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River Restoration: Institutions, Boundaries, and Social Ecological Dynamics

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RIVER RESTORATION: INSTITUTIONS, BOUNDARIES,

AND SOCIAL ECOLOGICAL DYNAMICS

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On behalf of the Graduate Committee for Eileen Sylvan Johnson we affirm that this manuscript is the final and accepted dissertation. Signatures of all committee members are on file with the Graduate School at the University of Maine, 42 Stodder Hall, Orono, Maine

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Dissertation Co-Advisors: Dr. Kathleen P. Bell and Dr. Jessica Leahy

An Abstract of the Thesis Presented
in Partial Fulfillment of the Requirements for the
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This human dimensions research, consisting of three manuscripts, explores the social and ecological dimensions of river restoration through an examination of the restoration trajectories of the Androscoggin, an impaired system, and the Kennebec, a restored system. Manuscript one examines the influence of biophysical and community attributes and institutional rules on policy stakeholders goals and actions within the two watersheds. For manuscripts one and two, we conducted semi-structured interviews with key informants, assembled documents pertaining to restoration actions, and conducted participant observation at stakeholder meetings. We qualitatively analyzed transcripts and documents. Results suggest that policy stakeholders' understandings of biophysical and community attributes influence watershed goals. Collaborations leverage institutional rules in use differently as a function of restoration state to achieve goals. Within impaired systems, collaborations invest in shifting public perception to build support for longer term restoration actions.

Manuscript two examines factors contributing to emergence of boundary management processes associated with addressing river restoration challenges. Our second objective was an examination of the influence of restoration state on four functions of boundary organizations: convening, collaborating, translating, and mediating. Results indicate that the underlying restoration state influences the nature of collaborations at an individual and organization level

differently. At an individual level within the impaired watershed, stakeholders valued the role of researchers in lending neutrality. At an institutional level, boundary organizations occupied varying roles, shifting public perception at one end of the restoration spectrum and leveraging restoration gains into community benefits at the other end. Certain functions transcend the state of restoration such as the role of student learning in fostering collaborations.

Manuscript three examines the social dimensions of river restoration. Using spatial analysis, we examine spatial-temporal patterns of water classification shifts, and interaction with the creation of amenity infrastructure and landscape patterns along the river corridors. Despite historical differences in patterns of water classification levels, these two systems were comparable in the level amenity infrastructure and in many landscape metrics. The pace of amenity development differed over time and along the rivers, raising questions about the larger role of amenity investment in increasing community awareness of river systems.

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I have been fortunate that my work rests within a larger research project examining river restoration in Maine and I would like to acknowledge help from colleagues on this research project and for their unwavering support. In particular, I'd like to express my gratitude to Dr. John Lichter, who kindly provided guidance throughout this process, shared advice on writing and researching, and encouraged me to take time for my dissertation.

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Words cannot express how much my family has done for me. My husband and best friend Gordie who believed in me every step of the way, for pitching in on so many levels, making dinners for me, taking on so much on the home front to give me the time and space to complete this, thank you. And to my two daughters, Kristina and Cat, you are the most amazing daughters. You never begrudged the time my work kept me from soccer games or the many other events of your lives. Your notes of encouragement next to my computer remind me daily of your faith in me. You are my source of inspiration.

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LIST OF ABBREVIATIONS

CSO - Combined Sewer Overflow

CWA - Clean Water Act

ESA – Endangered Species Act

FERC - Federal Energy Regulatory Commission

KRI - Kennebec River Initiative

KRRT - Kennebec River Rail Trail

LKRCHSA - Lower Kennebec River Comprehensive Hydropower Settlement Accord

MWCA – Maine Water Classification Act

INTRODUCTION

This research is comprised of three parts and explores the social and ecological dimensions of river restoration in Maine, specifically examining the influence of restoration trajectories of the Androscoggin and Kennebec rivers. Manuscript one is a qualitative analysis that employs the Institutional and Analysis Framework to examine the influence of biophysical and community attributes and institutional rules on policy stakeholders goals and actions within two watersheds at different points of the restoration spectrum. We conducted semi-structured interviews with policy stakeholders and analyzed interview transcripts and documents associated with watershed collaborations goals and actions. Results suggest that policy stakeholders' understandings of biophysical attributes and community attributes influence collaborations goals and actions. Collaborations in the two watersheds leverage institutional rules in use differently to achieve goals, resulting in varied application of governance at federal and state levels. Watershed collaborations within impaired systems may invest in shifting public perception to engender support for longer term restoration actions. Investment in shifting perception comes at a cost of investing in discrete restoration actions such as water quality improvements but may build a broad based constituency that can support longer term restoration actions that may require decades of dedicated action. Within the more restored system, we found that investments in specific actions such as restoration of anadromous fish resulted in dramatic success within this particular arena, but stopped short of developing support for additional restoration actions such as leveraging community benefits deriving from a restored fisheries. Developing broad constituencies can be critical to longer term restoration success and enable watershed collaborations to continue and evolve beyond initial achievements of goals.

Manuscript two examines factors contributing to emergence of boundary management processes associated with addressing river restoration challenges. Boundary management emphasizes the need for knowledge to be salient, credible, and legitimate while providing a means of addressing multi-scale systems that are dynamic. Specifically we examined factors that contribute to the emergence of boundary organizations and the ways that the restoration state influences four functions of boundary organizations: convening, collaborating, translating, and mediating. We conducted semi-structured interviews with academic researchers and policy stakeholders and analyzed transcripts of these interviews and documents produced from meetings between researchers and stakeholders. Results indicate that the underlying restoration state influences the nature of collaborations at an individual and organization level differentially. At an individual level, stakeholders within the more impaired state valued the role of researchers in lending neutrality. At an organizational level, boundary organizations occupied varying roles, providing opportunities to shift public perception at one end of the spectrum and creation of models for leveraging restoration gains into community benefits at the other end. Certain functions transcend the state of restoration such as the role of student learning had a specific role in fostering collaborations within both watersheds. By exploring the influence of the underlying restoration state, our research informs the process of how boundary organizations may need to evolve in response to natural resource state changes.

Manuscript three examines the social dimension of river restoration. Using spatial analysis, we document and analyze spatial-temporal patterns of water classification shifts, and assess the interaction among these shifts and the creation of amenity infrastructure and landscape patterns along the river corridors. Despite historical differences in patterns of water classification levels, these two systems were comparable in amenity infrastructure and in many landscape metrics. The pace of amenity development differed over time and along the rivers, raising questions about the larger role of amenity investment in raising community awareness of river systems and pointing to the complexity of social trajectories.

CHAPTER 1 - CHANGING COURSE: COMPARING EMERGING WATERSHED INSTITUTIONS IN RIVER RESTORATION CONTEXTS

1.1 Introduction

Collaborative watershed institutions that address complex water management systems provide important insights on the role of collaborative resource management in resolving collective action dilemmas (Imperial, 2005; Leahy & Anderson, 2010; Ostrom, 1990; Sabatier, 2005). Specifically, watershed management has provided opportunities to examine institutional response to the shifting social and ecological roles of rivers in the United States. Over the past century, many of the societal services of the nation's rivers including transportation, power generation, and waste disposal have contributed to the economic vitality of river communities while at the same time causing ecological impairment to river systems. Restoration of rivers to new economic and biophysical roles can inform our understanding of the dynamics of social and ecological systems.

In the first two decades after passage of the Clean Water Act in 1972, river restoration actions in the United States relied on command and control approaches to address the wide spread pollution of the nation's waterways. Focused on industrial and municipal point source dischargers, command and control approaches resulted in significant improvements in water quality. Although effective at reducing and managing point-source discharges, these regulatory structures were less effective at managing dispersed sources of pollution (Barbour et al., 2000; Sabatier, Weible, & Ficker, 2005). Watershed institutions, collaborative activities by two or more policy stakeholder organizations aimed at watershed management, emerged as a viable complement to traditional command and control approaches (Imperial, 2005; Pahl-Wostl et al., 2007; Sabatier, Weible, et al., 2005). Collaborative development of best management practices for nonpoint source pollution, land conservation, and dam removal are mechanisms that have successfully been employed by watershed institutions to improve or restore the environmental health of river systems (Hardy & Koontz, 2010; Imperial, 2005; Leach, Pelkey, & Sabatier, 2002). How collaborative institutions respond to shifts in dynamic social-ecological systems is an enduring research question within the field of collaborative natural resource management (Lubell, 2013; Ostrom & Cox, 2010).

Several characteristics of watershed collaborations make them of great interest to institutional researchers. First, they vary in scope and scale, ranging from loose affiliations between one or two organizations addressing localized concerns, to formal watershed organizations established to provide oversight of watershed management (Bidwell & Ryan, 2006; Hardy & Koontz, 2009). Second, they align well with the classical research questions posed by institutional researchers; watershed collaborations have overcome natural resource management challenges, formally referred to as collective action dilemmas, to achieve restoration goals that benefit of users that are often heterogeneous and have competing interests in the resource (Kerr, 2007; Leach et al., 2002; Lubell, Scholz, Mete, & Schneider, 2002). Finally, research has explored their ability to overcome transaction costs (e.g., the costs of creating and maintaining new institutions) in order to implement restoration actions (Hardy & Koontz, 2009; Imperial, 2005; Lubell, 2005).

Restoring complex systems such as impaired water bodies may require actions on many fronts and shifts in goals as progress is achieved. Within the extensive line of research on watershed collaboration, much research has focused on resulting outcomes, with emphasis given to shifts in ecological systems in response to action. Fewer studies examine how the changing ecological state of river systems in response to restoration actions subsequently influences the structure and success of watershed collaborations (Fryirs, Chessman, & Rutherfurd, 2013; Hardy & Koontz, 2010; Lubell, Douglas, & West, 2010; Ostrom & Cox, 2010).

Our research contributes to the institutional analysis literature through an investigation of the relationship between the policies and structure of watershed collaborations and shifts in the state of river restoration. Our research also advances understanding of the feedback systems between the biophysical attributes of resources and the collaborations that emerge to manage them by examining differences in the goals and structure of watershed collaborations within a restored and an impaired watershed. Specifically, we focus on two research questions:

(1) how do differences in biophysical, community attributes and institutional structures influence policy stakeholders' goals and actions in impaired and restored watersheds, and

(2) how does the structure of watershed institutions at the operational, collective choice and institutional level differ in impaired and restored watersheds?

Understanding how watershed collaborations successfully navigate adjusting goals as restoration progress is achieved can help improve their ability to manage watersheds as complex systems. An exploration of these dynamics can lead to an enhanced understanding of the resiliency of institutions, and in particular explain why certain institutions continue to exist and achieve success while others collapse in response to state changes (Brock & Carpenter, 2007; Cox & Arnold, 2010; Lebel et al., 2006; Young, 2010).

1.2 Literature Review

We address these research questions using the Institutional Analysis and Development (IAD) framework (Ostrom, 1990, 2007) (Figure 1.1), a prevalent conceptual framework applied by institutional researchers to study collaborations. This framework provides a strong foundation for our institutional analysis of watershed collaborations for two significant reasons. First, the IAD framework provides a means for examining collaborative actions as occurring at multiple, interrelated levels: operational (e.g. specific actions), collective action (e.g. development of policies such as management plans) and institutional (e.g. establishment of institutions) (Imperial, 2005; Ostrom, 2007). Second, the IAD framework stresses the significance of biophysical, community, and institutional characteristics on the decision-making environment for individuals and organizations (i.e., the action arena; see Figure 1.1) (Hardy & Koontz, 2010; Ostrom, 2007).

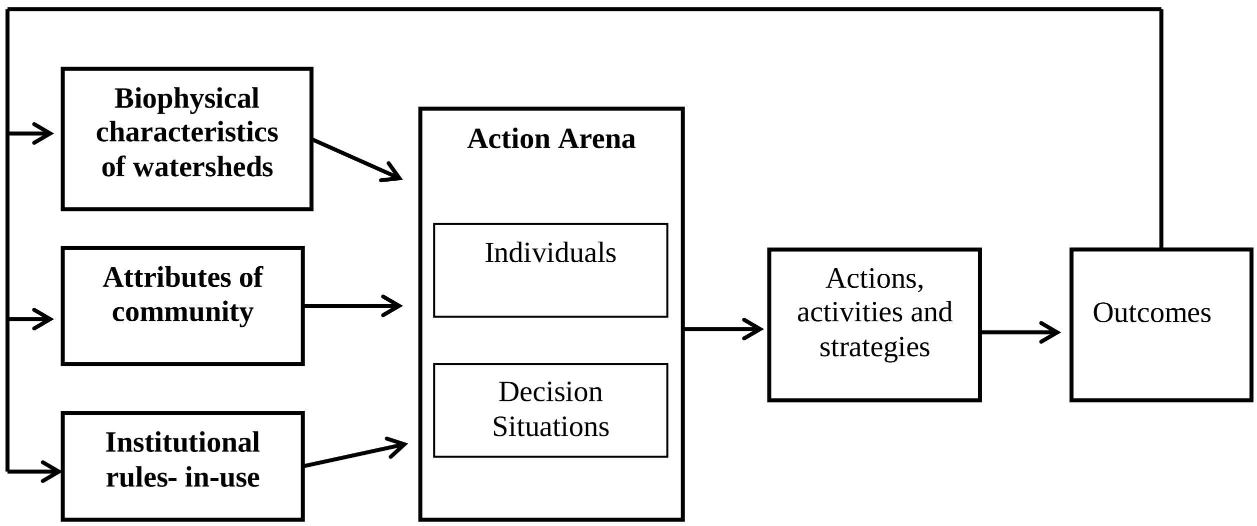

Figure 1.1 IAD framework. Adapted from Ostrom's IAD Framework (2007)

For any given complex resource system, the action arena may be comprised of multiple linked arenas that include operational, collective choice and institutional rules in use (Ostrom, 2007). Operational level actions are directed at impacting the resource such as monitoring or implementing educational programs. Collective choice actions also referred to as collective choice institutions, involve multiple organizations working collaboratively to advance collective restoration goals such as developing a management plan. Constrained by institutional rules in use, collective action institutions may be a precursor to more formalized watershed organizations. Institutional actions include the creation of formal watershed organizations with associated organizational rules (Hardy & Koontz, 2009; Imperial, 2005).

Within any one action arena, there may also be multiple collective choice institutions or “policy games.” Actions within one policy game or collaborative institution may have impact other collaborative institutions within the same arena. The existence of multiple collaborative institutions may increase transaction costs for policy stakeholders to participate in more than one institution resulting in fragmentation of restoration actions. For example, actors may participate in collaborations around dam removal to the exclusion of collaborations focused on water quality improvements (Ananda & Proctor, 2013; Lubell et al., 2010; Lubell, 2013).

Biophysical watershed characteristics influence watershed collaboration emergence and outcomes. The efficacy and structure of collaborations is a function of the severity of the resource problem and specific type of biophysical threats such as water quality impairment or habitat loss (Hardy & Koontz, 2010; Leach et al., 2002; Lubell et al., 2002). In response to the biophysical state, collaborations address resources challenges at varying levels such as implementing water quality monitoring programs at the operational level, adoption of a watershed management plans at the collective choice level, or creation of storm water utilities at the institutional level (Hardy & Koontz, 2010; Leach et al., 2002). Direct place-based experience rather than strict reliance on scientific knowledge are a basis by which stakeholders perceive restoration state, specifically in terms of water quality (Freitag, 2014; Lukacs & Ardoin, 2014). Stakeholders' perception of the restoration state may have a greater influence in determining what actions they adopt rather than the underlying state itself. How stakeholders' perception of restoration progress reflects the underlying restoration state in shifting goals has been addressed to a lesser degree in the literature.

Community characteristics, such as connection to place and the existence of social capital reduce transaction costs and serve as motivating factors for participation in watershed collaborations (Lubell et al., 2002; Lukacs & Ardoin, 2014; Spink, Hillman, Fryirs, Brierley, & Lloyd, 2010; Wondolleck & Yaffee, 2000). Relevant community characteristics also include knowledge of social ecological systems and shared mental models of these systems. When actors share a common mental model such as current or potential state of restoration, they are more willing to invest in collective actions with other actors (Ostrom, 2009). Membership composition of watershed collaborations impacts operational level outcomes and perceptions of success

(Lubell et al., 2002; Moore & Koontz, 2003). Further, membership composition also affects development of institutional rules in use at a collective choice and institutional levels (Hardy & Koontz, 2009). For example, watersheds collaborations comprised of members of the general public rather than agency personnel are more likely to focus on enacting policies (Moore & Koontz, 2003). Engaging a broader range of stakeholders in a collaborative process is critical if water quality improvements are to be achieved. Diverse membership has the advantage of reflecting a range of restoration goals and broader local knowledge in informing these goals. However, building collaborations with diverse memberships requires investments of time for capacity building, which can increase transaction costs (Bidwell & Ryan, 2006; Jacobs et al., 2010). To date, the literature has focused primarily on existing community characteristics and less on how the dynamic nature of community attributes might influence watershed collaboration structure and goals. As collaborations achieve success and make progress towards restoration goals, understanding how community characteristics enable the establishment of new goals and outcomes is key to exploring the feedback systems between collaborations and the underlying systems that they manage.

Institutional rules in use give structure to participation in watershed planning, and are shaped by boundary mismatches between watershed and governance units, and power and information asymmetries that complicate their formation and success (Hardy & Koontz, 2010; Imperial, 1999; Kerr, 2007; Lubell et al., 2010). Member composition may serve to dictate the scale of the biophysical space addressed by the watershed collaboration. At the same time, a more appropriate scale may lower transaction costs as smaller scaled institutions, those at a sub-watershed level for example, may encounter fewer challenges in collaborative management than watershed based collaborations. Within any arena, there may be multiple watershed collaborations acting at various scales either nested or acting independently, which can increase institutional complexity (Imperial, 1999; Kerr, 2007; Lubell, 2013; Ostrom, 2007). Collaborations with more diverse affiliations such as a range of agencies or organizations, or collaborations within watersheds with greater number of governance units, described as "institutionally thick" experience higher transaction costs which subsequently influences the outcomes of these collaborations (Bidwell & Ryan, 2006; Hardy & Koontz, 2009, 2010; Imperial, 2005; Sabatier, Leach, Lubell, Pelkey, & William, 2005). Existence of power asymmetries and information asymmetries increase transaction costs. Further, power dynamics influence institutional rules in use as actors will invest in maintaining power asymmetries to maintain existing institutions. A broader base of members can serve to attenuate power asymmetries (Imperial, 1999; Lubell & Lippert, 2011). How watershed collaborations seek to diversify membership, establish appropriate boundaries, and address power and information asymmetries has been a focus of collaborative resource management research. Less well understood is how changes in restoration state affects institutional factors such as scale of governance, power asymmetries, and establishment of new institutions.

As watershed collaborations successes cause the underlying system to move beyond existing regulatory requirements, such as achieving water quality standards, how these collaborations adjust and create new institutional structures to capture these benefits is critical to understanding long term success (Fryirs et al., 2013; Gregory, Brierley, & Le Heron, 2011). This research examines how institutions manage dynamic and complex resources, overcome transaction costs, and shift goals in response to a resource system change in the form of river restoration.

1.3 Methods

1.3.1 Study area

The study area is defined by the Androscoggin and Kennebec watersheds (Figure 1.2). Located in Maine, these two watersheds provide a strong setting for this research as they share a common historical legacy of pollution, but currently are at very different points along restoration spectrum.

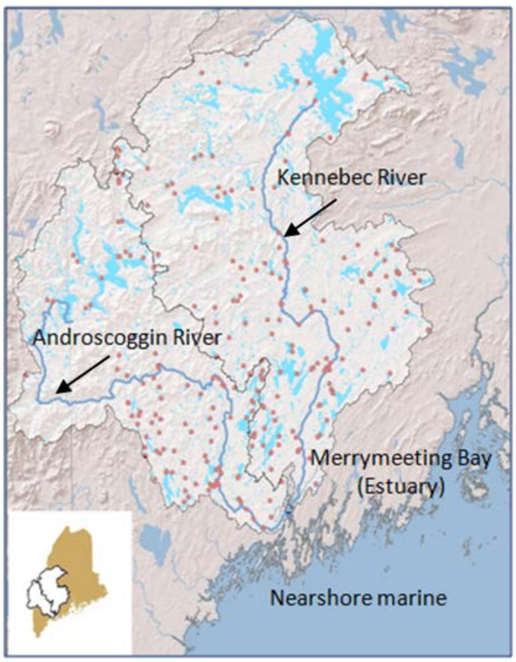

Figure 1.2 Study area

The biophysical characteristics of the two systems are distinct in their hydrology, and extent of current and historical anadromous fish habitat. Originating in northern Maine, the Androscoggin meanders along the 170 miles of its length into the neighboring state of New Hampshire before winding back into Maine. The Androscoggin watershed drains a total of 3,525 square miles in this region. The Kennebec River's watershed, at 5,890 square miles, is nearly double the size of the Androscoggin, although the Kennebec at 150 miles is not as long as the Androscoggin and remains wholly within the state of Maine. Both rivers discharge into the Gulf of Maine.

The Androscoggin River drops 1,500 feet over this course of its length, more than any other river in Maine (Davies, Tsomides, DiFranco, & Courtemanch, 1999). Identified early for its potential for power generation, by 1930 there was more hydropower generated by the Androscoggin River than any other river in Maine (Maine Development Commission, 1929; Wells, 1869). A second significant difference is flow volume and implications for dilution potential. The Androscoggin's flow is 6,156 cubic feet per second (cfs) compared with a flow of 9,015 cfs for the Kennebec (Davies et al., 1999).

Ecologically, pre-settlement river herring spawning habitat has been estimated at 48,680 acres for the Kennebec watershed but only at 11,342 acres within the Androscoggin watershed. As of 2009, Kennebec river habitat provided an estimated 19,268 acres while the Androscoggin watershed currently only provided 4,660 acres of spawning habitat (Hall, Jordaan, & Frisk, 2010). The Kennebec has a thriving recreational fishery and is home to many recreational guides who operate in the estuary. By contrast, fish passage on the Androscoggin remains problematic with an estimated 59,960 river herring at the first fish ladder at the head of tide each year as compared with 2.3 million anadromous fish that passed the Benton Falls dam in 2014 (Maine Department of Marine Resources, 2014).

