THE ROLE OF SOCIAL CAPITAL IN NATURAL RESOURCE POLICY DEVELOPMENT

A Dissertation

by

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ABSTRACT

Social capital is used as a framework to focus on the nexus of society and natural resources in three case studies in the Texas Coastal Bend, USA. Social capital incorporates diverse social phenomena such as trust and reciprocity, engagement and cooperation, common rules and norms, and social networks. Capital exists in the relations among actors and the resources embedded in them (e.g. information and influence) that provide valuable assets that can be leveraged for individual or collective gain.

I examined social capital as a resource for potential community involvement in whooping crane management using qualitative analysis of semi-structured interviews of 35 individuals. Community networks of reciprocity and trust formed bonding ties strengthened by active engagement; shared values and community identity; and institutions fostering leadership and service. Bridging ties offered opportunities for knowledge sharing and legitimacy. Social capital in this community provided a potential resource to save time and money in addressing ongoing efforts to protect this charismatic endangered species.

A case study of collaborative modeling provided an opportunity for stakeholders to learn more about an estuarine system and strengthen network ties. Using Bloom's Taxonomy, I demonstrated how this social learning process led to increased cognitive skills in understanding the estuarine system. Through engagement and networking, participants established social capital useful for addressing watershed issues.

Affiliation network analysis of five water management groups over a ten-year period was based on meeting attendance records. I examined stakeholder heterogeneity within each group. Network density provided insight as to how actors are connected and the likelihood that groups function cohesively. Network measures of betweenness and eigenvector centrality indicated important individuals within the networks that serve as leaders within and bridges between groups. Important brokering roles within the networks, of connecting otherwise un-connected groups, were filled by regional water authorities and conservation organizations. Network visualization showed the differences and similarities, and integrity of all groups. Together, these studies demonstrated how social capital is an invaluable resource for successful management of natural resources in the Texas Coastal Bend.

DEDICATION

I dedicate this to Gay for her faith in me – looks like we both made it; to Jessica for her encouragement and help – often my rock; to Jeremy for his unflagging confidence in me – pushing me to new heights; and to John for his patience and wisdom– who says it's *always* about the fish. I love you all!

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NOMENCLATURE

BBASC	Basin and bay stakeholder committee
BBEST	Basin and bay expert science team
EARIP	Edwards Aquifer Recovery Implementation Plan
GSA	Guadalupe, San Antonio, Mission, and Aransas Rivers and Mission, Copano, Aransas, and San Antonio Bays
NERR	National Estuarine Research Reserve
Region N	Region N water planning district
SB1	Texas Senate Bill 1, 75th Legislature, Regular Session
SB2	Texas Senate Bill 2, 77th Legislature, Regular Session
SB3	Texas Senate Bill 3, 80th Legislature, Regular Session
TCEQ	Texas Commission on Environmental Quality
TWDB	Texas Water Development Board
USFWS	United States Fish and Wildlife Service
USA	United States of America

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CHAPTER I

INTRODUCTION

"The environment is where we all meet; where all have a mutual interest; it is the one thing all of us share." —Lady Bird Johnson

Over the past few decades, we have become increasingly aware that the earth is in crisis, largely from anthropogenic pressures of population growth and tremendous use of natural resources. Managing natural resources for social well-being in the 21st century requires attention to scale – natural resources involve complex ecosystems that cross local, regional, and national boundaries – and attention to the demands and pressures of human society. We can neither set national policy that does not address community needs, nor simply manage the commons at the local level (Kamoto et al., 2013). Good natural resource policy should be flexible enough to address a changing environment, based in good science, and involve diverse input (Bodin et al., 2006; Charnley and Engelbert, 2005; Daniels and Walker, 2001; Ostrom, 2000; Peterson et al., 2006).

The 1970 signing of the National Environmental Policy Act (NEPA) focused attention on citizen input into decision-making processes that lead to environmental policy and land use decisions (Innes and Booher, 2004; Walker, 2004). Early models of citizen engagement often failed: ineffective public comment and meetings informed rather than engaged audiences and often resulted in increased conflict (Innes and

Booher, 2004), dialog without expanded decision sharing resulted in disappointment (Schwarze, 2004), exclusion or marginalization of important voices resulted in poor support of decisions (Peterson and Horton, 1995), and engagement processes often compromised rather than built trust (Parkins and Mitchell, 2005; Peterson et al., 2007; Walker, 2004). Yet, strong arguments remain for broader participation that facilitates robust environmental policy that meet diverse needs and maximize public support (Charnley and Engelbert, 2005; Peterson et al., 2006).

The means to effectively engage a broader audience in environmental decision-making is not clear, even after 40 years of research (Booth and Halseth, 2011). Monetary and time costs involved in often long-term (years) processes are obstacles in developing relations of trust and mutual understanding among diverse stakeholders (Daniels and Walker, 2001; Westermann et al., 2005). Social capital, the relational resource available to individuals and groups that persists over time (Adler and Kwon, 2002; Brunie, 2009; Lopez-Gunn, 2012), is a largely unrecognized asset that may mitigate the costs of time and money required for extended stakeholder involvement.

Social capital is a multidimensional concept that incorporates diverse social phenomena such as trust and reciprocity, engagement and cooperation, common rules and norms, and social networks (Bodin et al., 2006; Coleman, 1987; Lopez-Gunn, 2012; Mountjoy et al., 2013; Ostrom and Ahn, 2003; Pretty, 2003; Uphoff, 2000). Capital exists in the relations among actors and the resources embedded in them (information, influence, etc.) that provide valuable assets that can be leveraged for individual or collective gain (Barnes-Mauthe et al., 2015; Coleman, 1988). These ideas hark back to

Marx's definition that capital exists within the process of exchange; something that can be bartered and stored. Because it is a broad concept, there has been criticism that social capital is not well defined, and that it serves as both a dependent variable, perceived as the outcome of successful management where trust and networks are deliverables and goals in themselves, and as an independent variable explaining how social capital facilitates collective action (Bodin and Crona, 2008; Lopez-Gunn, 2012).

A holistic view of social capital encompasses both structural and cognitive dimensions of social capital. Both the structure of the relations and the quality of relations are critical in building social capital and it is difficult to separate the relations from the capital in social capital. Structural dimensions include the networks and institutions as well as engagement and common rules and sanctions that emerge from relations (Mountjoy et al., 2013; Ostrom, 1990, 2010*a*; Putnam, 2000; Uphoff, 2000). Cognitive dimensions provide the context within which these structural elements are understood, namely trust, reciprocity and cooperation, and shared values (Bodin et al., 2006; Coleman, 1987; Ostrom and Ahn, 2003; Pretty, 2003; Putnam et al., 2004). Social capital functions as a public good and is characterized by communities functioning cohesively, insuring access to information, influencing social ties, and establishing social credentials (Lin, 1999).

Networks consist of actors (nodes) connected through (ties) that form patterns of relationships between individuals and the groups they comprise. Network analysis metrics attributed to social capital include density of relations, strength of ties within and between groups, and embeddedness and connectedness of individuals and groups (Bodin et al., 2006; Coleman, 1988; Granovetter, 1983; Monge and Contractor, 2003). Engagement describes individual or collective actions to address specific issues and has been implicated in societal ability to react and adapt to change (Bodin and Crona, 2008; Putnam, 2000). Common rules and norms are assumed to emerge from networks and engagement, and over time may present either as advantages or disadvantages to adaptive responses (Coleman, 1987; Ostrom, 2010*a*).

Structural social capital dimensions are insufficient as either drivers or predictors of social consequences, and are best understood within the context of cognitive social capital dimensions (Krishna et al., 1999; Uphoff, 2000). The social context of shared values, reciprocity and cooperation, and trust are essential for successful action. Shared values, strengthened within dense networks, include commonly held ideas of what is worthwhile or important, and are the basis for ethical behavior (Ostrom and Ahn, 2003). Reciprocity and cooperation of goods and knowledge serve to mutually benefit those connected within the network and offer incentive as the capital asset of network relations (Pretty, 2003). Trust is the foundation for positive action, most notable when it is absent. Cooperation and trust can offset negative social manifestations of exclusivity and corruption.

Social capital is a precautionary tale as certain dimensions of social structure and thus social capital may be destructive. Overly dense networks with many tight bonds may exclude some members of civil society (Ballet et al., 2007). Network homogeneity expressed as both redundancy of roles and values may be indicative of low adaptive capacity as it limits the knowledge base and decreases the capacity for innovation (Folke et al., 2005). While social capital, the networks and common purpose, are beneficial in terms of efficiency and progress, they may also lead to exclusion of others and less robust decisions. Empirical studies should consider that social capital exists within a wide spectrum of positive and negative dimensions, and should be examined structurally and cognitively.

Within the disciplines of natural resource management and conservation, if the social dimensions and capital perspectives are clearly defined, social capital provides a powerful lens through which to compare disparate efforts to manage complex ecosystems. Case studies have used multidimensional and structural network approaches to examine social capital and its relation to cooperative management, resilience, and response to climate change (e.g. (Bodin et al., 2006; Ernoul and Wardell-Johnson, 2013; Newman and Dale, 2005; Uphoff, 2000). Key outcomes from the research span both structural and cognitive social capital dimensions. Structural dimensions include network characteristics such as position in the network that provides access to knowledge and influence, density of bonding ties that lead to cohesive groups and the likelihood of excluding non-network actors, and the importance of leadership and brokering roles within networks (e.g. (Bodin and Crona, 2008; Kusakabe, 2012). As well, engagement, and the institutions and common rules that emerge have been examined for their role in successful resource management (e. g.(Carlsson and Sandström, 2008; Uphoff, 2000). These structural dimensions are often examined within cognitive dimensions that explore the basis of ties such as learning or knowledge exchange, norms of behavior, reciprocity, and trust (e.g. (Cheng et al., 2015; Floress et al., 2011; Prell et al., 2009). The overarching conclusion is that social capital is a dynamic and persistent resource.

CASE STUDIES

The three investigations in this dissertation use social capital as a framework to focus on the nexus of society and natural resources in the Texas Coastal Bend, USA. I investigate community capacity to contribute to endangered species management, development of informed policy through science and stakeholder collaboration, and overlapping networks of working groups that facilitate successful watershed management. Social capital emerges as community level potential, watershed level social learning, and networks of active stakeholders. Chapter II examines how social capital serves as a resource for potential community involvement in whooping crane management in the wintering grounds in of the Texas Coastal Bend, USA. This chapter takes a qualitative and holistic approach, examining structural and cognitive social capital dimensions within the community. I used inductive analysis of semi-structured interview data of community members and others as a means for natural resource managers to proactively address existing societal resources within the community to mitigate costly and time consuming efforts to build social capital within a community when addressing community involvement in endangered species management.

Chapter III presents a case study of collaborative modeling of an estuarine system of the Texas Gulf coast. Scientists and stakeholders collaboratively built a shared systems model to better understand complex freshwater inflow issues. I analyzed the process in terms of the social learning facilitated by the process and the social capital that is established during this 3 year process. Again, this study uses a holistic approach to social capital, examining cognitive dimensions of shared learning and common goals as well as network relations that emerge and are strengthened through the process.

Chapter IV examines overlapping networks of active watershed working groups in the Texas Coastal Bend from 2005 to 2014. Longitudinal network analysis can reveal evolution as it relates to structure, function, and the roles that network actors assume over time (Alexander and Armitage, 2015). Data are from publicly available meeting attendance records for four watershed groups, and from the collaborative modeling process explored in Chapter III. These attendance data are used to construct a 2-mode affiliation matrix of all actors involved by event (meeting or workshop). I use structural network measures of density and centrality within the historical context within which these watershed groups function.

Together, these three chapters contribute to a rich picture of natural resource conservation within the Texas Coastal Bend at multiple temporal and geographic scales.

CHAPTER II

THE ROLE OF SOCIAL CAPITAL IN ENDANGERED SPECIES MANAGEMENT: A VALUABLE RESOURCE

Whooping cranes (*Grus americana*) were first protected in 1967 under the U.S. Endangered Species Act (ESA) (Udall 1967). Unfortunately, this charismatic megafauna still faces innumerable threats such as loss of habitat, increased pressure from commercial and residential development, human activities, intense Gulf of Mexico storms, rising sea levels, lack of freshwater inflow to wintering ground estuaries, and more (Canadian Wildlife Service and USFWS 2007, Davis et al. 2009, USFWS 2009*b*). Because of their relative scarcity and tenuous survival, endangered species pose unique management challenges, including increased conflict, less room for error, and persistent crisis decision requirements. Conflicts arise from private property owners who perceive that mandated endangered species conservation may infringe on personal property rights interests; as passionate disagreements in cases where both predator and prey are endangered and warrant protection; and in human-human conflicts regarding management strategies (Parker and Feldpausch-Parker 2013, Peterson, M. N. et al. 2004, Roemer and Wayne 2003, Sorice et al. 2011). Small misjudgments in management strategies may have large consequences, increasing strain on decision processes that already face limited financial resources and time. Even if whooping crane populations increase to the point of downlisting or recovery status, they likely will remain a conservation-reliant species that needs continued management and protection because major threats will not be eliminated (Scott et al. 2010).

A broad spectrum of federal, state, and local interests are needed to manage conservation-reliant species within a complex social, political, and cultural context. In the past 50 years, efforts to broaden public involvement in wildlife management have evolved from minimal participation via public comment or public meetings criticized as too little involvement, too late in the process (Depoe et al. 2004, Hamilton and Wills-Toker 2006) to participation based on ideas of knowledge building (Daniels and Walker 2001, Peterson et al. 2006, Thompson et al. 2010, van den Belt 2004) and increased decision space (Daniels et al. 2012, Norton 2007, Senecah 2004). Public involvement facilitates policies that meet diverse needs, sustainable development, environmental protection, conflict management, and greater acceptance (Charnley and Engelbert 2005, Daniels and Walker 2001, Depoe et al. 2004, Norton 2007, Schusler et al. 2003). The drawback to participatory processes is that they often require a substantial time commitment and significant expense (ibid.).

Although community involvement in whooping crane management has a high potential for success, state and federal agencies have not fully capitalized on this potential (Bernacchi et al. in press). This potential is found in existing structural and relational social capital. Social capital is the resource, grounded in social relations, available to individuals or groups that enhances their ability to solve problems (Adler and Kwon 2002, Ostrom and Ahn 2003). If management agencies capitalize on this existing community resource they may mitigate both time and cost of community participation, and increase their chance of facilitating improved crane conservation into the future in the overwintering grounds in the Texas Coastal Bend. This is important because whooping cranes, for the foreseeable future, are going to be reliant on conservation resources. A social capital perspective addresses the challenges of endangered species management as it encompasses structural dimensions that facilitate positive action and cognitive dimensions that predispose success in natural resource management. The purpose of this paper is to demonstrate how social capital can be a substantial conservation resource.

WHOOPING CRANE HISTORY

In 1938, only 17 whooping cranes remained in the wild. The sole self-sustaining flock (Aransas - Wood Buffalo population, AWBP) nests in Wood Buffalo National Park in northern Canada and migrates 2,500 miles south to winter in the Coastal Bend area of Texas. The current whooping crane population as of February 2015 is estimated at approximately 600 birds, of which half are part of the AWBP flock (http://www.fws.gov/refuge/Quivira/wildlife_and_habitat/whooping_crane.html).

Historic declines of whooping cranes are the result of habitat destruction and hunting (USFWS 2009*a*). The current recovery plan involves:

> “protection and enhancement of the breeding, migration, and wintering habitat for the AWBP to allow the wild flock to grow and reach ecological and genetic stability; reintroduction and establishment of self-sustaining wild flocks within the species’ historic range and that are geographically separate from the AWBP

> to ensure resilience to catastrophic events; and maintenance of a captive breeding flock to protect against extinction" (p. 7, USFWS 2009*b*).

The management plan is directed towards protecting the crane population and their habitat so it can be reclassified to threatened status (downlisted) with the projected timeline no sooner than 2035 (Canadian Wildlife Service and USFWS 2007). The United States Fish and wildlife Service (USFWS) recovery plan states that to move towards downlisting, management should include the interests of a concerned and informed public through education and outreach (Canadian Wildlife Service and USFWS 2007). Endangered species management requires understanding how to secure the cooperation of local communities through thoughtful involvement of stakeholder groups to build trust and reciprocity (Peterson, M. N. et al. 2004). Social capital in this community is essential to meeting challenges faced by this conservation-reliant species, and is an especially valuable resource available for often minimally funded conservation efforts to negotiate complicated environmental issues.

SOCIAL CAPITAL

Social capital is a concept that has been used to describe community potential for positive action; that is, prior civic engagement is more likely to produce future action (Hanifan 1916, Putnam 2000). Social capital researchers have examined how social relations (expressed as social networks and associations) and action (as engagement, community enhancement, collective action, and economic benefits) might contribute to knowledge building, social mobility, poverty reduction, economic prosperity, disaster recovery, common pool resource management, civic and collective action, and more

(Borgatti and Lopez-Kidwell 2011, Coleman 1988, Jacobs 1961, Putnam 2000, Schultz 1961). Researchers recognize that structural (i.e., relations and ties) and cognitive (i.e., knowledge, trust, and reciprocity) dimensions of social capital must be coupled for positive actions to result (Adler and Kwon 2002, Grootaert and van Bastelaer 2002, Minato et al. 2012, Putnam et al. 2004, Uphoff 2000). Consequently, we examine both the structural and cognitive dimensions of social capital in the overwintering grounds of whooping cranes (Table 1).

Structural social capital is described as social networks and institutions that facilitate engagement and lead to common rules, roles, and sanctions (Pretty and Ward 2001, Lin 1999, Minato et al. 2012, Jones 2010, Grootaert and van Bastelaer 2002). Social networks refer to patterns of relationships that extend over time, and consist of bonding (within groups) and bridging ties (between members of dissimilar groups) (Blakely and Ivory 2006, Brunie 2009, Ishihara and Pascual 2009, Uphoff 2000). Civic engagement is a positive externality of structural social capital that leads to development of civic value and a disposition towards greater trust (Adler and Kwon 2002, Brunie 2009, Putnam 2000, Woolcock and Narayan 2000). Communities work together to make a difference in civil life as in regard to decision-making, and governance over who, how, and by whom a community's resources will be allocated. Common rules and sanctions are social constructs established through social interactions and engagement. They increase compliance and lower transaction costs (i.e., time and effort) and represent established patterns that make productive outcomes from cooperation more predictable and beneficial (Lopez-Gunn 2012, Ostrom 2000, Pretty and Ward 2001, Serra 2011, Uphoff 2000).

Cognitive social capital dimensions (Table 1) provide the context within which participatory natural resource processes operate and become a positive resource for change (Ballet et al. 2007). Cognitive social capital manifests through shared values and attitudes and norms of behavior, and through the dynamic factors of reciprocity and trust (Grootaert and van Bastelaer 2002, Lopez-Gunn 2012, Mountjoy et al. 2013, Pretty and Ward 2001, Uphoff 2000). Reciprocity and trust are essential elements of successful natural resource management that if not present must be developed over time through information exchange and learning opportunities (Hamilton and Wills-Toker 2006, Norton 2007, Ostrom 2000, Peterson et al. 2006, Senecah 2004, Wagner et al. 2007). Where trust is lacking, social interaction and ultimately collective action fails (Gutierrez et al. 2011, Jones 2010, Lopez-Gunn 2012, Pretty 2003, Uphoff 2000).

A social capital perspective provides a robust framework to examine the potential for community involvement in crane conservation. This is because structural social capital dimensions facilitate action through social networks and prior engagement reflected by formal groups, established roles, and rules, norms, and sanctions. Cognitive social capital dimensions provide the context for successful participation through shared values, attitudes, reciprocity, and trust.

