB
PRI min vs. D 1st R^2	0.0059	0.082	0.39	0.14
PRI min vs. D 2nd R^2	0.007	0.15	0.45	0.33
PRI min vs. D R_s	0.043	-0.32	-0.64	-0.46
PRI max vs. D 1st R^2	0.019	0.069	0.39	0.09
PRI max vs. D 2nd R^2	0.037	0.079	0.43	0.24
PRI max vs. D R_s	0.16	-0.27	-0.56	-0.34
PRI min vs. C_D 1st R^2	8.00E-04	0.12	0.74	NA
PRI min vs. C_D 2nd R^2	0.017	0.12	0.74	NA
PRI min vs. C_D R_s	0.13	-0.23	-0.82	NA
PRI max vs. C_D 1st R^2	0.00091	0.14	0.77	NA
PRI max vs. C_D 2nd R^2	0.039	0.14	0.78	NA
PRI max vs. C_D R_s	0.086	-0.15	-0.83	NA

5. Analytical code

Analytical code, written in the R language environment using the packages network and sna (Butts et al. 2014; Butts 2013).

```
#Create network object.

sesNet<-as.network(t(dataMatrix))

#Create id2 to call a numeric ID when calculating MBI

set.vertex.attribute(sesNet, "id2", c(1:length(seq_len(network.size(sesNet)))),
v=seq_len(network.size(sesNet)))

#Create function for Everett and Borgatti (2005) equation 4.10 (Everett and Borgatti 2005).
Note, if the bipartite network has a 1xM or Nx1 structure, the denominator in equation 4.10
reduces to 0 and the function below will return NA. The proper interpretation in this case is
centralization equals 1 and NAs must be recoded as such.

EverettBorgatti2modeCent<-function(twomode){
  dcM1<-subset(rowSums(twomode),rowSums(twomode)>0)
  dcM2<-subset(colSums(twomode),colSums(twomode)>0)
  normM1<-dcM1/length(dcM2)
  normM2<-dcM2/length(dcM1)
```

```
  allNodesNorm<-c(normM1,normM2)
  if(max(dcM1)==max(max(dcM1),max(dcM2))){No<-length(dcM1);Ni<-length(dcM2)}else{No<-
length(dcM2);Ni<-length(dcM1)}
  return ((sum(max(allNodesNorm)-allNodesNorm)) / (((((No*Ni)-Ni-No+1))*(Ni+No)) / (Ni*No)))
}

#Create a list of vectors representing EE edges as EE edges are recoded to zero in the SES matrix to prevent their inclusion in get.neighborhood(). Thus, for analysis, the EE edges are represented in a list of vectors. For this example, the ecological nodes e1 through e5 have the matrix index numbers 9 through 13 and there are edges between e1-e2, e2-e3, and e2-e5.

eeList <- list(e1e2 <- c(9,10),  e2e3 <- c(10,11), e2e5 <- c(10,13))

#Run for loop through SES matrix

outdata<-NULL

for(i1 in mylist){

#Extract S nodes connected to the two E nodes

twoegos <- union(get.neighborhood(sesNet,v=i1[1]),get.neighborhood(sesNet,v=i1[2]))

net2e <- get.inducedSubgraph(sesNet,v=twoegos)

#Track which EE edge is running through the loop

v1<-(get.vertex.attribute(sesNet, 'vertex.names', null.na=TRUE)[i1[1]])
v2<-((get.vertex.attribute(sesNet, 'vertex.names', null.na=TRUE)[i1[2]])

#Calculate MBI

se2<-dataMatrix[as.numeric(c(get.vertex.attribute(net2e,"id2"))),c(i1[1],i1[2])]

seC2<-se2[,1]+se2[,2]+se2[,2]

#Set vertex IDs to indicate MBI membership

delete.vertex.attribute(net2e, "SEmembership")

set.vertex.attribute(net2e, "SEmembership", seC2, v=seq_len(network.size(net2e)))

#Block model data, with block summery = sum to be used below when subsetting blocked data.

blocks<-blockmodel(net2e, seC2, block.content="sum", mode="digraph", diag=FALSE)

#Blockmodel creates a list-like object. Convert blocked data into a matrix to extract blocks.
```

```
bmat<-as.matrix(blocks$block.model)
```

#Create a table of MBI to know *N* of each group. Use "c(1:3)))-1" to create a dummy set of each MBI where *N* = 0 so that MBI values will always be in the same position (1,2,3) even if there are no 1s or 2s in seC2. Otherwise, a seC2 vector with no 1s would put 2s in the first table position and the wrong value would get called in this case.

```
bnodes<-c(table(c(seC2,c(1:3)))-1)
```