Population levels are similar across the two watersheds with a slighter higher population and rate of population growth in the Kennebec watershed communities (300,858) compared with Androscoggin communities (249,021 in 2010). There are no distinct differences in terms of education attainment, median income, percentage employed in forest products industries, median income, percent of population below the median income, and participation rates in benefits transfer programs.

Institutional factors have influenced the history of restoration of the two rivers. The Androscoggin and Kennebec rivers occupy distinct roles in the history of water management in the United States. The Androscoggin river served as inspiration for the Clean Water Act of 1972, as its sponsor, Senator Edward Muskie had witnessed the river's polluted state first hand while growing up in Rumford, Maine (McFarlane, 2012). Twenty five years later, in 1999, the Edwards Dam on the Kennebec became the first federally licensed hydropower dam in the United States to be removed over the objection of the facility owners for the express purpose fisheries restoration in the United States (Lowry, 2003).

The Maine Water Classification Act of 1987, a revision of the earlier 1965 Water Classification Act, established a four tiered classification based upon management levels derived from existing biological conditions and highest attainable management goals. Management goals are established through a public and legislative process (Courtemanch, Davies, & Laverty, 1989; Davies & Jackson, 2006). These classes range from pristine levels (class AA) to the lowest level (class C), which is the water quality level that achieves the interim goals of the Federal Water Quality Act . In 1987, 99% of the main stem of the Androscoggin River was classified as meeting the lowest water quality or class C standards, while 57% of the Kennebec met this standard. By 2011, 79% of the Androscoggin still met class C, while only 8 % of the Kennebec met class C (E. S. Johnson, Bell, & Leahy, 2014b).

1.3.2 Approach, data and analysis

We employ a qualitative comparative case-study approach (Yin, 2009) to contrast the policy actions, outcomes, and structure of watershed collaborations in two watersheds, one an impaired watershed (Androscoggin), and one a restored watershed (Kennebec). Our research focuses on policy stakeholder organizations that have collaborated in the development and implementation of watershed improvements at the collective choice and institutional levels.

We conducted thirty-three semi-structured interviews with key informants, 14 from the Androscoggin watershed, 14 informants from the Kennebec watershed, and 5 informants affiliated with state and federal level governmental organizations or non-profit organizations who could provide comparison of both watersheds (Seidman, 2006). We employed a purposive sampling strategy to identify these key individuals who could best articulate watershed actions stakeholder organizations. Interviews lasted between 60 and 90 minutes and were recorded.

Documents associated with stakeholder organization articulation of goals and actions were a second source of data. Mission statements, strategic plans associated with anadromous fish restoration, and written and oral testimony given in connection with water quality upgrades and Federal Energy Regulatory Commission (FERC) relicensing provided information on the range of organizations engaged in restoration actions, and the structure of collaborations that emerged in association with restoration actions (Hardy & Koontz, 2010; Leach et al., 2002; Sabatier, Leach, et al., 2005).

Finally, we conducted participant observation at 30 meetings of watershed collaborations using standard participant observation protocol (DeWalt & DeWalt, 2011). These meetings included watershed wide conferences and advisory board meetings for emerging watershed collaborations.

We analyzed interview transcripts, documents, and participant observation notes qualitatively (Cox & Arnold, 2010; Hardy & Koontz, 2009, 2010; Leach et al., 2002; Miles & Huberman, 1994; Saldana, 2009). We coded qualitative data inductively as well as deductively based upon codes associated with Institutional and Analysis Development (IAD) variables using the computer software NVivo 10. In addition to the primary coder, several coders analyzed portions of the transcripts to confirm strong intercoder reliability.

1.4 Results

1.4.1 Influence of IAD variables

IAD variables, specifically biophysical characteristics, community characteristics, and institutional rules in use influenced policy making differently between the two watersheds as function of the underlying restoration state (Table 1.1). Our findings indicate that the perception of biophysical characteristics by policy stakeholders played a role in shaping restoration goals, specifically differences in perceptions of historical legacies, current water quality, hydrology, and ecological potential. Androscoggin policy stakeholders described the lingering influence of industrialization as still limiting the river's potential, while Kennebec policy stakeholders focused largely on the ecological potential of the system. Reflecting differences in biophysical potential between the watersheds, policy stakeholders acknowledged a shared common social and economic history that diverged due to investments that were made on the Kennebec as compared to the Androscoggin river.

> The two rivers have a pretty common history in terms of their industrial uses…within the past, say, 20 years the Kennebec has gotten a lot more attention in terms of restoring the health of its ecosystem both in terms of removing dams, building fishways…even on the water quality issue.

The historical legacy of the Androscoggin was a prevalent characteristic in shaping policy stakeholders' goals. "In the early 80's some people did not want to put in fish passage as they viewed the river as an industrial river." The unique hydrology of the Androscoggin, the elevation difference as well lower dilution potential limited policy stakeholders vision of its ecological potential. "It's a beautiful river and it's the most dammed river in the state." As a result, policy stakeholders have not focused as much on anadromous fish restoration, but rather on overcoming the challenges inherent in improved water quality and of the system's underlying hydrology. "I would say it is driven by its geology and that this river is not the Kennebec. The opportunities are not the same as the Kennebec or Penobscot [another major river in Maine]."

Policy stakeholders described the system's current state and potential for anadromous fish restoration as a characteristic of the overall Kennebec system.

> The Kennebec historically had tremendous runs of migratory fish which support the Gulf of Maine ecosystem. So I often think about it in terms of ecosystem services or the economic benefits that the river provides because of its intrinsic beauty, it's recreational opportunities and the amount of fish it generates.

Community characteristics influencing restoration progress include characteristics of policy stakeholders such as shared mental models of the social and ecological systems by the policy stakeholders themselves and power asymmetries that existed among actors including industrial users and state agencies. A second component of community attributes was the general policy stakeholders' understanding of the general public's perception of restoration state.

Policy stakeholders' mental models of the rivers' potential restoration state differed between the two watersheds, influencing the ways in which organizations articulate restoration goals and formed collaborations for the purpose of achieving these goals.

Androscoggin policy stakeholders described the Androscoggin as a multipurpose river with a diversity of actors ranging from paper mills, hydropower, recreationalists and economic development opportunities.

> I think the river was always just taken for granted. And now I think people realize that we need it. We need it both as a recreational thing, and we also need it – you know paper companies need it for hydro power and in their process. And you have to find that balance between using it economically and also using it for recreation.

Policy stakeholders along the Kennebec talk about specific events leading to improvements along the river, specifically removal of the Edwards Dam and water classification upgrades. "Since the removal of the Edwards Dam in '99…we've seen the removal of the dam on the Sandy River …and then the Fort Halifax Dam, … and so we've opened up a lot of habitat and converted these former impoundments to free-flowing rivers and that's really been dramatic both aesthetically but also ecologically."

Within the Kennebec watershed, stakeholders describe community development as inextricably linked to restoration of fisheries. "So I often think about it in terms of ecosystem services or the economic benefits that the river provides because of its intrinsic beauty, its recreational opportunities and the amount of fish it generates…that are major economic components that are part of the river." Having witnessed significant increases in fish populations, Kennebec policy stakeholders were able to more directly describe the potential benefits of restoration from an ecological perspective, and a potential economic perspective.

At the same time, informants expressed reservations about the potential to more fully capitalize on restoration achievements due to lack of organizational structure and the reality of competing with other world class fisheries as a "potential that may never be realized in this river." Kennebec policy stakeholders described the need for a coordinated effort to market the river.

The dramatic improvements also created a dual vision of the river in which certain policy stakeholders believed sufficient restoration gains have been achieved in terms of water quality. "I'd like it to stay where it is today. You know, status quo; maintain, you know … maintain water quality and environmental quality." In contrast, other policy stakeholders described the unrealized potential of the system that will require sustained coordinated effort. "Well, if fish continue to come back and return because the number of fish in the river is still at about maybe 1% of what it should be." This duality presented problems for development of a cohesive vision the next stage of river restoration.

Finally, acknowledging a greater level of restoration achievements along the Kennebec, policy stakeholders, unlike their counterparts along the Androscoggin, described emerging threats such nonpoint source pollution associated with increased development and the consequent implications for freshwater fish.

One of the critical differences between the systems was power asymmetries associated with the Androscoggin that were essentially dismantled along the Kennebec when the Edwards Dam was removed. The Androscoggin saw a slower transition from a heavily industrialized river to its current levels of restoration in part due to the role the river occupies in the state, "It is a beautiful river that is still considered the poor step child of Maine's rivers." Androscoggin policy stakeholders described a shift in control of the river from paper mills to hydropower. "There is little that will change the fact that the Androscoggin will remain an industrial worker and take the paper mill side, the heavy manipulation from hydroelectric really is the industry today." This notion of the Androscoggin as "poor stepchild" has inspired policy stakeholders to invest in both shifting perception and restoration goals as a way of correcting a perceived inequity.

> I think the Androscoggin, for 100 years, has both in terms of the state, in terms of decision makers…has kind of been a second-class river, versus the Kennebec, going through Augusta, kinda being more prevalent, probably got a little more attention and also I think a lotta the municipalities and folks along the Androscoggin didn't necessarily see as much potential in the river or kinda got used to seeing it as more of a degraded river…probably some of the more entrenched industrial interests …on the Androscoggin…fought harder against some of the changes, which was certainly a detriment.

Public perceptions held by community members towards the rivers often differed from policy stakeholders' perceptions of the restoration state. Public perceptions of the river lagged behind actual restoration gains and shaped policy stakeholders' goals in response to these community perceptions.

> There was a very high level of interest in recreational opportunities on the Androscoggin but there was also quite a high level of distaste for what they felt was excessively poor water quality that I thought that seemed out of place for its actual water quality. Its actual water quality… is higher than the public perception of it. In contrast on the Kennebec there does seem to be a real enthusiasm and real acknowledgment of the beauty of the river and a lot of that I think in my mind is kind of related to the removal of the Edwards Dam and sort of a reawakening of awareness about the river.

To a large extent, perception is a function of tenure and age of residents and an awareness of shifts that are occurring, as the older, longer term residents are replaced by a younger generation. Policy stakeholders believed that shifts in perception will occur, but need to be accompanied by discrete actions targeting newer and younger populations.

> Because if you talk to the more adult people, they don't have the enthusiasm; like these kids would go home and they started telling their parents, 'Oh, you gotta see the river. You gotta see how clear the water is.' And I think that's sort of where you really get the education out there on the value of the river, the asset it is, and get them involved young so that they will always protect the river.

Within the Kennebec watershed, public perception of water quality has increased over time in response to dam removal and water classification upgrade. As a result, there was a lack of discussion on engendering support for continued improvement and revitalization of river communities in response to restoration gains. "I think that most people think that…the water quality, has been resolved. Without the mills going into the river, with CSO's [combined sewer overflows] being taken care of, I think most people believe the river is about as good as its going to get."

Institutional rules included pre-existing federal and state laws that governed restoration within the two watersheds. Policy stakeholders differed across the watersheds in perception of the efficacy of existing institutional rules in use. Policy stakeholders identified three federal acts, the Clean Water Act of 1972, the Endangered Species Act of 1973, and the Federal Water Power Act of 1920 as impacting restoration to the greatest degree. Informants also describe the inconsistent enforcement of these acts as having influenced restoration goals.

Across both watersheds, policy stakeholders pointed to the Clean Water Act of 1972 and its amendments as being pivotal in bringing about the most dramatic improvements to both systems through regulation of point source discharge, "Well it is certain the Clean Water Act set the stage. The state has moved obviously with color, odor, foam and other regulations to push, there is a great lingering challenge."

Policy stakeholders also described a shift in power asymmetries between the point source dischargers and communities due to the impact of federal legislations. "Regulations [were] …really the driving factor that did it…forced them to clean up the rivers, and…mills have, over the years, taken on the responsibility and almost embraced it because it's in their best interest to do so." In both watersheds, the role of Federal Water Power Act of 1920 in establishing regulation of hydropower has been important. While Androscoggin policy stakeholders cited passage of the Clean Water Act as having the most impact on restoration, Kennebec policy stakeholders pointed to the removal of the two dams as more important. "Those types of legislation have certainly facilitated retaining the high quality of the water compared to other rivers in the state of the Maine… I've seen an increase in fish population, and I believe it's a result of the dam being removed."

While collaborations along the Kennebec engaged effectively with the FERC process there was frustration with the FERC relicensing processes in the Androscoggin watershed. The challenge of the FERC relicensing process has been its long timeline and narrow windows of opportunity to engage. "At Brunswick because basically they have known for almost 30 years that the fish ladder does not work and nobody has done anything. Thirty years is long enough to wait." Due to the complexity of the FERC regulatory process, there was limited success with engagement. "And trying to wrestle with that is just going to be huge challenge going forward, it takes someone with a legal background in these regulations to even try and navigate it let alone a very small organization."

The role of the Endangered Species Act has been limited to date in each of the watersheds. With the Kennebec restoration largely in process, some informants describe the Endangered Species Act as having the potential to shift work on anadromous fish restoration on the Androscoggin.

> We've also had a really long, lengthy battle to remove the Fort Halifax Dam and so now that that's happened, I think most of the larger dam removals on the Kennebec have happened…and then on the Androscoggin, other than weighing in on some of the water quality issues, really did not do a lot of work on the Androscoggin up until about three years ago, so with the expanded Endangered Species listing of Salmon to include the Androscoggin, we're focusing more time there.

Maine's Water Classification Act influenced restoration in two important ways, by benchmarking water quality improvements and ratcheting up water quality standards at the scale of river segments. Policy stakeholders described specific opportunities provided by the law to advocate for upgrades including managing water quality monitoring programs to support upgrade petitions, submitting letters of support for agency proposed upgrades, and finally proposing upgrades legislatively.

Within the Androscoggin watershed, there was a frustration with implementation of the water classification act. “If the river doesn’t meet B, they will not upgrade it to B but if they don't upgrade it to B, they can't encourage incremental improvements of the municipalities and the industries. So it is a catch-22 situation.”

For many policy stakeholders, investing in water quality improvements that could lead to upgrades was an important mechanism for improving public perception. The law focuses on risk management, and for those portions along the Androscoggin that have been upgraded, policy stakeholders described the benefits of the guaranteed continual improvement. “The river was reclassified as a class B river and that …is critical, if it were downgraded, if it did not pass…we wouldn’t have to close the doors but it would be much more difficult.”

In contrast, Kennebec policy stakeholders described water classification as less critical than anadromous fish restoration and amenity development. Policy stakeholders did not identify the public awareness of classification levels as relevant. “I don’t think that one person in a hundred caught on to the notion that water quality was being reclassified…people just came to realize over time that the river was in fact cleaner… and say gee that’s really great it has a lot of potential.” Upgrades that occurred along portions of the Kennebec were related to removal of the Edwards Dam and required less citizen engagement.

IAD Variables	Influence on policy making	
	Androscoggin (Impaired)	***Kennebec (Restored)***
Biophysical Characteristics		
Hydrology	Water quality improvements	Fish passage
Ecology	Limited potential for and hence investment in anadromous fish restoration.	Anadromous fish restoration occupies major component of restoration
Current Water Quality	Focus on water classification upgrades, negotiations over licensing agreements, upgrades to treatment processes	Focus on leveraging gains of water quality improvements
Community Characteristics		
Policy stakeholders perception of system	Biophysical improvements Reconnecting communities to river Development of river as multiuse Expand recreational opportunities and access	Leveraging ecological gains from Edwards Dam removal Identification of emerging threats from gains Economic potential of system
Community perceptions of river	Shifting perception	Envisioning river as an asset Developing infrastructure for asset development
Power asymmetries	Water classification upgrades	
Institutional Rules in Use		
Federal regulation Clean Water Act 1972 and amendments Federal Powers Act, 1920 - FERC Endangered Species Act	 Engagement with point source discharges Investments in negotiating expanded recreational opportunities Dam Removal	 Effective restoration of water quality Edwards Dam Removal LKRCHSA
State regulation – Water Classification	Water quality monitoring Petitioning for classification upgrade	Investment in amenities to leverage gains from upgrades

Table 1-1 Influence of IAD variables on stakeholder policymaking

1.4.2 Structure of watershed collaborations

Along both rivers, informal collaborations and formalized watershed institutions emerged to implement actions as a reflection of policy stakeholders' shared understanding of the biophysical state, community characteristics and influence by institutional rules in use (Table

1-2). Policy stakeholders engaged in collaborations at the collective action level focused on three specific areas: water quality improvements, anadromous fish restoration, and community investments which included perception shifting and establishment of amenity infrastructure. At an institutional level, watershed institutions have emerged to achieve goals within each of these areas.

While advocating for point source improvements has occurred primarily at the institutional level along the Androscoggin, at the collective action level, collaborations have emerged to achieve two main goals, elimination of combined sewer overflows (CSOs) and advocating for water quality classification upgrades.

In addition to federal requirements, reasons for collaborations around combined sewer overflows (CSOs) removal were explained as "com[ing] down to money," and the reality of collaborations enhanced efficacy in access grants through collaborations, rather than competing for the same funds. In the Androscoggin, there is a growing recognition that removal of CSOs may enable the achievement of upgrading the classification levels. "As those CSOs are eliminated, as we're able to see the river quality and the river rating go to a B from a C, I think just that classification alone will help the mindset of folks that, 'Gee, it really has improved.'"

Androscoggin watershed collaborations organized around petitioning for water classification upgrades as a means of shifting perception and lead to economic gain for riverside communities. "We understood the value of raising that classification. So we went out and communicated to all the communities along the river and got them to submit letters supporting that efforts." Policy stakeholders collaborated in proposing legislation, requesting letters of support for proposed upgrades, and organizing testimony at the agency and legislative levels.

For Androscoggin policy stakeholders, the lower water quality classification reflected not just biophysical characteristics of the river but a necessary step towards revitalizing river communities.

> [It is]…socially desirable and appropriate to upgrade the lower Androscoggin. The Board and the Department have it within their power to change public perception about the lower Androscoggin. You have it in your hands to encourage people to use the existing trails and boat launches along the river, build more trails, boat launches and parks, make prudent investments in businesses along the river corridor and continue our efforts to clean up the remaining sources of pollution.

While investments in anadromous fish potential occupied the focus of Kennebec policy stakeholders, there was little discussion of the need for water quality improvements at a collective action or institutional level. Rather, policy stakeholders along the Kennebec describe the need for leveraging the river as an asset. "What is missing today, what is missing today are social and economic components to take advantage of that incredibly significant change."

Engagement with the FERC relicensing process along the Androscoggin focused on providing additional access to the river and less on anadromous fish restoration until recently. Acknowledging the challenge of finding a balance in managing a multiuse system, policy stakeholders were unsure about the potential for restoration programs. "Values associated with hydropower won't make any of those dams feasible for removal and so you need to kinda improve things as much as possible and probably focus on the tributaries with different species."

Policy stakeholders described the FERC relicensing process as providing an opportunity to leverage industrial use by hydropower companies into direct benefits for the communities in the form of river access and parks. Negotiations for these community rights were at times contentious and required a broad range of policy stakeholders to provide opportunities for the general public to engage in the relicensing process. "Now some at the meeting really changed because people sat back and said wait a minute so they are manipulating our river, they don't want to make an investment, they are profiting from this, and all the money is leaving the state and we don't get the cheap power out of it?"

With improving water quality, there was an emerging awareness of the potential for restoration of native fisheries. Tied to that vision was the recognition of what a restored fishery would also mean in terms of shifting perception, "We have to get fisheries back because the day somebody can go fishing and catch native fish in the river is the day that those people stand up and fight for the river."

Along the Kennebec, the landmark removal of the Edwards Dam, the result itself of a decade of collaboration among multiple policy stakeholders resulted in the establishment of the Lower Kennebec River Comprehensive Hydropower Settlement Accord (LKRCHSA) with resulting implications for installation of fish passage and removal of two additional dams. Policy stakeholders within the Kennebec watershed pointed to organized, effective opportunities for negotiating outcomes that result in restoration of anadromous fish habitat and for greater control of water flows, critical for recreational use of the river.

Androscoggin collaborations invested in shifting perceptions as a necessary next step in engendering support for restoration measures. Androscoggin policy stakeholders recognized that direct experience as being critical to shifting these perceptions and have invested in providing these opportunities.

> People have a certain view of the river, and while they always read about how dirty the river still is …the first time they get in the river they are completely blown away. I have not yet had a single person not start just shouting praises of one amazing resource it is the first time they can at least get out there…They start asking more technical questions and not 'is the river safe to touch' it then becomes these other more ecologically focused questions which is a good place for the debate.

There was a tension among collaborations who share a common goal of river restoration but differed in perspectives on achieving these broader goals. Policy stakeholders described a lack of cohesiveness among the many watershed collaborations. Policy stakeholders invested in collaborations for the purpose of water quality improvements do not see the value of investing in shifting perception. Similarly policy stakeholders who engaged in collaborative "perception shifting" described challenges with the focus of the other collaborations' focus on water quality improvements.

Finally, there was a general sense that although there was a high level of engagement, there was a lack of coordinated efforts and the need for a means of integrating the many individual restoration programs. “There’s still a long ways to go, you know there are so many groups working on the Andro river and I think we could benefit from a better mechanism for regularly getting together and talking about ways we can collaborate to be more effective together rather than individual level things for everybody.”

Kennebec policy stakeholders engaged in amenity development stated their view that restoration to date was sufficient and described the need to invest in infrastructure in place of improving current water quality levels.

> It probably would take enormous amounts of money to change that classification and it may not be worth it. So from that perspective, I don’t see much gain in talking about river restoration, I see the issue as much more being how do you keep the river healthy and improving somewhat. …How do you utilize this incredible asset so that people will actually want to come live and work and recreate in this part of the country.

Institutional collaborations emerged within both watersheds to achieve goals tied to the underlying state of restoration. The emergence of institutional structures and goals established differed significantly across the two watersheds.

Within the Androscoggin, two separate watershed organizations emerged through a “bottom up” process. The focus of these organizations varied. In one case the organization’s focus was to balance competing interests in the river among multiuse of the river and shifting public perception. The second organization focused on advocating for water quality improvements.

The first organization focused on finding a balance among the multiple users, stakeholders at the institutional level convened the many actors along the river in order to share knowledge on progress to date and initiate discussions on potentially contentious restoration actions. “There’s a sort of collaborative aspect to it that we are bringing together interested stakeholders, interested people from both sides of the political boundary. And we are all up and down the river.”