METHODS

We used purposive sampling and qualitative methods to explore community social capital that may enhance whooping crane conservation in the Texas wintering

Table 1. Structural and cognitive social capital dimensions, definitions, and emergent coding themes. Indicators shown in italics represent an *a priori* coding scheme based on social capital dimensions identified in the literature. Emergent themes refer to specific coding categories.

	Social Capital Indicators	Definitions	Emergent Themes
Structural Dimensions	*Networks*	Patterns of social interactions and relationships that persist over time (Uphoff 2000)	Bonding and bridging relations, relations relevant to crane conservation, communication
	Institutions	Organized or established groups (Ostrom 1990)	Important community organizations for conservation and cranes, roles
	Engagement	Individual or collective actions to address specific issues (Putnam 2000)	Community engagement, volunteerism, and political activism
	Common rules and sanctions	Social constructs that have evolved through ongoing network relations (Ostrom 2010*a*)	Sustainable development, supplemental feeding
Cognitive Dimensions	*Shared values*	Commonly held ideas of what is worthwhile or important, and the basis for ethical behavior (Ostrom and Ahn 2003)	Conservation, crane status, and community identity
	Attitudes	Way of thinking about something or someone, standard pattern of conduct (Brooks et al. 2006, Coleman 1987)	Crane recovery, habitat needs, role in ecosystem function
	Reciprocity	Exchange of goods and knowledge for mutual benefit, or continuing relations over time (Pretty 2003)	Working together, sharing information and knowledge
	Trust	A belief that someone or something is reliable, good, honest, effective, etc. (Bodin et al. 2006)	Trust within community; trust regarding those with decision authority

grounds. We conducted semi-structured interviews of individuals initially identified from media sources because of their involvement in civic or crane-related activities. Within the short time frame of funding and research, we conducted as many interviews as possible with those who responded. Of the 40 individuals identified and contacted, we received 35 responses that all elected to participate in the study. Table 2 summarizes stakeholder affiliation based on self-identified affiliation, community and non-community members interviewed, and gender representation.

We analyzed transcripts of all community members that represent collectively the whooping crane management community in the Texas wintering grounds. Respondent ages ranged from the early 30’s to 80’s with most in their 40’s and 50’s. Interviews were conducted at the convenience of respondents, digitally recorded, and lasted from 45 minutes to three hours. Interview questions were designed to gauge the capacity for community involvement in crane conservation Table 3 using the same open-ended questions for each interview as approved by the Texas A&M University Institutional Review Board for Human Subjects (IRB 10-0355). We transcribed interviews verbatim and anonymized them by assigning random gender indicative pseudonyms to each respondent. These pseudonyms are used throughout the results section to reference direct respondent quotes (in parentheses as single names).

Table 2. Stakeholder affiliation, community affiliation, and gender of all interviewees (n = 35 total). Note that individuals self-identified into multiple stakeholder groups such that an individual might be a rancher, a local elected official, and a fisherman.

Stakeholder group affiliation	**Number**	**Occupation/organization/social group**
Environmental NGOs	2	Audubon, Sierra Club, etc.
Local civic and conservation groups	10	Birding clubs, nature trail group, civic groups
Agriculturists and ranchers	5	Farmers and ranchers
Business	10	Tourism, real-estate, industry
Government representatives	4	City, county, and state offices
Natural resource managers	8	State and federal agencies
Scientists	8	University academics or biologists
Recreational users	10	Birders, water sport enthusiasts
Harvesters	1	Recreational and commercial fishers
Community Affiliation		
Community members	27	Live or work in crane wintering grounds
Non-community members	8	Live and work outside wintering grounds
Gender		
Female	12	
Male	23	

Interview transcripts were organized and analyzed by the first author using NVivo10© software (QSR International Pty Ltd. Version 10, 2012). Transcripts were unitized at the level of the sentence as sentences represent the natural grammatical break in speech (Tesch 1990). Data analysis was a generative process begun by reviewing all

Table 3. Interview questions asked during each interview; order of questions varied due to differences in flow of conversation.

Order	Question
1	What is your relationship to Whooping Cranes?
2	If I were to say “Whooping Crane”, what comes to mind?
3	This project is about community-based conservation. What does this mean to you?
4	What lead you to participate in this process? Potential follow-up questions: a. What are your hopes for this process? b. What are your concerns regarding this process? c. Where did/do you receive information regarding this process?
5	How would you describe the culture surrounding Whooping Cranes?
6	How would you describe the local politics/your relationships within the community?
7	How would you describe the politics of crane conservation?
8	How would you describe the economic situation locally as it relates to cranes/conservation? a. What would increased tourism do to this area? b. How does crane conservation impact how you make a living and what it is you do?
9	Who do you have conversations or communications with about Whooping Cranes? What do you talk about?
9	How do you think cranes function for conservation? What is their position in the bigger picture of conservation?
11	How would you describe the current situation in the Aransas area? Potential follow-up questions: a. What are the most important aspects of the Aransas area situation? b. What are the critical questions that you think need to be answered regarding this situation?
12	How long have you lived here?
13	Is there anything else that we should have asked that we didn’t, and is there anything else you would like to tell us?

transcripts for categories or themes relevant to structural and cognitive social capital. In subsequent rounds of coding, emergent themes were re-examined and refined, and identified as structural or cognitive social capital indicators (Table 1). This analysis strategy most closely resembled Analytic Induction, valued for generating contextual understanding in conservation research (Goetz and LeCompte 1981, Lincoln and Guba 1985, Moon and Blackman 2014, Tesch 1990). Sentences could be coded under multiple themes. For purposes of network analysis, we divided self-identified community members into four sub-groups: community-based organization members, community private business owners, local or county government officials, and community members (citizens and other non-specific identification). Coded transcripts of both community members and non-community members were used to determine network relations within the community and beyond. Other social capital indicators (all except network relations) were analyzed from only community member transcripts. The final round of coding involved data queries and searches for phrases or subjects. In this round we reached a 'stop collecting and processing decision' as the sources were exhausted, categories were saturated (little new information was gained), and new information was far removed from social capital indicators (Lincoln and Guba 1985).

RESULTS

Structural Social Capital

Social capital depends on social structure, specifically bonding and bridging ties that build common knowledge. We evaluated two emergent themes as evidence of network relations. The first included unsolicited 'relationship' comments made prior to asking the interview question, "Who do you see as potential participants in a dialogue about whooping cranes and why?" and similar comments made after this question. All coded ties in response to the interview question, or as unsolicited information, were classified as either bonding ties (i.e., between community members) or bridging ties (i.e., between community and non-community members or between groups). We calculated the percent of bonding ties and bridging ties as a proportion of total coded tie references (n=355). Almost two-thirds are bonding ties (63%) and slightly more than a third (37%) are bridging ties. Bonding ties were most often discussed in reference to "working together" with individuals and organizations within the community. As individuals represent city or county government, local regulatory boards, and are concurrently business owners involved in local environmental and/or civic organizations, bonding ties represent connections occurring across a wide spectrum of community members. Bridging social capital was represented by network ties between community members and non-community members (Figure 1). Community members and local private business owners were most well connected outside the community. There was some differences between community group connections to non-governmental organizations (NGOs), state, or federal representatives, although there was little contact with university or academic representatives. Non-community ties were mentioned in the context of working together, sharing information on relevant projects related to cranes and conservation, as influential contacts, and as valuable knowledge resources.

All respondents suggested specific institutions and often specific individual's names, framing responses as "you should talk to" or "this person/group is important to crane conservation." In response to the question "Who should we talk to about cranes?" relations were described in terms of expert knowledge or mention of others as community leaders. Persons described as whooping crane experts were identified as scientists outside the community (bridging resources) or citizen experts (bonding resources). Citizen experts included long-term crane tourism operators and naturalists.

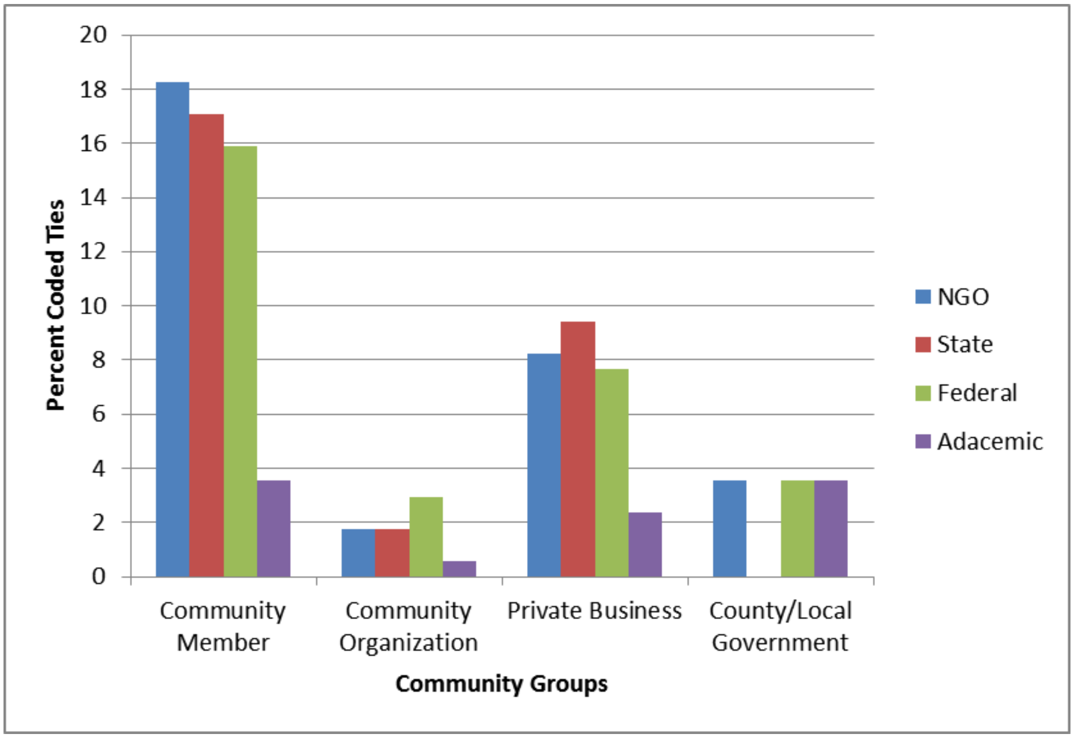


Figure 1. The percentage of coded ties between community groups and non-community groups. Bars represent the percent of all bridging ties (n=355).

Community networks were maintained and strengthened through communication and shared knowledge about whooping cranes and their issues. Community newsletters reached "thousands of people" (Joshua) and were able to reach hundreds of people in short time periods. "I think there was once an occasion when I wanted to put a little bit of pressure on an elected official at the state level; I only had time to send the email out to about eight people but within five or six hours I had gotten about 40 or 50 emails on the subject" (Landon).

Institutions or more formal community groups included regional groups supporting whooping crane education and advocacy, non-profit organizations involved in political action, local non-profit organizations promoting land stewardship, local environmental clubs, state mandated natural resource policy advisory committees, local government officials and committees, and state government-related organizations (See in Table 2.). Community members were involved as leaders in local government, as representatives on city and county boards, as community leaders, as organizers and heads of environmental advocacy groups, and as actively engaged citizens. Often, their roles were voluntary. Thirteen of the 25 community members assumed leadership roles in organizations, which was not surprising as our sample bias was towards individuals active in the community or identified as important in crane conservation efforts.

Civic engagement in the community involved participation in community art, museum, and environmental projects; educational outreach; and political activism. The majority (82% of references coded as 'engagement') of the respondents framed engagement in terms of activities directly related to crane management or habitat protection. The value of engagement was described as "education and appreciation, interpretation, because that leads to caring about cranes and habitat, actually" (Connor). Community members were proud of contributions in establishing birding trails or observation kiosks, routing kayak trails, cleaning up beaches, protecting unique trees, and participating in sound wastewater management plans. Much of this was accomplished through volunteerism as echoed in the sentiments of a local tourism operator who said “So, I have never lived in a community that has had so much volunteerism and so much support for volunteerism.” Amelia described it as “anytime anybody needs help, I’ll put out an email to 300 people.”

Environmental concerns in the community have led to political activism in the form of litigation concerning regional water issues. “Last year there wasn’t enough water flow into [the estuary] to keep blue crab populations up and whooping cranes just about starved to death” (Ben) and “there was actually salt water going up the rivers and, as that was happening, it was not a good environment for the blue crab that the cranes have as a staple for their food” (Carter). How much freshwater is required to sustain the ecosystem and therefore the crane is an often asked question: “It’s not that inflows aren’t affecting whooping cranes, but can you say that inflows killed 23 whooping cranes in Aransas last winter” (Daniel). These concerns were the basis for a lawsuit based on protecting whooping cranes under the ESA to require state regulatory agencies to maintain adequate freshwater flows to the estuarine ecosystem (The Aransas Project vs. Shaw et al. 2011). Jackson described community involvement in the lawsuit as “to a person, was not more concerned about the fate of their natural resource” and linked “bay quality, cranes, and fishing sort of all together, 'cause I think those were sort of the ties that brought everybody together” in the lawsuit. As well, the community closely monitored and, in some cases, actively participated in state watershed policy initiatives (http://www.twdb. state.tx.us/surfacewater/ flows/environmental/index.asp).

Civic engagement led to more formal societal constructs such as common rules and sanctions. An example concerns protection of iconic wind-deformed trees peculiar to this area of the coast: “The tree ordinance was a citizen’s movement, and was actually done by citizens until it got brought into the city governments, now a committee of the city” (Michael). Other issues that are expressed as needs for sanctions or regulation include sustainable development and supplemental feeding. Encroaching human development was described as a significant threat to whooping cranes via adverse impacts on habitat and inevitable human-crane interaction. One resident said “Yeah, it’s [development’s] going to happen, so, can we develop in such a way to minimize the impacts to the resources, that’s just the question.” Connor described the Texas Coastal Bend as similar to other areas regarding sustainable development:

> “I think it is inevitable that more people will move to the coast, and you run out of land for them to move to. But I think … down here, they are very acutely aware, and I think all of the United States is becoming this way, on well, we can’t drain every well; we can’t cut down every tree to build more houses and more stores, because then this place won’t be special. It’ll be hot and mosquito infested. So, I think it will be – oh, conscientious growth or you know growth with a little bit of awareness. So, I think it’ll be growth, inevitable growth, with precautions thrown in.”

But statements varied as to what ‘precautions’ entailed for growth and development. Some favored a moratorium on all development within 300 yards of the shore; others argued that the ephemeral nature of shorelines due to weather, tides, currents, and climate change necessitated shorelines remain entirely undeveloped. Some suggested that sparse development was sustainable with cranes coexisting with humans; and others suggested clustered human development interspersed with intact crane habitat. Within the responses, definitions were lacking as to how to define ‘too much’ development or ‘too many’ people.

With the most recent Texas drought (2011 – present), and its impacts on primary productivity in the estuaries, cranes have taken advantage of readily available food from deer feeders (primarily dried corn). Community members stated that supplemental feeding provided a useful food resource for cranes during severe drought. Whooping cranes were also reliably easier to observe at deer feeders, a boon for local tourism as one person reflected, “I'm not that adventurous, so I like the convenience of driving up and being able to see them.” This was juxtaposed with concern that deer corn might not provide adequate nutrition, may harbor bacteria or insecticides that could harm cranes, and could entice cranes away from marsh habitats into areas frequented by predators. “When whooping cranes move off the refuge looking for food and show up in your backyard, people get the dog inside because they love the birds” (Landon). William told the story of reducing brush cover near a deer feeder “’cause a bobcat is gonna catch one of the whooping cranes. It wasn’t ten days later … in the winter and a bobcat ran out of the brush and flew in the air and caught a whistling duck in its mouth.” A longer term concern with supplemental feeding concerned young cranes habituated to easy food access resulting in poor native foods foraging skills.

Cognitive Social Capital

We examined cognitive social capital dimensions including shared values and attitudes and reciprocity and trust (Table 1) using survey questions about people’s impressions of, and relationship to, cranes as well as how whooping cranes affect local culture, politics, and the economy (Table 3) Experiences with cranes were described as “ethereal,” “causing goose bumps,” as experiences to share with good friends and family, and as a stimulus to go birding during an outdoor lunch break. Whooping crane-related tourism impacted the economy, “our restaurants, our gas stations, our convenience stores, our restaurants – I mean just the revenue that they bring in is in itself wonderful, but it's also an impact on whether (tourists are) eating here – which if they're staying overnight, they're eating here” (Carter). Another resident observed that “There are many people here, who make their living off of whooping cranes, guides who take people out in their boats to view whooping cranes. So, there’s an industry around the whooping cranes, and most of that industry is awareness and education. But, you don’t protect what you don’t care about.” Connor remarked that “education and appreciation… leads to caring about (whooping cranes), and habitat;” and “through that education, then there’s going to be more tolerance and understanding” of whooping crane conservation needs (Mia).

Community identity reflects shared values and generalized reciprocity and is an indicator of cognitive social capital (Table 1). Respondents described the small-town feel, shared appreciation of natural resources, and long history in the area. They spoke of local elections involving neighbors and long-time friends; art and tourism centered around the environment and whooping cranes in particular; and valuation of a beautiful place to live and work. Recreation was mentioned frequently and included fishing, hunting, boating, birding, photography, or daily exposure to nature in and around the estuarine ecosystem. Natural beauty has drawn people to this area of the Texas Coast, and makes them stay. As one person stated: "…you have a population of people who have moved here who choose to live here. They could live a number of places but they choose to live here because of the fishing, because of the natural environment, those kinds of things."

Shared values about the environment and caring for cranes carried over to attitudes towards addressing perceived needs for recovery. There was concern that insufficient habitat exists to support an increasing whooping crane population. Community ideas for crane management included: having conservation easements on private lands to increase usable habitat, promoting sustainable development that preserves existing habitat as much as possible, managing public spaces such as parks as crane habitat, creating buffers between crane habitat and developed areas, and coexisting with cranes. "This 200, 250, whatever the number (of cranes) was this year, that's not sustainable. You've got to get to a much higher number for the population, and you've got to have habitat for them (Ethan)." Connor stated:

"One of the best things you can do for the whooping cranes is to leave them alone. Don't shoot them. Don't pluck their feathers. Don't take their eggs. Okay, that's obvious. But don't take their land away from them. Don't keep taking the land away from them. Give them a place to live, and if you want more than 200, give them room to expand, because if you think about, during that drought, which was horrible here, and they just sat here and took it."

One landowner pointed out, "if we don't see habitat on private land, we're not gonna have a habitat left" (Sophia). Habitat options on private lands depend on owners improving and protecting habitat through good stewardship and conservation easements: "but to me, crane conservation is about stewardship. It's about the relationship of humans with the earth and that we have obligations beyond those to ourselves, that we have obligations to other animals that we share the planet with" (Jackson). Conservation easements provide an opportunity for expanded habitat "if people, care (Owen)" to protect the habitat "into perpetuity (Jacob)."

This community expressed a broad understanding of the role that whooping cranes play within the ecosystem. Whooping cranes are a highly valued non-substitutable asset and if crane numbers decline because habitat is not protected, "if there's no more wetlands, there will be no more whooping cranes, and a large part of our nature/tourism dollars are gone" (Connor). Amelia described whooping cranes in terms of a healthy ecosystem that includes the estuary, flyway, and breeding grounds in Canada. Daniel, a local citizen, summed it up by saying "so really the issue of saving the whooping cranes basically comes down to saving the bay productivity so that's shrimp, that's oysters, that's a way of life, that's sports fishing – it's everything." Whooping cranes were part of community identity and community life, and integral to coupled natural and human systems.