#Calculate density for local-local (Dll), local-regional (Dlr), regional-regional (Drr) and total SMB (Dtsmb).

```
Dll <- (bmat[1,2]+bmat[2,1])/(2*(bnodes[1]*bnodes[2]))

Dlr <- (bmat[3,1]+bmat[3,2]+bmat[1,3]+bmat[2,3])/(2*(bnodes[3]*(bnodes[1]+bnodes[2])))

Drr <- (bmat[3,3])/(bnodes[3]*(bnodes[3]-1))

Dtsmb <-
(bmat[1,2]+bmat[1,3]+bmat[2,1]+bmat[2,3]+bmat[3,1]+bmat[3,2]+bmat[3,3])/((2*((bnodes[1]*
bnodes[2]) + (bnodes[3]*(bnodes[1]+bnodes[2])))) + (bnodes[3]*(bnodes[3]-1)))
```

#Calculate centralization

#Convert blocked data to matrix

```
bData<-as.matrix(blocks$blocked.data)
```

#Extract relevant sections of blocked data. Subsets the blocked.data using MBI represented as a count, for the index. Note, the use of "c(1:3)))-1" to add a dummy set to insure proper indexing.

```
bMem<-c(table(c(blocks$block.membership,c(1:3)))-1)
```

#Subset relevant blocks to calculate local-local (blockLL), local-regional (blockLR), and regional-regional (blockRR)

```
blockLL<-as.matrix(bData[(bMem[1]+1):(bMem[1]+bMem[2]),1:(bMem[1])])

blockLR<-as.matrix(bData[(bMem[1]+bMem[2]+1):(sum(bMem)),1:(bMem[1]+bMem[2])])

blockRR<-bData[(bMem[1]+bMem[2]+1):(sum(bMem)),(bMem[1]+bMem[2]+1):(sum(bMem))]
```

#Calculate centralization. Use if-else to control for when there are no edges in block 2x1 (i.e. local-local) or 3x1 and 3x2 (i.e., local-regional). If no data, return -999. This is an important step because subsetting will not work when bMem[1] or bMem[2] == 0, as the 0 introduces indexing errors.

```
if(bmat[2,1]==0){Cll=-999}else{Cll<-EverettBorgatti2modeCent(blockLL)}

if(bmat[3,1]==0 & bmat[3,2]==0){Clr=-999}else{Clr<-EverettBorgatti2modeCent(blockLR)}
```

#Create if-else controls to deal with possibility of zero block (3x3) triggering error in statnet built in centralization command. Recall, this block is not bipartite. Use two if-else statements to remove isolates and calculate centralization. First control for iso=integer(0) which returns an error. If no isolates, return the original blocked data. If isolates, remove them. Second, control for a zero block (3x3). In this case, return -999.

```
if(length(isolates(blockRR))==0){block3x3<-blockRR}else{block3x3<-blockRR[-
(isolates(blockBrok)),-(isolates(blockRR))]}

if(sum(block3x3)==0){Crr<-(-999)}else{Crr<-centralization(as.network(block3x3),degree)}
```

#Compile results. Note, we also calculate the number of nodes in each MBI and the number of possible edges in each block for various visualizations and analyses. Writing these objects should be rather intuitive from the code above; thus, we omit them for the sake of brevity.

```
results <- data.frame(v1,v2,Dll,Dlr,Dtsmb,Cll,Clr,Crr)

outdata<-rbind(outdata,results)

gc()}
```

#print the results

```
outdata
```

#Calculating PRI uses the same code logic as above but makes the following changes.

#The input social-ecological matrix is valued. The values are given the attribute “pro.”

```
sesNet<-as.network(t(dataMatrix),ignore.eval = FALSE,names.eval = 'pro')
```

#The values are carried through into the block model by converting the network object back to a matrix.

```
blocks<-blockmodel(as.matrix(net2e,attrname='pro'), seC2, block.content="sum",
mode="digraph", diag=FALSE)
```