A second significant action implemented by the organization was sponsoring regular events for the purpose of raising awareness of the river. An example of one program to shift perception is an annual canoe event that runs the length of the river and is one of the longer term river wide events along the Androscoggin. Policy stakeholders acknowledged that longer term actions like the trek are starting to have an impact in shifting perception. "But it very much links the communities along the way. It gives people an opportunity to show off what they have done and we all want to be proud of how we have, how our river has been saved from destruction."

The focus of the second organization was addressing protracted restoration challenges along the river. Specifically, this second watershed organization emerged to in response to frustrations associated with regulation of point source discharge. Policy stakeholders describe actions to advocate for point source improvements as contentious at times. "They are the ones who are willing to get legal and try and read through these big documents about classification and go to court or whatever it takes." Institutional goals started to shift from point source discharge improvements to broader goals of developing a more comprehensive vision of ecologic and economic health through anadromous fish restoration and community development

In response, there was an emerging interest on the part of industrial users of the river to engage more effectively with policy stakeholders in mediating differences among the many users, resulting in the emergence of a nascent organization. Multiple stakeholders initiated meetings to explore the formation of a new organization, or boundary organization, that would encompass a broader based of stakeholders and provide a means of mediating differences. Participants in the development process described the role of a new organization as:

> Founding partners…are diverse members of a coalition or network of educational, corporate and community partners representing the breadth of issues and opportunities inherent in river based communities. These partners are committed to a shared vision, strategic goals and specific roles…Their vision is not in service to one cause. It supports the environmental, social and economic health of the Androscoggin River watershed.

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Within the Kennebec watershed, removal of the Edwards Dam and upgrades of water classification of significant portions of the river have precipitated three separate institutional responses: implementation of the actual agreement for further fish restoration, development of a new regional river trail, and establishment of a watershed wide initiative through state agency action in response to restoration gains.

In order to head off court challenges to the 1989 Federal Energy Regulatory Commission (FERC) decision for removal of the Edwards Dam, a collaboration of organizations and state agencies negotiated an agreement, the LKRCHSA, leading to state ownership of the dam and securing of external funding for ongoing anadromous fish restoration. The agreement required installation of fish passage at seven dams along the Kennebec and funding for fish restoration, subsequently referred to as the "Kennebec River Watershed Anadromous Fish Restoration Program." The agreement also included funding for the downtown revitalization of the City of Augusta. The restoration program has been managed almost exclusively by state agencies with limited involvement with nonprofit organizations. At key times, however, multiple policy stakeholders, who had been involved in the original agreement negotiations became involved again to press for adherence to the agreement at certain pivotal moments. "[We] worked very, very hard to make sure that the letter of this agreement that the ladder was put in or the dam was taken out. We worked really hard for about six years, that is about how long it took."

Subsequent to removal of the Edwards Dam and the upgrades in water classification, Kennebec collaborations emerged around development of amenity infrastructure including trails and parks, imagining that this infrastructure might lead more directly to economic benefits for communities. One signature outcome was the development of the Kennebec River Rail Trail (KRRT), the result of collaborations among river municipalities, establishment of a memorandum of understanding among the communities to create the trail, and the formation of a new nonprofit to manage development and maintain the system. This arrangement of a new nonprofit formed and working collaboratively with a governing board of supervisors "is the first example in Maine of a regional trail" organized with this specific form of governance structure.

A third institutional response was the establishment of a watershed wide planning initiative that derived from a growing awareness of the river in the aftermath of water quality and restoration of native fisheries through state agency action. The Kennebec planning process, referred to as the Kennebec River Initiative (KRI) involved over 300 participants and resulted in a management plan to identify areas for protection, access and development and with the intent through convening stakeholders throughout the watershed, to create a longer term watershed institution to carry out the plan's goals. Despite a broad constituency that might evolve into a more permanent program focusing on the river, the effort ended when funding ran out. As one policy stakeholder described the process, "…so we had a series of meetings, pretty good meetings …We had [river] reach committees and then we had overall committees that met but beyond getting this report, there was no money."

Kennebec policy stakeholders involved with these institutional actions identified the lack of connections between the biophysical and social dimensions of restoration. A significant dimension of the argument for removal of the Edwards Dam was the economic benefits that could accrue from a restored fishery. Policy stakeholders pointed out that the potential economic benefits watershed wide and for the City of Augusta have not factored into the actual administrative aspects of the LKRCSH accord. The implications of restoration in the absence of considering social dimensions and potential benefits, had unintended consequences.

> I think (removal of the Edwards Dam) was the right thing to do on many accounts. The problem is the lay person who sees that nothing happened, and the promises were here and the results were there. It limits our opportunities to start to deploy what our vision as environmentalists could be. And it leaves a bad taste in some people's mouth. There was actually probably very little vision beyond removal of the dam.

Policy stakeholders have expressed frustration with the stalling of this work and the lack of a larger term vision that would result in economic development opportunities associated with restoration gains. “Everyone agreed that economic development was important and that it had to be tied to the river as a destination …So this is the part that didn't quite come together - an organized vision for making this happen.”

Policy stakeholders that point to the KRRT as one example of successful response to restoration gains, also identify limitations of what one project could contribute towards a broader vision of the river’s role in the regional economy, “I might say, let’s do trails, but you need to think of trails in the context of other things to achieve social, economic change. And without that, the trail building…is not going to achieve much in improving, significantly improving the economics of Maine.”

Although institutional actions successfully resulted in the achieving initial goals, implementation of a negotiated agreement for the purpose of anadromous fish restoration, development of amenity infrastructure, and development of a corridor plan that engaged multiple stakeholders, policy stakeholders stated that the challenge has been the lack of integrated vision that translated restoration gains into social and economic benefits. Policy stakeholders described the need to develop a comprehensive plan for integrating the social dimensions of restoration with the ecological gains that had been achieved.

> What is missing today are social and economic components to take advantage of that incredibly significant change. And that is where we need to sort of develop models…for social economic development, so that the river, which has been historically why all of these communities are here, can serve as a social, economic engine again. But the piece that is largely missing is no one knows how to integrate or relate, or create those relationships. The natural resources people think of biology and environment and tend not to think much about the social-economic aspects.

	Androscoggin (Impaired)	*Kennebec (Restored)*
Collective Action		
Water Quality Improvements	CSO removal (CWA) Advocate for water classification upgrades (MWCA) Land conservation Impaired stream plans (CWA)	CSO removal (CWA)
Restoration of Anadromous Fish	Barrier survey	Removal of 2 dams (FERC) Installation of fish lifts (FERC) Lower Kennebec River Comprehensive Hydropower Settlement Accord (FERC) Barrier survey
Community Investments: Shift Perception	Inventory of access points and signage Paddling events Greenway planning process	
Community Investments: Amenity Development	Petitioning for recreational access (FERC) Park and trail development Establishment of state park Development of head water conservation plan	Negotiations on water release for recreational purposes (FERC)
Institutional Level		
Water Quality Improvements	Formation of watershed wide organization to advocate for water quality improvements (CWA)	
Restoration of Anadromous Fish	Removal of dam (ESA) Monitoring of fish passage	Kennebec River Watershed Anadromous Fish Restoration Program (FERC)
Community Investments: Shift Perception	Source to the sea trek Annual conference Exploration of new boundary organization	
Community Investments: Amenity Development	Development of canoe trail	Formation of new organization for river trail development Watershed wide initiative to develop conservation plan

Table 1-2 Watershed actions and goals at collective action and institutional level

1.5 Discussion

Our study investigated feedbacks between the social and ecological dimensions of river restoration and the emergence and evolution of watershed collaborations at a collective action and institutional level in response to restoration state. Addressing our first question that explored the influence of biophysical, community attributes and institutional rules in use on restoration goals, we found that biophysical and community conditions interacted to influence policy stakeholders' goals. Further, policy stakeholders accessed institutional rules in use differentially for the purpose of achieving restoration goals in response to biophysical and community attributes.

Policy stakeholders invested in restoration actions in response to a shared understanding of the biophysical and social restoration potential. Previous studies have examined the discrete impact of biophysical and community attributes in shaping restoration goals (Bidwell & Ryan, 2006; Hardy & Koontz, 2010). However the interaction of biophysical and community attributes is also significant, for example, social factors can impede approaches for addressing biophysical challenges (Ananda & Proctor, 2013) and researchers have called for the need for collective actions response to a configuration of social and biophysical factors (Fryirs et al., 2013; Gregory et al., 2011; Ostrom & Cox, 2010).

We found that public perception and the existence of power asymmetries were important dimensions of community attributes in shaping restoration goals. A shared mental model of a natural resource system reduces transaction costs among stakeholders (Ostrom, 2009). Perception of water quality, connection to place, and integration of social values rather than over-emphasis on biophysical characteristics is key to engaging interest in restoration (Freitag, 2014; Lukacs & Ardoin, 2014; Spink et al., 2010). We found that place-making, scale, and social dimensions of restoration are important contributors to engendering public support. Perception shifting in the form of providing experiential knowledge of the river versus providing technical information reflected policy stakeholders' understanding of these variables in fostering supporting for restoration actions. Similarly, collaborations reasons for lobbying for water classification upgrades was linked to these the importance of place, scale and social values.

In addition to public perception, the existence of power asymmetries shaped restoration goals. Power asymmetries played out through the water classification and FERC relicensing processes, with removal of the Edwards Dam representing a significant shift in the control of the river by industrial interests. As a result, policy stakeholders could invest in continued restoration actions and identify opportunities for leveraging restoration gains. Prior literature on power asymmetries identify their role in water management and the ways in which policy stakeholders invest in gaining political power to further restoration goals (Lubell & Lippert, 2011; Lubell, 2013). Resource managers invested in actions to overcome power asymmetries, whether it involved convening a diverse group of stakeholders to mediate differences, or lobbying for changes in institutional rules rather at the expense of investing in actual restoration actions.

Institutional rules in use in the form of federal and state laws were applied consistently, but were leveraged very differently to achieve restoration by policy stakeholders in the two watersheds. Institutional rules in use can be as much of a determiner of the emergence and success of watershed collaborations as the underlying biophysical attributes and influences the ways in which stakeholders interact to achieve restoration goals (Hardy & Koontz, 2009, 2010). We found that collaborations access institutional rules in use to implement restoration actions, rather than being shaped by institutional rules in use and is dependent to some extent on the underlying biophysical state. While collaborations in the impaired watershed engaged with the FERC relicensing process to advocate for greater access to the river, collaborations in the Kennebec watershed engaged with the relicensing process specifically for the purpose of anadromous fish restoration. The result was greater opportunities for access in one and dramatic improvements in anadromous fish restoration in the other.

In responding to our second research question, we examined the impacts of the restoration state on the emergence and structure of watershed collaborations at the collective action and institutional level. Our research points to two key implications, the role of fractionalization in impeding progress and the efficacy of collaborations focused on discrete versus broader restoration goals.

Within each of the watersheds, collaborations emerged based upon identified restoration priorities and in both watersheds, there was limited interaction among these collaborations, leading to fractionalization. The Ecology of Game framework describes ways in which policy actors within a social-ecological system engage in different policy games to achieve discrete objectives, but due to bounded rationality have limited awareness of other policy games within the same arena, leading to fractionalization among collaborations organized to address resource challenges within the same watershed (Lubell et al., 2010; Lubell, 2013). Factors impeding restoration described by stakeholders often connected to one or more dimensions of ways in which hydropower controlled the biophysical characteristics of the river by impacting anadromous fish habitat and water quality, and social characteristics by affecting recreational opportunities. However, collaborations engaged separately, and at time at odds with each other, through completely different institutional rules in use to achieve dam removal, advocated for increased access, requested changes in water releases, or lobbied for water classification upgrades. As a result, watershed collaborations did not have the overview that they were engaging within the same policy arena to achieve restoration goals, working at times at cross-purposes, and resulting in fractionalization of effort.

Watershed collaborations that organize for the purpose of a discrete outcome such as dam removal to achieve anadromous fish restoration, can achieve dramatic success as evidenced by the restoration accomplishments achieved within the Kennebec watershed. However, in the long term, by focusing strictly on one dimension, ecological restoration, institutional capacity building towards restoration at a socio-ecological level may not occur. Developing flexible institutions to address water resource management from a social-ecological perspective through collaborative watershed management requires cultivating a broad base of stakeholders (Bidwell & Ryan, 2006;

Jacobs et al., 2010). Engagement of a broad base of constituents is a necessary step in developing institutions that can adapt to changing conditions and to anticipate social benefits that might accrue from ecological gains (Lebel et al., 2006; Young, 2010). Our research highlights the challenges of collaborative management structures that can integrate social and ecological goals into longer lasting institutions. Despite the identification of social dimensions as a key metric of success within the Kennebec watershed, establishment of longer term collaborations to address restoration through an integrated ecological and social lens have been elusive.

By examining the interaction between IAD variables and policy making in the context of watershed collaborations at differing levels of restoration, we contribute to a broader understanding of the interaction between social and ecological systems and the feedback systems that exist. Our research also highlighted the reality that biophysical potential and community attributes may result in the establishment of different baselines for systems, and policy stakeholders need to set restoration goals and measure restoration success accordingly. One of the broader lessons is the value of approaching restoration within a social-ecological systems framework. A more limited view of ecological restoration may result in dramatic achievements but potentially at the expense of a achieving advances within a more integrative social ecological system (Fryirs & Brierley, 2009; Gregory et al., 2011; Spink et al., 2010). The need for identifying potential social and ecological benefits of restoration, integrating sense of place and local knowledge, and engaging policy stakeholders can result in the creation of collaborations not only among policy stakeholders, but also across social and ecological divides (Gregory et al., 2011).

From an applied perspective, investment in perception shifting may have created more engaged and broader based collaborations that are more effective in the long run for leveraging biophysical restoration into social benefits. However, investment in perception shifting may come at the cost of achieving substantive progress on discrete restoration goals, such as dam removal or installation of fish passage. A second policy implication is existence of multiple collaborations or policy games within the larger context of restoration. Identifying connections among restoration programs, such as a comprehensive approach to managing river systems for ecological and economic value in balance with energy needs may require formation of bridging institutions that can serve to connect collaborations towards a unified vision of restoration.

As a case study of two discrete systems, our study is limited to examining two systems at different levels of restoration but at one specific point in time. A temporal analysis of systems that have undergone longer term restoration could further contribute to the feedback systems between restoration gains and goal setting, and the interaction between social and ecological barriers to and benefits of river restoration.

1.6 Conclusions

By examining how watershed collaborations implement goals and actions at the collective and institutional level in response to restoration gains, our research investigated the influence of the level of restoration on ways in which policy stakeholders established goals and implemented restoration actions. Our results identified a spectrum of restoration along which policy stakeholders will transition from “perception shifting,” investing in shifting perception to “amenity investment,” investing in amenities as a form of leveraging restoration gains. Although investment in perception shifting may seem to come at the cost of restoration gains, these investments engender the establishment of broader based constituencies that can serve to both sustain restoration progress and prove to be more integrative in terms of socio-ecological benefits. Redefining restoration to incorporate social and ecological systems at the outset provides the opportunity to invest in collaborations, set benchmarks for measuring success that incorporate both social and ecological systems, and create institutions that may be more adept in leveraging ecological gains into community benefits.

CHAPTER 2 - RIVER RESTORATION PATHWAYS: IMPLICATIONS FOR EMERGING BOUNDARY ORGANIZATIONS

2.1 Introduction

Since passage of the Clean Water Act in 1965, progress has been made on many fronts to restore the biological, physical, and chemical integrity of the United States' waterways (R. W. Adler & Landeman, 1993; Barbour et al., 2000; Norton et al., 2009). Yet, given the wide ranging roles these river systems occupy, the process of restoration has not been without controversy and challenges (Judd & Beach, 2003; Judd, 1990; Sabatier, Weible, et al., 2005; Wohl, 2005). Industrialized river systems have been particularly prone to resource management challenges, causing the impairment of vast stretches of the nation's rivers (Council on Environmental Quality (U.S.), 1971). Restoration of these systems have traditionally pitted resource managers against one other in promoting divergent and competing visions for river systems (Judd & Beach, 2003; Judd, 1990; Sabatier, Weible, et al., 2005; Wohl, 2005).

The establishment of effective collaborations between research scientists and policy makers is one mechanism for resolving resource management dilemmas (Guston, 2001; Osmond et al., 2010; Taylor & Short, 2009; White et al., 2010). Research scientists can lend neutrality, expertise, and address uncertainties within a complex resource system to these collaborations (Clapp & Mortenson, 2011; Karl, Susskind, & Wallace, 2007; Taylor & Short, 2009; White et al., 2010; White, Corley, & White, 2008). There are however, inherent challenges associated with these collaborations, specifically in managing the boundary between the research and policy-making process. Maintaining a boundary between scientists and stakeholders preserves the credibility of the research process and protects the researcher from political influences (Gieryn, 1983; Jasanoff, 1987; Michaels, 2009; van Kerkhoff & Lebel, 2006). At the same time, spanning the science-policy boundary can be critical in ensuring that research based knowledge is adequately informed by resource managers to ensure its salience and efficient support of policy making (Anderson, Michael, & Peirce, 2010; Bell, Lindenfeld, Speers, Teisl, & Leahy, 2013; Cash et al., 2003; Cash, Borck, & Patt, 2006; Clark & Dickson, 2003; Clark et al., 2011; Lyons, Leahy, Lindenfeld, & Silka, 2014).

Boundary organizations have received increasing attention as a means of facilitating collaborations between researchers and policy makers (Calhoun, Jansujwicz, Bell, & Hunter, 2014; Cash et al., 2006; Cash, 2001; Clark et al., 2011; Guston, 2001; White et al., 2008). A boundary organization is an institutionalized approach to convening policy stakeholders and researchers to address resource management questions, specifically in the face of changing ecological and social conditions (Clark et al., 2011; Guston, 2001). As one example of a boundary organization, cooperative extension services based at state universities serve as a bridge between university researchers and practitioners in addressing a wide range of resource challenges including water pollution (Osmond et al., 2010). Cash (2006) further refined the functions of boundary organizations as *convening* policy stakeholders and researchers, *translating* information across the researcher-practitioner boundary, facilitating *collaboration* towards development of joint outcomes, and *mediating* among competing perspectives and visions of the resource. Thus, boundary organizations enable researchers to both retain autonomy while actively working with stakeholders to coproduce salient knowledge about a given resource (Guston, 2001).

Our research examines the shifting boundary between science and policy, and the role of boundary organizations in facilitating exchange among researchers and stakeholders. The context of our study is boundary management within two watersheds that are similar in scale and regulatory oversight, but located at different points along the river restoration spectrum. By examining differences in boundary management within these watersheds, we explore how the underlying restoration state of river systems influences the emergence of boundary organizations.

Our research specifically addresses two primary questions: (1) what social and biophysical factors contribute to the emergence of boundary organizations to facilitate research-resource manager exchanges and (2) how does the restoration state of the underlying resource influence the relative emphasis on four functions of boundary organizations: *convening*, *translating*, *facilitating collaboration*, and *mediating*?

2.2 Literature Review

How collaborations between research scientists and resource managers come to exist is one area of increasing interest within the field of boundary management. Prior research on boundary management and boundary organizations has identified factors that provide the conditions for the emergence of formalized collaborations between researchers and policy stakeholders. In the context of natural resource management, these factors include perceived threats to a resource, the existence of conflicts among resource appropriators, availability of resources to invest in collaborations, and the existence of social capital and social networks among managers (Folke, Hahn, Olsson, & Norberg, 2005; Hutchins, Lindenfeld, Bell, Leahy, & Silka, 2013; Kallis, Kiparsky, & Norgaard, 2009; Lavina & Vaast, 2005; Lyons et al., 2014; White et al., 2008).

The presence of individuals with particular expertise in boundary spanning contributes to the emergence of boundary management processes, such as facilitating collaborations among researchers and stakeholders. Boundary spanners translate information across the science-policy boundary by effectively representing actors on each side of the boundary. By fostering trust, boundary spanners reduce transaction costs for participating in collaborations when perceptions of the underlying resource state differ (Freitag, 2014; T. R. Johnson, 2010, 2011). The field of technology-transfer has examined the role of students and work place mechanisms such as internships in facilitating boundary processes by strengthening networks between university and industry and lowering the cost for researchers and industry representatives to invest in collaborations (Peach, Cates, Jones, Lechleiter, & Ilg, 2011; Santoro & Gopalakrishnan, 2000; Suding, 2011; Thune, 2007; Whitmer et al., 2010). Although more recent sustainability science has identified a potential role of student learning opportunities as a boundary process, a gap exists in examining this role within the broader knowledge-action systems (Camill, Hearn, Bahm, & Johnson, 2012; Cook, Mascia, Schwartz, Possingham, & Fuller, 2013; Suding, 2011; Whitmer et al., 2010).

Boundary management research emphasizes the need for knowledge to be salient, credible, and legitimate while providing a means of addressing multi-scale systems that are dynamic (Cash et al., 2003; Clark et al., 2011; Folke et al., 2005; White et al., 2008). Less well understood is how the state of the underlying resource interacts with the role of science in the establishment and evolution of boundary organizations, and how the resource may play a factor in the emergence of the four major functional roles of boundary organizations: *convening*, *translating*, facilitating *collaborations* and *mediating* (Cash, 2001; Eden, Donaldson, & Walker, 2006; Freitag, 2014).

A challenge within boundary management is integrating multiple forms of knowledge, specifically knowledge derived from practitioners that may be more locally based and representative of the underlying status of the resource, with knowledge produced by research that provides knowledge at a systems level (Cash et al., 2006; Clark et al., 2011). Boundary organizations can play a key role in integrating these different forms of knowledge by *convenin*g researchers and resource managers. For complex resources systems, practitioners and researchers may have differing understandings of the state of the system. Boundary organizations provide a two-way flow of information between scientists and resource managers as a means by reconciling these differences by increasing communication, contending with uncertainty, and resulting in a shift in shared vision of the resource, leading to enhanced opportunities for collective action (Clark et al., 2011; Folke et al., 2005; Lebel et al., 2006; Miller, 2001; van Kerkhoff & Lebel, 2006).