Often expressed as working together, reciprocity was prevalent in the whooping crane management community. “Everybody out here works together” (local landowner) in the community; and “we work very closely with all the different organizations that are involved in protecting the environment.” A community leader described interaction on a weekly basis with citizens and state and federal agencies. Working together well was reflected in prior action to protect natural resources - from developing tree protection policies (late 1980’s) to stormwater management policies (2008) – and mentioned as groundwork that has brought together “intergovernmental with private sector” (Dylan) to “talk about what we can do for the cranes (Ryan).” Local government jurisdiction covered stormwater runoff and local zoning and some influence on bay navigation, but state agencies determined freshwater inflows, and federal agencies oversaw coastal dredging and rural shoreline development. Community members expressed trust that local government would faithfully act in the interests of the community, but they were less certain that state or federal decisions would reflect community values. Community members complained that the USFWS and US Army Corps of Engineers were not fulfilling their federal purview to protect whooping cranes: “I’m furious at times that (*USFWS*) don’t do more” (Amelia) and “I want (*the US Army Corps of Engineers*) to not just accept everything, to look at it and go ‘that’s not right’ and to know that [*shoreline dredging*] shouldn’t be happening” (Liam). “I think counties need an authority to protect [the coastal environment] (Owen).” Frustration over inaction led in part to support for the legal action regarding freshwater inflows and the significance for whooping cranes because “the whooping crane gets mentioned a lot because you have the power of the

ESA that can theoretically do something to protect the crane, whereas you don’t have an ESA for an oyster” (Daniel). There was concern that legal action might harm bridging relations between the community and state and federal management agencies, and ultimately jeopardize future community involvement. This was described as unfortunate if “this lawsuit shuts off any conversation on crane conservation” (Emma). Lack of influence on both state and federal issues has been detrimental to establishing trust. As one individual stated “Well, I think, you know from my perspective that if you truly want to have success at something like a, you know community grassroots type of solution to a resource problem you need to be able to establish trust” (Chloe).

DISCUSSION

Social capital provides a theoretical framework to examine social factors important to resource managers. It also recognizes that networks, trust, and leadership alone may not be predictive of successfully involving community members in participatory processes. By examining structural and cognitive social capital dimensions, we concluded that this community is ready, capable, and inclined to be a positive force in whooping crane conservation. In the US, natural resource management is primarily the responsibility of government sponsored agencies, with a long history of community involvement dating to 1949 with Aldo Leopold, who admonished wildlife professionals to work with local communities whose support was crucial to successful management (Newton 2006, Peterson, M. N. et al. 2004). Community involvement can take multiple forms but successful strategies share common factors, namely strong leadership, strong social cohesion, clear boundaries and membership, congruent rules, and the exertion of influence in decisions (Daniels et al. 2012, Gutierrez et al. 2011, Ostrom 1990, Senecah 2004). These factors have parallels to beneficial structural and cognitive social capital dimensions found in the whooping crane management community.

Social capital was assessed from the perspective of established bonding and bridging networks that are the foundation for potential community involvement in whooping crane recovery efforts. The percentage of bonding ties in this study is comparable to other natural resource studies where greater than 50% bonding ties within community groups was associated with successful coordinated action (Bodin and Crona 2008). Through bonding ties, this community has contributed to the creation of common knowledge that facilitates trust, reciprocity, and shared values and attitudes (Doerfel et al. 2010, Ishihara and Pascual 2009, Mountjoy et al. 2013, Ostrom 2010*a*, Woolcock 1998). This may explain the past successes this community has had in working together to protect iconic trees by developing a tree ordinance, establishing birding trails, changing local wastewater management regulations, and successfully launching a lawsuit against the state to sue for greater freshwater inflows. These past successes have established local institutions and groups that represent acknowledged resources in the community. As important as bonding ties are for successful collective action, bridging ties that comprise relations of respect and mutuality link the community to valuable external resources and enable a larger knowledge pool beneficial for natural resource management (Bodin et al. 2006, Ishihara and Pascual 2009, Mountjoy et al. 2013). We found that connections between community members and NGOs, state and federal management personnel and groups provide a mechanism to share knowledge and the potential for these external levels of authority to play a role in legitimizing community involvement in management (Ishihara and Pascual 2009, Lopez-Gunn 2012). Communication within and beyond the community level is key to maintaining and strengthening valuable bonding and bridging ties.

Organized groups or institutions are social structures that typically require leadership and other functional roles, rely on rules and guidelines of normative behavior, and often lead to responsible citizenship and collective management of resources. Leadership in particular is considered a crucial indicator of success for collective natural resource management (Gutierrez et al. 2011, Lopez-Gunn 2012, Ostrom 1990, Serra 2011). As an example, the formal and informal fishing institutions off the coast of Maine have influenced state level rules that restrict fishing and lead to credible rules with high compliance (Dietz et al. 2003). Across Illinois, successful community based natural resource management, is attributed to motivation and leadership as well as shared vision and common values among participants (Mountjoy et al. 2013). We found that this community has established groups that address ongoing natural resource needs including wastewater management, intracoastal shipping traffic, and freshwater inflows. Respondents with leadership and other skills are potential participants important to community involvement in whooping crane management.

Civic engagement has been described as a positive externality of social capital that is associated with solidarity and citizenship (Adler and Kwon 2002). Respondents reported being actively engaged in the community around environmental issues, and expressed civic pride and increased caring for whooping cranes. This may account for consistent views regarding the value of sustainable development. Debate on supplemental feeding continues to evolve and perhaps presents an opportunity for open discussion and knowledge and trust building between the community and state and federal agencies. Solidarity established through bonding capital may lead to strong social norms and beliefs which encourages compliance (ibid.). Civic engagement has many elements but is intrinsically about participation in decision-making or governance over how resources are allocated. If engagement is based in shared values, where all involved are working towards common goals, and if contributions are meaningful (i.e., legitimate and valued), then collective action will likely build social capital and be a positive community force (Brunie 2009, Putnam 1995, Putnam et al. 2004, Woolcock and Narayan 2000).

A criticism of studies focusing exclusively on structural social capital dimensions is that they fail to recognize the importance of the cognitive dimensions that shape successful natural resource management (Ballet et al. 2007, Krishna and Uphoff 2000, Putnam et al. 2004). As an example, Bodin and Crona (2008) found high levels of social capital in a fishing community in Kenya, but the reluctance to report rule breaking was also high; thus the context within which management strategies were implemented was problematic. In our study, structural social capital dimensions are set in the context of a community that values nature and cranes, and sustainability and decisions based on best practices for crane feeding. There is a broader context of a strong sense of community that reflects ‘the norm of generalized reciprocity’ that resolves problems of collective action and a commitment to the common good (Adler and Kwon 2002, Urquhart and Acott 2014).

Public or community involvement in natural resource management often requires an initial knowledge building phase to develop shared ideas and norms. Frequently managers work with decision groups using techniques such as structured decision-making (Gregory et al. 2012), collaborative learning (Daniels and Walker 2001), or mediated modeling (Peterson, T. R. et al. 2004, van den Belt 2004) to build shared knowledge and facilitate greater acceptance of multi-dimensional policies (Depoe et al. 2004, Norton 2007, Peterson et al. 2006). These techniques assume that groups often have little experience working together, few shared ideas, and minimal established relationships and so require substantial time commitments. We found strong community identity, an actively engaged public that works together, and attitudes that align with primary goals of the current whooping crane recovery plan, specifically habitat conservation, protection, and creation (USFWS 2009*a*). Thus, there is a solid foundation of resource valuation from which to build. Interviews revealed opportunities for discussion and shared learning regarding supplemental feeding, habitat protection, watershed management, and potential community involvement in shared management decisions. Sustainable development is an issue that may be addressed within the context of crane management, but is complicated by economic constraints and diverse opinions.

An important aspect necessary for addressing complex environmental problems that involve participatory management processes involves understanding system component function and interconnected consequences (Daniels and Walker 2001, van den Belt 2004, Walker and Salt 2006). The U.S. Forest Service, for example, used collaborative learning as a tool to help stakeholders in Oregon understand and address the complexity, controversy, and uncertainty inherent to the ecological and economic conflicts over old growth forest preservation, spotted owl recovery, and logging (Daniels and Walker 2010). As demonstrated in interview responses, many of the people living in the region where the cranes winter understand whooping cranes as an integral part of the larger system, and want to contribute to the cranes' recovery. Those tasked with managing natural resources in the Coastal Bend area of Texas may minimize time and effort needed for successful conservation by building on this important conceptual framework.

Social capital rests on individual attitudes and behaviors that translate into a general readiness to trust and cooperate beyond specific settings and purposes (Brunie 2009). The expectation of in-group reciprocity (if you think someone is going to participate, you will) serves as a deep heuristic that builds solidarity and cooperation, and ultimately trust. Reciprocity and trust are especially important in endangered species management situations where common purpose and trust are critical factors in public involvement (Brooks et al. 2006, Gutierrez et al. 2011, Jones 2010, Parker and Feldpausch-Parker 2013, Pretty 2003). In Texas, 98% of Texas land is privately owned (http://www.nrcm.org/documents/publiclandownership.pdf), which means that increasing habitat requires cooperation of private landowners. The Endangered Species Act places whooping cranes in the middle of two significant norms, namely the intrinsic right to control personal property without government intervention and a duty to be a good land steward (Olive and Raymond 2010, Parker and Feldpausch-Parker 2013). Community involvement, however, does not guarantee a clear path through controversy. In the case of the Key deer in Florida, a community-based conservation process was unrealistic and poorly communicated with no resolution of conflict (Peterson, M. N. et al. 2004). As well, a community-based conservation process intended to resolve controversy over the Houston toad in Texas ended in a stalemate with the USFWS, again attributed to unrealistic expectations and poor communication (ibid.).

Although we found that residents of the whooping crane management community may disagree about specific implementation practices, they do not disagree about the importance of continued whooping crane recovery. We found a strong indication that stewardship may prevail with respondents favoring sustainable development, conservation easements, and increased protection of important habitat. One potential barrier in this community may be the lack of trust that federal management agencies will adequately address protection measures. Successful community participation in whooping crane conservation may depend on providing opportunities for the community and state and federal representatives to establish more positive relations based on shared knowledge building and decision-making experiences that build trust, with an emphasis on open communication. Perhaps the greatest potential risk lies in not engaging this community.

Recovery of this endangered species is an ongoing process, and success can be measured by effort as well as outcomes. Substantial social capital exists in this community and is available to aid conservation of this endangered species and the habitat it relies on. Whooping cranes are part of the larger ecosystem and regardless of their fate, the ecosystem and cranes define both a way of life and quality of life. This community wants to make meaningful contributions to endangered species management. Chloe added to this perspective when she commented:

“I think there’s value in people coming into contact with whooping cranes; you know I think it increases their support for the species. I mean we can develop that way of thinking, but getting there early in the game so that we’ve created a viable habitat to be left in. I mean some would say, you know protect them from all the disturbance and that sort of thing. And I don’t think that’s our best strategy. I think local communities are important if we’re to be successful in the long term.”

We suggest that community social capital provides a realistic baseline resource for community involvement in whooping crane management. This engaged proactive, success-under-their-belts community has knowledge and shared values about the environment on which they rely for their livelihoods and quality of life. They have established trust and reciprocal relations over long periods of engagement and have the potential to effectively participate in creative problem-solving ventures with management agencies. By evaluating social capital before deciding how to involve the public, managers are more likely to make appropriate choices about public involvement strategies. Successful community involvement in natural resource management is associated with early involvement, adequate decision space and voice, and shared values (Depoe 2004, Hamilton and Wills-Toker 2006, Peterson et al. 2006, Senecah 2004, Schusler et al. 2003). Both the community and management agencies need to trust each other – the communities that the agencies will protect their way of life, and the management agencies that the community shares long term conservation goals.

Social capital in the whooping crane management community may save time and money for successful efforts to protect and manage whooping cranes. Established networks bond the community around shared values and bridge community members to valuable outside resources. A history of active engagement and reciprocity along with attitudes that align with established recovery plan goals are a resource and opportunity for management agencies to work with this community. Established institutions provide requisite leadership and experienced organizers as well as prior experience. Community awareness of sustainable development and supplemental feeding, as well as habitat concerns provides a jumping off point for shared discussion. A potential concern is the lack of trust in federal agency decisions.

There are multiple ways of accomplishing successful management with greater public involvement. Natural resource managers should be careful in their approach to community involvement in whooping crane conservation. This passionate and caring community should be invited to sit at the table while decisions are made, because they understand the tenuous nature of protecting cranes and have a long history of being a positive force in local resource issues. It can take the form of collective action that includes the community in partnership with current management agencies, meaningful community representation in current efforts, or responsive top-down management. Regardless of the methodology, it will still require collaboration and forging of new bonds of trust between the community and federal agencies through communication and transparent decisions.

MANAGEMENT IMPLICATIONS

Re-framing public involvement as a social capital investment rather than a legal requirement may alter a contentious participatory exercise to one where participants step into productive cooperative involvement in natural resource management (Leahy and Anderson 2010). A conservation-reliant species requires a paradigm shift from top-down agency driven management that might include citizen input, to more inclusive decision-making practices. This shift suggests focusing more directly on preexisting social resources, literally capitalizing on the resources that exist within the community.

CHAPTER III

COLLABORATIVE MODELING: A SOCIAL LEARNING TOOL FOR BUILDING SOCIAL CAPITAL

Successful management of ecological systems requires sufficient understanding of complex systems, the ability to formulate adaptive responses to system changes, and broad acceptance of policies (Ascough II et al., 2008; Beall and Zeoli, 2008). Ecological models offer a way to improve understanding of complex ecosystems, and expand the capacity for adaptive responses to system change, but model implementation, including acceptance of policies suggested by modeling results, suffers without early stakeholder involvement (Salerno et al., 2010; van den Belt et al., 2010; Voinov and Bousquet, 2010; Voinov and Gaddis, 2008). Ecological modeling juxtaposed with collaborative learning principles, or collaborative modeling, is the practice of building models *with* rather than *for* stakeholders and may contribute directly to stakeholder acceptance of management policies (Bourget et al., 2013; Sandoval-Solis et al., 2013; van den Belt et al., 2013). Collaborative modeling is grounded in collaborative learning theory, which emphasizes engagement and shared learning (Daniels and Walker, 2001; Thompson et al., 2010; van den Belt, 2004). It implies collaboration among stakeholders with associated ideas of democracy, shared ownership, and recognition that diverse voices are joining together to build the model (Bourget et al., 2013). We suggest that collaborative modeling is a tool that meets the goals of successful ecological systems management.

Collaborative modeling, sometimes labeled as mediated or participatory modeling, has been used to address greenhouse gas emissions (Thompson et al., 2010), management of conflicts between wildlife habitat and livestock grazing (Vanwindekens et al., 2013), national parks, urban water management (Musacchio and Grant, 2002; Pahl-Wostl and Hare, 2004), and watersheds (Sandoval-Solis et al., 2013; van den Belt et al., 2013; Voinov and Gaddis, 2008). It is an intentional and systematic approach for investigating and synthesizing options; often fostering a sense of ownership that reinforces commitment to selected policies. Collaborative modeling processes typically include a preparation phase to select stakeholders and determine what is reasonable, followed by a series of workshops to develop a conceptual model of the system, and finally quantitative model development, simulations, and evaluations to aid in deciding on an action plan (Thompson et al., 2010; van den Belt, 2004; Voinov and Bousquet, 2010).

Like many system modelers, our focus is on the modeling process rather than the resulting model, because engagement in the process provides learning opportunities that enable participants to develop more thorough understanding of complex systems, formulate adaptive responses to system changes, and accept implementation of management policies that eventually emerge (Grant and Swannack, 2008; van den Belt, 2004; Voinov and Gaddis, 2008).

Learning, and social learning in particular, is ubiquitous in successful natural resource management as a key element of collaborative processes (Cundill and Rodela, 2012). Social learning occurs when a group with diverse interests and perspectives engages in an iterative, interactive, and intentional process of linked experiences, reflection, and experimentation to address common issues (Kolb, 1984; Reed et al., 2010; Schusler et al., 2003; Sol et al., 2013). Transformative learning progresses through cognitive dimensions of remembering and understanding, to evaluating, synthesizing, and creating new ideas and approaches (Krathwohl, 2002). Through collaborative modeling, social learning enables participants to explore their own values and mutually perceived challenges, building trust and commitment (Sandoval-Solis et al., 2013; Schusler et al., 2003). Within a social context, this progression to higher order thinking corresponds to actionable change (Cundill and Rodela, 2012; Pappas et al., 2013; Reed et al., 2010). We suggest that collaborative modeling, through social learning, builds social resources that are the basis for collective action, namely, social capital.

Collaborative modeling has the potential to build social capital, or the relational resource of networks, shared ideas, reciprocity, and trust that remain in place regardless of the outcomes of the modeling process (Brunie, 2009; Ragland et al., in press; van den Belt, 2004).Social capital, is an enduring relational resource, which encompasses cognitive dimensions of common purpose and shared ideas, and structural dimensions of networks of engaged individuals committed to joint action (Grootaert et al., 2002; Ostrom, 2000; Putnam, 2000; Ragland et al., in press; Uphoff, 2000). Structural dimensions materialize as social networks, and include both bonding or within-group ties that reflect network cohesion, and bridging or inter-group ties that provide access to new resources and information (Woolcock and Narayan, 2000). Social capital, like social learning, recognizes that a diverse but well-connected group is required for adaptive response in natural resource management (Bodin et al., 2006). Cognitive social capital dimensions include shared values, reciprocity, behavioral norms, and trust (Adler and Kwon, 2002; Putnam et al., 2004). Collaborative modeling processes facilitate network building through focused participant engagement. Engagement involves working together to influence who, how, and by whom a community's resources will be allocated and leads to trust and development of shared values (Adler and Kwon, 2002; Putnam et al., 2004; Putnam, 2000). Thus, social interactions such as collaborative modeling build the structural dimensions of social capital, which often lead to and are reinforced by its cognitive dimensions (Krishna et al., 1999; Putnam et al., 2004). For this project, we examined how collaborative modeling advanced these goals by: 1) providing a structure for successful social learning critical to successful ecological systems management; and 2) building social capital through engagement and networking opportunities.

METHODS

Study Area

The collaborative modeling process focused on the Mission, Copano, Aransas, and San Antonio Bays in Texas, USA (Figure 2). Upstream demands include the metropolitan areas of San Antonio and Austin as well as agricultural and recreational users. Rivers supply freshwater to these productive estuaries that support recreational piscine and crab fisheries, the world's second largest chemical industry, energy extraction, the Gulf Intracoastal Waterway, and the Aransas National Wildlife refuge notable as habitat for several rare species including the federally endangered whooping crane, *Grus Americana* (USFWS, 2009*a*).