#After subsetting the blocked data (i.e., blockLL in the above for loop), create a table to count the number of each edge types by value in the relevant block. Below local-local is given as an example. Control for zero blocks in the block model using if-else as zero blocks cause errors when subsetting the blocked data. Create a dummy set of values, where the count of each edge type is 0, to ensure that edge values are always in the same position of the table. The example below has edge values 1 to 5 and “no data” of 99.

```
if(bmat[2,1]==0){llPro=rep(0,7)}else{llPro<-c(table(c(blockLL,c(0,1,2,3,4,5,99)))-1)}

#Write each edge count to an object. These objects can then be used for the calculation of PRI.

 llP1<-llPro[2]
 llP2<-llPro[3]
 llP3<-llPro[4]
 llP4<-llPro[5]
 llP5<-llPro[6]
 llP99<-llPro[7]
```

A.6. Permutation analysis for comparing observed and expected densities

We simultaneously permuted the rows and columns of the social-social component of the SES matrix by subsetting it and then using the rmperm() command in the sna package (Butts 2013). We crated 1,000 SES networks with random social-social components. We then calculated density measures for each.

P-values where calculated as follows:

$$p = (m+1) / (n+1)$$

where m = number of permuted statistics smaller than observed and n = number of permutations. Thus, p = 0.04 and 0.96 would be significant at the 0.05 cutoff and would illustrate observed findings that are less and greater than expected, respectively. For clarity, we “flipped” the greater than values and reported p = 0.96 as significant at the p < 0.05 standard. The permutation runs are depicted graphically in Figures A.5 through A.8.

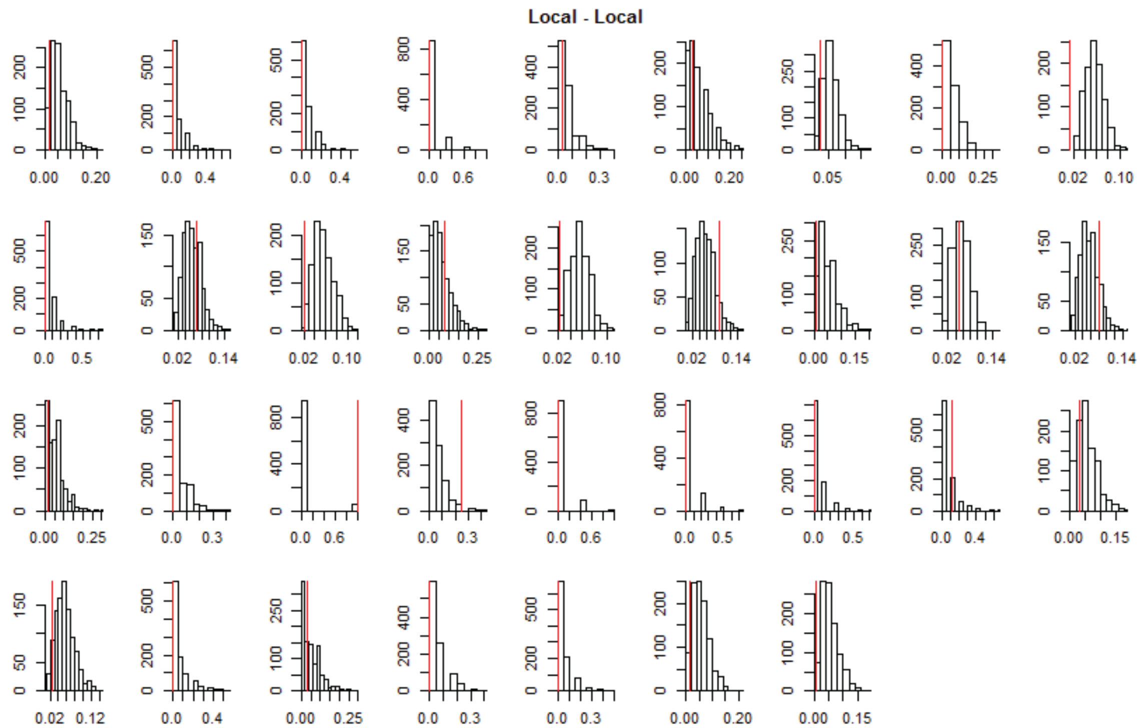

Figure A.5. Observed (red line) vs. expected (histogram) local to local scale mismatch bridging density. Each plot represents the SS edge density between two ecologically connected nodes. The total number of histograms is less than other scale mismatch bridging levels because some ecological nodes did not have local nodes.