Dynamic resource systems require flexibility in adjusting management goals. Boundary organizations provide a mechanism to facilitate *collaborations* as a means of moving participants towards agreement of shared management goals through the production of joint management plans, or boundary objects (Clapp & Mortenson, 2011). Boundary objects result in the coproduction of knowledge that can lead to the development of trust, social networks and resolution of seemingly intractable resource management dilemmas associated with complex systems (Clapp & Mortenson, 2011; Lejano & Ingram, 2009; Michaels, 2009; Rogers, 2006; White et al., 2010). The institutional arrangements provided by boundary organizations can lower costs of collaboration by providing opportunities for the coproduction of boundary objects in the form of scenarios, plans or data visualizations (Folke et al., 2005; Kallis et al., 2009). In developing relevant boundary objects, collaborations between researchers and stakeholders need to be responsive to changes in the underlying system.

The state of the resource can also influence the type of knowledge shared by researchers and stakeholders. Differing understandings of the resource state may require *translation* of knowledge across the boundary (Cash et al., 2006; T. R. Johnson, 2011). As the resource state changes, stakeholders' understanding of these changes may not align with researchers' assessment of these same changes. For example, improving water quality may be perceived differently by actors on both sides of the boundary (Freitag, 2014). In providing a structured means for translating information between researchers and stakeholders, boundary organizations can enable more efficient monitoring of resource state and adjustment of management goals as a result.

Boundary management recognizes a potential dichotomy between "policy-relevant" science in contrast to "pure science." Academic researchers are viewed as providing independence and rigor, while non-academic scientists provide day to day knowledge of a resource system (Eden et al., 2006). The legitimacy of boundary organizations rests in their accountability to both sides of the boundary and hence the inclusion of actors from both realms into the decision making structure (Cash et al., 2003; Guston, 2001). In contested resource systems, the role of science as a neutral voice can serve to *mediate* conflicts (Cash et al., 2006). Boundary organizations provide a means to assemble multiple parties towards a shared understanding of the resource system as a critical component of resolving resource dilemmas. Within the context of boundary work therefore, science is viewed as both an agent in the coproduction of knowledge, and an entity that that lends neutrality, particularly in arenas of conflict (Cash et al., 2006; Clark et al., 2011).

Understanding how boundary functions respond to shifts in restoration state is important to ensure that the production of knowledge is salient, credible and legitimate in addressing ongoing resource challenges. Our research develops an enhanced understanding of science's sometimes competing role in the production of knowledge as contrasted with the role that science plays in lending credibility, legitimacy, and mediating differences (Cash et al., 2006; Cash, 2001; Clark et al., 2011; Guston, 2001; White et al., 2008).

2.3 Methods

2.3.1 Study area

The study area is defined by the Androscoggin and Kennebec watersheds in the State of Maine, USA. Our research operationalizes the state of restoration within these watersheds as improvements in water quality and anadromous fish habitat. Although both systems have legacies as industrialized rivers, subject to the same federal and state regulations, the Kennebec has achieved a higher level of restoration. An inspiration for passage of the original U.S. Clean Water Act of 1972, the Androscoggin remains at the lower water classification level for 80% of its length, while the Kennebec has seen dramatic increases in water classification levels. Restoration of anadromous fish habitat has also advanced at a very different pace within the two watersheds following removal in 1999 of the Edwards Dam and subsequent removal of an additional dam and installation of fish passage at two other main stem dams (Crane, 2009; Robbins & Lewis, 2009). Despite progress, the full potential of the Kennebec has yet to be realized both in terms of anadromous fish restoration, and the translation of these water quality and fish passage improvements into social gains in the form of increased tourism and economic development for river communities. Our research traces the evolution of the emergence of boundary organizations within these two watersheds and the ways in which resource managers came to understand the role of science and envision the role of the boundary organization in addressing restoration challenges.

2.3.2 Data

Our research incorporates semi-structured interviews, document analysis, and participant observation (Glesne, 2010). We employ a case study method to examine the role of emerging boundary organizations over a three year period between researchers and resource managers in the two watersheds (Yin, 2009). We conducted forty-one semi-structured interviews with researchers and policy stakeholders in the two watersheds (14 from the Androscoggin watershed, 14 informants from the Kennebec watershed, 5 informants affiliated with state and federal level nonprofit or governmental organizations who could provide comparison of both watershed, and 8 researchers) using standard interview methods protocol (Seidman, 2006). Using purposive sampling, we selected key informants from organizations and institutions that were both engaged in river restoration actions and had worked with researchers. Interviews took between 45 minutes and one hour and were recorded and transcribed.

Our second source of data were documents associated with organizational meetings between stakeholders and researchers held over a three year period which provided additional sources of information. Documents included meeting minutes and planning documents, with content ranging from statements of vision and mission to specific stated goals. In addition, we conducted participant observation at 30 meetings held between researchers and stakeholder during the time period using standard participant observation protocol (DeWalt & DeWalt, 2011). The documents combined with observations provided the basis for examining how participants described the need for a new organizational structure and the value and need for participation by research scientists in the structure within each of the watersheds.

2.3.3 Analysis

We analyzed interview transcripts, documents, and participant observation notes qualitatively using NVivo 10 software (Saldana, 2009). To address our research question on the connections between the structure of boundary organizations and underlying restoration state of the resource system, we coded data inductively and deductively to identify distinct differences between the two watersheds associated with stakeholder perceptions of the two river systems, preferences for models for engaging with researchers, and vision for the role of an institutionalized "boundary organization" (Glesne, 2010; Miles & Huberman, 1994). We analyzed data inductively to understand differences between how informants described the state of "restoration" within each watershed and their vision for the systems and ways in which stakeholders described preferred models for stakeholder-researcher collaborations. Deductive codes based upon Cash's (Cash et al., 2006) definition of the role of boundary organizations provided insight on distinct differences between the watersheds (Miles & Huberman, 1994; Saldana, 2009). To evaluate for sufficient intercoder reliability, several coders analyzed portions of the transcripts in addition to the primary coder.

2.4 Results

Our results reveal distinct patterns in terms of the resource condition and boundary organizations. Although the state of restoration influences the predominance and role of certain boundary functions, some boundary functions transcend the restoration state. Informants conceptualized boundary processes as scalar. At an individual level, boundary processes created mechanisms to enable researchers and stakeholders to interact more frequently to coproduce knowledge. At an organizational level, boundary processes provided opportunities to advance restoration through improvements of natural and social systems.

2.4.1 Boundary organization functions influenced by resource.

Stakeholders and researchers articulated roles of a boundary organization that were distinct in two areas: the ways in which the boundary organization would engage with communities, and the role it would play in restoration of the natural system.

The goal of community engagement spanned from shifting perception of the general public to reflect current level of restoration achieved at one end of the spectrum, and at the other end of the spectrum to craft a vision envisioning the river in order to leverage restoration gains into community benefits.

Androscoggin policy stakeholders described a disconnect between the level of restoration achieved and the public's sense of the river as still polluted, preventing greater access and use of the river. Stakeholders emphasized that improving public perception of the river was a necessary step in developing a broader constituency to support continued restoration. A formalized collaboration between stakeholder organizations and academic institutions could provide opportunities for measuring shifts in perception. "If we are trying to understand people's perception of the river and their understanding of recreation or their use like before and after recreation experience, …we may have the skill set to get the families on river, but the college may have the skill set to develop the questionnaire that we could deliver." Policy stakeholders also described the need to disseminate information to help shift perception to align with current water quality and recreational opportunities. "The biggest I guess I would have to say the public just does not know all of the facts."

For Kennebec stakeholders, the lack of comprehensive vision of the river as an economic force was identified as a barrier to moving forward. "The promise is that if more is done, the public's appreciation of the value of the Kennebec as an asset will be enhanced and that a more valuable asset will drive prosperity for the people in the valley." Recognizing that earlier restoration successes had not translated into direct social benefit, informants described a new approach to awakening the communities to the river and assist in communities' reconceptualization of the Kennebec as an ecological, economic and community resource.

Researchers described the need to address the social dimensions of restoration along the Kennebec through addressing community development. "Within ten years I would like to see the greater community really understand that this is just a fantastic resource that we have." A collaboration could provide knowledge on models for leveraging restoration gains to "increase economic activity in a way that can be appreciated in terms of the things that municipalities as entities want to have happen."

At one end of the restoration spectrum, informants described goals of a boundary organization as focusing on water quality improvements, while at the other end of the spectrum, they described need for development of a comprehensive approach for creating amenity infrastructure. Androscoggin policy stakeholders identified the role of a boundary organization as evaluating and strategically identifying opportunities for continued restoration of the Androscoggin. The most significant challenges were improving water quality and restoration of native fish. Recognizing significant strides had been achieved, informants also acknowledged that future restoration measures would require substantial investments. Policy stakeholders stated the need to work collaboratively with research institutions to strategically identify restoration goals. "We have to understand the river today, and we have to know what it can be. Then we need to analyze, is that investment worth, is there going to be a return on the investment that makes it a worthwhile venture?"

As part of a visioning session for a boundary organization, stakeholders stated the need to understand the current status of water quality and implications for restoration of native fish. Policy stakeholders proposed that academic institutions could infuse resources into existing, but resource limited research programs. Policy stakeholders identified the need for continued engagement by academic institutions as a dimension of anadromous fish restoration. "It would be great to have partners with universities, in terms of monitoring, you know, pre- and post-removal,…kinda required for projects but you don't have a lot of resources to put into it so it would be nice to have partnerships."

Kennebec stakeholders described the major role of a boundary organization as developing asset infrastructure to support expanded economic development opportunities to capture restoration gains through conservation planning and downtown revitalization. "To accomplish landscape conservation, habitat protection, river restoration, and downtown revitalization recognizing the Kennebec as the regions premier quality of place asset."

From the perspective of policy stakeholders, the role of science was to prioritize asset development, in contrast with the Androscoggin stakeholders who identified the role of science as informing prioritization of restoration project. "If I can take this information and then use it to substantiate some of the initiatives that we want to get going here, in terms of our economy, in terms of our tourism, in terms of our recruiting marketing community – I can see lots of places for that." The mission statement for a proposed researcher-stakeholder collaboration identified developing a common vision for conservation to preserve and protect the corridor into the future as a priority.

Of the four boundary functions, *mediation* was most influenced by the underlying state of the resource and was most prevalent in association with the Androscoggin, the more impaired of the two rivers. In its place, innovation was a critical function of an emerging boundary organization as identified by Kennebec stakeholders.

Informants identified the overall outcome of formalized boundary processes as facilitating effective co-creation of salient knowledge about the current state of the river and potential achievable levels of restoration. Describing researchers as neutral actors, both in the roles they occupy and the processes they used to produce information, informants depicted coproduction of knowledge with active participation of academic institutions as being more credible in the public's eye as a result. "So having a university would certainly, I think most people would look at as a more independent review entity, or independent authority. I think would add some credibility to it." Researchers' perspective mirrored the value of maintaining neutrality, "Put science in a neutral ground where science can inform policy. We need bottom-up processes with science in the middle ground. Science is a neutral tool for the public to use."

Conceptually, academic research was valued due to its neutrality, but informants described varying perspectives on how easily neutrality can be maintained by all actors. Policy stakeholders pointed out that researchers may have varying biases that influence research outcomes. "An educational institution where ideally it's not someone with an agenda and I think at times, colleges and universities will do research with an agenda." How researchers work with the range of actors may also influence the credibility of the information produced, as a dimension of neutrality required active engagement with a wide range of actors. "Academics need to feel comfortable working with business and finding common goals."

While there was value placed on neutrality, informants describe differing perspectives on the role that researchers might play in furthering restoration. Initially, many policy stakeholders articulated the need for researcher and academic institutions to be more engaged as members of the community, particularly as advocates for restoration. "Push colleges in local area to address community issues." Researchers engaged in the process described a level of discomfort with balancing the role of research and engagement. "And it's challenging though because you have to be really careful and make sure you're doing objective research and not doing someone else's advocacy work."

During the course of the three year process, stakeholders moved towards describing the role of researchers as providing neutrality, facilitating participation of a broader base of policy stakeholders and mediating differing restoration goals. "The intention is to bring communities together along the river; offer neutral, unbiased forums about water quality, science, fisheries, economic development and other topics; coordinate research vital to all sectors; and educate and involve community members of all ages."

Informants also described a preference that researchers stay somewhat removed from restoration processes. "I think from a modeling standpoint it is best for the researcher not to become the practitioner. It allows you to stay apolitical which is a good place for an educational institution to be if they are the one doing the research… and they also have the ability to be objective to come back 10 years later and say let's revisit this and were the recommendations… followed and what did we learn from that." Similarly, informants described a preference for stakeholders to be somewhat separate from the research process to preserve credibility. "That's strictly professors, scientists, that is the only way you are going to get a reliable scientifically supported, peer review stuff."

Kennebec stakeholders describe researchers' roles as providing innovation. Given the challenges of leveraging restoration gains, informants identified the need for new and innovative approaches provided by academic institutions. Informants valued researchers' role in developing models that could translate restoration gains into economic development strategies for the corridor. "We think the work might benefit from the infusion of new ideas about how to approach this task." Reflecting frustration with earlier planning processes focused on the Kennebec corridor, stakeholders described the value of developing a collaboration with researchers as an opportunity to re-energize earlier planning processes and provide new insights on next steps. "With comparatively little going on in the way of conservation, land protection, and river restoration…, innovation in our approach to the Kennebec is a good and necessary thing."

2.4.2 Boundary organization functions that transcend resource management state

Many boundary functions leading to the formalization of researcher-stakeholder partnerships were not specific to the underlying restoration state. Development of formalized *collaborations* for the purpose of knowledge coproduction required not only investment of resources, but shared expectations of resource availability and requirements. Incorporation of academic research institutions had implications for *convening* a diverse group of stakeholders. Mechanism for *translation* of information across researcher-stakeholder boundary had certain commonalities regardless of the underlying state. Associated with each of these functions, informants in both watersheds identified boundary processes that include the role of students and development of more informal systems such as networks.

Policy stakeholders stated that more formalized collaborations enabled greater level of communication leading to improved management of the resource. "I think it's a matter of just working closely with whoever it is that you're trying to get the information…and the more time you spend the more, the more communication and understanding you have, I guess the more, the better the product it is you're going to get out of it." Researchers recognized that participating in collaborations enabled access to a broader knowledge base, a key component of producing knowledge that is more salient. "So instead of having a couple of opinions, it's actually like five or six and it's interesting to weigh those opinions against each other and what are the commonalities, what are not."

Policy stakeholders and researchers acknowledged the necessity of investing time in the collaborative process to build trust and craft a research process leading to production of legitimate and salient information. “But obviously it takes time to build up that trust; it’s not gonna happen the first meeting in.” Stakeholders and researchers believed that a greater level of trust also improves the quality of data shared across the boundary.

Both researchers and policy stakeholders described the challenge of finding a balance between investing time in developing partnerships to conduct collaborative research and requirements for their respective institutional demands. For policy stakeholders, time associated with developing formalized structures for policy stakeholders may come at the cost of demonstrable outcomes. “I really believe in collaboration and all of that kind of thing, but I also believe in getting things done. Kind of walking that line.” Researchers’ acknowledged the time required to build collaborations, but that the investment could serve as a barrier. “What I've found is that as an academic you kind of have a limited amount of time and energy. And getting these collaborations going off it takes time, and it takes face time in particular.”

There was a divide between researchers and stakeholders on the best way to move research forward. Although stakeholders generally stated that all phases of the research process should be collaborative, researchers expressed concern that stakeholders may not understand the research process sufficiently to develop a research question that is hypothesis driven. “And they don’t have the training to effectively identify a research question that’s researchable.” Similarly, informants acknowledged that structuring the research questions would benefit from input by policy stakeholders who better understood community needs. “So I think, yeah the questions seem to be generated in a collaborative fashion to ensure that both interests are met.”

Although both researchers and policy stakeholders pointed out the need for resources to create a new institutionalized structure, policy stakeholders perceived that academic institutions had more resources available to commit to the overall process. “They are part of these communities. They need to invest some money and create this entity whatever that is.” Although investment in community based research was valued, stakeholders also envisioned academic institutions as necessarily playing a larger role with greater investment of resources.

> I love community-based work, but on a big picture, it is not going to produce anything. This is a challenge for the college, a major player, partner in this effort, they potentially have the resources, they have the knowledge base, in terms of faculty and students, they have research abilities. And this is a challenge… they need to get their hands dirty.

Development of formalized collaborations to conduct research may require reconciling differing expectations between researchers and stakeholders regarding resource availability, time investments required, and shared ideas of the research process. Formalization of collaborations could be enhanced through development of agreements to clearly state objectives and expectations from the outset. "Well, coming up with a very defined set of parameters of where you are collaborating. What is in, what is out, then it gets easier able to call someone out for doing something outside of the realm of what was expected if they've agreed to parameters on the front end."

Policy stakeholders across both watersheds described students as playing a range of roles on both sides of the boundary. Both researchers and policy stakeholders' past experiences with students in facilitating collaborations across the boundary was resoundingly positive. Students' roles varied from participating in community based research within an academic institution, to based within a policy stakeholder organization as part of a fellowship. The opportunity for students to occupy a role within a policy stakeholder organization and a continued role within academic institutions benefited students personally through professional development and helped build capacity towards collaborations.

Policy stakeholders valued the role of students engaged in community based research as providing and synthesizing existing information. "She got copies of those student reports as well. They were wonderful to have. We'd have them come in, and a number of times, would make a presentation to the board." Policy stakeholders also described ongoing needs that formalized community based research might address. "I'm sure that an advisor and a grad student could find all sorts of things that would be worthwhile as far as a thesis project or summer research project here. And it you combine them all, that is how you create the body of knowledge."

Students provided new ideas and a level of enthusiasm policy stakeholder found particularly beneficial. "Every year I just couldn't wait for the students, because for one thing they'd bring such excitement and that young enthusiasm into it. Because you work at this and you get beaten down and worn out but these kids come in fresh and eyes wide open and excited and so I always try to have a whole list of projects available that they could undertake and really have meaningful input."

Stakeholders acknowledged the value of a formalized internship program in facilitating collaborations between policy stakeholders and researchers and among policy stakeholders to address restoration actions. "I also think the college's work in having shared interns and shared project across the region rather than our own single town has helped us to get together and work together. And also the project was a good vehicle for getting a bunch of stakeholders from that region talking together and planning together." In addition to what students provided, stakeholders also valued the investment on the part of colleges to ensure structured student programs were effective. "First of all, the students are fabulous. But also, the college provides such a great support for them, and has been incredibly productive. And it seems to be mutually beneficial."

Both stakeholders and researchers addressed concerns about demands of time and resources associated with student roles in boundary process. Although most policy stakeholders described positive experiences with these formalized programs, they also acknowledged the need to invest resources in developing opportunities for engagement and supervising students who worked with the organization. "They have been helpful to us on a host of fronts doing research… we're such a small organization… finding the best way to plug in student research that has value to the student and to us without it becoming cumbersome and sometimes it can be a challenge at times." For many academic institutions providing opportunities for student engagement through internship or service programs requires administrative time.

The overall positive experiences led to policy stakeholders identifying the value of an organization that could more efficiently link the student experience in the form of internships or community based research to restoration needs. Academic institution participants stated that an organizational structure that could provide a steady source of ideas for internships would be beneficial. Working group members identified students' potential roles in a boundary organization, as "Engage students as emissaries to reach out to stakeholders. Make it a full-on student engagement, where they lead, not just follow." In exploring opportunities to house a new organization within an academic institution, institutional support required specifically that, "it must involve students."

Although development and management of student engagement requires time on the part of academic institutions and organizations, collaborating for the purpose of managing these experiences provides opportunities for stakeholders and researchers to meet to share information and exchange ideas, providing greater opportunity to coproduce knowledge. As one informant stated, "And so in my opinion, the best way to get research that both fulfills a professor's need and a community need is to sit down together to discuss that and to talk about what's important to both of those entities and how they could do some work that's going to provide helpful information for both of them."

What is critical in terms of implications for boundary management is the ability for students to move back and forth across the boundary, the benefits gained by the academic institution and the organization, and finally the need to invest on development and management of these structures, providing opportunities for collaboration between researchers and policy stakeholders.

Informants in both watersheds described the need to bring together a broader base of stakeholders in order to more fully realize the potential of the resource. For Androscoggin stakeholders, convening a more diverse group that includes academic institutions encouraged participation by stakeholders in what has been viewed as contentious former collaborations. The boundary organization was described as achieving, "…collaborative, collective action, enhance current relationships, develop new relationships (where they may not have been formed), find new ways of working together." The vision held by the policy stakeholders is one of a river that meets and balances a multitude of users. Multi-uses include "…industrial, hydro, water recreation, commercial fishery."

For Kennebec stakeholders, a boundary organization would provide opportunities to bring many groups together in order to better leverage restoration gains. As part of the mission statement crafted by participants, the value of sustained engagement across many sectors was "…to take action on multiple fronts involving multiple partners."

In both watersheds, informants valued the role of a potential institute as connecting the many policy stakeholders and the collaboration that exist among them. Recognizing redundancies as well as fragmentation of efforts, policy stakeholders identified the need for an overarching entity that can better connect efforts. "And in some ways, an umbrella type of organization has to kick the towns in the rear end in order to get on board with a greater vision for the river."

Stakeholders and researchers within both watersheds did not necessarily see the need for a new organizational structure. Instead, informants described the need to better connect existing initiatives through the creation of a network. Networks were also perceived in certain ways as a more positive alternative to a new entity as it would not compete for resources. At the same time, networks may not be perceived as being as legitimate as a formalized institute .

Organizing documents for a new Androscoggin boundary organization describe its role as serving as a hub for the many existing organizations and collaborations and serving in the role of convening discussions. "This group could provide the backbone (hub), but NOT the work. The role would be to "convene the conversation" around the issue." Similarly, a description of a river network along the Kennebec described as easier to develop and maintain than an entirely new organization. "The group agreed to explore the clearing house idea in depth. It discussed using a social media approach as the vehicle for the clearing house on the basis of it being less expensive to establish and maintain." With fewer online resources available about the river, Kennebec stakeholders stated that a network could serve as a clearing house of information on the river.