Our project is situated within efforts in Texas, USA, for broader stakeholder participation in water resource management, most recently from state mandates to address environmental flows when granting perpetual water use permits (USFWS, 2009*a*). Environmental flows refer to the quantity, quality, and timing of fresh water to sustain all parts of a watershed through instream flows to rivers and streams and freshwater inflows to estuary systems (texaslivingwaters.org). In 2007, the Texas Senate

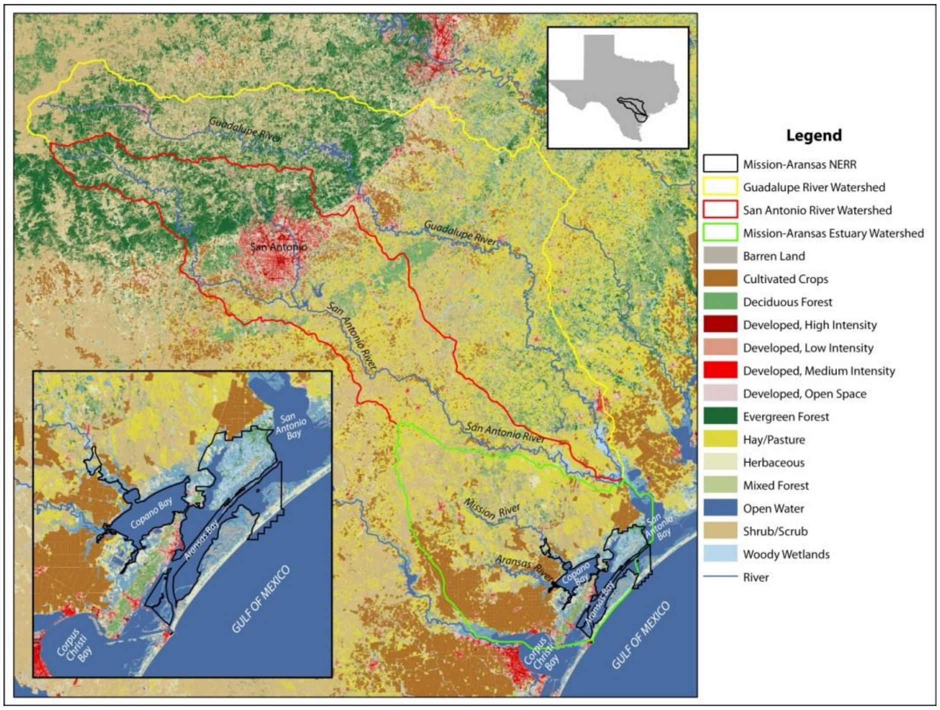


Figure 2. Map of the Guadalupe, San Antonio, Mission, and Aransas Rivers and Mission, Copano, Aransas, and San Antonio Bays (GSA) watershed, Region N water planning area, and Aransas National Wildlife Refuge. Inset shows estuary region that was the focus of the modeling process.

passed Senate Bill 3 (SB3) establishing a stakeholder process for the development and implementation of environmental flow standards applicable to new appropriations for surface water use, including the watershed that impacts this estuary system (www.capitol.state.tx.us/BillLookup/ Text.aspx? LegSess=80R&Bill=SB3). The collaborative modeling process was part of a transdisciplinary project designed to produce scientific results that could inform SB3 stakeholder policy recommendations regarding environmental flows for the GSA watershed (www.missionaransas.org/post_sciencecollaborative.html).

Collaborative Modeling Process

Collaborative modeling provided the framework for social learning through linked experiences, reflection, and experimentation. Collaborative modeling was accomplished in a series of seven workshops (Figure 3) over a 3 year period with stakeholder participation moving progressively from developing a shared conceptual model of the system (Year 1), quantitative model simulation and parameterization (Year 2), and, finally, reflection on model use and application (Year 3).

Workshops in the first year focused on developing a shared framework of understanding among participants. Icebreakers were used to set the interactive tone, introduce workshop themes, and as informal ways for participants to understand diverse perspectives represented in the process. In the first workshop, participants examined the estuary from a systems perspective by asking basic questions about estuary components, actions that affect these components and issues that affect estuarine function. After

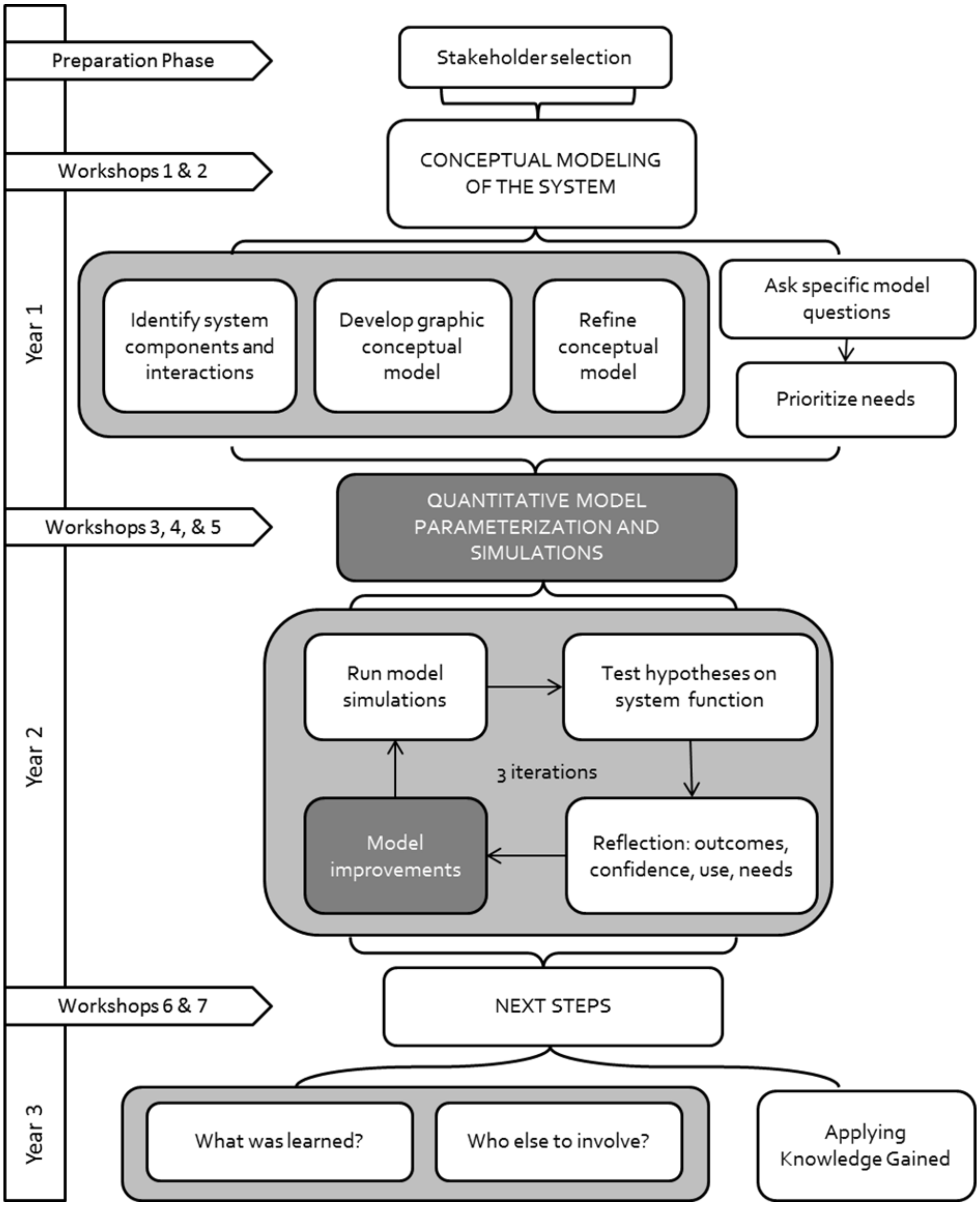


Figure 3. Flow chart illustrating the collaborative modeling process used to develop a systems model over the three year time period. Dark gray boxes indicate modeling expert input during year two of the process. Light gray boxes capture the tasks accomplished each year.

individual reflection, they worked in small groups to draw conceptual diagrams of the system. A composite of these diagrams was the basis for the second workshop, when participants further examined component relationships and prioritized questions about system function that addressed needs and concerns. To develop a quantitative model, we asked participants what they wanted or needed from the estuary, how the estuary satisfied those needs then and into the future, and finally, what question could they ask from a systems model that would address their needs. We gathered individual and group responses to these questions. The group identified Blue crabs as a central indicator species for system health, and as a possible focal point for quantitative modeling.

Working from the stakeholders' conceptual model, the scientific team designed a quantitative model using NetLogo free software (Wilensky, 1999) to explore how freshwater inflows influence blue crab populations in the Mission-Aransas and Copano Bay system. The three workshops in the second year were devoted to the iterative process of testing and improving the model (Figure 3, Year 2). Participants provided written feedback on whether and how results fit their expectations, what they found most useful from simulations, the confidence they had in the model, how they might use the information or scenario results, and offered suggestions for improvement.

A concern in this type of process is that each workshop is attended by an entirely new set of individuals with little carryover of ideas. We addressed this concern by carefully summarizing results of previous workshops to establish a common knowledge baseline, and displaying conceptual model diagrams during subsequent workshops. We capitalized on the social memory of prior attendees by pairing more experienced users with those who were attending a workshop for the first time during the second year of quantitative model experimentation. We used repeat attendance over all workshops to gauge institutional social memory resulting from participation over time.

Throughout the collaborative modeling process, we asked participants what they had learned through the collaborative modeling process, what knowledge gaps remained, and how the model might be useful in water policy decisions in terms of how and to whom to communicate these findings. In the final year (Figure 3, Year 3), we had participants discuss their insight within the context of the SB3 process and develop specific steps to incorporate knowledge and insights into an action plan.

Stakeholder recruitment

Diverse stakeholder representation is critical to both social learning and social capital as a source of new ideas and social resources (Brunie, 2009). To expand stakeholder involvement beyond that afforded by the state SB3 process, we identified over 500 people who had been active in coastal issues during the previous five years, targeting potential participants with high influence and interest. We used public print and web-based media to advertise workshops and garner participation of anyone not included in our list. Workshops were open to the public, and invitations specifically encouraged participation of stakeholders from “the agriculture, commercial fishing, and recreation industries; local government; water resource agencies; scientists; and citizens”. We used attendance records (names and self-identified affiliation) to categorize participants into stakeholder groups relevant to water policy (Prell et al., 2009; Price et al., 2012). This provided information to examine diversity of stakeholder types attending each workshop and attendance fluctuation throughout the modeling process.

Social learning

We used two methods to evaluate social learning. First, we followed Schusler et al. (2003) to evaluate reported learning by canvassing participants at the conclusion of each workshop, asking whether "their knowledge or understanding regarding freshwater inflows increased as a result of this workshop?" Response choices included: yes, no, or unsure. We calculated the percent of each response as a total of all responses for that workshop.

To gain a better understanding of 'transformative' learning where individuals develop their cognitive abilities through the learning process we used Bloom's Taxonomy of Educational Objectives (Krathwohl, 2002). Bloom's Taxonomy was created in 1956 as a tool to encourage and evaluate cognitive levels of learning. Action verbs that describe cognitive levels (understand, apply, evaluate, or create) can be used purposefully in assessment design (exams that ask students to identify, evaluate, or create) or as indicators of learning or sensemaking. Here, we evaluated workshop participant responses during the quantitative modeling workshops (Figure 3, Year 2) for action verbs characteristic of specific cognitive levels as described in Bloom's taxonomy (Table 4). Worksheets asked for feedback on hypotheses tested, results, and difficulties encountered and posed two questions pertinent to social learning: 1) What did you find most useful?, and 2) how would you use this information? Responses varied from short phrases to complete sentences, but often involved the use of verbs. We used illustrative

Table 4. Bloom’s taxonomy of cognitive skills based on Anderson and Krathwohl (2001) and Krathwohl (2002). Table presents example action verbs used within each cognitive domain (italicized verbs were used by participants in this study).

Domains:	**Remembering**	**Understanding**	**Applying**	**Analyzing**	**Evaluating**	**Creating**
Bloom’s Definition	Retrieving relevant knowledge.	Determining the meaning of facts and ideas.	Carrying out or using a procedure in a given situation.	Break into parts and detect how parts relate to one another and overall structure or purpose.	Making judgments based on criteria and standards.	Putting elements together to form a novel, coherent whole or make an original product.
Verbs	*Choose* Define Find How Label List Match *Observe* Omit Recall Recognize Show Tell *What* When Where *Which* Who Why	Classify *Compare* Contrast Demonstrate Determine *Explain* Illustrate *Impact* Infer Interpret Outline Relate Rephrase Show Summarize Translate	*Apply* *Choose* Construct *Develop* Execute Experiment with *Guide* Identify Interview Implement Make use of *Manage* *Model* Organize Plan Select Solve	Analyze *Assume* Classify Conclusion Differentiate Discover Dissect Divide Examine Function Inference Organize *Refine* Relate Survey Take part in *Test for* Theme *Trend*	Agree Appraise Assess Award Conclude *Criticize* Decide Defend *Determine* Evaluate Explain Importance Influence *Interpret* Judge Justify Measure Prioritize Recommend *Verify*	Adapt Build Change Create Construct *Design* Develop Imagine *Improve* Invent Maximize/Minimize Modify Originate Plan *Predict* Propose Solve *Test* Theory

verbs as a coding guide to assign participant response verbs to the various cognitive domains (Anderson and Krathwohl, 2001; Domin, 1999). Because verbs can denote more than one skill level, we used the context of the phrase in analysis. For example, the verb ‘describe’ can indicate understanding when paired with ‘how’ or application when paired with ‘can be used to’ in the following statements: “describe how freshwater inflows affect crab mortality”; or “describe how salinity information can be used in flow recommendation”. The second statement would be coded in the context of application, a higher cognitive level than understanding.

Social Capital

To evaluate collaborative modeling as a social resource we examined potential contributions to relationship building and networking and requisite engagement that serve as indicators of social capital (Brunie, 2009; Lin, 1999; Lopez-Gunn, 2012; Putnam et al., 2004; Uphoff, 2000).

Engagement

In the social capital literature, engagement is most often measured as participation or membership in organizations, but in its broader sense is described as collective action designed to identify and address common issues of concern (Putnam et al., 2004; Woolcock and Narayan, 2000). In this study, we used repeat attendance to measure participation over time. Repeat attendance, or attending multiple workshops, describes ongoing commitment or engagement of participants in the process. Repeat attendance was calculated as the percent of individuals attending a workshop who had attended a previous workshop.

Networking

Networking opportunities during the collaborative modeling process included interactions during model simulation as well as informal and formal opportunities for dialogue about model use. During the collaborative modeling process we asked two questions about networking opportunities. The first question, “Did your ability to access resources (e.g., people and information) relevant to your work increase as a result of this workshop?” was scored as either yes, no, or unsure. We calculated positive responses as a percent of total responses for each workshop. We also asked whether participation in the workshops were provided with opportunities provided for networking (e.g., opportunities to meet new people). Responses were scored on a five-point Likert scale from ‘very dissatisfied’ to ‘very satisfied’.

We used anonymous surveys during the 4th workshop to examine network contacts outside the workshop setting. Respondents identified their primary stakeholder role in the workshop as well as other roles they assumed in water related issues. Roles choices included: resource manager (state, regional, or federal), civic or community member, environmental or conservation group, scientist or academic, tourism operator, other business, land user (rancher, agriculturist), and recreational user (boater, bird watcher, etc.). Respondents identified with whom they discussed freshwater inflows outside of the workshops. We coded ties as either bonding (within group) or bridging (outside group) ties. Bonding and bridging ties were reported as a percent of total ties for each respondent role category. Bonding ties included ties within each role category (example of environmental role associated with other environmental tie). Civic or community members were included in a group with local business owners, recreational users that lived in the area, and ranchers. If reported ties could not be categorized as to their role, the response was not used in analysis.

RESULTS

Social Learning Through Collaborative Modeling

Collaborative modeling led to a shared framework of understanding. The tone was set by use of icebreakers. One participant commented that icebreakers were “not serious enough”, but others commented that they enjoyed hearing about where each person was involved in estuary work. Conceptual model diagrams were generated in the first workshop. Participants described important relations between freshwater and various hydrogeological and biological components in the system. Humans were mentioned as important, but their place was generally outside of estuarine system interactions in a position of influence only. Diagrams were similar in terms of the relations that were depicted, which allowed us to draft a composite diagram useful as an aid to guide discussion regarding relationships between system components during the second workshop.

Individual reflection about needs and concerns led to development of questions that might be addressed through quantitative modeling. Example questions included:

> Will freshwater inflows be adequate?
>
> How can we manage freshwater inflows in the face of climate change and growing human population in order to maintain a properly functioning estuarine ecosystem?

> How many acre feet of water are needed to create a salinity range acceptable for a healthy estuary during certain times of the year and under certain climatic conditions?

From participant responses, 85% of questions addressed environmental concerns (estuary sustainability, health, biodiversity, viability, balance). Questions also addressed recreation needs (6%), freshwater inflows (4%), the economy (3%), and future generations (2%). The questions generated by individuals were then used in a small group activity to identify which system components might be involved in answering the questions and how these components related to each other within the conceptual model. Final discussion during this workshop centered on a single question for quantitative model development, namely, increased knowledge of a focal estuarine species and its life cycle in relation to freshwater inflows to provide valuable information for the environmental flows process.

The final step in the Collaborative Modeling process was an evaluation of the learning outcomes and use of the model within the broader context of the SB3 process. It was suggested that future models could include other estuary components and relationships specifically about the effects of freshwater inflow changes (i.e. salinity) on other organisms within the estuary and bays. Several participants commented that human influence has been largely left out of discussions and future efforts should “look at how water issues not only affect the environment, but also human health and livestock.” Participants reflected that they intended to communicate lessons learned to peers and family members as well as through educational outreach to change attitudes of “people and water providers" and their understanding of important connections and parameters in the system.

During final discussion, participants said that this collaborative modeling process allowed them to integrate components of different studies to see effects on management decisions and identify knowledge gaps. The high repeat attendance during the final two workshops gave participants the opportunity to hear the results of the focal species studies, water circulation studies, and land cover change predictions as well as engage in discussion of next steps. They especially appreciated the interaction and access to technology which they had not had with other stakeholder processes. The model was described as useful for decision support because it was science-based. Suggestions for model use included crab fishery management: adjusting the harvest season around crab life cycle and inflows, using a predictor of what reasonable catch limits might be based on drought scenarios, looking at critical crab habitat based on salinity and temperature parameters. Suggestions for communicating these results included preparation of a summary for policy makers focused on the relationship of these results to the larger environmental flow regime. State regulatory agencies involved in environmental flows decisions-makers did not participate in the SB3 process, nor were represented in this process. The timing of and venue for this communication was uncertain, in part because the SB3 process does not clearly indicate how new scientific information is to be incorporated into the state decision process.

Stakeholder diversity

The diversity of stakeholders represented at each meeting and as compared to the state environmental flows process is shown in Figure 4. We categorized stakeholders as to their functional roles in natural resource management issues (Gray et al., 2012; Prell et al., 2009). The eleven stakeholder categories included: scientists and academics, environmental NGO (local and national), citizens, municipal/county government officials, natural resource managers (state and federal), other state agency personnel, regional water authority representatives, industry representatives, reporters, and primary resource users (agriculture, ranching, fisher, boat captain, recreational fisher).

A number of stakeholders involved in this process were also involved in the state mandated SB3 environmental flows process, and so made recommendations about watershed priorities and management directly to state regulatory authorities. All groups represented in the SB3 process were represented in the collaborative modeling process (workshops 1 and 3 of Figure 3). Environmental non-governmental organization (NGO) representatives and citizens were involved in comparatively greater numbers in this case study. Local decision makers, both county and city representatives were present at all but one meeting. Additionally, state and federal natural resource agency and state transportation agency representatives, who were ineligible to serve as BBASC (Basin and Bay Stakeholder Committee) or BBEST (Basin and Bay Expert Science Team) members in the SB3 process. This diversity enhanced learning by exposing participants to recognize the legitimacy of other viewpoints as one participant reflected in an evaluation response: “so many people had different backgrounds that made it very interesting to hear their perspectives.”