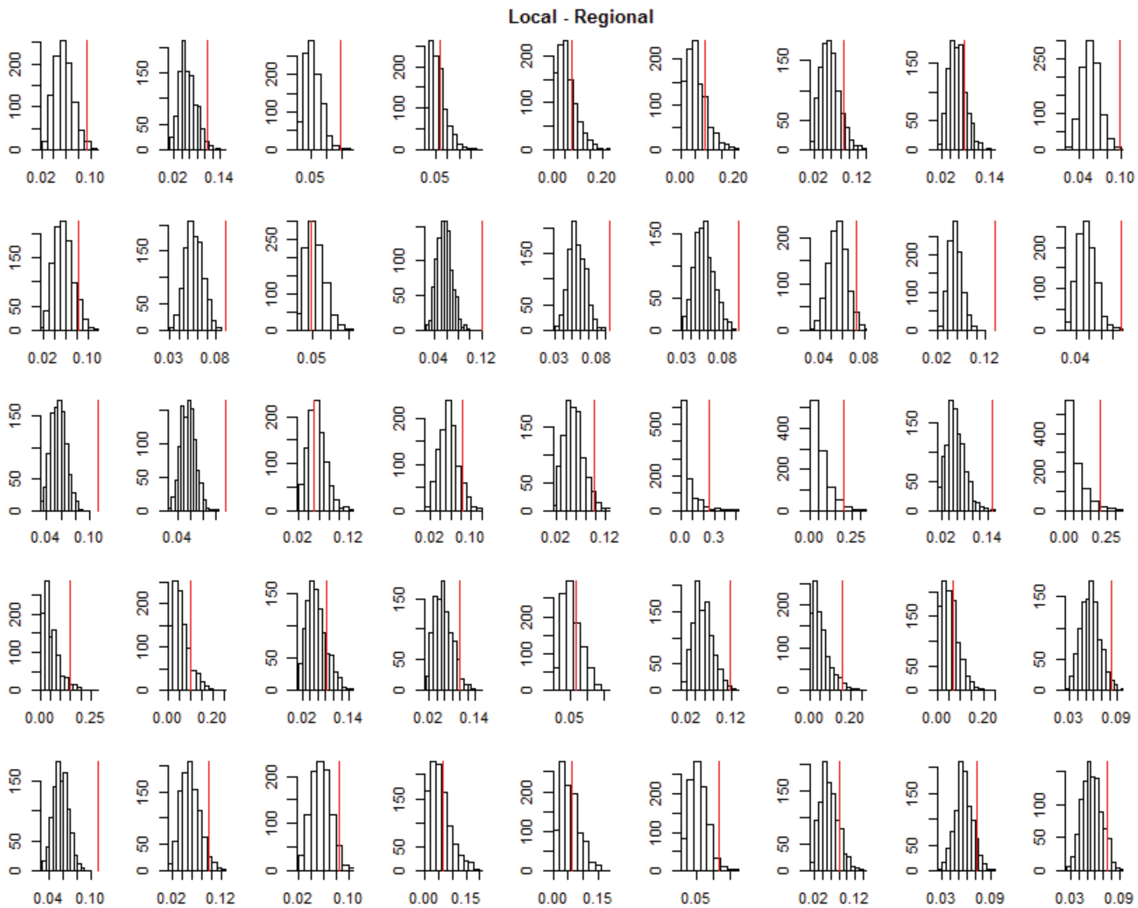

Figure A.6. Observed (red line) vs. expected (histogram) local to regional scale mismatch bridging density. Each plot represents the SS edge density between two ecologically connected nodes.