In addition to convening a broad base of stakeholders, the advantages of a network would be to enable collaborations to compete more efficiently for resources. In both watersheds, informants identified the need for new approaches to access resources that included both financial resources, and human capital. Policy stakeholders all shared the belief that a new organization would provide a new approach for efficiently attracting funding targeting broader based collaborations as well as additional funding that researchers might access. Informants viewed a network as better addressing opportunities for leveraging resources in an environment where competition for limited resources was already tight, "Elevate the power of grant applications." The converse of this potential benefit was the concern shared by many stakeholders that a new entity would compete for resources. "What remains to be seen – is there leadership that can bring in additional funding so everyone benefits – more research, larger pot of funding, etc."

Informants across both watersheds consistently identified translation as a key function in synthesizing existing information and disseminating information to the general public. "So I think a lot of the research has been done in pieces, I think there is going to be a need if that is the direction that we go for someone to begin to pull it together. And synthesize and that kind of thing."

Despite an identified lack of time, informants valued face to face opportunities for information dissemination. An advantage of face to face dissemination was the opportunity for information sharing and knowledge coproduction through convening stakeholders with a range of understanding of the underlying systems. "Having researchers go to meetings, ..listening in both directions is useful.. [Stakeholders] may say…either information or questions that may prompt a researcher to say, this is great, we should consider spending a little more time on this issue, I think it can work both ways."

Meetings were also valued as a means of building relationships and for many policy stakeholders, a more effective way of having knowledge translated. "A place where you can go and get additional information and be able to ask questions and have interaction with person with the person that pulled the information together." For several stakeholders, concerns were expressed about the technical nature of information contained in written materials and a preference for opportunities in a more interactive way to gain a greater understanding of the river system.

Policy stakeholders placed less value on traditional research outputs such as journal articles. "A paper that would appear in a peer reviewed journal that would appear in a fisheries journal about fisheries biology or something, we don't end up reading those things." Instead, stakeholders emphasized a need for more summary documents and executive summaries and events such as symposia to supplement journal articles. "It'd be nice to have more condensed, easier-to-understand because, a lot of times, with the academic research, it's really dense so getting it in easy-print, easier-to-read format for citizens and stuff would be helpful but also having research symposiums or special presentations where the researchers can go into more depth, I think it would be helpful as well."

2.5 Discussion

Our study examined factors that influenced the emergence of stakeholder-researcher collaborations and the roles that the underlying restoration state played in influencing boundary processes and functions. We found evidence of the interaction of the four functions (convening, translating, collaborating, and mediating) and the underlying restoration state in influencing boundary processes. Our first objective was to examine social and biophysical factors that contribute to the emergence of research-stakeholder partnerships. Our research indicated that there is a scalar dimension to these collaborations (Table 2-1).

	Resource State Dependent **Impaired** — **Restored**	**Transcends Resource State**	**Resource State Dependent** **Impaired** — **Restored**	**Transcends Resource State**
Scale	**Individual Actors: Coproduction of Knowledge**		**Organizational Structure: System Improvements**	
Convene				Convene multiple stakeholders Development of network as organizational structure
Collaborate	Produce shared model of restoration that integrates social and ecological functions Develop economic models for leveraging restoration gains	Student role Trust building Effective communication	***Engagement with social system*** Shift Perception Envision as Asset ***Engagement with natural system*** Natural System Restoration Asset Development	Student role
Translate		Interaction for the purpose of sharing information		Dissemination of information to the public through on-line and face to face communication
Mediate			Lend neutrality and credibility to organization	
Innovate			Source of innovation	

Table 2-1 Boundary functions by scale and state of restoration

At the level of individual researchers and resource managers, collaborations can lead to coproduction of knowledge that is more salient, credible and legitimate. Collaborations at an individual scale benefit from the investment of time required for trust building, for developing a common language, and shared understanding of research questions, but these investments may also serve as barriers (Cash et al., 2006; Clark et al., 2011). Institutional structures such as boundary organizations with active participation by researchers and stakeholders can address resource challenges by convening a broad base of stakeholders, translating knowledge, and mediating differences among multiple resource appropriators.

Barriers to collaboration at an institutional level include differences in institutional incentives for researchers and stakeholders, and the need for resource investments to establish entities such as boundary organizations (Cook et al., 2013; Lyons et al., 2014). Our research supports the benefits and challenges inherent at both levels. Researchers and stakeholders both acknowledged the value of investing time for the purpose of developing trust. However stakeholders struggled with balancing time required for trust building with time needed to achieve measurable outcomes, while researchers expressed concern about the time required to carry out credible research with research outcomes that the collaboration could point to as shared success.

In our case policy stakeholders and researchers had differing expectations related to resource investments necessary for both knowledge coproduction and ultimately establishment of more formalized structures for longer term collaborations. In convening a broad base of actors, boundary organizations have provided opportunities to expand resource availability in the form of technical knowledge and financial resources associated with participants' networks (Folke et al., 2005; Guston, 2001). For many informants, an institutionalized collaboration represented an opportunity to access resources in forms such as possible grant opportunities for innovative organizational structure encompassing academic institutions and stakeholder organizations.

However, creation of a new organization requires investment of resources that may ultimately be diverted from priorities on either side of the boundary, such as research grants or funds to support restoration projects (Cook et al., 2013; Kallis et al., 2009). Concerns about resource availability and differing expectations about the respective contributions made by participants can negatively influence boundary processes (N. Adler, Elmquist, & Norrgren, 2009; White et al., 2008). Stakeholders believed that academic institutions should be more engaged in establishing a new organization and expressed the hope that involvement of academic institutions would potentially lead to investments in the institutional structure of the organization.

Our research identifies an important role for students as a component of boundary ordering processes. Prior literature has identified the role of boundary objects such as data repositories models, and the role of boundary spanners in facilitating effective partnerships by serving convening researchers and stakeholders across the boundary (Cutts, White, & Kinzig, 2011; Freitag, 2014; T. R. Johnson, 2011; White et al., 2010, 2008). The field of knowledge transfer or regional innovation has implications for sustainability science in terms of the ways that students and formalized internships can facilitate researcher-stakeholder collaborations (N. Adler et al., 2009). Studies on university-industry collaboratives have identified the role of students and internships as providing motivation for industry and university researcher to enter into partnerships with benefits that accrued to both industry and university representatives. Students serve as a key channel for knowledge transfer, and a critical component of building and strengthening networks between researchers and industry representatives (Ramos-Vielba, Fernández-Esquinas, & Espinosa-de-los-Monteros, 2009; Santoro & Gopalakrishnan, 2000; Thune, 2007).

Across both watersheds, informants identified students as occupying a unique role by providing a source of innovation, and lowering the transaction costs for researchers and stakeholders to collaborate. Mechanisms for student engagement represented a shared space where investments by both sides of the boundary were valued, policy stakeholders as supervisors, and academic researchers as mentors. Students play a unique role as transitory agents with an ability to seamlessly travel across the academic-practitioner boundary, serving more of a role as boundary "sojourners" than boundary worker. As students do not have the expertise or agency associated with the boundary spanner role, they potentially occupy a role distinct in boundary management processes. To some extent the mechanism of student development may serve as the convener as much as the student themselves. Both stakeholders and researchers described the benefits of collaborating in development of the student experience, which may play a role closer to that of a boundary object.

Our second research objective was to examine how the underlying restoration state influences specific boundary functions (Cash et al., 2006). Institutional structures such as boundary organizations with active participation by both researchers and policy stakeholders can play varying role in addressing resource challenges by *convening* a broad base of stakeholders, *facilitating collaborations*, *translating*, or disseminating knowledge, and *mediating* differences among multiple resource appropriators, particularly as management or ecological systems shift (Calhoun et al., 2014). The state of the underlying resources plays a factor in how functions play out at each of these scales, but particularly emphasized at the organizational level.

The role of science within emerging boundary processes varied across the two watersheds in response to differing restoration states. Within the Androscoggin watershed, *collaborations* were often for the purpose of shifting perception or investing in restoration actions. Kennebec informants described the need to facilitate *collaborations* around investments in assets and developing models for communities to leverage restoration gains. In contrast, *translation* of science across the boundary from policy stakeholder to researcher was consistently identified as important by stakeholders within both watersheds as achieving similar purposes.

The role of *mediation* occupied differing role in how stakeholders envisioned the structure of a boundary organization in furthering restoration gains. Mediation was more important within the Androscoggin, the site of prolonged contested battles over restoration actions. While Androscoggin stakeholders identified the role of academic researchers as lending neutrality and thereby increasing credibility of the organization among a wide range of stakeholders, language on mediation and neutrality was largely absent among Kennebec policy stakeholders. Instead, we found evidence of a newer function, that of innovation, for systems that are not necessarily impaired but stalled in achieving longer term goals.

Moving collaborations forward towards an institutional level such as a boundary organization is challenging. There can be a gulf between willingness to participate by researchers and stakeholders, expectations of what each group is willing to invest in terms of time and resources, and payoffs that accrue. Stakeholders may not willing to continue to meet without a specific outcome. For academic researchers, investments must be tied to funding requirements or rewards provided from their academic institutions through funding, promotion, or requirements to participate in engagement.

Development of clear goals and identification of expectations associated with time investments, resources and anticipated outcomes be discussed at the outset. First, expectations regarding outcomes and success need to be clearly articulated. For academic institutions, outcomes are tied to development of research programs and publication of results (Lyons et al., 2014). For stakeholder organizations, outcomes are tied to tangible results, which may or may not align with the research process (Cook et al., 2013). Policy stakeholders may need to readjust timelines for measuring "success" and recognize the production of peer reviewed knowledge may not respect the schedule of restoration outcomes. At the same time supporting concrete measures of restoration gains may require diverting resources away from producing peer reviewed information. One approach may be to create memorandum of understandings as formalization of researcher-stakeholder partnerships are explored.

The influence of underlying state of the resource on boundary processes should be considered. Beyond their traditional role of producing knowledge, researchers may be ascribed a role that can facilitate larger boundary processes among stakeholders. For example, stakeholders both identified the value of scientific inquiry but also identify the role of researchers in lending neutrality. For researches who conceptualize stakeholders as an aggregated group, understanding how the state of the underlying state may influence the ways that participants visualize the role of collaborations and maintaining boundaries is critical. The goals of stakeholders themselves may change from resolving conflicts and advocating for improvements, to developing innovative solutions for leveraging restoration gains. As roles of policy stakeholders and their goals change, the role occupied by researchers and hence the institutional structure may need to evolve.

To lower the resource demands for institutionalizing collaborations, actors should identify boundary processes that allow collaborations using existing mechanisms. These include broadening the models for information exchange, through revamping symposia to include practitioners, and to include researchers in the development of conferences sponsored by stakeholders. A second mechanism is expanding the role of students as boundary sojourners. An intentional program that successfully connects work based experiences with independent research into the academic year may have the potential of serving as a convening function. This function has been successfully employed in the technology transfer field but largely overlooked in sustainability science. The opportunity to bring researchers and stakeholders together through the student experience enables the potential of knowledge coproduction by connecting practice based and research based pedagogy. Developing these approaches may be a necessary first step to providing increased opportunities for engagement between researchers and stakeholders, which is a necessary part of building the base for a boundary organization.

2.6 Conclusions

Addressing resource challenges, such as restoring river systems, or leveraging restoration gains can benefit from active collaborations between researchers and policy stakeholders. Formalizing boundary processes through establishment of new structure such as a boundary organization has implications for managing the boundary and provision of resources towards achieving restoration goals. Our research focused on a case study of two river systems in Maine at differing locations along the restoration spectrum. Future research is needed to explore shifts in boundary processes through a state change within one resource system and an examination of boundary processes in a range of resource systems undergoing state changes. A second area of future research is to examine the role of students as "boundary sojourners." In examining the role of students within boundary management processes, it will be important to identify the specific and unique roles of student learning across the academic-practitioner boundary, and the power asymmetries students may experience as relates to questions of boundary work. Understanding this difference has implications for boundary management in terms of investing in the students as actors or boundary spanners, or investing in fellowships as a boundary object to enable enhanced opportunities for researcher-stakeholder collaborations.

The role of the boundary organization needs to be clearly defined and can be influenced by a range of factors including the underlying state of restoration. Laying out expectations initially may enable all participants to clearly state vision, availability of resources including in the form of human capital, and what actors must gain in order for the processes to be supported. As restoration gains are achieved, these functions may need to be reevaluated as well as the role of the individual actors themselves in response to state change.

CHAPTER 3 - DISAMENITY TO AMENITY: SPATIAL AND TEMPORAL PATTERNS OF COMMUNITY RESPONSE TO RIVER RESTORATION PROGRESS

3.1 Introduction

River communities have long managed river systems to capture a wide range of societal benefits, including power generation, transportation of goods, and a readily accessible source for disposal of wastes. A legacy of industrialization of river systems has led to direct community benefits such as expanded local economic opportunities but sometimes at the cost of the impairment of vast stretches of the world's rivers. Investments in restoration stem from growing awareness of rivers' broader ecological, and physical, and social functions, and reconsideration of the social value of rivers to river communities. At a global level, many countries have adopted legislation to restore the biological functioning of river systems. For example, the European Union 's Water Frame Directive establishes water quality goals through management of rivers at a basin level to restore rivers to previous ecological status (Everard, 2012). Likewise, in the United States, passage of amendments to the Clean Water Act in 1972 initiated a multidecade-long process of river restoration. As restoration processes change, the biophysical and social roles of river systems within river communities continue to evolve over space and time. As rivers emerge from decades of impairment and shift from disamenities to amenities, assessment of river restoration progress provides critical information to resource managers and offers a mechanism for advancing understanding of the alternative futures of river communities and river systems.

While there is an extensive literature on biophysical benefits of improvements in river systems, no comparable literature in terms of breadth and depth exists on social responses to river restoration (Westling, Lerner, & Sharp, 2009). As river systems move along the continuum from impaired to restored states, significant positive benefits may accrue to river communities (Everard & Moggridge, 2011). Social benefits of river restoration include enhanced quality of place, expanded tourism, and economic development opportunities (Ayalasomayajula, Jeanty, & Hitzhusen, 2007; Everard & Moggridge, 2011; Hitzhusen, Ayalasomayajula, & Lowder, 2007; Howard, 2008). These social benefits may trigger further restoration actions, such as the establishment of conservation and recreation areas along restored river corridors. In turn, river restoration also imposes social costs by attracting development in the form of impervious surfaces with consequent impact on water quality, gentrification of river corridors as these areas become more attractive locations to live, and loss of jobs from traditional industries relocating away from river communities (Eckerd, 2010; Everard & Moggridge, 2011; Gould & Lewis, 2012; Hong et al., 2009). The extent to which restoration processes deliver positive net benefits to river communities and society at large can greatly influence the trajectory of river systems and their social and biophysical roles.

Prioritization of restoration projects has relied to a large extent on ecological, physical, and technical benefits due to a lack of comprehensive understanding of social benefits (Westling et al., 2009). One notable exception is economics valuation work that has greatly informed assessments of major public projects such as dam removals or changes in national water quality regulations and standards (Hitzhusen, Kruse, Abdul-Mohsen, Ferreti-Meza, & Hnytka, 2007; Robbins & Lewis, 2009). While some social science research examines resident perceptions and preferences for restored systems (Tunstall, Penning-Rowsell, Tapsell, & Eden, 2000; Wagner & Gobster, 2007), there remain numerous uncertainties regarding public support for restoration measures more generally (Everard & Moggridge, 2011; Suding, 2011; Westling et al., 2009). The lack of comprehensive documentation and understanding of social impacts undermines advances in our conceptualization of river systems as dynamic social-ecological systems, and therefore problematizes project and policy evaluation. In this manuscript, we bring attention to the importance of an improved understanding of the dynamic nature of restoration and associated social impacts such as improved community wellness or expanded development. We advance suggestions for improved metrics of restoration progress and social responses to river restoration (Everard & Moggridge, 2011; Suding, 2011; Westling et al., 2009). An enhanced understanding of the nature and triggers of different types of social feedbacks could better inform assessments of river restoration projects by focusing attention on the range of the patterns of restoration and potential outcomes from restoration projects, and the dynamic impacts of changes in public support for further restoration actions.

The consideration of rivers as natural amenities and the consequent impact of amenities on regional community and economic development processes presents a useful framework to begin further examination of the social dynamics of river restoration (Kim, Marcouiller, & Deller, 2005; Marcouiller, 2004). The literature on shifting social preferences points to the value of investments in restoration in influencing social preferences to move river systems further along the continuum of river restoration (Gobster, Nassauer, Daniel, & Fry, 2007; Gobster & Westphal, 2004; E. S. Johnson, Bell, & Leahy, 2014a; Westling et al., 2009). Another, complementary perspective suggests watershed collaborations establish amenities in response to environmental improvements such as improved water quality to provide access to better capture amenity value of restored systems (Deller, Lledo, & Marcouiller, 2008; Eden & Tunstall, 2006). Our research addresses gaps in understanding of river restoration progress by focusing on the interaction between restoration level and the point at which communities start to invest in amenity development and start to re-conceptualize river systems. We add to the literature on feedback systems between river restoration and social responses by examining the interactions among water quality improvements, and amenity investments, and landscape changes associated with amenity investments.

Connecting restoration progress with social response at a community scale raises many interesting challenges. Identifying an understandable metric for restoration progress is the first step in understanding the linkage of biological and physical dimensions of river restoration to how communities start to re-conceptualize and use rivers. Upgrades of river system classification levels provide an excellent means of tracking restoration progress. Geographic information systems (GIS) offer a means to organize these data and jointly with statistics provide tools for assessing patterns over space and time. Developing a metric for measuring amenity development in response to discrete shifts in water regulation and quality is a second important component of exploring the linkage. We consider the potential for measures of landscape change and investments in recreational facilities in areas adjacent to rivers to serve as such metrics. Analysis of landscape patterns in land cover through the use of spatial metrics and mapping enables examination of shifts in urbanization and identification of emergence green open spaces in response to broader community scale changes (Buyantuyev, Wu, & Gries, 2010; Guneroglu, Acar, Dihkan, Karsli, & Guneroglu, 2013; J. Li, Li, Zhu, Song, & Wu, 2013; Tian, Jim, & Wang, 2014).

Our research contributes to the literature on social dimensions of restoration by comparing patterns of water quality improvements in the form of classification upgrades across two river systems. Two objectives drive our research: (1) assessing restoration progress by documenting the spatial-temporal pattern of water classification upgrades in two river systems in Maine and (2) assessing patterns of social responses to river restoration using quantitative measures of amenity investment and land cover change. We explore conceptually the interactions between restoration measures and mechanisms by which communities choose to invest in amenity supply and capture. Specifically, we report on empirical analyses that examine over space and time changes in river segment water classifications, amenity investments/infrastructure, and changes in surrounding land cover. We complete our empirical analyses at two spatial scales, along river corridors and across river communities. We present data on shifts in water classification levels, the spatial and temporal pattern of amenity creation, and shifts in land cover patterns at these scales.

3.2 Background

Amenities are defined as "location-specific" public goods that make a location an attractive place in which to work, live and recreate. Amenities such as parks or lakes impact local economies by attracting tourism and influencing the in-migration of retirees and/or residents (Goe & Green, 2005; Howard, 2008). Conversely, disamenities such as urban congestion have social implications such as discouraging inmigration (Eckerd, 2010; Shumway, Otterstrom, & Glavac, 2014; Weiss et al., 2011; JunJie Wu & Plantinga, 2003).

As natural resources are finite and therefore typically non-producible, the supply of natural amenities can only be the result of a gradual transformation of existing resources, shifts in community perceptions towards existing natural resources, or policies that result in a reconceptualization of a natural resource as an amenity (Åberg & Tapsell, 2013; Deller, Marcouiller, & Green, 2005; Irwin, Jeanty, & Partridge, 2014; Marcouiller & Clendenning, 2005; JunJie Wu & Plantinga, 2003).

Natural amenities are also non-tradable, and as a result, regions make investments for the purpose of expanding access and promoting natural amenities through the development of amenity infrastructure or “built amenities”. Built amenities to improve access include the provision of recreational services, parks, trails and access points such as marinas. As a result, few models that examine the influence of amenities are based solely on the presence of natural resource attributes or “natural amenities,” but also incorporate the interaction between natural amenities and “built” amenities (Deller et al., 2008; Irwin, Randall, & Chen, 2008; Marcouiller & Clendenning, 2005; Marcouiller, 2004).

The temporal nature of amenity development is an important component of understanding the interaction between amenities and rural development. Marcouiller and Clendenning (2005) propose that the Environmental Kuznet Curve (Figure 3.1) can provide an explanation of the temporal nature of amenity development and serve as a theoretical framework for understanding the capture of amenity demand. At certain stages, communities may value natural resources, such as rivers, for providing services such as power generation or waste disposal which result in modification of these resources, as has occurred in the industrialization of river corridors. As communities rely less on these resources as sources of power or for waste disposal, social preferences shift, and the amenity value of these resources increases and consequently amenity management starts to become a priority (Åberg & Tapsell, 2013; Marcouiller & Clendenning, 2005). An examination of amenity development in the context of river restoration is particularly relevant. As one form of a natural amenity, river systems are somewhat unique in requiring creation of proximate build amenities such as expanding river access or provision of riverside trails to increase awareness of the resource s (Marcouiller & Clendenning, 2005).

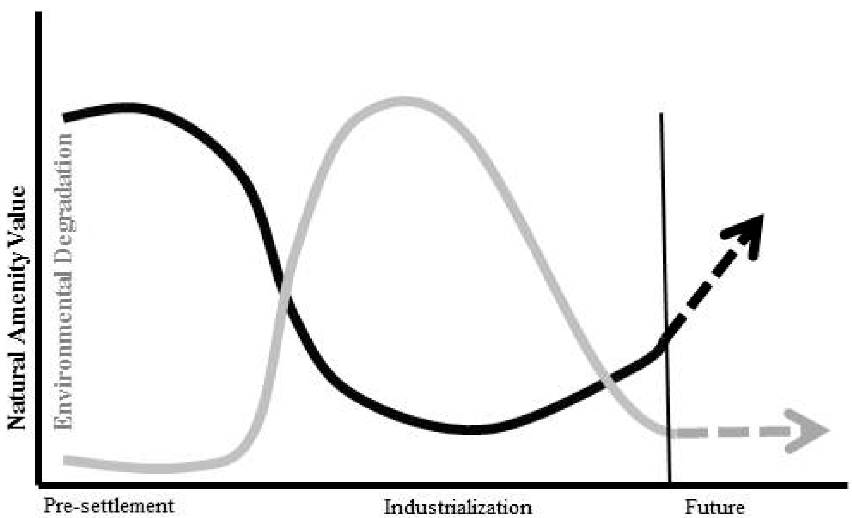

Figure 3.1 Environmental Kuznet curve. Adapted from Marcouiller and Clendenning (2005).