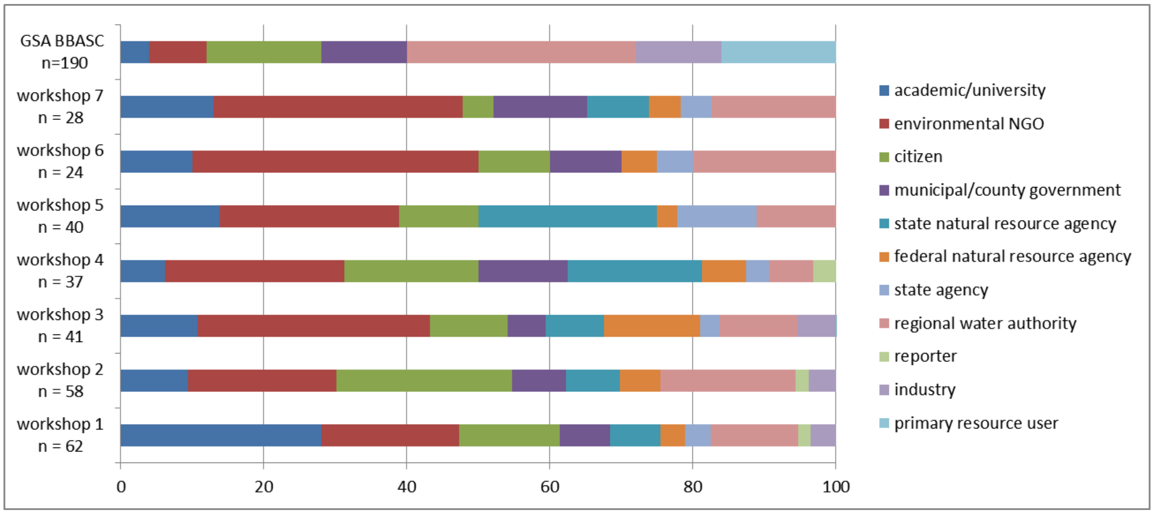


Figure 4. Diversity of stakeholders as a percentage at each workshop. Regional water authorities include river authority, groundwater conservation district, and soil & water conservation district representatives. Primary resource users include fishers, agriculturalists, and ranchers. The top row reflects the stakeholder groups represented in the state mandated environmental flows process (BBASC is Basin and Bay Stakeholder Committee; see Figure 2 for GSA boundaries).

To facilitate social learning in workshops that were several months apart, we summarized results of prior workshops and displayed conceptual models in the room. We also gauged institutional knowledge carryover from repeat attendance (Table 5) which revealed that an average of 71% of participants had some prior experience in this process.

Learning evaluation

Social learning, gauged in all workshops via evaluations asking whether ‘knowledge or understanding’ increased as a result of workshop activities (Table 5), was lowest in the fourth workshop, the second session of the iterative quantitative model parameterization. This workshop involved the most intensive scenario testing and model discussion. Participant discussion centered on model changes to remove whooping crane predation as it produced non-observable impacts on crab life cycle. Further, participants wanted to have salinity data that could reflect weekly changes rather than monthly changes for greater manipulation during model testing. Between the fourth and fifth workshops, whooping cranes were removed as a significant predator in the model, crab trapping data were improved, and the modeling

Table 5. Attendance, reported learning, and social capital gains for each workshop. Learning and social capital are presented as the percent of returned evaluations.

Workshop	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Attendance	62	58	41	37	40	24	28
Percent Repeat Attendance	--	45	61	78	60	100	82
No. scored evaluations	27	23	21	24	32	20	22
Increase in knowledge or understanding (percent responses for each workshop) [1]							
Yes	54.5	69.6	81.0	41.7	54.6	88.9	100.0
No	45.5	8.7	9.5	29.3	33.3	11.1	0
Unsure	0	21.7	9.5	29.2	13.2	0	0
Increase in access to relevant resources (percent responses of each workshop) [2]							
Yes	69.6	90.0	86.0	70.8	71.9	90.0	91.0
Level of satisfaction with networking opportunities (not satisfied =1 to very highly satisfied = 5) [3]							
Average score	4.2	4.1	4.4	3.8	4.4	3.8	4.4

1. Has your knowledge or understanding of freshwater inflows increased as a result of this workshop?
2. Did your ability to access resources (e.g., people and information) relevant to your work increase as a result of this workshop?
3. How satisfied were you with the opportunities provided for networking (e.g., opportunities to meet new people)?

team acquired a more precise salinity data set. Thus, this fourth meeting represented a turning point in model development.

Application of Bloom's taxonomy action verb analysis of written responses to questions about what was most useful and how the information might be used during the quantitative modeling workshops showed a progression from lower cognitive domains to higher domains (Figure 5). Responses evolved from general comments as to how to use the model and suggestions for model improvement, to critical evaluation of the model as a decision tool.

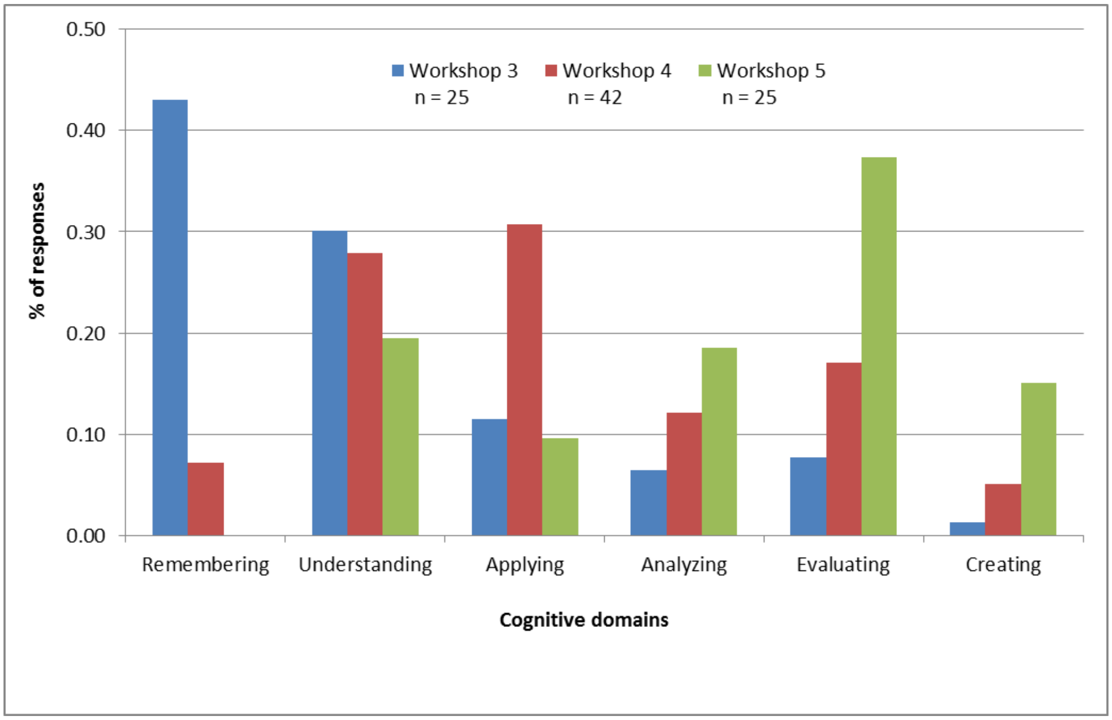


Figure 5. Action verbs in responses to questions of model usefulness and use asked during quantitative model simulations were coded according to Bloom's taxonomy of cognitive domains (see Table 4). Bars represent percent of coded responses during each of 3 simulation testing workshops (n = total responses coded per workshop).

Feedback from the first model simulation workshop focused on improving input options and output visualization which were incorporated into the model before the second model iteration: which parameters could be altered during simulation runs, how output data were displayed, and increasing options on the control panel. In the second model iteration, participant feedback regarding model parameterization became more specific as regards the algorithms used in the model and source of input data. As one person commented, “using the model is relatively easy, comprehending is harder.” This was echoed in suggestions to provide additional documentation that further explained the assumptions and limitations of the model as a means of enhancing understanding and increasing confidence in the model. Sample phrases of participant written responses during these second year meetings (workshops 3-5) that were coded according to Bloom’s taxonomy action verbs are shown in Table 6. The science team provided guidance to stakeholders throughout the modeling process, but the dynamics were participant driven. The modeling team, the scientists, and the stakeholders were all involved in joint learning during this iterative process.

Participants reported that they learned about spatial distribution of crabs, especially in thinking about differences in male, female and juvenile distributions in the estuary. Participants realized that blue crabs might not be a good indicator species due to its high salinity tolerance ranges. The model did not provide definitive answers to freshwater inflow needs, and workshop discussion focused on whether this was due to not enough variables, or that variables were not indicative of significant freshwater effects. Participants asked questions about underlying model assumptions and data sources used in the model to verify that the model would be useful, dependable, or worthwhile in decision making or education regarding freshwater inflows.” There was also discussion that baseline data for the model came from monitoring stations centrally located in the estuary rather than edges where salinity extremes are more often observed.

Table 6. Example responses coded using Bloom’s Taxonomy. Action verbs used for coding are italicized. Responses are all taken from the three workshops during the quantitative model parameterization and simulations of the second year (workshops 3-5).

Cognitive Domain:	**Participant responses:**
Remembering	*Identify* the additional impacts. *How* much more quickly would fishery have collapsed? (workshop 3) *Identify* other important factors influencing # and size.(workshop 3)
Understanding	Fluctuations in crab numbers vary with variations in flows. (observation) (workshop 3) Population lower than expected. (workshop 4)
Applying	*Managing* commercial harvest to a seasonal level. (workshop 4) To help *adjust* flow regime. (workshop 4)
Analyzing	Since your data is by year and week it would be easy to *segment* time periods. (workshop 4)
Evaluating	*Estimate* changes in the population of blue crabs to manage fishery. (workshop 4) That the results *were significantly different* from all drought or all heavy inflow years. (workshop 4) Cranes have no impact on crab population due to *how model is built*- get rid of it then, confusing to have non-functional button. (workshop 5)
Creating	Use the predicted crab population to *design* crab population studies. (workshop 5) May need to make decisions now but keep adding to our data to *improve* model. (workshop 5)

One participant wrote “we conclude that things are very complex in the estuary and will require careful evaluation.” Participants requested future incorporation of state flow standards in the model, BBASC and BBEST recommended flow standards, and a comparison of these three.

Social Capital Through Collaborative Modeling

Engagement

We used two measures to quantify stakeholder engagement in the collaborative modeling process: attendance and repeat attendance (Table 5). Attendance was greatest at the initial meeting and lowest at the sixth meeting when many state, federal, and regional natural resource managers were responding to an oil spill in the Houston ship channel (March 22, 2014). Commitment to this collaborative modeling process remained relatively high, with average repeat attendance over 6 workshops of 71% (range of 45-100%). Of those attending beyond the first meeting, 27.3% attended 3 or more workshops, 17.3% attended 4 or more workshops, and 5 people attended all meetings.

Engagement was judged on the basis of qualitative factors as well. Never more than 10% of participants exited a workshop early, and those that did previously informed meeting facilitators of other commitments prior to commencement of the workshop. As well, participants were observed to be attentive during long workshops, with little off-topic discussion and infrequent use of digital social media (cell phone use, web surfing, etc.).

Networking

Workshops provided networking opportunities through semi-structured icebreakers, small group discussions, mini-breaks, and working lunch sessions. In workshop evaluations, participants reported that their relative ability to access resources (people and information) increased as a result of each workshop and remained high throughout the three year process (Table 5). In several comments from workshop evaluations, participants said that “hearing ideas from outside agencies and organizations” was the most useful part of the workshops. Participants responded positively (average score of 4.2 on a 5-point Likert scale (5=very satisfied)) regarding their satisfaction with networking opportunities. One participant, during the final workshop in year 3, responded on the workshop evaluation that the most useful part of the workshops was the “opportunity to network with estuary researchers.”

Social network data regarding relations or water resource issue ties outside of the workshops was collected during the fourth workshop. Multiple responses were received for only four of the possible stakeholder categories (Figure 6): civic or community members, scientists or academics, environmental or conservation groups, and natural resource managers (3, 5, 4, and 13 respondents, respectively). Bonding ties reflected ties within the respondent’s group while bridging ties involved ties outside respondent’s group. We observed the greatest percent of bonding ties among community sample size may distort results, groups reporting greater numbers of bonding than bridging ties also reported, on average, fewer ties per person. The environmental and natural resource manager groups were better connected outside of their groups and had almost double the average number of total ties per person.

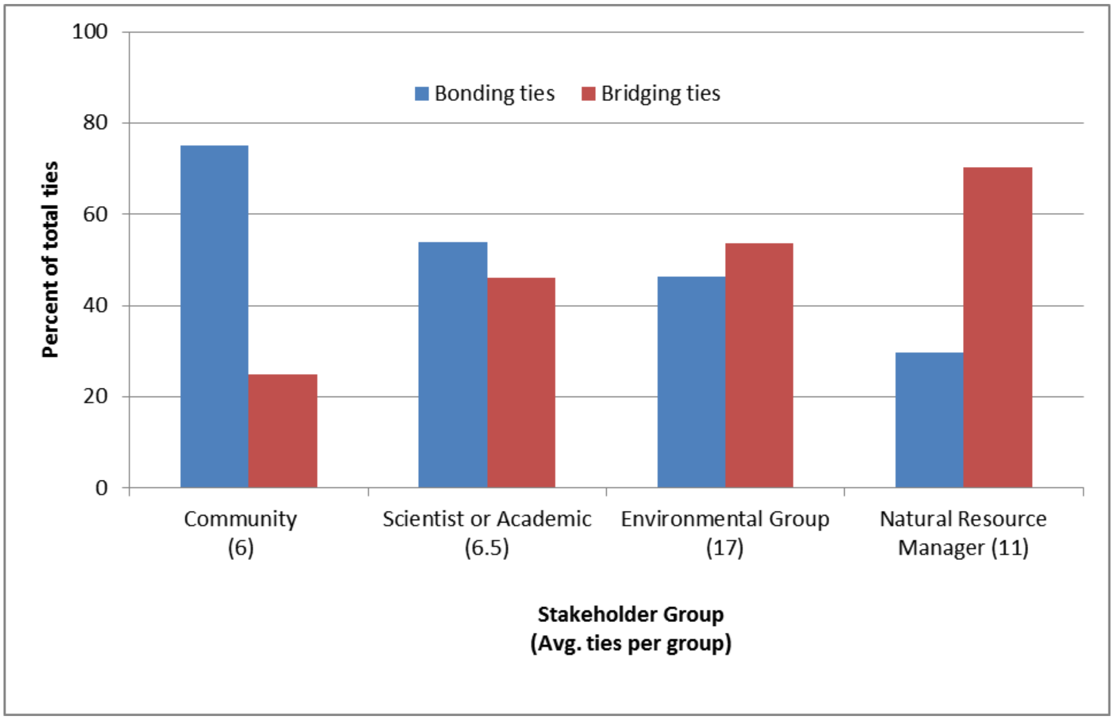


Figure 6. Network ties reported outside of workshops. Bonding ties (within group) and bridging ties (external to group) as a percent of all ties from self-reported network relations. Numbers in parentheses after each stakeholder group are average number of ties, bonding and bridging combined, for that group.

DISCUSSION

Successful management of ecological systems requires sufficient understanding of the system to respond to system changes within a broad framework of stakeholder involvement in policy development (Ascough II et al., 2008; Beall and Zeoli, 2008; Cundill and Rodela, 2012). In this study, social learning and social capital facilitated these goals. Collaborative modeling led to better understanding of the estuarine system through the transformative social learning process. Rather than passive learning offered by presentation-style stakeholder workshops, collaborative modeling participants engaged in analyzing and evaluating underlying issues and potential effects of freshwater inflows into the estuary. Initially, they used a systems approach to develop conceptual models. This approach facilitated active learning, and provided the common conceptual framework and vocabulary needed for holistic understanding that is pluralistic and accessible (Daniels and Walker, 2012; Grant, 1998). Processes similar to the first year of this study (conceptual modeling) have found that iterative processes addressing major issues of stakeholders build consensus, foster communication and help define research objectives valuable for innovative approaches to complex issues (Salerno et al., 2010). Participants re-framed their ideas about crabs, whooping cranes, variation in salinity, and freshwater inflows as they analyzed relationships and experimented using the quantitative model. Collaborative modeling, and social learning, fostered legitimacy of learned and shared ideas through group evaluation of the estuarine system (Ishihara and Pascual, 2009).

Collaborative modeling increased the diversity of voices engaged in the ‘collaborative learning journey’ that moved participants from their comfort zone to ‘bold steps towards solutions’ (van den Belt et al., 2013). The diversity of participants in this three year process enhanced learning by exposing participants to new perspectives that may benefit decisions made about freshwater inflows.

This process challenged the expert modelers to find better data sets, with greater detail, to accommodate participant inquiries, improving the model and reinforcing participant confidence to question and evaluate the underlying science. Non-scientists groups rarely examine validity and we saw this critical inquiry as a positive step (Boschetti et al., 2012). Social learning does not necessarily show final outcomes, but further steps, of digging deeper and finding out that there is more to know, in this case, next steps in communicating model outcomes and identifying important research gaps (Kolb, 1984). Stakeholder engagement through modeling increases the chances that knowledge is more likely to transfer to those making management and policy decisions (Price et al., 2012).

While greater stakeholder involvement and social learning are recognized as important for adaptive policy development, the challenge is to demonstrate that social learning has occurred (Cundill and Rodela, 2012; Reed et al., 2010). In this case, we were able to demonstrate social learning as transformative change in cognitive skills through collaborative modeling. Bloom's Taxonomy provided a useful tool for evaluating change in cognitive skills corresponding to actionable changes in behavior (Krathwohl, 2002; Pappas et al., 2013). Participants advanced their understanding of the estuarine system, applied, and evaluated, synthesized, and created new ideas and new approaches to estuary management. The transformation of participants' cognitive skills through social learning suggests collaborative modeling process may be a tool useful for adaptive policy development.

Social learning, as a component of social capital, enables collective or joint action (Ishihara and Pascual, 2009; Lin, 1999; Pahl-Wostl and Hare, 2004; Schusler et al., 2003; Sol et al., 2013). Ostrom (2000) differentiates between short term projects whose goal is to enhance citizen participation but frequently fails to make substantial change, versus more meaningful participation that involves responsibility in decision making processes and leads to successful collective action. By using Bloom’s taxonomy, we provided a tool to substantiate that learning occurred over the course of this process. This is a critical factor that justifies the time and effort needed for participatory modeling.

Social capital is not simply the networks, but also the common knowledge that facilitates action by lowering transaction costs through the lubrication of trust and compliance via shared ideas (Grootaert et al., 2002; Ishihara and Pascual, 2009; Lopez-Gunn, 2012; Pretty, 2003). In this case, social learning contributed to social capital through the collaborative modeling process. In turn, social capital reinforces bonding and bridging ties, strengthens the nature of ties, and provides positive manifestations of cooperation, trust, and institutional efficiency, potentially ameliorating sectarianism, isolationism, and corruption (Woolcock and Narayan, 2000). Through conceptual modeling of the system, quantitative model parameterization and simulation, and final reflection on next steps, this well connected group is now a powerful voice to be reckoned with.

CONCLUSIONS

Our purpose has been to learn whether and analyze how collaborative modeling facilitates social learning and builds social capital, ultimately addressing the challenges of managing complex ecological systems. We found that participation in collaborative system modeling enabled diverse stakeholders to evaluate aspects of a complex ecosystem and apply their knowledge to formulate next steps in developing adaptive responses. The use of collaborative modeling changed what could have been a series of informational workshops about ongoing scientific research into a meaningful social learning journey exploring ecological implications and next steps in policy development. Including in the discussion a greater diversity of stakeholders in environmental policy development strengthened legitimacy and acceptance of robust adaptive policies that address complex issues (Ishihara and Pascual, 2009). Through the lengthy collaborative modeling process, these participants became critical thinkers about complex issues. As well, through engagement and networking, they gained social capital that portends a positive future for successfully addressing freshwater inflows in this estuary.

CHAPTER IV

SOCIAL NETWORKS OVER TIME: SOCIAL CAPITAL IN A TEXAS WATERSHED

> “The primary message of the 2012 State Water Plan is a simple one: In serious drought conditions, Texas does not and will not have enough water to meet the needs of its people, its businesses, and its agricultural enterprises.” - from the 2012 State Water Plan, Edward G. Vaughn, Chairman of the Texas Water Development Board.