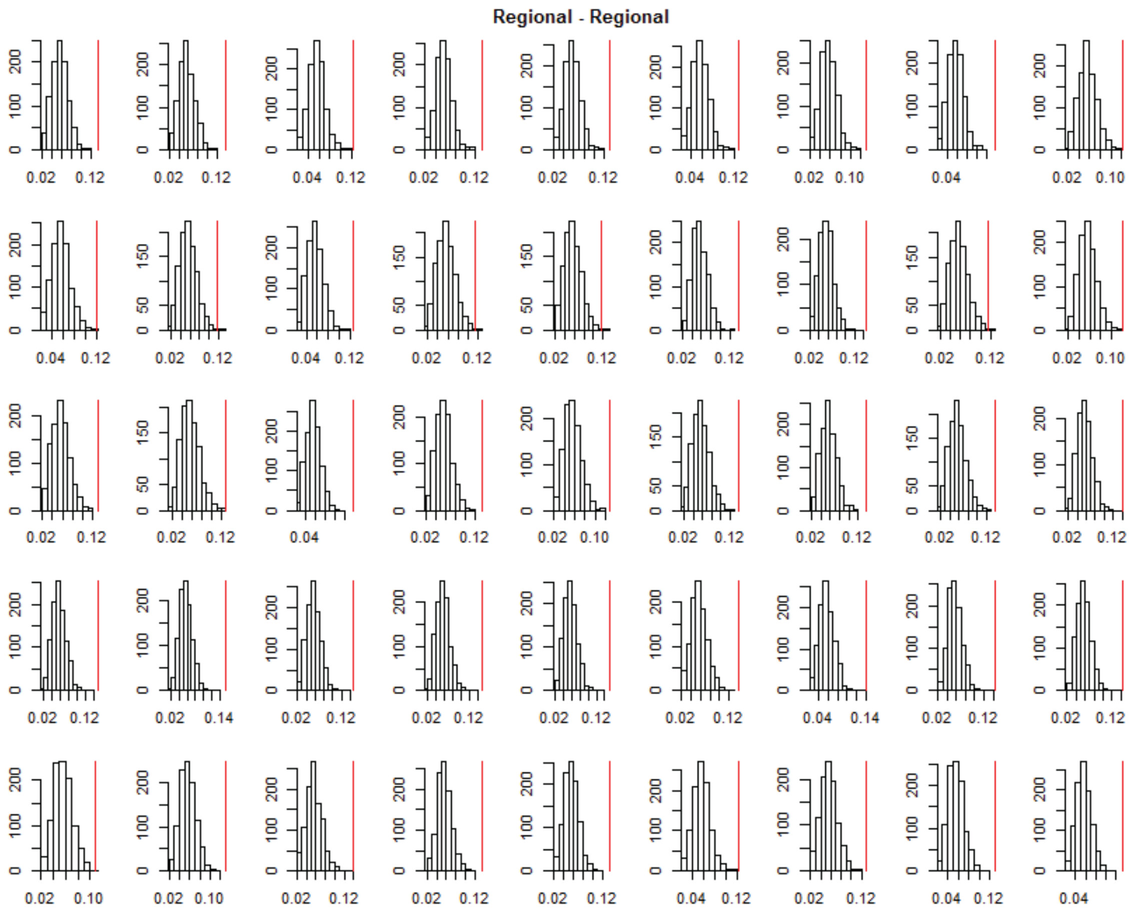

Figure A.7. Observed (red line) vs. expected (histogram) regional to regional scale mismatch bridging density. Each plot represents the SS edge density between two ecologically connected nodes.