Integrating a temporal dimension also has direct implications for the consideration of restored river systems as amenities. Impaired river systems, which are the result of historical legacies of industrialized pollution and channelization, have historically been considered a disamenity. Conversely, restored river systems are often considered natural amenities as they can provide a wide range of societal values including recreational opportunities and scenic views (Everard & Moggridge, 2011; Lee & Lin, 2013; Lewis & Acharya, 2006; Westling et al., 2009). Nonetheless, the future trajectory of many river systems remains uncertain, and it is unclear to what extent the Kuznet curve applies across systems and within river systems across multiple spatial scales.

Similar to policies that facilitate conservation of open spaces or change the status or management of federal, water policy can influence amenity supply by ratcheting up water quality improvement levels and ensuring long term maintenance of these levels. In the United States, water classification of river systems provides a mechanism by which states can manage portions of river systems for specific uses and adopt management strategies to ensure that river systems meet these management goals. Classification and management aimed at recreation uses such as swimming, fishing, and boating has the potential to influence the range of goods and services provided by river systems and other related amenities.

Shifts in community conceptualization of rivers as disamenity to amenity can trigger positive feedback loops that serve to enhance rivers as natural amenities. For example, establishment of built amenities such as parks and trails in proximity to restored river systems can contribute to public health outcomes, enhanced well-being, and aesthetics (Boone, Buckley, Grove, & Sister, 2009; Comber, Brunsdon, & Green, 2008; Gobster et al., 2007; Jorgensen & Gobster, 2010; Westling et al., 2009). As populations become healthier and scenery improves, use of parks and trails near rivers may increase, offering further momentum to river restoration efforts and expanded engagement with river restoration programs. Shifts in community conceptualization can also trigger negative feedback loops. Improved river systems may attract residential development along river corridors. Increases in impervious surfaces associated with such development can adversely impact water quality.

There has been limited research on feedback loops between dynamics of ecological improvements of river systems and the point at which these restoration measures translate into investment in amenity infrastructure. (Che, Yang, Chen, & Xu, 2012). Whereas extensive lines of research employ statistical and spatial methods to examine the impacts of land use and cover on water quality, far less research applies these same approaches to consider the impacts of water quality on land use and land cover (Irwin et al., 2014; Linke, Pressey, Bailey, & Norris, 2007; Zhou, Wu, & Peng, 2012).

Landscape pattern analysis provides a means of examining emergence of urban green space and quantification of landscape changes adjacent to river systems (C. Li, Li, & Wu, 2013; J. Li, Li, Zhu, Song, & Wu, 2013; Park, Hepcan, Hepcan, & Cook, 2014; Jiayu Wu & Thompson, 2013; Zhou et al., 2014). Further, landscape metrics offer a means to quantify and compare such patterns across river systems and at multiple spatial scales. Landscape metrics have been employed to characterize patterns of green spaces in terms of correlations between composition and shape of recreational areas and value for recreation and community wellness, documenting that heterogeneous, more complex landscapes provide greater opportunities for interaction with green spaces (Chen, Yao, Sun, & Chen, 2014; Cho, Poudyal, & Roberts, 2008; Guneroglu et al., 2013; Kong, Yin, James, Hutyra, & He, 2014; Liu, Wang, & Chen, 2010; Tian et al., 2014). Together, insights from the natural resource amenity, water policy and classification, and landscape change literatures provide a solid foundation for our empirical analyses.

3.3 Methods

3.3.1 Study area

With a 40 year history of water quality monitoring and classification, Maine, USA provides an excellent setting in which to develop and explore the interaction between water classification as a form of amenity supply and community responses in the form of built amenities and land cover change. Maine’s Androscoggin and Kennebec rivers (Figure 3.2) define the study area for this research. These two rivers share similar historical legacies as industrialized rivers that have also witnessed dramatic improvements in ecological function and water quality (Crane, 2009; McFarlane, 2012). There are a total of 39 municipalities adjacent to the rivers in our study area. These communities range from small rural towns with populations less than 1,500 to communities with manufacturing industries and paper mills.

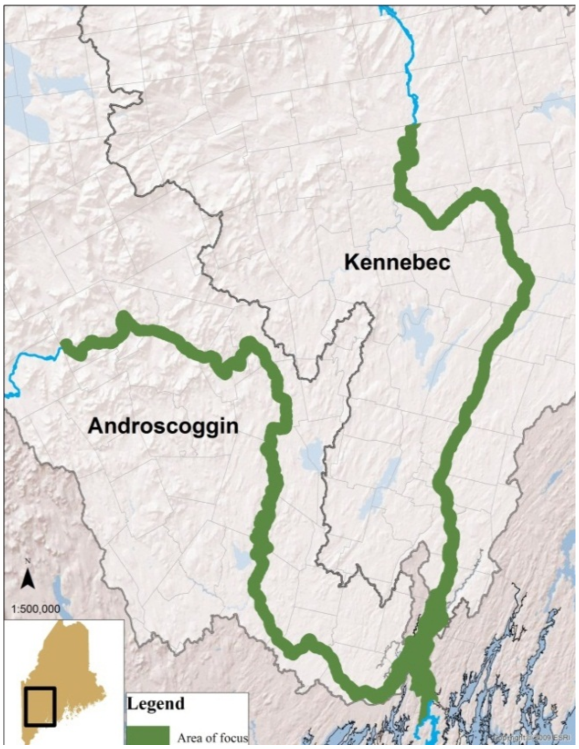

Figure 3.2 Study area

The trajectory of these rivers has been influenced by distinct differences in their physical characteristics due to significant differences in power generating capacity and differences in flow volume. This dimension of the biophysical differences factors into larger regulatory and classification levels (Davies et al., 1999; Maine Development Commission, 1929; Wells, 1869). As early as the 1950s, these rivers were at the center of ongoing conflicts between industry and recreationalists amidst a growing re-imagining of the economy of the state and its natural resources. The State of Maine's regulation of water quality, is nested within a broader national regulatory structure for managing river systems at an individual unit based upon established management goals derived from current water quality (R. W. Adler, 2014; Andreen, 2003; Judd, 1990). At an international level, management of Maine's river systems correlates to approaches contained within the European Union's Water Framework Directive (Liefferink, Wiering, & Uitenboogaart, 2011; Ravenscroft & Church, 2011).

Maine was one of the first states to adopt water classification standards and has managed water classification levels continuously since the late 1950s (Barbour et al., 2000; Courtemanch et al., 1989; Davies & Jackson, 2006; Judd, 1990). Most of Maine's water bodies had designated classifications by the mid-1950s and many of these recommendations were enacted into law by the late 1950s. In the early 1960s, the Kennebec was the first industrialized river in Maine to be classified (Judd, 1990). In establishing its recommendation for water classification levels for the Androscoggin, the Water Improvement Commission of 1966 based its level upon the river's recreation potential and not current water quality, reflecting an emerging understanding of the role of rivers within the state's tourism economy (Maine Water Improvement Commission, 1966).

The Maine Water Classification Act of 1965 established a four tiered classification system (Table 3-1) based upon existing biological conditions and the potential for achieving the highest water quality with classes ranging from the lowest water quality classification level requiring no water quality improvements (class D), to the highest water quality classification level (class A) (*Water Improvement Commission Revised Statutes*, 1965).

The 1987 Maine Water Classification Act revised the biological and management standards by introducing a new biological criteria component and now requiring that all water bodies meet the 1972 CWA standards at a minimum (Courtemanch, 1995). From 1987 forward, Maine operationalized water quality standards through a four tier classification system ranging from the lowest level quality level meeting federal standards (class C) to highest standard denoting pristine water levels (class AA). River sections maintained at a class C level from 1965 to current day would as a result be regulated more stringently due to the administrative changes deriving from the 1987 law (Courtemanch et al., 1989; *Water Improvement Commission Revised Statutes*, 1965). Drawing on these water classification data, we compare and contrast outcomes across the two river systems using different spatial units to represent our study systems. We track water classification shifts at a scale of individual river segments. We summarize built amenities across land parcels located within a 1000 meter buffer. Lastly, we examine shifts in land cover at the watershed scale and on lands located within a 1000 meter buffer of the rivers.

Time Period	Class	Management	Impact	Performance/ Integrity
1965-1987	**D**	Primarily devoted to the transportation of sewage and industrial wastes without causing a public nuisance	None	None
	C	Satisfactory for recreational boating, fishing and other uses except potable water supplies and swimming, unless adequately treated to meet standards	DO regulated depending upon river	None
	B2	Acceptable for recreational boating, fishing, industrial and potable water supplies after adequate treatment	DO and coliform standards	None
1987 to present	**C**	Suitable for the designated uses of drinking water supply after treatment; fishing; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation	DO with temperature standards, coliform standards	Sufficient to support indigenous fish species, species composition may occur, but structure and function of aquatic life maintained
	B	Suitable for the designated uses of drinking water supply after treatment; fishing; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation	DO and coliform standards	Sufficient to support life stages of all indigenous species, only non detrimental changes in community composition may occur.
	A	Suitable for the designated uses of drinking water disinfection; fishing; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation	DO and coliform as naturally occurring	Aquatic life as naturally occurs

Table 3-1 Water classification standards as applied to study area

3.3.2 Data creation and analysis

To construct shifts in water classification levels from passage of the original 1965 law, we examined legislative documents for references to river segment description and classification assigned. Since 1965, there have been 12 revisions at the State level either through legislative changes in classification levels or through administrative changes by the Maine Board of Environmental Protection, of these, 8 revisions had a direct impact our study area. For each segment referenced, we compiled classification level, and date of change. Using ArcGIS10.1, we assigned classification levels and dates of classification shifts to river reach segments from the USGS National Hydrological Data set (NHD) for the Androscoggin and Kennebec main stems. Within our study site, we considered a change in class such as from class D to class C as an upgrade, while considering shifts resulting from the 1987 law (class C in 1965 and class C in 1987) as reclassification. We aggregated classification upgrades and reclassifications by type, date, and length at the reach level and at a municipal level.

Once established, we generated descriptive statistics on upgrade levels at different scales, including working with corridor-scale, individual river segments, and aggregated at a community community-scale data. We compared these upgrade changes with changes in levels of amenity development and landscape characteristics. To examine spatial and temporal shifts in water classification, we created maps of water classification shifts and compared these spatially with changes in amenity development.

To characterize built amenities near rivers we assembled the location of infrastructure in the form of parks, open space, trails and boat launches intended to enhance recreational opportunities next to or on the river systems. To develop this database, we first identified land parcels within 500 meters of the two rivers (Androscoggin communities, n=12,254 parcels; Kennebec communities n=14,371). We then examined ownership data from individual towns' assessor databases of all publicly owned lands including location, date of transfer, and land use to determine if the parcel was an amenity (e.g. park) (Androscoggin communities, n=468 parcels; Kennebec communities n=486). In some cases, river amenities were not included in town level GIS data sets, such as trail easement held by a nonprofit organization such as a land trust. To address this concern, we examined state spatial data sets of state parks, conservation areas and boat launches and spatial database records of regional conservation organizations to identify additional amenities such as boat launches, state parks or regional recreational sites for location and date of establishment. Finally, we verified locations in the field by mapping and recording attribute information along the river corridors.

As the footprint of amenity infrastructure varied from one boat launch to a full trail corridor, we mapped these data as vector data to capture the area of the amenity and assigned amenity type and date established (pre-1965 to present day).

We generated descriptive statistics of amenity development at total number established, area of land converted to amenity infrastructure, and percent of amenity lands as a percentage of total land available within the buffer during set time intervals that aligned with water classification upgrade intervals. To examine spatial patterns we mapped the location of amenities over time and generated point density statistics.

To examine patterns among water classification and adjacent land cover we used remotely sensed data to characterize landscape differences between the two watersheds and along the river corridors at a scale of a 1000 meter buffer and at a community scale (Gatrell & Jenson, 2008; Hoalst-Pullen, Patterson, & Gatrell, 2011; Pearsall & Christman, 2012). We assembled available NOAA's Coastal Change Analysis Program (C-CAP) data sets for the time intervals of 1996, 2001, 2006, and 2010. The C-CAP data have been used to examine spatio-temporal shifts in land cover and for land use management (Ellis, Spruce, Swann, Smoot, & Hilbert, 2010; Erickson, Lovell, & Méndez, 2013; Thatcher, Brock, & Pendleton, 2013). As land use decisions are established at a local level and influenced by ownership at a parcel level, we selected a buffer distance of 1000 feet to establish a distance that would encompass parcels located within 500 meters of the river (Lieske & Gribb, 2012; Zhou et al., 2014). We combined land cover categories to differentiate vegetated (agriculture, forest, grassland areas) and developed or non-vegetated areas to examine changes in developed areas as a proxy for increasing development, and vegetated areas to examine patterns of green spaces.

To explore potential relationships between water classification shifts and land cover shifts, we employed the FRAGSTATS software package (McGarigal & Marks, 1995) to examine the composition and patch shape of areas proximate to the river. Based upon prior research examining the characteristics and patterns of green open space, we selected patch density (PD), mean patch size (MPS), percentage of landscape (PLAND), and largest patch index (LPI) to compare landscape composition (Guneroglu et al., 2013; Ji et al., 2006; C. Li et al., 2013; McGarigal & Marks, 1995; Park et al., 2014; Tian et al., 2014; Zhou et al., 2014). These metrics afford a means of comparing differences between developed and vegetated areas (forested, agriculture, grasslands/parks), to determine if these land cover types were more or less fragmented, or conversely, exhibited patterns of aggregation. For developed areas, lower patch density are an indication of infill development due to patterns of fewer and larger patches (Ji et al., 2006). Infill development or aggregation of green spaces could indicate emergence of amenities such as parks.

Patch and class shape metrics provide insight on potential anthropogenic impacts on the landscape, such as elongated patches that might indicate the presence of river side trails. We selected shape metrics including landscape shape index (LSI), area weighted mean radius of gyration, (GYRATE-AWM), and area weighted mean fractal dimension (FRAC-AWM) (Gatrell & Jenson, 2008; J. Li et al., 2013; McGarigal & Marks, 1995; Shi, Sun, Zhu, Li, & Mei, 2012; Shrestha, York, Boone, & Zhang, 2012). Patches with more complex shapes, signaling trail corridors for example, may provide greater amenity value to the public over smaller and fragmented green spaces (Tian et al., 2014).

We computed each landscape metric at a class level for our four identified land cover categories (forest, agriculture, vegetated, developed) at a corridor (1000 m) scale and at a scale of community level for each of the 39 communities adjacent to these river systems in our study area. Finally, we examined spatial statistics for each of these metrics over time scales and across the two watersheds at a corridor and community level to identify trends in landscape patterns. We also compared and contrasted these results with changes in water classification and amenity development.

3.4 Results

3.4.1 Water Classification Upgrades

Patterns of water classification upgrades have varied distinctly between the two river systems from 1965 to 2010. While the classification of the Androscoggin in our study area has consistently remained at the same level (class C) level since the main stem was first classified the 1960s, upgrades have occurred along all of the Kennebec during the same time period (Figure 3.3). Further, the patterns of these upgrades have exhibited heterogeneity along the stretch of the river's length (Figure 3.4).

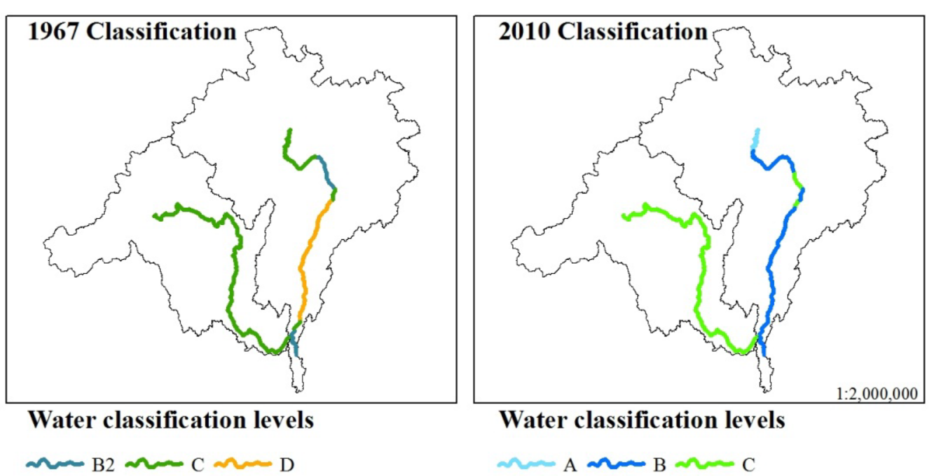

Figure 3.3 Water classification levels, 1967 and 2010

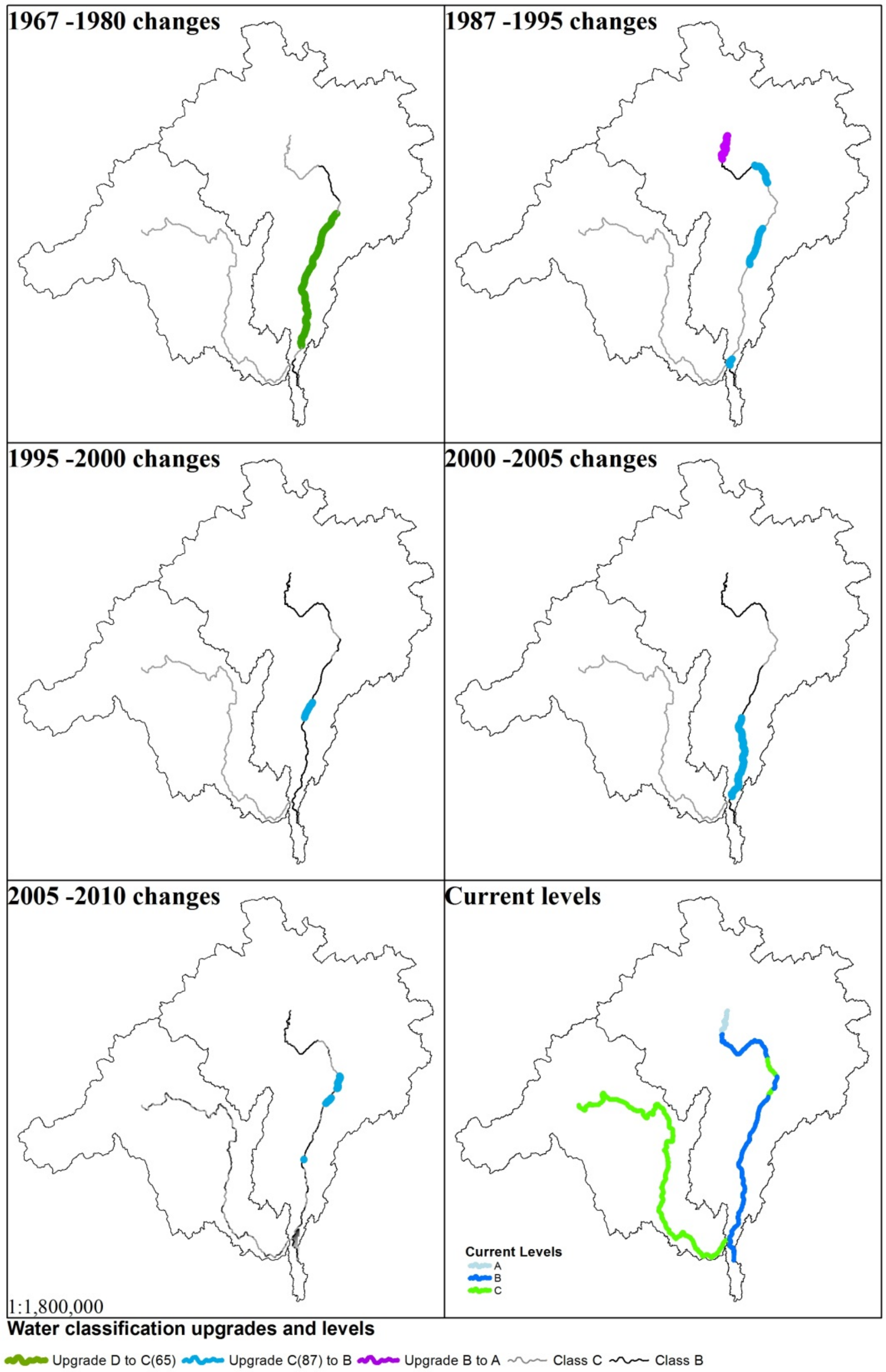

Figure 3.4 Water classification shifts, 1967 to 2010

Since passage of the original 1965 Water Classification Act, water classification through legislative and agency actions along the two rivers has taken a dramatically different course. Along the Androscoggin portion of our study area, there have been no upgrades. Along the reach of the Kennebec river within the study area, there have been water classification upgrades at every legislative opportunity from 1965 (Figure 3.4). In 1965, the Kennebec was the first major industrialized river in Maine to receive a water classification level, receiving the lowest classification along significant stretches. By 1969, all of these river segments had been upgraded to more stringent regulatory levels.

With passage of the Water Classification Act of 1987, all former water classification levels were revised to the current legislation's standards. As the water quality standards in 1987 were more stringent in the 1987 law, this in essence translated into a water classification upgrade for all regulatory water bodies. Within our study area along the Androscoggin, all segments were classified at the lowest classification level established by the 1987 legislation (Table 3-1). Along the Kennebec, many portions were classified to this same classification with upper portions reclassified to a higher class within the first few years after passage of the law but upgraded two years later. Within 12 years, all but 8% of the Kennebec in our study area was upgraded to class B.

3.4.2 Measuring Amenity Development

We identified a total of 338 discrete river amenities (river side parks, trails and access points) with a total area of 10,879 acres within our study area. Of these 281 sites were established since the mid 1960s. As of 2014, there are greater numbers of amenities along the Kennebec (174) as compared with the Androscoggin (164) (see Table 3-2). However, overall acreage of amenity infrastructure is greater along the Androscoggin (5,626 acres) as compared with amenities along the Kennebec (5,253 acres). Controlling for area within the two corridors, a slightly greater percentage of land is dedicated to recreational uses (6.1%) along the Androscoggin compared with the Kennebec (5.5%) (Figure 3.5).