In Texas, USA, water governance is complicated by complex water rights and centuries of controversy. As it moves through the hydrologic cycle, a single molecule of water changes ownership multiple times according to which geologic container is under discussion (surface water is state owned, diffused surface water and groundwater are privately owned). The complexity, the 1950’s severe drought, increasing environmental concerns that emerged in the 1970’s, and top down management style left litigation as the only venue to settle disputes regarding ownership and use (www.lrl.state.tx.us/legis/waterTimeLine.cfm). In response, a series of Texas Senate bills in the past 20 years have led to greater stakeholder involvement in water management. Regional planning was initiated in 1997 as a consensus process involving multiple stakeholders. Planning districts submit management plans to the state for review, analyzing water needs (economic and natural) and water sources (quantity and quality) with the goal of assuring adequate water availability into the future (Roach, 2013). Senate Bill 2 (2001) established an instream flows program to maintain a sound ecological environment, but was criticized because it did not have a means to operationalize the goals (Porter, 2014). In 2007, the Texas legislature passed Senate Bill 3 (SB3) establishing a stakeholder-driven process using best available science to determine environmental flow recommendations within 11 designated watersheds. Environmental flows describe the quantity, quality, and timing of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems (Dyson et al., 2003). The SB3 process has met with mixed success, with multiple watersheds either unable to meet deadlines or come to consensus recommendations (Roach, 2013). Adding to the complexity of governance, groundwater is managed by Groundwater Conservation Districts that have both local and regional jurisdiction as well as Priority Groundwater Management Areas in sensitive areas. Surface water is managed by almost two dozen river authorities that sell water access permits (Roach, 2013). Urban and suburban water supplies are managed by municipal and investor-owned utilities, special districts, municipal utility districts (suburban or exurban developments), water control and improvement districts (storage and supply as well as water quality), and special utility districts (provide water and wastewater services). Two state agencies coordinate these many pieces of water governance: the Texas Water Development Board (TWDB) coordinates planning and funding of water infrastructure, and the Texas Commission on Environmental Quality (TCEQ) handles surface water use permitting.

In this study, we examine one watershed in Texas that has had success in navigating the complexity of water governance. Successful natural resource management stresses benefits to society and sustainability of the resource (Decker et al., 2012). Success has been characterized as the ability to resolve conflict where trust allows all involved to actively participate in positive processes that lead to desirable social and environmental outcomes (Bodin et al., 2006; Mountjoy et al., 2013). Frequently, this is described as some form of consensus rather than a voting process resulting in winners and losers (Peterson et al., 2004). Inherent in any discussion is the inclusion of diverse stakeholders, ensuring that social outcomes are broadly reflective and legitimate, and environmental outcomes are adaptive and flexible (Bodin and Crona, 2008; Mountjoy et al., 2013; Prell et al., 2009; Reed et al., 2009). In the case studies presented here, all groups achieved group consensus on controversial water issues pertinent to the stated purpose of the group (see Table 2). All of the water groups involved diverse stakeholders in the decision processes, and outcomes were legitimized through acceptance by either regional, state, or federal incorporation or approval.

Social capital, established through networks of multiple water groups over time, has contributed to successful management. Social capital is the relational resource available to individuals and groups for addressing shared issues (Kusakabe, 2012; Mountjoy et al., 2013; Ostrom and Ahn, 2003). Brunie (2009) characterized social capital as the ability to utilize social contacts to obtain resources. Social capital is a multidimensional concept of structural and cognitive dimensions of networks, engagement, norms, reciprocity and trust (Ragland et al., in press). Important characteristics of successful management such as leadership, knowledge, social memory, trust, and redundancy can be operationalized through social network analysis (Barnes-Mauthe et al., 2015). Much weight has been given to the value of leadership and established social networks as desirable social outcomes (Bodin and Crona, 2008; Gutiérrez et al., 2011).

In the past two decades, social networks have gained attention in discussions of natural resource management involving greater participation and co-management (Bodin et al., 2006; Ostrom, 2010*b*). Social networks represent patterns of communication and cooperation that potentially reduce transaction costs, making natural resource management through collective action more feasible and profitable (Uphoff, 2000). Networks are composed of actors (nodes) and the relationships between them (ties). Actors represent roles that relate to them as individuals (such as stakeholder type) as well as their position in the network. The ties between actors can be based on friendship, information flow, economic ties, and much more. Overall network structure is multidimensional, varying in terms of density, clustering, and complexity.

Actors may be tied to actors within their network (bonding ties) or beyond (bridging ties), each tie type having advantages. Within networks, ties tend to be stronger and enable information transfer, reinforce shared norms, facilitate reciprocity, and build trust (Bodin et al., 2006; Prell et al., 2009). A tension exists, however, between bonding that builds cohesive communities and bonding that leads to exclusion of others, isolating the network and limiting potential to innovate and adapt (Ballet et al., 2007). The exclusionary tendency of bonding ties may be offset by bridging relations or ties between groups that serve as a source of fresh ideas and innovation (Bodin and Crona, 2009). Bridging ties represent access to resources and influence outside the group. Group heterogeneity may also offset strong bonding ties, and has been a focus of social capital and social network studies (Prell et al., 2009).

Network density describes all actors and ties and is measured as the total number of ties divided by the number of possible ties in the network. Dense networks are more likely to have redundant actors (multiple actors filling the same role in the network) such that loss of one or several does not lead to disconnected actors. Dense networks are associated with greater social memory, learning and relations of trust, all important factors in adaptive natural resource management (Bodin et al., 2006; Newman and Dale, 2005). However, very dense networks, may tend towards homophily and exclusion of outside influence, subsequently inhibiting adaptive capacity and innovation.

The position of actors within networks can either facilitate or constrain their opportunities for action (Coleman, 1988; Lin, 1999). Actors may be peripheral (few ties) or centrally integral to the network (many ties). Central actors are identified through measurements of betweenness (Freeman, 1979), a calculation of the number of times an actor falls along the shortest path between two others, or eigenvector centrality (Bonacich, 1972) which describes the extent to which an actor is connected to well-connected others. Betweenness centrality has been used to examine individuals serving in brokerage roles who carry exclusive links to groups that would not otherwise be connected (Crona and Parker, 2012). Their loss in the network would therefore lead to network fragmentation. High eigenvector centrality is associated with actors that have relatively greater influence in the network through their connections to well-connected others. Peripheral actors may contribute diverse ideas and resources even though their position within the network may not reflect their connections elsewhere.

One of the major criticisms of social network analysis is that it treats networks as static systems, taking a ‘snapshot’ view, when in fact they are fluid and subject to change (Borgatti and Lopez-Kidwell, 2011; van der Hulst, 2011). Thus our analysis covers a 10 year time period of affiliation networks. Affiliation networks consist of linkages among actors through membership or joint participation in events, and are well suited to address social capital and stakeholder engagement questions regarding the diversity of the groups, the emergence and persistence of leadership, and how various groups interact through joint participation.

In this paper, we analyze affiliation networks of watershed groups to examine network characteristics associated with successful watershed management: diversity of actors, density, and centrality. First, we use stakeholder analysis of each group to look at heterogeneity within the groups and as a comparison among groups. Then, we examine density over time, to examine how cohesion varies with significant accomplishments of each group. We use centrality measures to identify key individuals within and across these water groups, and visualize the networks to determine specific actors that function as brokers or inter-group connection points. Visualization of the networks provides a way to compare the groups not otherwise possible with such complex data sets. It reveals relative bonding and bridging actors within each network, cohesion and structure characteristic of each group. This study provides rich data characterizing water groups that have successfully negotiated processes of consensus decision-making to determine legitimate policy decisions.

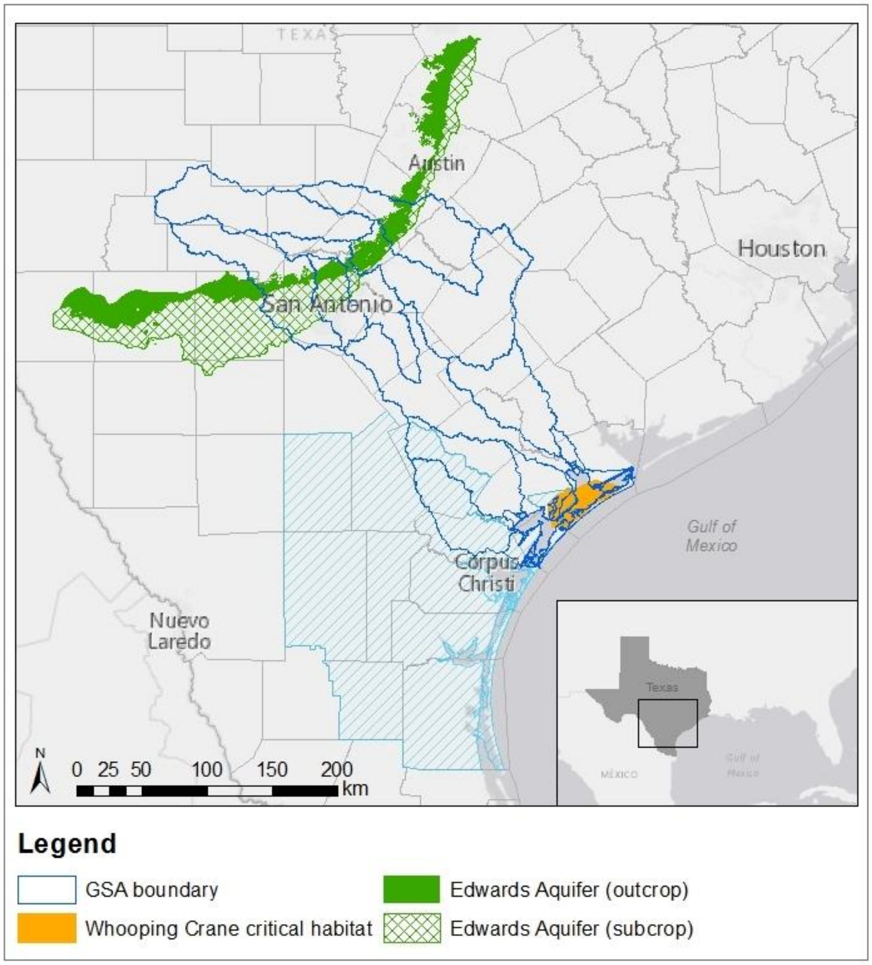


Figure 7. Geographic location of watershed groups in the Texas Coastal Bend watershed. The NERR Collaborative involved stakeholders across all boundaries.

Table 7. Timeline of events and implications for watershed management and water groups including: Region N planning district (RN), Edwards Aquifer Recovery Implementation Plan (EA), GSA Basin and Bay Stakeholder Committee (ST), GSA Basin and Bay Expert Science Team (SC), and the Mission-Aransas NERR Collaborative (NC). Numbers in water group columns refer to number of meetings during each year for which data were available.

Year	RN	EA	ST	SC	NC	Event:	Implication for watershed management:
1917						Constitution amended River Authorities	State charged with the duty to protect state natural resources. In response to flooding, river authorities established to manage and develop surface water of distinct segments of watersheds.
1950's						Severe drought	Drought conditions led to increased use of wells that in some cases entirely depleted surface water in certain areas.
1967-1969						Surface water adjudication	Adjudication of some 10,000 pre-Independence rights. Permits based on 'first in time, first in right' principle.
1985						Sunset Bill and others	Instream protection of biota and habitat leads to mandatory, but unachievable water releases of instream flows.
1991						Sierra Club files lawsuit against USFWS	Lawsuit claims USFWS inadequately protected endangered species in Edwards Aquifer, constituting a 'take' as defined under ESA.
1993						Ruling favors Sierra Club	Spring flow must be maintained even during drought. Led to establishment of the Edwards Aquifer Authority governed by elected board.
1997						Senate Bill 1	Creates regional water planning (16 regions) and Texas Water Code. Requires state comprehensive water plan by TWDB.
2000						San Marcos River Foundation (SMRF)	SMRF and others file a water rights application to pledge unallocated Guadalupe River surface rights to a trust to remain instream.
2001						Senate Bill 2: Texas Instream Flows Program	Provided funding needed for regional water plans. Required data collection and evaluation to determine flows for a 'sound ecological environment'.

Table 7. Continued

Year	RN	EA	ST	SC	NC	Event:	Implication for watershed management:
2002						State Court affirms EAA power to regulate State Water Plan	After 9 years of litigation regarding property rights, EAA determines a plan for pumping. First state plan adopted since SB1.
2003						SMRF files lawsuit	Lawsuit filed against Texas Commission on Environmental Quality regarding instream flow permit. Other water groups follow suit.
2005	6						
2006	3						
2007	5	8				Senate Bill 3 (SB3) EARIP	Establishes stakeholder-driven process designed to use best available science to recommend environmental flow standards to TCEQ. State mandates collaborative, consensus-based stakeholder process to develop habitat protection plan by 2012 for listed species of Edwards Aquifer.
2008	5	8					
2009	4	11	1			The Aransas Project - TAP	TAP files notice of intent to sue TCEQ for harm to whooping cranes in violation of ESA.
2010	4	5	11	8		Drought TAP lawsuit Region N Water Plan	Beginning of drought period which will not begin to abate until 2015. TAP files lawsuit. Regional water plan submitted to TWDB for review.
2011	4	12	18	2		EARIP plan GSA recommendations	Consensus plan fails due to lack of funding support. GSA BBASC/BBEST submit recommendations to TCEQ

Table 7. Continued

Year	RN	EA	ST	SC	NC	Event:	Implication for watershed management:
2012	1	19	5		2	GSA Work Plan EARIP plan GSA flow standards State Water Plan NERR circulation study	GSA BBASC Work Plan submitted to TCEQ Consensus plan funded by user fees on pumpers submitted to USFWS. TCEQ flow regimes ignore recommendations for Guadalupe River. State Water Plan 2012 incorporates Region N plan. NERR Collaborative initiates estuary water circulation study.
2013	3	18	4		3	EARIP plan approved TAP lawsuit decision Collaborative Modeling	USFWS approves 15 year incidental take permit issued by EAA. Judge rules against TCEQ in TAP lawsuit, case is appealed. NERR Collaborative Modeling project complete.
2014					2	TAP Appeal decision Focal species study	Judge rules lack of inflows responsible for crane deaths, but state not liable. NERR Collaborative focal species study complete.

WATERSHED NETWORKS IN TEXAS: A CASE STUDY

The focus of this paper is on the Guadalupe, San Antonio, Mission and Aransas Rivers and Mission, Copano, Aransas, and San Antonio Bays (GSA) and Nueces watersheds of the Texas Coastal Bend (Figure 7). These watersheds encompasses hill country uplands of the Edwards Aquifer where millions of people live and work in and around the metropolitan areas of Austin and San Antonio along with a number of rare aquifer inhabitants; one of the most popular riverine corridors in Texas that draws year-round recreation users; and the coastal plain with metropolitan Corpus Christi, a national park and wildlife refuge that protect endangered Kemp’s Ridley sea turtles and wintering Whooping cranes. We chose this area of Texas because a number of effective groups have operated in this watershed over many years (Table 7). This includes citizen and conservation driven lawsuits protecting endangered species in the headwaters and on the coast (Gulley, 2014), two regional water planning groups (Region N and Region L), and GSA SB3 groups, the BBASC (Basin and Bay Stakeholder Committee) and BBEST (Basin and Bay Expert Science Team). These last two groups, the GSA BBASC and GSA BBEST successfully delivered recommendations and a work plan ahead of schedule in the SB3 process. Figure 7 shows geographic jurisdiction of these groups.

METHODS

Data Collection

Attendance records and attendee affiliation were gathered from online public records of meeting notes and sign-in sheets from 2005 to 2014 for the Region N Water Planning District, the GSA BBASC, the GSA BBEST, and the Edwards Aquifer

Recovery Implementation Plan (EARIP). Attendance records for the National Estuarine Research Reserve (NERR) Science Collaborative.

Table 8. Watershed management groups examined in this study.

Group	Purpose of Group	Structure
Regional Water Planning District N (Region N) for 11 counties	Determine population and water needs five years into future.	Approx. 20 appointed stakeholders using consensus to draft regional plan.
Edwards Aquifer Recovery Implementation Plan (EARIP)	Protect habitat for threatened and endangered species in San Marcos and Comal Springs, especially during drought.	Texas Legislature required aquifer authority and state and municipal agencies to participate in collaborative, consensus-based stakeholder planning process required by USFWS.
GSA Basin and Bay Area Stakeholders Committee (BBASC)	Balance water flow standards of quantity, quality, and timing that protect the ecology of the rivers and bays/estuaries and address water supply needs across stakeholder groups."	25 member stakeholder group appointed by state to achieve consensus on recommendations regarding environmental flow standards and strategies.
GSA Basin and Bay Expert Science Team (BBEST)	Analyze and recommend flow regimes suitable for river basin and bay system.	11 member science team appointed by GSA BBASC to achieve a consensus on flow recommendations.
NERR Collaborative	Research regarding freshwater needs region as identified in GSA BBASC work plan. Involve stakeholders in systems dynamics modeling.	Science and stakeholder collaborative to examine freshwater needs in a changing environment.

(NERR Collaborative) about freshwater inflows were acquired from research notes (IRB Protocol #2012-0187). The NERR Collaborative involved stakeholders across all regions shown in Figure 1. Region L Water Planning District was not included in this study as records were not publicly available. Table 8 provides background of each study group, highlighting how they are structured. Group accomplishments during the 10-year study period and implications for watershed management are listed chronologically in Table 7.

Table 9. Stakeholders were identified as to their primary role in watershed management for stakeholder analysis. The total number of each stakeholder type is noted in parentheses.

Identifier	**Stakeholder type**	**Role**
AS	Academics and Scientists (67)	Research, university teaching, or other education.
CT	Citizens (18)	Citizens and local community members. Includes special interest groups.
CN	Conservation organizations (59)	Local, regional, and national non-governmental environmental groups.
DA	Decision-making authority (56)	Work with decision agencies (TCEQ, TWDB) or identify as making water policy decisions (Region N voting members).
FD	Federal Government (38)	Federal agencies.
GV	Local/ state official (20)	Elected government officials.
IC	Consultants (41)	Consultants with engineering or other expertise.
IE	Energy industry (27)	Resource extraction industry.
IG	General industry (9)	General, chemical, and water related industry.
LG	Legal representatives (10)	Lawyers and other legal advisors.
MD	Media representatives (3)	Newspaper, magazine, and radio media.
MU	Municipal representatives (50)	City planners and representatives.
PR	Primary resource users (12)	Fishers, agriculturalists, and ranchers.
ST	State agency (68)	State agencies, natural resource and other.
UN	Unknown (86)	Unable to determine affiliation.
WA	Water management representatives (87)	Groundwater, municipal, and river water authorities.

Stakeholder Analysis

We used stakeholder analysis to examine heterogeneity within groups. Actors were identified as to their stakeholder role in the watershed (Ragland et al., in press) and assigned four digit identifiers denoting stakeholder affiliation and unique numerical identifier (Table 9). Characteristics of each water group were determined over the life of each group: number of meetings, average attendance, and stakeholder composition. We calculated the percent of each stakeholder type and average attendance within groups and among all groups of each stakeholder type. Stakeholder numbers reflect all attendees, regardless of number of meetings or workshops attended.