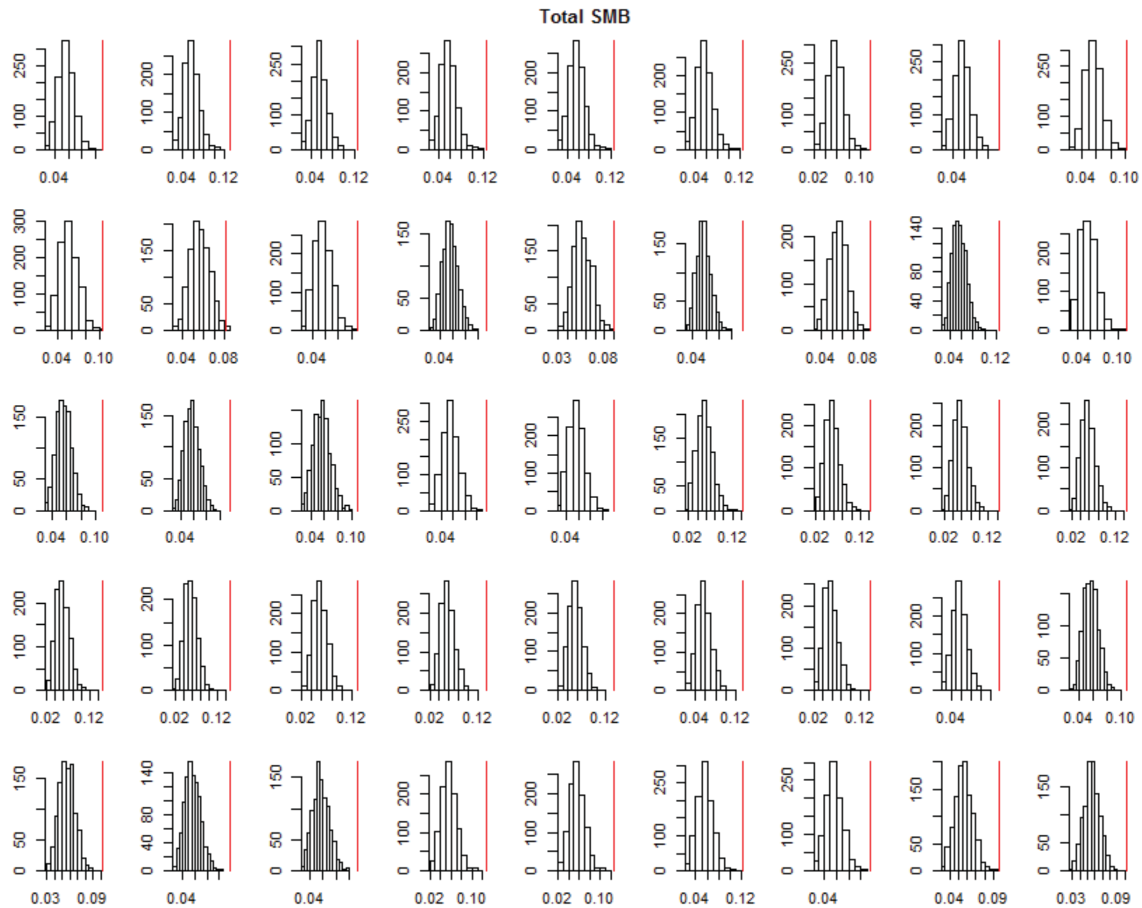

Figure A.8. Observed (red line) vs. expected (histogram) total scale mismatch bridging density. Each plot represents the SS edge density between two ecologically connected nodes.

A.7. Literature cited

Butts, C. T. 2013 sna: Tools for social network analysis. R package version 2.3-2.

Butts, C. T., M. S. Handcock, and D. R. Hunter. 2014. network: Classes for relational rata. R package version 1.10.

Everett, M., and S. P. Borgatti. 2005. Extending centrality. In *Models and methods in social network analysis*, ed. P. Carrington, J. Scott, and S. Wasserman, 57–76. Cambridge: Cambridge University Press

Pickett, S. T.A., J. Kolasa, and C. Jones. 2007. *Ecological understanding: The nature of theory and the theory of nature* 2nd ed. London, UK: Elsevier.

Watershed Boundary Dataset (WBD). 2010. A coordinated effort between the United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS), the United States Geological Survey (USGS), and the Environmental Protection Agency (EPA). Watershed Boundary Dataset for NHDH 171, HU 8. Available at: http://datagateway.nrcs.usda.gov. Accessed 02 September 2010

Wilhere, G. F., T. Quinn, D. Gombert, J. Jacobson, and A. Weiss. 2013. *The Puget Sound watershed characterization project volume 2: A coarse-scale assessment of the relative value of small drainage areas and marine shorelines for the conservation of fish and wildlife habitats in Puget Sound Basin*. Olympia, WA.

APPENDIX B

SUPPLEMENTAL INFORMATION FOR CHAPTER THREE

B.1. Supplemental results for lower and upper quartile PM scores and MRQAP regression