The most significant difference is the trajectory of amenity creation along the two rivers. Establishment of amenities along the more impaired of the two systems proceeded at a faster rate in one decade with the number of amenities along the Androscoggin jumping up sharply. Starting in the early 1990s to a point in 2000, amenity investment in the Androscoggin watershed jumped up sharply. As a result, by 2000, there were an equivalent number of as many amenities along the Androscoggin as along the Kennebec. From 2000 to 2010, there were an overall increase in the number of amenities along the Kennebec.

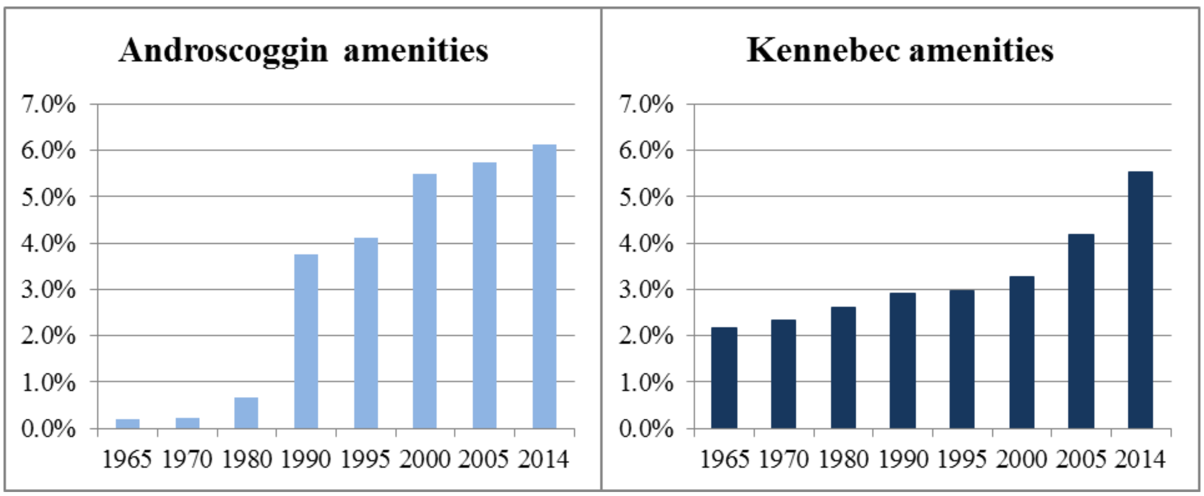

Figure 3.5 Amenities (percent of total acres) within buffer (1000 meters)

		Total 1965	**65-70**	**70-80**	**80-90**	**90-95**	**95-00**	**00-05**	**05-10**	**Total 2010**
Androscoggin	class C(%)	100	100	100	100	100	100	100	100	
	Amenities (#)	23	13	7	24	24	28	22	23	164
Kennebec	class D (%)	42								
	class C (%)	37	71	71	40	34	30	14	8	
	class B (%)					60	50	64	70	
	class A (%)					16	20	22	22	
	Amenities (#)	34	7	10	40	13	15	19	36	174

Table 3-2 Water classification levels (percent) and amenities (sites established during time period)

We found diverging spatial temporal patterns within the two study sites, with complex relationships between water classification shifts and amenity investment, and greater investment in amenity infrastructure at certain time intervals within communities proximate to impaired river segments. Examining the spatial distribution of amenity infrastructure, Androscoggin river amenities are distributed along the river length during the 1970s and into the early 1990s. (Figure 3.6, Figure 3.7). During the period from 2000 to 2010, establishment of amenities has primarily taken place along the lower portions of the river. Similarly along the Kennebec, amenities emerged along the length of the river from the 1970s into the late 1990s. From 1990 to 2010, while Androscoggin amenities have been more concentrated in the lower portions, Kennebec amenities continued to be established along the entire length of the river. In comparing establishment of amenities with water classification upgrades along the Androscoggin, amenity creation proceeds despite the lack of shifts in classification levels. Along the Kennebec, the pattern of amenity establishment appears to track water classification upgrades to some degree.

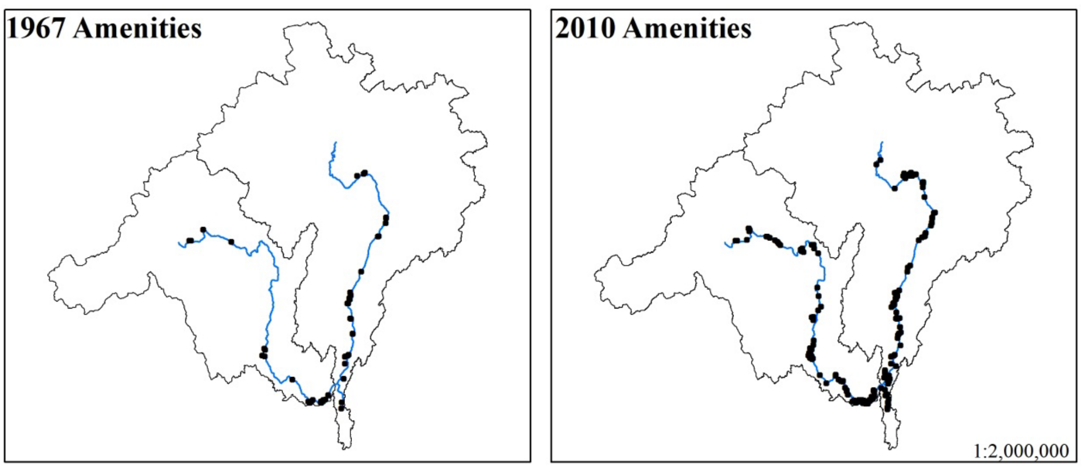

Figure 3.6 River amenity locations

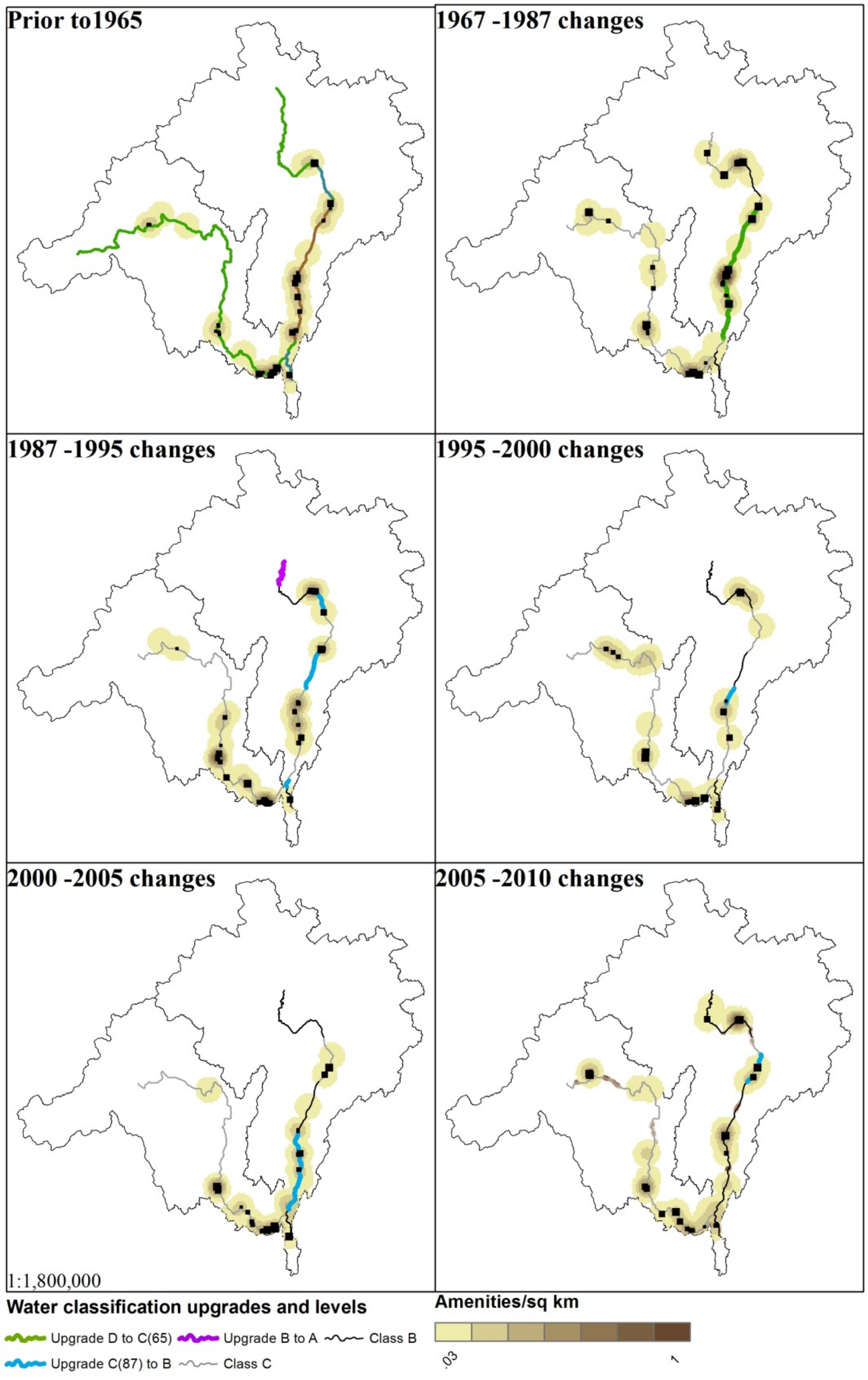

Figure 3.7 Spatiotemporal patterns of water classification upgrades and amenity density (square meter)

3.4.3 Landscape characteristics

We found many similarities and a few distinct differences in comparing landscape metrics across the two watersheds. The Androscoggin buffer had a slightly greater percentage of green areas (forested, agriculture, vegetated) in comparison with the Kennebec buffer (Figure 3.8). Between 1996 and 2010, there was little change in percentage of land cover within the two study areas at the scale of the 1000 meter buffer. Within the Androscoggin buffer combined forested, agriculture and vegetated area decreased from 69.0% to 68.5% while these combined areas within the Kennebec buffer decreased from 64.1% to 61.5%.

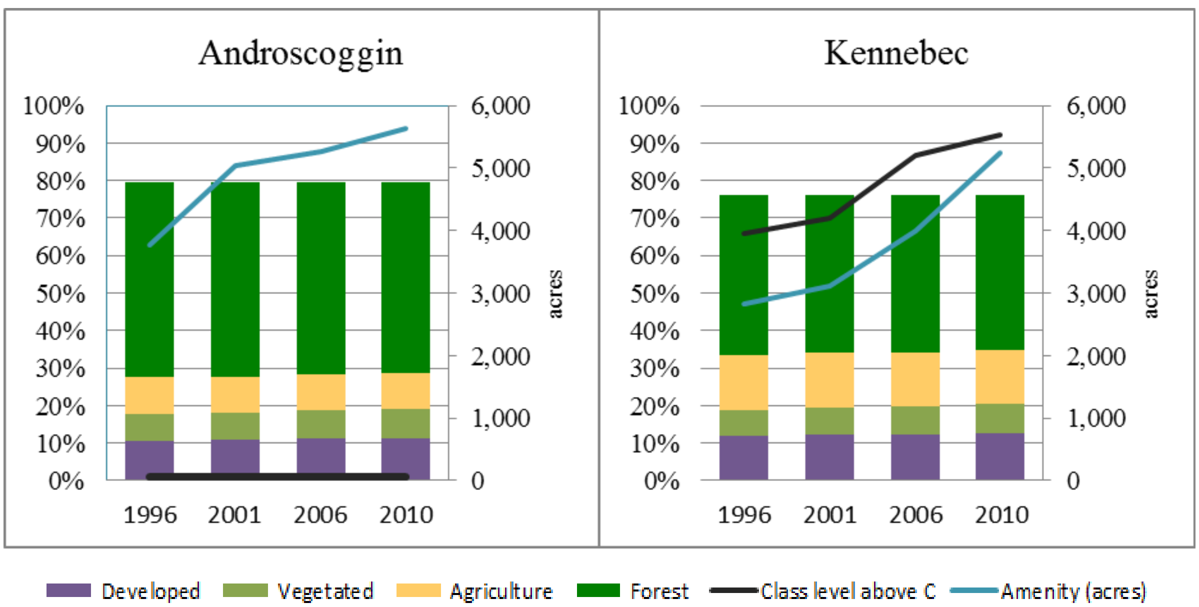

Figure 3.8 Percent land cover (PLAND), percent classification levels above C, and amenities (acres) within buffer (1000 meters)

During this same time interval, developed areas within the Androscoggin buffer increased from 10.6% to 11.2% while developed areas within the Kennebec buffer increased from 11.9% to 12.6%. Visually, these patterns show limited interaction with changes in amenity infrastructure and water classification levels. In both watersheds during this same time period, there was a comparable increase in land converted to amenity infrastructure from 3,770 acres to 5,626 acres within the Androscoggin and an increase from 2,825 to 5,253 acres within the Kennebec. While the Kennebec had increases in water classification levels from 66% of the river above class C levels to 92% of the river above class C, the Androscoggin classification levels were maintained over this time period.

Our analysis of landscape composition metrics provided additional insights on landscape patterns over time near these river systems. For both watershed buffers, patch density is greatest for vegetated (non cultivated grass areas, parks), which might represent either smaller sized parks along the corridor, or potentially patterns reflecting urbanization, with a higher percentage of patch density within the Androscoggin (Figure 3.9). The level of patch density has not varied between 1996 and 2010. Mean patch size is also greatest within the Androscoggin corridor and exhibits slight decrease from 1996 to 2010 (Figure 3.9). Within the Kennebec corridor, MPS is comparable for developed and forested, showing a slight increase in patch size for developed areas. Although the largest class type by percent within the Kennebec watershed is forested areas, values for largest patch index (LPI) are comparable with developed areas (Figure 3.9). A lower LPI indicates greater fragmentation of forested and developed areas within the Kennebec buffer as compared with forested patches within the Androscoggin.

We selected several metrics to evaluate patch complexity and shape as a potential proxy for trail corridors and parks. Values for Landscape Shape Index (LSI) are comparable among the two watersheds and were consistent over the time period of 1996 to 2010. Higher values for vegetated patches indicate that these areas have more complex shapes than other land cover types. These higher values for LSI also point to a greater degree of complexity of the Kennebec river corridor landscape in comparison with the Androscoggin river corridor (Figure 3.10).

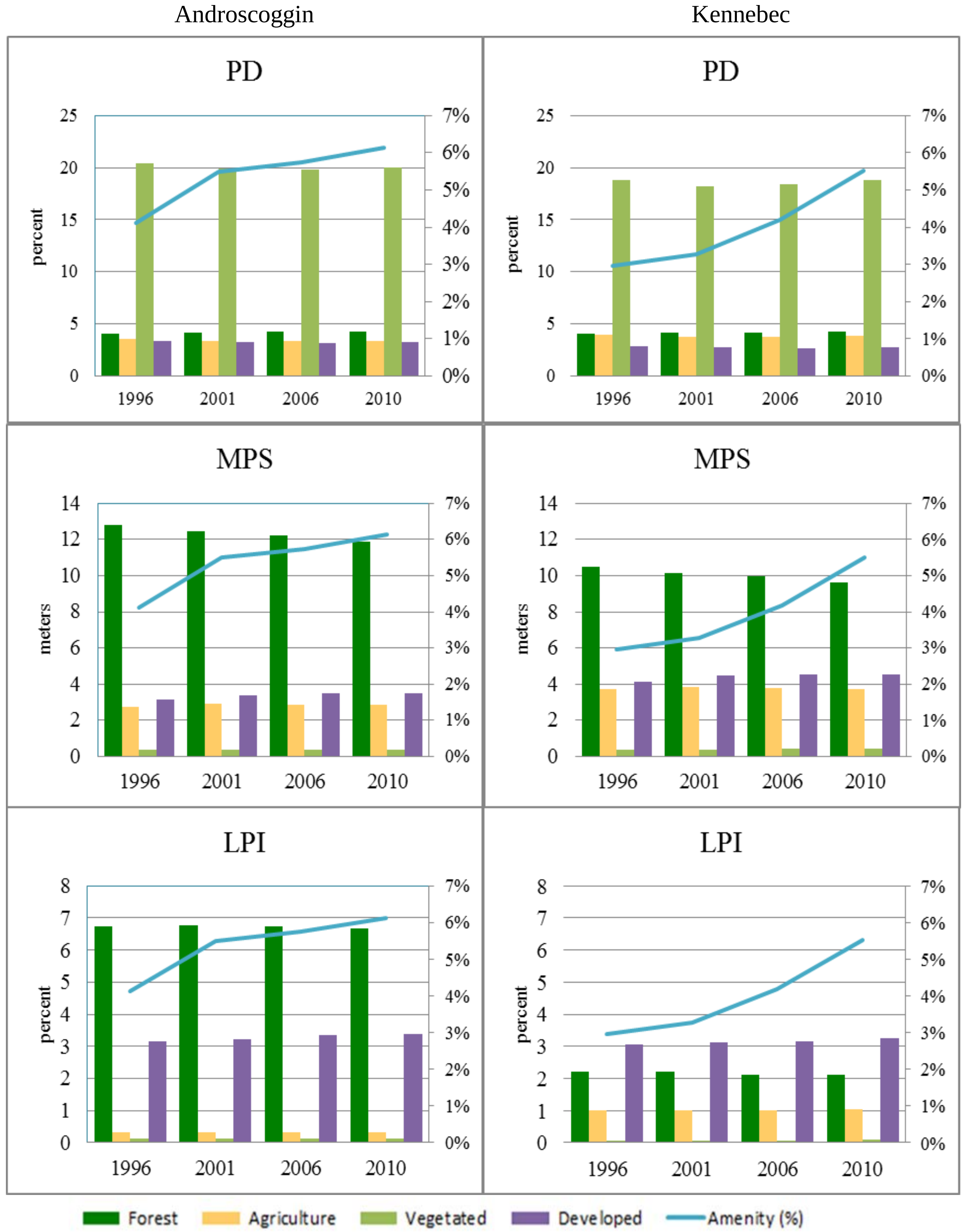

Figure 3.9 Land cover composition metrics and amenity change over time (percentage of total area) within buffer (1000 meters)

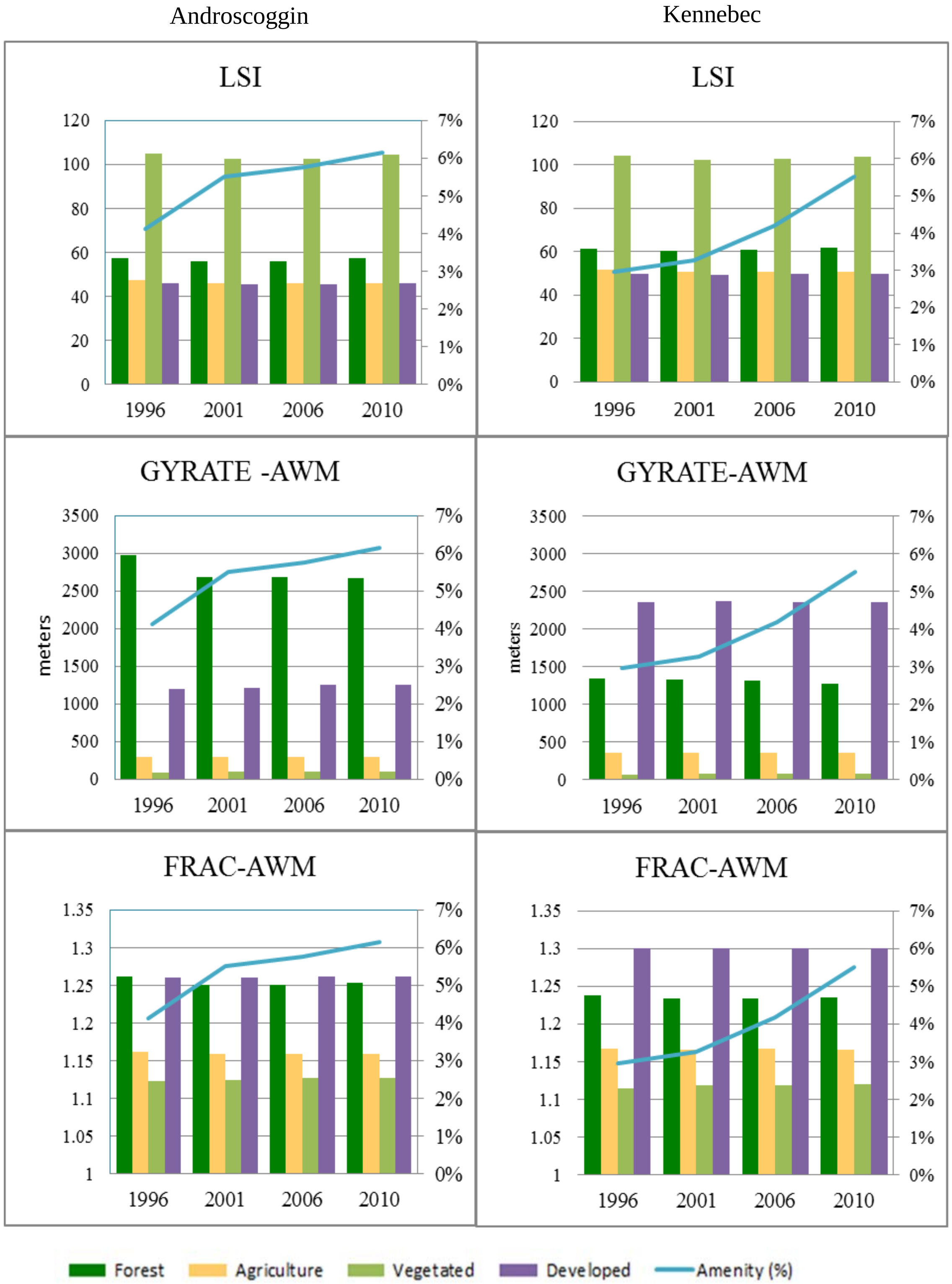

Figure 3.10 Land cover shape metrics and amenity change over time (percentage of total areas), within buffer (1000 meters)

The greatest difference between the two watersheds pertained the complexity of individual land cover types as specified in radius of gyration (GYRATE) and fractal dimension (FRAC) (Figure 3.10). GYRATE measures landscape continuity in terms of movement within the landscape by examining the distance an organism is able to travel within one particular patch. At a class level, there are higher values for GYRATE for forested area in the Androscoggin implying longer networks or continuity within this land cover type, while along the Kennebec higher values for developed patches. Similar to MPS, there is a decreasing trend in these values within the forested areas. As an indicator of patch shape complexity, area weighted fractal dimension was calculated for each land cover type. Our results indicate slight differences slight differences in the two watersheds, with developed land cover displaying greater shape complexity across the landscape.