Affiliation Network Analysis

We constructed a 2-mode, non-dyadic affiliation matrix of 651 individual actors (attendees) by 179 events (meeting or workshop) from meeting attendance data. We assume that that co-occurrence (attending the same meeting) is either an indicator of a relationship (tie) or represents the potential opportunity to establish one (Borgatti et al., 2013). When actors participate in multiple events, the probability of a relationship increases (ibid.). Other factors favoring establishment of a relationship include smaller group size and purposive nature of these group meetings. Thus, we include data on meeting size and frequency of co- occurrence as a factor in our analysis. As an example, attending the same 6 music concerts of 20,000 people is not likely to lead to a relationship between actors, but attending 6 meetings of 25 people is likely to lead to opportunities to interact or at least share information. Ties of co-occurrence represent information-sharing networks, a commonly studied network type in natural resource management settings (Bodin and Crona, 2008; Prell et al., 2009).

We used UCINET software (Borgatti et al., 2002) to examine network density and centrality measures in networks of each group over time, all groups, and years by group and overall. The 2-mode affiliation matrix was transformed into 1-mode adjacency matrices that generated actor x actor ties through co-occurrence of attendance and event x event ties through common participants. Network measures and their relation to social capital and natural resource management are summarized in Table 10. We used density to compare the various groups and time points for relative cohesiveness and redundancy within networks, assuming that higher density facilitated information transfer. Betweenness (Freeman 1979) and eigenvector (Bonacich 1972) centrality were used to identify central individuals with strong ties in the group networks. Centrality describes each individual actor's place within the network. Betweenness centrality refers to how actors lie along the shortest paths between others, representing more direct conduits of information. Eigenvector centrality uses an algorithm such that individual values increase if connected to well-connected others. We used a combined value of both measurements to identify individuals who were important as information transfer resources and well-connected within networks. Eigenvectors scores for each individual were normalized to suit the range of betweenness scores as the two centrality measures result in different measurement scales. Comparison among groups was restricted to the years 2010 to 2013 as this time period was the only time when at least four of the groups

Table 10. Network measures used in this case study and the relation of these measures to social capital and natural resource management. (Adapted from Bodin et al., 2006; Borgatti et al., 1998).

Network measure:	**Description:**	**Relation to social capital and natural resource management:**
Density (Burt 1983)	The total number of ties divided by the number of possible ties.	Higher density may facilitate trust, information transfer and compliance with social norms, and contribute to redundancy of network roles, but may increase homogeneity of the group and group ideas and ultimately impact adaptive capacity.(Bodin et al. 2006)
Centrality-Betweenness (Freeman 1979)	The number of times an actor falls along the shortest path between two actors, linking otherwise unconnected actors.	High betweenness creates opportunities for information and benefits transfer, reinforces heterogeneity, and facilitates learning. Prevalence of high betweenness may separate groups, and compromise trust. (Borgatti 2006).
Centrality – Eigenvector (Bonacich 1972)	The extent to which an actor is connected to well-connected others.	High eigenvector centrality is associated with greater reach and influence within the network, a useful tool for crisis response. It is a measure used to identify key actors (Bodin and Crona 2008).

could be directly connected through co-attendance (Table 7). We converted 2-mode affiliation matrices of all individuals active during this time period (2010=555, 2011=556, 2012=629, 2013=633) to actor x actor adjacency matrices. These matrices allowed us to examine important actors in the networks based on the combined normalized eigenvector and betweenness measures. We chose the top 15 from each group as this represented a natural break in centrality measures over all groups and represented approximately 10% of the average number in each group (average number of participants over all groups was 159), a more generous capture of central individuals as compared to other studies (Bodin and Crona, 2008). These central individuals were included with individuals who attended meetings of more than one group (bridges) to create a smaller subset of 148 'key' actors. Of the potential 75 actors identified from water groups, 9 individuals had attended meetings of a single water group; the remaining 66 individuals were already included as bridging individuals. We used this smaller subset of central and bridging individuals to construct actor x actor adjacency matrices that were more manageable for identifying relations among key individuals and for visualization purposes.

We also identified brokers within the networks. These are individuals who link groups not otherwise connected, and were identified by examining tie disappearance as the number of edges needed for a tie was increased. (Bodin et al., 2006; Prell et al., 2009).

We used NetDraw network visualization software (Borgatti et al., 2002) to illustrate network structure. The procedure uses several optimization algorithms to produce diagrams that easy to read (Borgatti et al., 2013). It places more central actors towards the center of the graph and more strongly tied actors closer together. Nodes are positioned so as not to overlap entirely, losing the information. Individuals with weaker ties were identified by their disappearance from the network as we increased tie strength (Prell et al., 2009). There is a preference for equal-length ties which lends a boxy appearance to the network diagram, but also facilitates observation of symmetries. The disadvantage of this optimization is some loss in accuracy of path distances between nodes. Matrix data were combined with attribute data to highlight stakeholder diversity, group relations, and structural changes over time.

RESULTS

Stakeholder Analysis

Stakeholder composition varied within each of the five groups. Overall, the two largest stakeholder types represented were regional water authorities and unknown. Unknown participants were most frequent in the EARIP group; representing 33% of all participants and of those, 43% attended two or fewer meetings. Other stakeholder types with significant representation included academics and scientists and state agency representatives (Figure 8).

Region N water planning group had the highest number of individuals identifying as decision makers with responsibility as regards water planning in the region. This group also included the highest percentage of government officials, consultants, and more than twice as many municipal representatives than any other watershed groups. Others well-represented included citizens and the energy industry.

The EARIP included many federal natural resource agency representatives, all representing the US Fish & Wildlife Service, the organizers of this Recovery Implementation Plan. Other prominent stakes included academics and scientists involved in determining endangered species needs, regional water authorities involved in managing input to the aquifer, and conservation organizations concerned with watershed preservation.

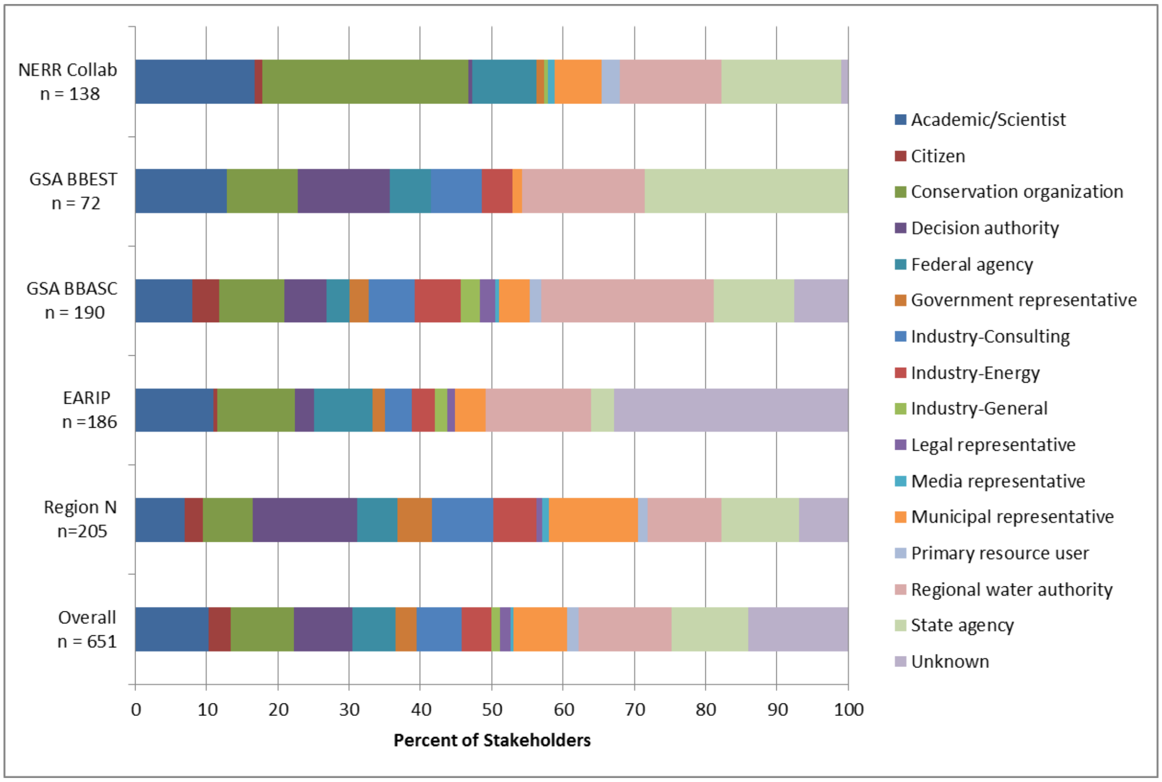


Figure 8. Stakeholder representation over all groups and within each group.

Proportionally, the largest stakeholder type in the GSA BBASC group was regional water authorities (24% of the group). Other well-represented stakeholder types included academics and scientists, state agency representatives, and conservation organizations. State agency representatives attended GSA BBASC meetings, but due to rules specified in the SB3 process, were not included as voting members of the stakeholder group. While proportionally scarce, citizens, general industry, legal representatives, and the energy industry over all five groups were best represented through this water group.

The GSA BBEST group had the lowest diversity of stakeholder types (only 9 categories) with a disproportionately large number of state agency representatives

(28%). Other prominent stakeholder types included regional water authorities, scientists, conservation organizations, and decision representatives. Members of this last group were mostly from the agency that would make final decisions on environmental flows, and served in an observational capacity for their agency. The NERR Collaborative included greater numbers of conservation organization representatives (29%), academics and scientists (17%), and federal natural resource managers (9%). State and regional representatives were also present in high numbers (16% and 14%, respectively). The scientific representation is not surprising as much of the workshops focused on four collaborative science objectives.

Group Network Analysis

We characterize groups as to number of meetings per year, average attendance, and density. These measures indicate the likelihood of meaningful relations within groups, as well as cohesion and redundancy of actors (Table 11). In this study, the probability of co-occurrence (attending the same meeting) is more likely to lead to an actual relation between individuals as the average meeting size is 24.8 people. Of all participants, 43% attended only a single event, 34% attended 2-9 events, and 23% attended 10 or more events. Density values can vary from 0 (no ties) to 1 (all actors inter-linked to each other). Average density measurements for all five groups varied according to average attendance, which is expected over longer periods of time with affiliation networks. However, the highest density was observed for the GSA BBEST 2010 (0.528) and GSA BBASC 2011 (0.256) networks. This suggests that an additional factor was higher attendance in those years by the same individuals; increasing the probability that co-occurrence resulted in relationship building. High density measurements preceded the consensus decisions reached within both groups that led to release of the environmental flows recommendation report in September of 2011. Density was highest for the EARIP group in 2012 shortly before consensus decision on finalization of the Recovery Implementation Plan for public review and approval by the US Fish & Wildlife Service. The initial meetings of the NERR Collaborative (2012) involved the highest attendance and density for that group. Many of the NERR Collaborative participants were also involved in the SB3 process. The Texas Commission on Environmental Quality (TCEQ) released its flow regimes shortly before the initial NERR meeting. The regimes did not follow GSA BBASC and GSA BBEST recommendations, and were a topic of discussion. TCEQ indicated that their flow regimes, while based on the same data as that used for recommendations, came to separate conclusions. The GSA BBASC workplan identified several areas of missing data that would be addressed through the NERR Collaborative, which likely contributed to higher engagement in the NERR Collaborative by individuals involved in the SB3 process (personal communication).

We visualized networks of all five groups over all meetings for each group using matrices of actor x actor ties, illustrating stakeholder affiliation, bridging, and brokering individuals (Figure 9, a-e). Visualization of Region N (Figure 9a) illustrates the dense central core of individuals with a large number of participants minimally connected (few ties) or attending only

Table 11. Group characteristics over time. Density could not be calculated for years in which only a single meeting occurred. High density values are indicated in bold italics.

Year	**All**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
All Meetings											
# meetings	179	6	3	13	13	16	27	36	27	28	2
Average attendance	24.8	28.5	23	16.7	24.31	23.6	27.8	25.8	26.4	21.6	26
Density	0.136	0.065	0.027	0.023	0.032	0.022	0.036	0.041	0.037	0.026	0.060
Region N											
# meetings	42	6	3	5	5	4	4	4	1	3	
Average attendance	28.5	28.5	23	29.2	29.8	29.5	25.8	27	30	28.7	
Density	0.139	0.065	0.027	0.067	0.063	0.046	0.040	0.041	NA	0.047	
EARIP											
# meetings	81			8	8	11	5	12	19	18	
Average attendance	16.5			8.9	20.9	19.7	14.6	12.8	22.2	16.1	
Density	0.093			0.018	0.064	0.072	0.024	0.037	***0.143***	0.077	
GSA BBASC											
# meetings	39					1	11	18	5	4	
Average attendance	33.8					42	36.3	34.2	28.8	27.8	
Density	.392					NA	0.188	***0.256***	0.075	0.063	
GSA BBEST											
# meetings	12						8	2			
Average attendance	25.3						25.6	25			
Density	0.360						***0.528***	0.176			
NERR Collaborative											
# meetings	7								2	3	2
Average attendance	41.3								59.5	39.3	26
Density	0.500								***0.334***	0.194	0.060

a single meeting (located on the outer edges and unconnected within the network). Only a single brokering (brokers are shown as large triangles) conservation stakeholder is central in this network (Figure 3a), although a number of bridging individuals (indicated as medium triangles) are involved in the network core.

The EARIP network (Figure 9b) is composed of four denser subgroups. Within these subgroups, over a third function as bridges or brokers to other groups. The subgroups may reflect the different working groups that emerged from the EARIP process: Implementing Committee, Stakeholder committee, Science Committee, and several more. As with Region N, there were also a number of individuals attending only a single meeting shown as unconnected within the network.

The dense structure of the GSA BBASC (Figure 9c) group reflects commitment by a large number of actors attending large numbers of meetings. The majority of central actors have bridging ties to other groups (small triangles) and 6 individuals serve as brokers within the watershed network. This group fulfilled their task of consensus on environmental flow recommendations within an 18 month period and prepared a work plan to guide further study shortly thereafter. The core group of voting stakeholders was generally well-known in their respective areas. Leadership in this group consisted of a regional water stakeholder and a citizen/conservation stakeholder. The GSA BBEST (Figure 9d), appointed by the GSA BBASC is the smallest network (N= 72) examined in this study. Most actors had bridging ties to other groups, and as with the GSA BBASC, a number of brokering actors were represented in the core group. This group was composed of greater numbers of scientists and academics due to the nature of their analysis task, with input from state agency and conservation organization scientists involved as central actors.

The NERR Collaborative group (Figure 9e) was the only group not directed by the state to reach consensus on a water policy recommendation. The network structure reflects involvement by diverse stakeholders, many of whom were bridges to other groups and several who were brokers within the watershed. The large number of unconnected actors attended 1 or 2 meetings, primarily the large initial meeting. Both scientists and conservation organization representatives were among the most active participants in the NERR Collaborative process based on measures of centrality.

Watershed Network

The temporal overlap of at least four groups occurring in years 2010 to 2013 allowed us to examine key actors in the watershed as well as group cohesion and interconnection. Key actors in the watershed network were identified using combined measures of eigenvector and betweenness centrality (Table 12). Notably, all individuals in Table 5 attended GSA BBASC meetings, and all individuals represent bridging individuals that attended more than single type of group. Regional water representatives (40%) and conservation organizations (24%) are prominent in this set of influential, central individuals.

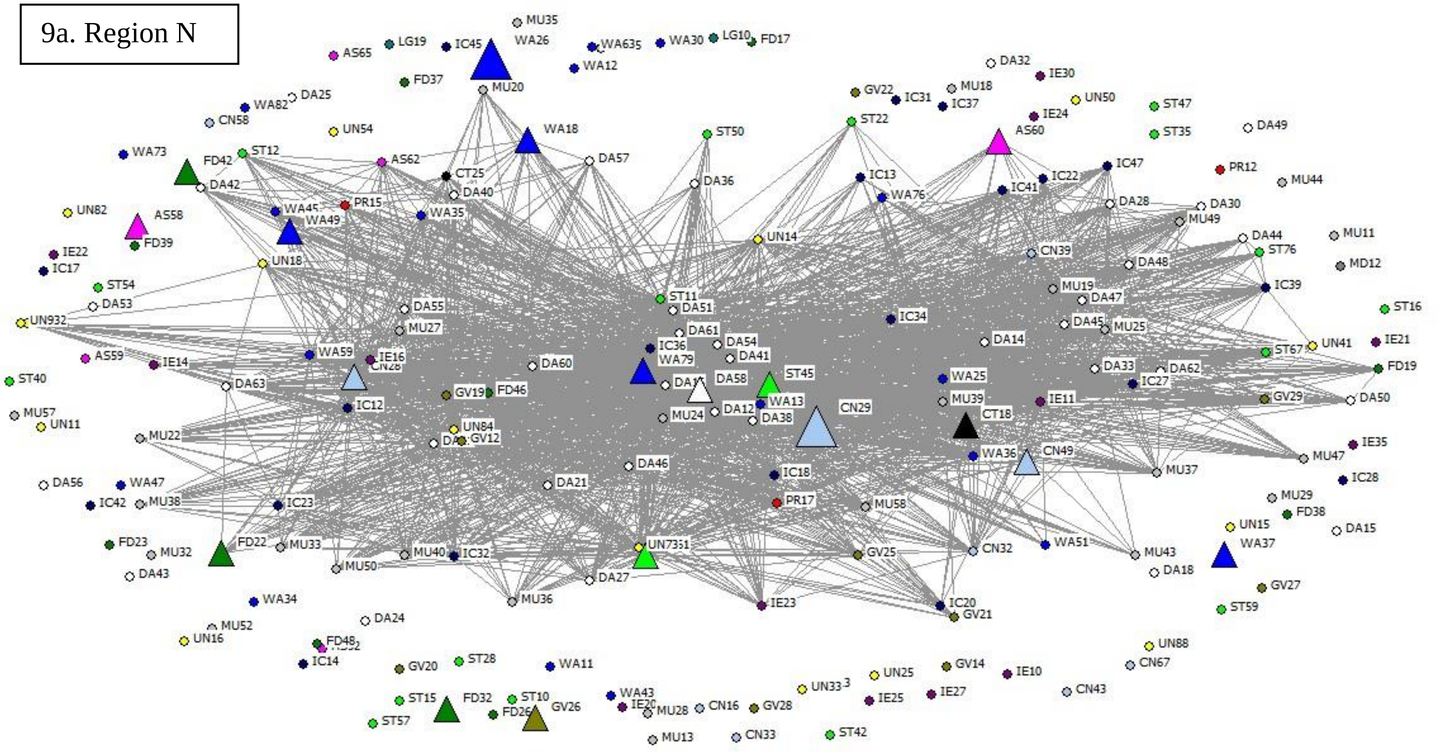

9a. Region N

Figure 9. Network figures were constructed with NetDraw (Borgatti 2001). Actors connected in this network attended 2 or more meetings (+2). Stakeholder types are indicated by color and letter (Table 9) and number code designation. Actors affiliated only with each group are indicated by small circles. Medium-sized up-triangles indicate actors attending 2 or more groups, and large up-triangles indicate the actor has high betweenness centrality within all groups and serves as a broker connecting groups otherwise not connected.