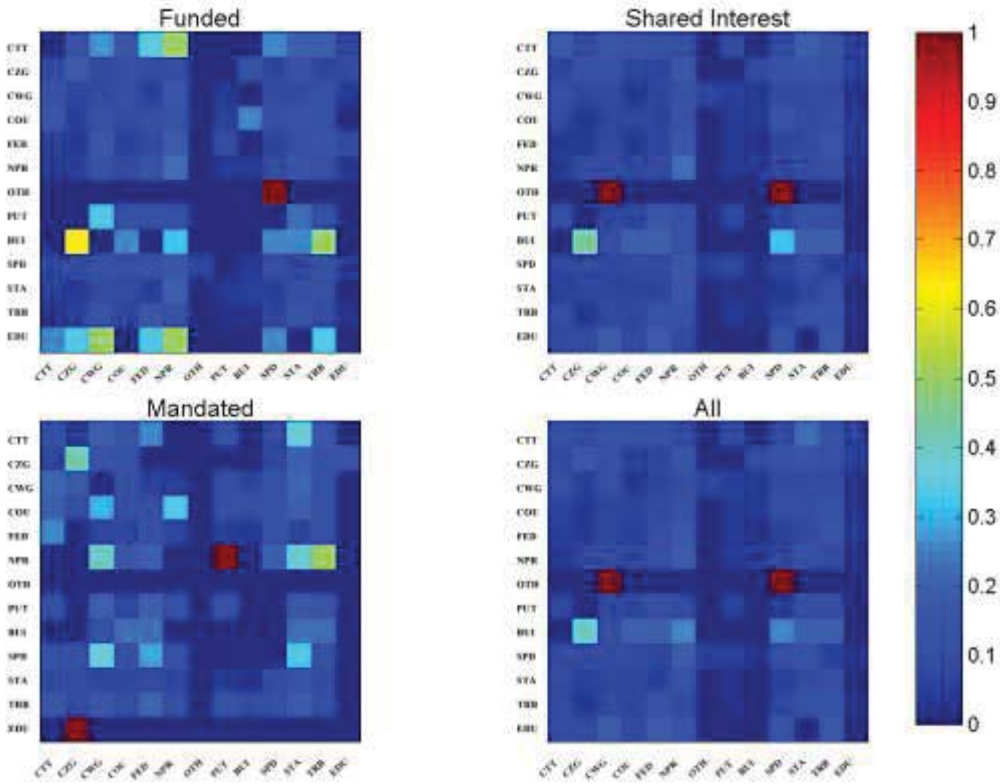

Figure B.1. Lower quartile module to module participation (*PM*) scores between different group types in the salmon restoration network. Colors indicate *PM* score. Data should be read across in rows; for example, top row represents *PM* scores from cities/towns (CTT) to other organization types. When analyzing different relationships types, isolates where removed. N = 151, 119, 200, and 210 for funded, mandated, shared interest, and all respectively.

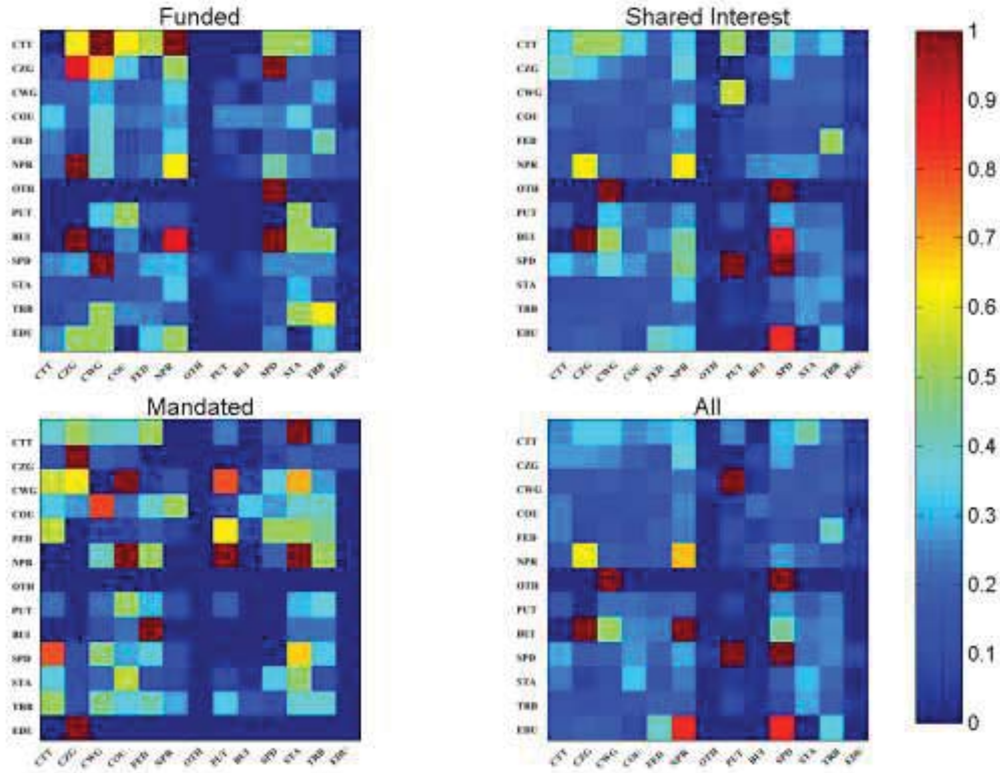

Figure B.2. Upper quartile module to module participation (*PM*) scores between different group types in the salmon restoration network. Colors indicate *PM* score. Data should be read across in rows; for example, top row represents *PM* scores from cities/towns (CTT) to other organization types. When analyzing different relationships types, isolates where removed. N = 151, 119, 200, and 210 for funded, mandated, shared interest, and all respectively.

Table B.1. MRQAP results for both maximum and minimum merge models (n = 210). The models show little difference. Therefore, the decision to merge responses to the program level by minimum or maximum has little effect on the results.