During this same interval of time, the percentage of land converted to amenities within the Androscoggin increased from 4.1% to 6.1% while conversion of land to amenities within the Kennebec increased from 2.9% to 5.5%. Not shown on these graphs is the shifts in water classification. As described earlier, water classification levels were maintained along the Androscoggin while the percentage of segments above class C increased from 66% to 92%. The patterns of land cover metrics indicate a greater predominance complexity of shape of forested areas along the Androscoggin, the system that has not experienced upgrades during this time interval. Along the Kennebec, which has the majority of study area classified to higher levels, although there is a predominance of forested areas, there is greater complexity of shape for developed areas.

We examined class-level land cover metrics calculated for the 1000 meter river corridor area at a community scale level, tracking communities from with the upper reaches to the lower sections. We characterized PLAND at a community level to explore potential variation along the river corridor. We graphed PLAND at a individual community scale starting with communities at the upper end of our study area and progressing to the mouth of the rivers (Figure 3.11).

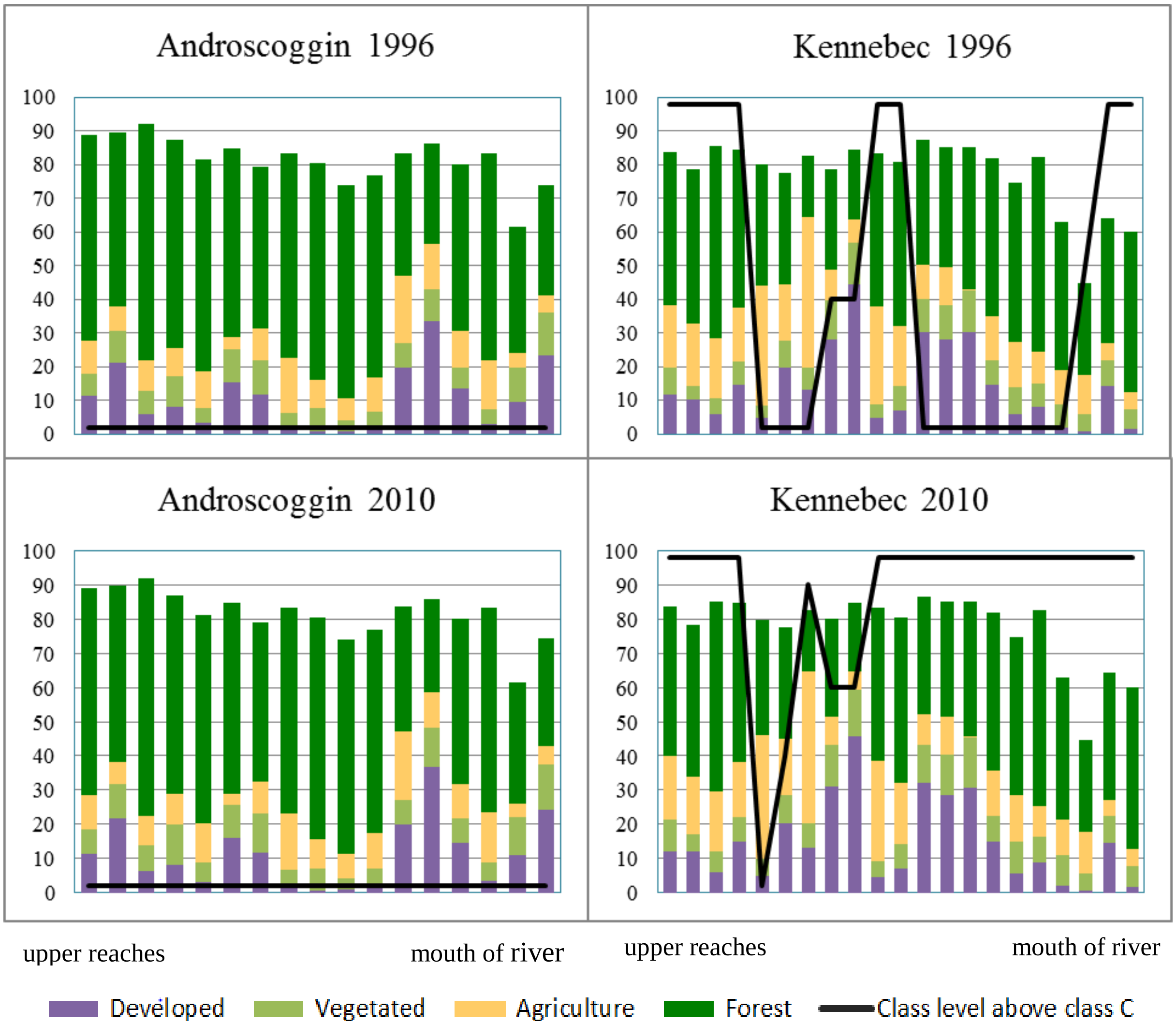

Figure 3.11 Percent land area (PLAND) and river segments classified at levels higher than class C (percent) at individual community scale change over time from headwaters to mouth of the river

Although PLAND was consistent at a corridor level between the two watersheds, PLAND varied to much greater degree along the length of both river systems. The percentage of land type (PLAND) differed between the two watersheds, with the Androscoggin having a substantially greater percentage of forested area along the majority of the corridor than other land cover types and than for the Kennebec corridor overall. PLAND varied to a much greater degree along the length of the Kennebec corridor with certain towns having greater percentage of developed areas, indicating potential dimension of landscape patterns as influenced by community level dynamics.

We compared these metrics with acreage of amenities established by the time intervals (1995 and 2010) to examine change over time. We included changes in percentage of river front classified at levels higher than the minimum standard, representing upgrades, similar to our comparison in Figure 7. Although at a corridor level, PLAND did not vary extensively across the two watersheds or over the two time periods, there were greater differences in PLAND values at the scale of individual communities than at the scale of the watershed buffer, and the results revealed potential interactions between water classification levels and percentage of land areas.

3.5 Discussion

Our study documented patterns of water classification levels over a 40 year period as a metric for river restoration progress and examined patterns of amenity establishment and landscape composition to identify potential interactions among river restoration and social response.

3.5.1 Patterns of upgrades

Although a program of assigning classification to Maine's rivers and streams has been in place since the early 1960s, there has never been a spatial and temporal examination of patterns of upgrades in classification levels. Assemblage of these data provides the first examination of progress in water quality improvements at an individual river segment level within the context of state and federal water quality regulations. As river segments must meet base biological and physical standards in order to receive a higher classification level, spatial and temporal analysis shows an increasing improvement in water quality along both rivers. As classification levels require water quality levels be maintained, these changes reflect movement towards more stringent regulation of these river systems.

Our analysis revealed strong differences in patterns of water classification shifts between the two river systems and along the river gradient within the more restored river system. A certain degree of heterogeneity can be explained through changes over time in the hydrology of the river systems themselves. For example, removal of a significant dam on the Kennebec impacted water classification levels above and below the former dam due to a shift in river function (Casper, Thorp, Davies, & Courtemanch, 2006; Crane, 2009). There was not comparable event on the Androscoggin River during this same time period. Second, there are distinct differences in the biophysical characteristics of these systems of these systems. As a system with lower flow and therefore less potential for dilution of point source discharges, the Androscoggin may be constrained by its physical characteristics (Davies et al., 1999).

In examining the heterogeneity of upgrades over time and along of the more restored system, these patterns raise interesting questions about interaction of biological and physical characteristics and levels of classification. As classification levels encompassed biological and chemical characteristics as well as management objectives (Table 1), the patterns of classifications along these two river systems imply that there may be broader influences on classification levels (Courtemanch et al., 1989). These management standards incorporate social values including “fishable” and “swimmable” and specific use objectives. For example, in order to be considered as a drinking water source, river segments must be classified appropriately (class B) and then managed to achieve this use objective. Thus, management objectives may in fact be one of the factors leading to water classification upgrades and why differences in classification levels have emerged.

Incorporation of management objectives and regulation to these standard may be a component of a broader approach to consideration of river systems for their social value as well as ecological integrity (Reuss, 2005). Our results concur with former studies examining the need for integrated management approaches to improving water quality. Thus, water classification serves as a metric for the ecological and social dimensions of river restoration progress, not only in reflecting improvements in biological and physical water quality, but also by integrating management objectives that incorporate social values.

3.5.2 Amenity infrastructure

To address our second objective we examined patterns of amenity infrastructure development to understand potential interactions with water classification levels of a metric for social response to restoration. Despite distinct differences in classification levels currently and historically, we found comparable levels of amenity investment at the present time along both river corridors and over the last two decades. An important pattern that may provide more insight on community response to river quality is the increased pace of amenity investment along the more impaired system between 1990 and 2005. During this time period, while classification levels remained the same along this river, water classification levels along the second river system saw greatest level of upgrades from 66 to 92 percent of the river but a slower pace of amenity development. The juxtaposition of the pace of amenity development and water quality levels along these two systems may provide insight on when communities invest in amenity infrastructure along impaired river systems. Creation of amenity infrastructure may be for the purpose of shifting public perceptions towards restoring river systems.

Patterns of water classification upgrades are complex. In one river system investments preceded water classification upgrades, while in the second system, creation of new amenities kept apace with water classification upgrades that took place along 80% of the study site. Former studies have examined the role of perception towards river system in response to water quality improvements and recreational use (Mullens & Bristow, 2003). Often water quality is linked to social variables such as increased use opportunity, cleanliness and aesthetics (Gobster &

Westphal, 2004). Research on greenways have identified the value of river parks and trails in connecting residents to riverscapes and the investments stakeholders are willing to make to improve these areas in association with sense of place. Further research on restoration has identified the role of connection to place as engendering greater support for and involvement with restoration actions and amenity development (Colocousis, 2012; Lukacs & Ardoin, 2014).

Along the Androscoggin River, there has been a concerted effort among many organizations to invest in shifting public perception towards the river (E. S. Johnson et al., 2014a). The existing of infrastructure in advance of classification shifts may indicate the role of amenity investment as a means of connecting the general public to the river systems, raising awareness and engendering support for further restoration initiatives. Conversely, the difference in classification levels and associated amenity development may also point out the disconnect that exist between classification levels and amenity development, and the willingness on the part of communities to invest in amenities independent of classification levels.

Finally, as the pace of amenity development increased at a greater rater between 2005 and 2010, the patterns of amenity infrastructure may highlight the potential for a lag effect between restoration progress and investment in amenities.

3.5.3 Landscape structure differences

To address our second objective, we also explored landscape metrics to measure influence of water classification on proximate land use. In both watersheds, we found that forested areas predominated as a land cover type, as overall percentage, larger patch size, and to a greater degree in the Androscoggin watershed, larger forested patches. Despite these similarities between the two watersheds, there were some surprising differences. First, within the buffer of the more impaired system, forested and vegetated areas occupied not only a greater percentage of the river corridor, but forested patches were greater in size, connectivity and complexity. Further, at a community level, landscape patterns exhibited greater consistency along the Androscoggin corridor in terms of the predominance of forested areas and the connectivity among these patches. As adjacent land uses impact water quality, a second surprising result is that of the two systems, the impaired systems had the higher level of vegetated areas in contravention to research on examining landscape patterns on water quality. Studies generating landscape metrics along waterfront areas such as riverine corridors have shown that increased levels of developed or impervious surfaces have a disproportionate negative impact on water quality. (Zhou et al., 2014, 2012). One possible explanation is that the level of impairment of the Androscoggin and the interrelated nature of poor public perception of the river has translated into forestalling of development. Resource economics literature identifies impaired river systems are disamenities that impact development patterns (Irwin et al., 2014).

These differences in patterns may be a factor of the legacy of development patterns within Kennebec communities, reflecting more road corridors in closer proximity to the river. Another possible explanation is that improved water quality has started to lead to greater development along the corridor. Further, differences in the nature of amenities between the watersheds, with amenities comprised of a greater degree of developed surfaces such as paved trails.

Finally, examining landscape patterns at a community scale rather than aggregated at a watershed or corridor level indicated a much greater degree of heterogeneity along both rivers and more specifically along the Kennebec, the more restored system. The scale of landscape pattern analysis is an important consideration in developing metrics for measuring social response to restoration, revealing important variations that may be a function of additional socioeconomic drivers. River corridors can exhibit variations in landscape characteristics, independent of water quality impacts or influences (Zhou et al., 2014). Social and ecological interactions play out at different scales. Accordingly, a multi-scale approach, such as the one we advance, seems most appropriate.

3.6 Conclusions

The need to manage rivers for both biological and social systems is becoming increasingly important to achieve restoration goals. Understanding the reciprocal nature of community investment in river restoration and how communities capture benefits that accrue from restoration progress is complicated by factors including scale of analysis, identifying a metric for restoration that is understandable to communities, and the challenges of assembling data comparable across ecological and social dimensions of river restoration.

Our study examined patterns of water classification shifts within two watersheds over a 40 year period as a metric for river restoration. By examining amenity investment spatially and temporally with river restoration upgrades, we highlight the potential reciprocal dimensions of restoration progress and the points along the restoration trajectory that communities begin to conceptualizing rivers as amenities. Despite historical differences in water classification levels, at present these two systems are comparable in the level amenity infrastructure and the predominance of green areas (forested, and vegetated areas) along the river corridor. However, we found important differences between the systems in terms of the pace of amenity development and landscape composition within the more impaired river system.

Riverscapes are an important focus of study as they provide opportunities to connect the public to river systems. The structure and function of riverscapes influences the public's connection to these spaces (Åberg & Tapsell, 2013). Communities may be choosing to invest in amenity development in advance of full restoration progress to provide greater connections to river systems. Understanding why and when communities invest in river amenities as a dimension of river restoration is critical to assessing opportunities for engendering support for restoration and gauging social capture of restoration benefits. The scale and level of impairment may be factors in determining when and why communities create opportunities for connection with rivers. A consideration of past patterns of amenity development is critical to more accurately describing the impact of water classification upgrades on communities and to understand the impact of these legacies.

Our study is limited to an analysis of water classification and amenity development within two watersheds and the availability and scale of land cover data for these study sites. Future studies could examine longer term landscape affects tracking upgrades to understand restoration progress on amenity development. Comparing classification systems in other areas of the country may provide insight on the ways in which classification levels interact with community processes. Finally, the scale of the analysis for amenity development and lag times between restoration achievements and community responses need to be further refined in order to effectively measure the social dimensions of river restoration (C. Li et al., 2013).

The social and ecological dynamics of river restoration are complicated. Understanding this interaction will be increasingly important to avoid conditions where restoration progress may be stymied by social responses in the form of expanded development adjacent to improving systems. At the same time, understanding how communities leverage restoration benefits may provide greater opportunities for enhanced social and ecological management of river systems.

CONCLUSION

Our research examined the social and ecological dynamics of river restoration, focusing on two river systems in Maine, the Androscoggin and Kennebec Rivers. We employed both qualitative and spatial methods to explore the dynamics of institutional response, boundary management and the interaction river restoration progress, in the form of water classification upgrades, with landscape patterns in areas proximate to these river systems.

In the first manuscript, we examined the influence of restoration gains on watershed collaborations' goals and actions. Drawing on the IAD framework, we investigated the influence of biophysical characteristics, community characteristics and institutional rules in use on policy stakeholders' goals and actions at the collective action and institutional levels. Within both watersheds, perceptions of biophysical potential influenced policy stakeholders' goals, shaping definitions of restoration. Within the more impaired of the two systems, policy stakeholders invested in shifting perception in order to connect communities to river and engender support for restoration actions. Although investment in perception shifting may seem to come at the cost of restoration gains, these investments contributed to establishing broader based constituencies that have to potential to sustain restoration progress beyond initial successes. Within the more restored system, we found that stakeholders focused more on strategies for leveraging restoration gains into community and economic benefits.

Our second paper was a qualitative analysis of emerging boundary organizations within the two watersheds. We found differences in how policy stakeholders described the role of researcher-stakeholder partnerships and commonalities in the roles these partnerships could play as a dimension of restoration. Reflecting a broader need to shift public perception and mediate past conflicts, stakeholders articulated the role of researchers as lending neutrality. Within the more restored system, policy stakeholders valued partnerships with researchers as an opportunity to develop models for economic benefits from restoration progress. In both watersheds, policy stakeholders and researchers described challenges with resources needed to formalize collaborations and time required to invest in developing these partnership. Our research identified some key opportunities for facilitating partnerships including examining the role of students within boundary management. Future research is needed to explore shifts in boundary processes through a state change within one resource system and an examination of boundary processes in a range of resource systems undergoing state changes. The role of the boundary organization needs to be clearly defined at the outset by all participants in organization development. Laying out expectations initially may enable all participants to clearly state vision, availability of resources including in the form of human capital, and what actors must gain in order for the processes to be supported. As restoration gains are achieved, these functions may need to be reevaluated as well as the role of the individual actors themselves in response to state change.

Our third paper employed spatial analysis to explore the social dynamics of restoration by examining patterns of water classification shifts as a metric for restoration. By investigating amenity investment spatially and temporally with river restoration upgrades, we examined the potential reciprocal dimensions of restoration progress by identifying points along the restoration trajectory when communities begin to conceptualizing rivers as amenities. Despite historical differences in water classification levels, these two systems were comparable in the level of amenity infrastructure and the predominance of green areas (forested, and vegetated areas) along the river corridor. However, we found differences between the systems in terms of the pace of amenity development and landscape composition.

Our study is limited to an analysis of two watersheds in Maine, and to data availability and scale and resolution of this data. Future research is needed to examine longitudinal processes within one watershed as well as examining similar factors in watersheds in other areas.

The social and ecological dynamics of river restoration are complicated. We have described the role of perception as one dimension that may need to be considered in management of rivers as social and ecological systems, and in developing metrics for measuring social response to restoration progress at a community scale. Additionally, the mental model of restoration held by stakeholders, and the composition and structure of partnerships including those with academic institutes are important dimensions of social ecological systems to be considered as a part of larger restoration goals. Redefining restoration to incorporate social and ecological systems at the outset provides the opportunity to invest in collaborations, set benchmarks for measuring success that incorporate both social and ecological systems, and create institutions that may be more adept in leveraging ecological gains into community benefits.

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APPENDIX A - LAND COVER CATEGORIES

Category	**CCAP Descriptions**	**Description**
Developed	Combines Developed, High Intensity; Developed, Medium Intensity; and Developed, Low Intensity	Contains land area covered by a minimum of 20% developed area
Managed Green Space	Cultivated Crops, Pasture/Hay	CCAP describe this as land actively managed for agriculture purposes. In visual inspection, significant areas fell within urbanized core
Forest	Deciduous Forest, Evergreen Forest, Mixed Forest	Comprised of mature forest stands
Vegetated	Scrub Land, Grassland, Developed Open Space, Scrub/Shrub	Vegetated areas managed less intensively than agricultural lands
Barren	Barren Land, Unconsolidated Shore	Areas where vegetation accounts for less than 10%, not under active management
Wetlands	Estuarine Forested Wetland, Palustrine Scrub/Shrub Wetland, Palustrine Emergent Wetland, Estuarine Forested Wetland, Estuarine, Scrub/Shrub Wetland, Estuarine Emergent Wetland	Dominated by wetlands, excluded from analysis
Water	Open Water, Palustrine Aquatic Bed, Estuarine Aquatic Bed	

Table A-3 Land cover categories

APPENDIX B - LANDSCAPE VARIABLES

Metric Name	Scale	Code/Range	Description and applicability to landscape patterns
Composition			
Percent Land /Class Percentage of Land	Class	PLAND % 100	Measure of landscape composition and can measure relative amounts of green spaces and impervious surfaces
Patch Density	Class	PD n/ha	Number of patches corresponding to land cover type divided by area of study (100ha?) and represents a base measure of class type or landscape. Indicates level of fragmentation and higher values indicate greater level of fragmentation and heterogeneity. Generally urbanization rates tend to increase this value. Green land use showed in increases.
Largest Patch Index	Class	LPI 0-100	Indicates the percentage of total land area comprised by largest patch, which is measurement of dominance of a land cover type and approaches zero when a particular patch type is small. It ranges from 0 to 100. Provides information on connectivity. Can be used to compare to compare different landscapes independently.
Shape			
Landscape Shape Index	Land	LSI 0-infinity	Measures the geometric complexity of a patch shape and approaches zero for compact (square) shapes and increases as patch shape becomes more complex. It can indicate connectivity in the case of urban green spaces as well as spatial heterogeneity of the overall landscape. It ranges from 0 to infinity.. Green spaces with more complex shapes may provide better diverse visual and amenity resources
Area Weighted Mean Fractal Dimension	Class	AWMPFD	Used to distinguish between anthropogenically and naturally regulated landscapes as higher fractal dimension values could enhance interaction with the surroundings. Could be used to verify LSI results. Green spaces with greater AWMPFD and lower MENN and PD have better ecological value
Radius of gyration – Area Weighted Mean	Class	GYRATE-AM	At class or landscape level provides a measure of landscape continuity and traversability. The mean distance between each cell in patch and patch centroid divided by sum of patch areas

Table B-1 Landscape variables

BIOGRAPHY OF AUTHOR

Eileen Sylvan Johnson was born in Syracuse, NY and grew up outside of Boston. She attended Cornell University and graduated with a BS in Environmental and Science Education. She completed her Master of Regional Planning at the University of Massachusetts, Amherst in 1990. Throughout her career she was worked in many fields, for a small nonprofit recycling program, as a county planner in Western Massachusetts, for the City of Lewiston, and as Lead Instructor in Environmental Technology at Southern Maine Community College. She is currently on the faculty at Bowdoin College where she teaches in the Environmental Studies Program and coordinates community based research opportunities for students. In her free time, she enjoys exploring the many trails and parks along restored river systems in the Northeast. She is a candidate for the Doctor of Philosophy degree in Ecology and Environmental Science from the University of Maine in December 2014.