Model: max merge	$\mathbf{R^2 = 0.6950}$	$\mathbf{Adj\ R^2 = 0.6950}$	**p = 0.0002**	
	Unstandardized coefficient	Standardized coefficient	p-value	Standardized error
Funding	1.08230	0.18763	0.00020	0.02348
Mandated	0.91547	0.11971	0.00020	0.02595
Shared	2.69096	0.64958	0.00020	0.02455
Intercept	0.01059	0.00000	0.00000	0.00000
Model: min merge	$\mathbf{R^2 = 0.6869}$	$\mathbf{Adj\ R^2 = 0.6868}$	**p = 0.0002**	
	Unstandardized coefficient	Standardized coefficient	p-value	Standardized error
Funding	1.03412	0.18195	0.00020	0.02314
Mandated	0.83404	0.11069	0.00020	0.02612
Shared	2.66743	0.65350	0.00020	0.02469
Intercept	0.01082	0.00000	0.00000	0.00000

B.2. Further comparison to Hoelting et al. (2014)

Hoelting et al. (2014) studied collaborations amongst individuals conducting research on a variety of nearshore restoration and recovery issues. While they limited their analysis of sectors and jurisdictions to percent representation in the network and used a slightly different classification, several informative direct comparisons can be made (Table B.2). Differences in academic representation are discussed in the main text. Other major differences include a smaller prevalence of federal and state organizations and larger prevalence of city/county and nonprofit organizations in our network. This may be a function of different units. State and federal organizations employ many individuals and combining these individuals into a single organization would lower state and federal prevalence in the network while increasing percent representation of other entities. While other explanations are possible such as study focus, sampling approach, and response rates (Table B.2), comparing these studies illustrates how network units may affect research conclusions.

Table B.2. Comparison to Hoelting et al. (2014).

	Hoelting et al.'s (2014) study based on individuals	This study based on organizations
Organization type	**% nodes in network**	**% nodes in network**
Academic	34%	2.4%[1]
Federal	23%	5.7%
State	16%	6.2%
City/County	5%	23.8%[2]
Tribe	6%	6.7%
Nonprofit	6%	19.5%
Industry/small business[3]	1.4%[3]	5.2%
Nonmatching categories between studies	7.1%[4]	30.4%[5]
Study attributes		
Study focus	Nearshore research broadly defined (salmon is one of several foci)	Salmon restoration broadly defined
Geographic range	Puget Sound nearshore	WB watershed continuum from headwaters to nearshore
Sampling	5 to 10 most frequent collaborators	All collaborators
Network size (nodes)	522	210
Survey response rate	65.2%	68.0%
Percent of network represented by survey respondents	48.5%	56.7%

[1]Includes 3 universities, 1 community college, 1 high school. [2]Combines cities/town (17.6%) and counties (6.2%) to be consistent with Hoelting et al. [3]Industry (1%) and small business (0.4%) were reported separately in Hoelting et al. and combined to match this study, which did not separate private sector based on size. [4]Includes consultants (5%), Canadian researches (1.1%), public outreach and education (0.4%), interagency partnerships (0.4%), and funders (0.2%). [5]Includes special districts (11.4%), coordinating and watershed organizations (9.5%), citizen group organizations (5.7%), public utilities (1.9%), other (1.9%).

B.3. Literature cited

Hoelting K, B. Moore, R. Pollnac, P. Christie. 2014. Collaboration within the Puget Sound marine and nearshore science network. *Coastal Managment* 42 (4): 332–354

APPENDIX C

INSTITUTIONAL REVIEW BOARD (IRB) APPROVAL DOCUMENTS FOR RESEARCH INVOLVING THE USE OF HUMAN SUBJECTS

ASU Knowledge Enterprise Development

Office of Research Integrity and Assurance

To:	Marcus Janssen MH
From:	Mark Roosa, Chair Soc Beh IRB
Date:	03/26/2012
Committee Action:	**Exemption Granted**
IRB Action Date:	03/26/2012
IRB Protocol #:	1203007596
Study Title:	Scale Mismatch in Estuary Restoration

The above-referenced protocol is considered exempt after review by the Institutional Review Board pursuant to Federal regulations, 45 CFR Part 46.101(b)(2) .

This part of the federal regulations requires that the information be recorded by investigators in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects. It is necessary that the information obtained not be such that if disclosed outside the research, it could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

You should retain a copy of this letter for your records.