Figure 9. Continued

9b. EARIP

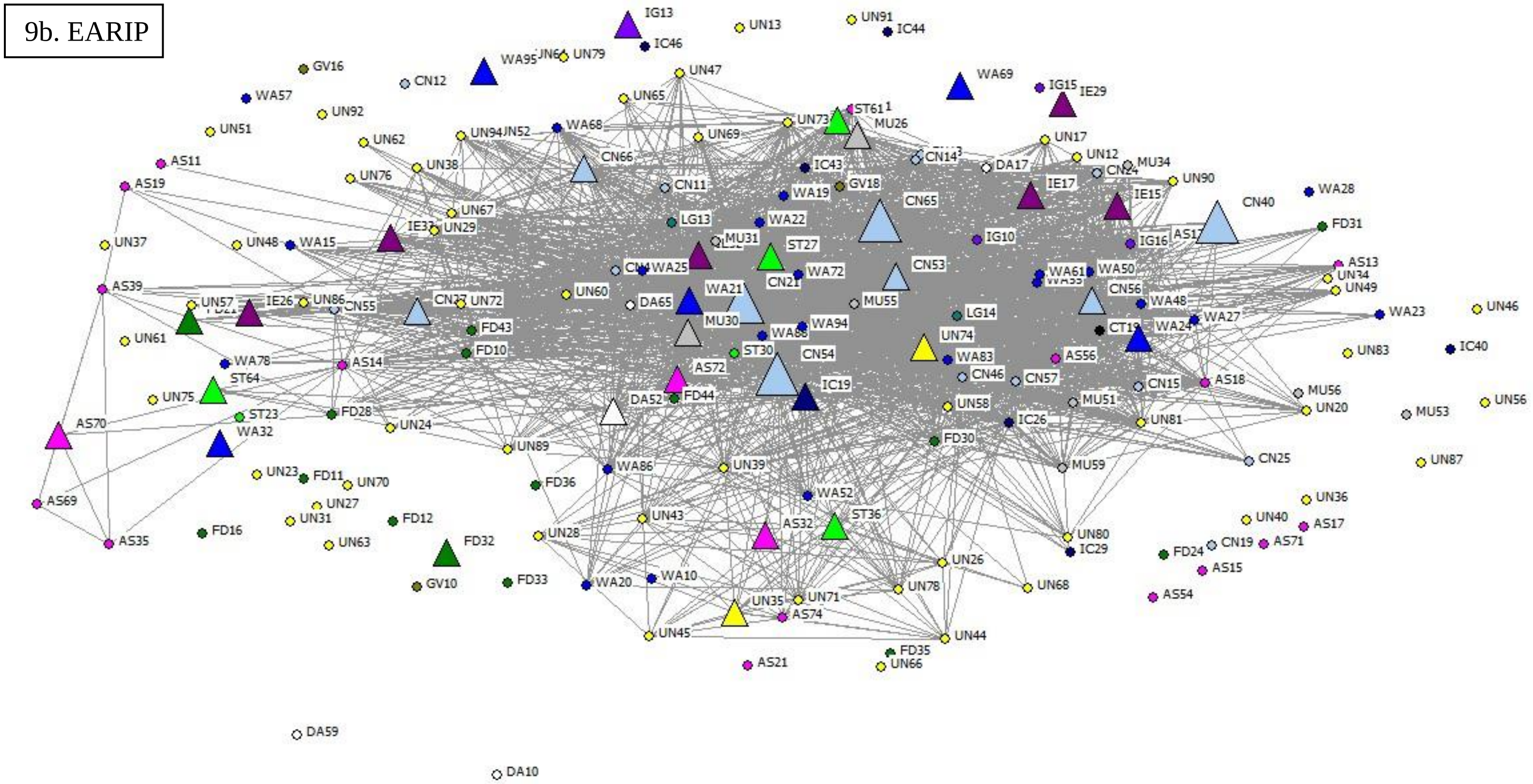


Figure 9. Continued

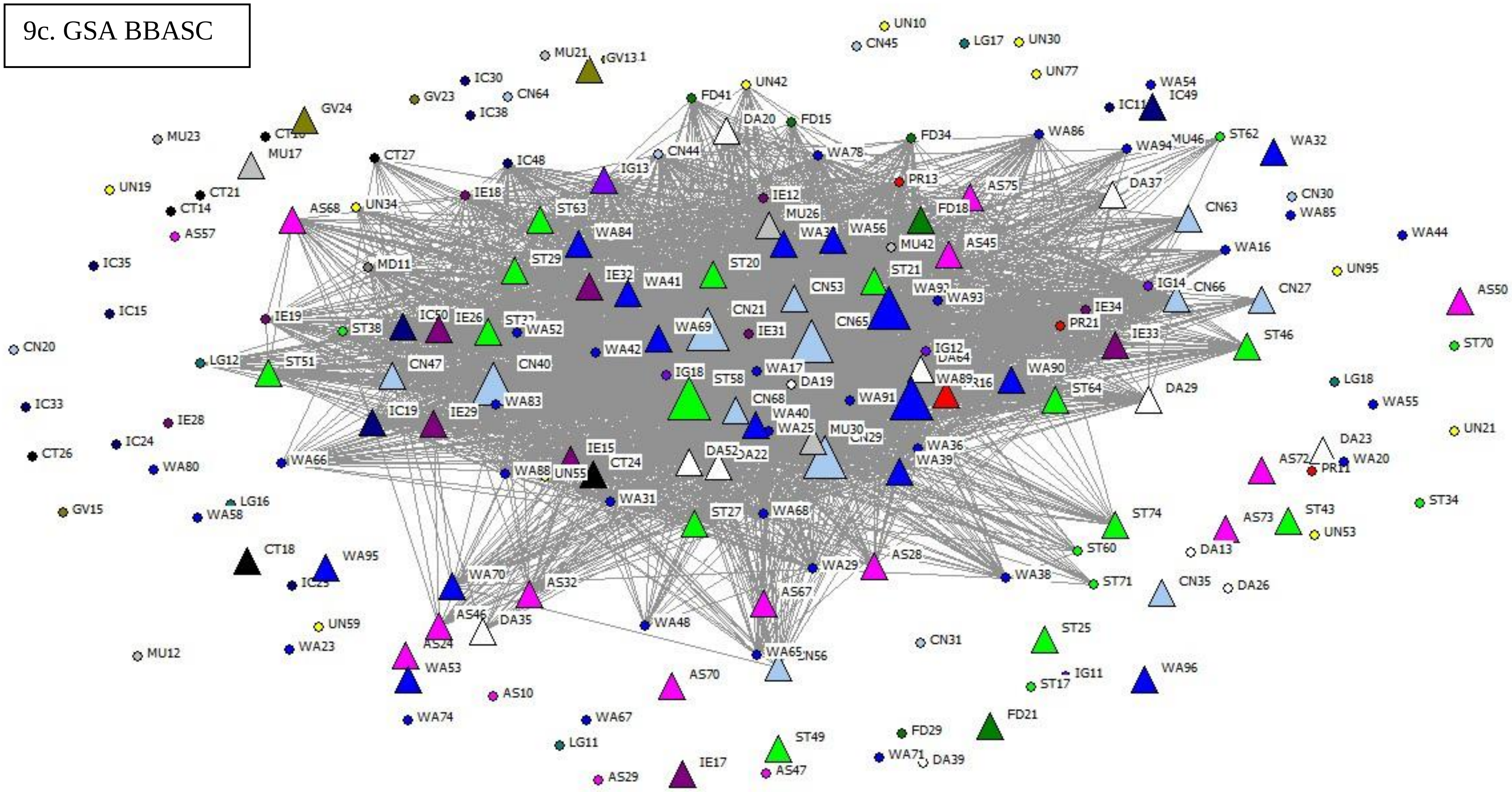
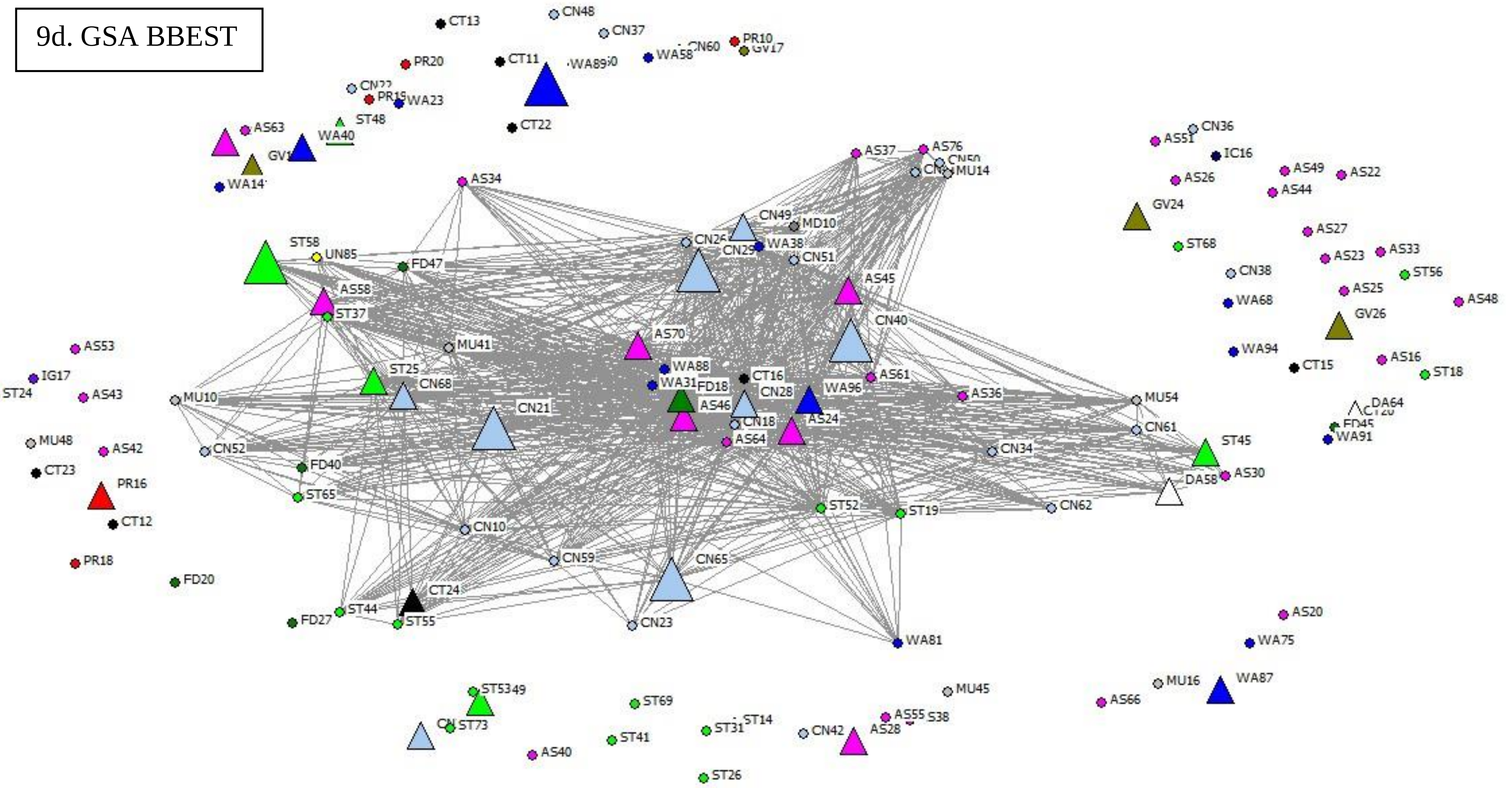

9c. GSA BBASC

Figure 9. Continued



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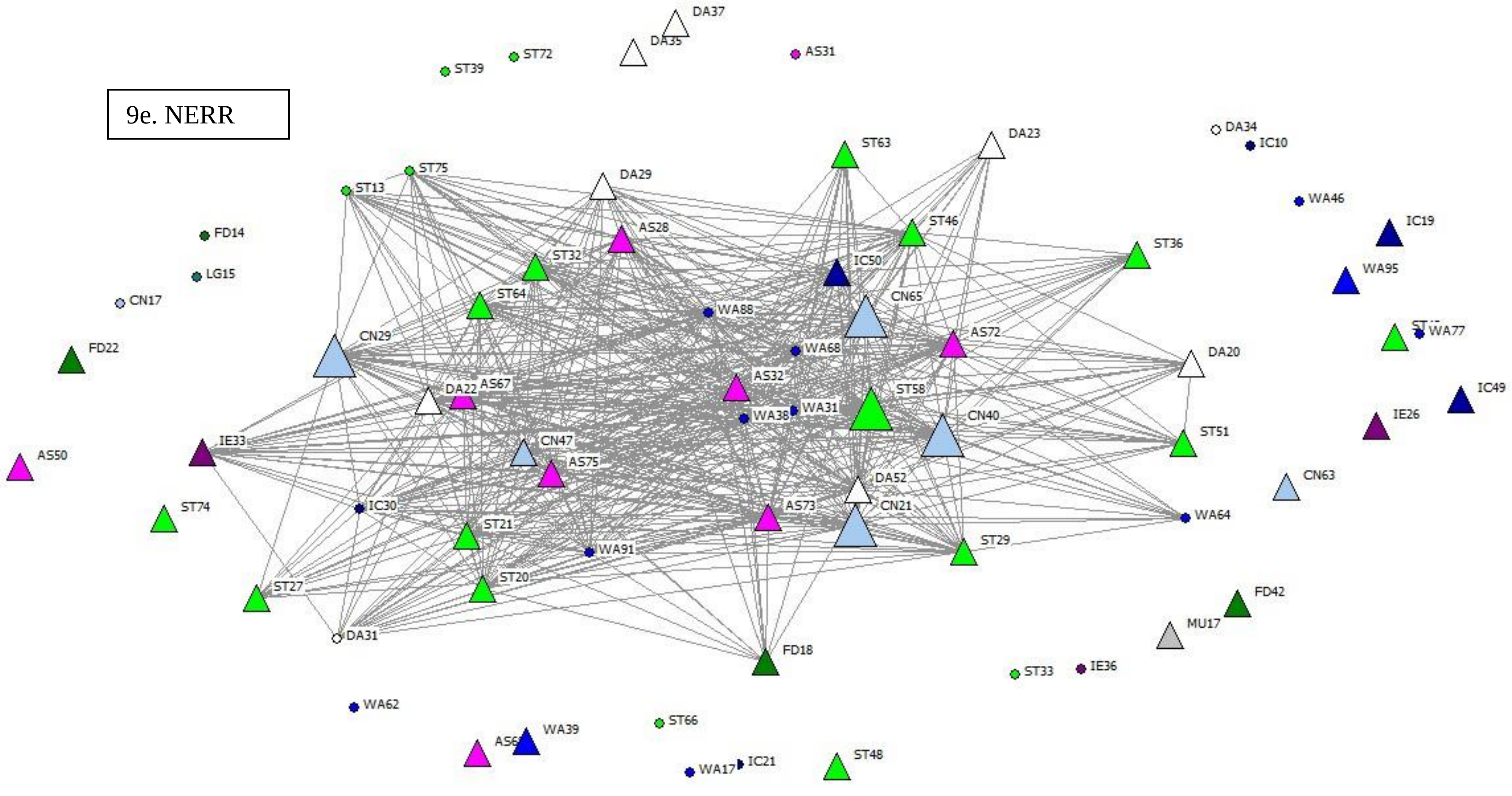

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Eight brokers were identified within the network (N=643). Half of these individuals represented regional water authorities and half conservation organizations. Broker function did not necessarily indicate high centrality. Of the top 10 central actors (Table 5), only 5 were brokers within the entire network (CN 29, CN65, WA25, WA31, and WA88). Two other actors were within the top 25 central actors between 2010 and 2013 (CN28 and WA83). A single broker, a conservation stakeholder, was not central within the network, but their removal would have led to disconnection of the EARIP group from other groups. CN65 brokered relations between the Region N group and the EARIP group. The remaining brokers had ties that extended across all groups.

Group overlap during the four years was visualized only for those individuals that attended events in multiple groups (bridges) or were the more central actors within each group based on combined centrality measures (N=148). We used the smaller subset because it most likely represented actors with credible relationships resulting from multiple co-occurrences (average meeting attendance for this group was 19.8 meetings), and avoided overly complex diagrams that obscured information. While the GSA BBEST and NERR Collaborative group meetings did not overlap in time, certain individuals were common to both groups.

Network structure of watershed relations was examined from the standpoint of how individuals tied the groups together (from an event x event adjacency matrix, Figure 10) as well as how events tied individuals' together (actor x actor adjacency matrix, Figure 11). In the first scenario (Figure 10), groups were visually cohesive. Group relations mimic geographic orientation with the least overlap between Region N

Table 12. Individuals with high eigenvector and betweenness centrality scores based on co-occurrences during 2010 to 2013. Brokering individuals within the network are noted by an asterisk. Group columns indicate which meeting group each individual attended. Year columns are sorted by combined score of normalized eigenvector and betweenness.

Name	Eigenvector Centrality: normalized	Betweenness Centrality	Region N	EARIP	GSA BBASC	GSA BBEST	NERR Collaborative	2010	2011	2012	2013
CN29*	738.2	738.3		■	■	■	■	WA25*	CN29*	CN28*	CN29*
WA25*	728.6	528.7	■	■	■			CN21	DA52	WA88*	CN28*
WA88*	718.4	206.3		■	■	■	■	CN65*	WA52	CN21	CN21
CN21	687.8	167.7		■	■	■	■	DA52	CN21	CN40	CN65*
CN65*	696.8	146.2		■	■	■	■	ST58	WA88*	WA94	WA88*
CN40	691.2	154.3		■	■	■	■	WA91	MU30	CN29*	CN68
ST58	673.3	97.1			■	■	■	DA22	WA25*	WA31*	CT24
WA91	685.6	97.7			■	■	■	IE33	IE26	WA91	WA31*
WA31*	684.5	102.0			■	■	■	ST64	ST58	CN68	ST58
DA52	680.6	96.6		■	■	■		ST20	ST20	ST58	WA83*
WA40	676.3	85.2			■		■	WA17	WA91	WA25*	PR16
CN68	673.2	82.6			■		■	MU30	WA83*	WA40	MU30
DA64	665.9	72.6			■		■	WA68	CN47	IE15	WA25*
MU30	658.5	64.9		■	■	■		CN53	IG18	AS46	CN56
FD18	657.9	77.6			■	■	■	AS72	CN65*	AS24	AS46
WA89	649.4	67.9			■	■	■	CN29*	CN68	AS70	IE15
WA38	649.0	89.1			■	■	■	ST29	ST32	CN53	DA52
WA69	636.1	61.2		■	■			DA64	WA42	MU30	WA40
WA68	634.7	75.0		■	■	■	■	WA40	DA22	CN65*	ST49
CN53	635.9	54.2		■	■			ST21	WA40	WA89	IE31
IE15	632.2	59.1		■	■	■		DA19	FD18	ST27	WA69
WA17	619.4	33.9			■	■		WA89	WA31*	DA64	WA89
ST27	616.6	46.5	■	■	■			WA36	IE15	WA38	WA39
DA22	614.2	34.3			■	■		CN68	WA69	IE29	WA38
DA19	611.7	26.5			■			ST27	DA19	WA83*	IE29

(coastal) and EARIP (aquifer). The GSA BBASC and GSA BBEST groups were well integrated as would be expected from their common purpose in the SB3 process. The NERR Collaborative meetings tied the GSA BBASC and GSA BBEST cluster to Region N. Region N meetings were also less closely tied by the actors involved than were other groups.

The watershed network based on actor x actor adjacency matrices of central actors for years 2010-2013 illustrates stakeholder affiliation, group affiliation, and bridging and brokering roles in the network (Figure 11). Overall network structure again reflects the relative isolation of Region N from other groups in the network (lower left). During the year 2012, the single bridging regional water actors was absent (year data not shown), further isolating this group.

Analysis of individuals important as brokers, whose removal would disconnect clusters within the network (shown as larger nodes in Figure 5, and noted with an asterisk in Table 5) revealed 9 brokers: 3 were regional water authority representatives, 5 were conservation organization representatives, and one represented a state natural resource agency. One of the conservation brokers (CN54) is not shown in Table 12. This conservation stakeholder was a leader in the EARIP process, having the highest combined centrality score in that group, but did not attend meetings of other groups and thus their combined centrality scores were closer to the 100th position, beyond the top 25 listed in Table 12. Actors in Table 12 provide connections within the networks that represent opportunity to transfer critical knowledge and contribute to successful management of the watershed.

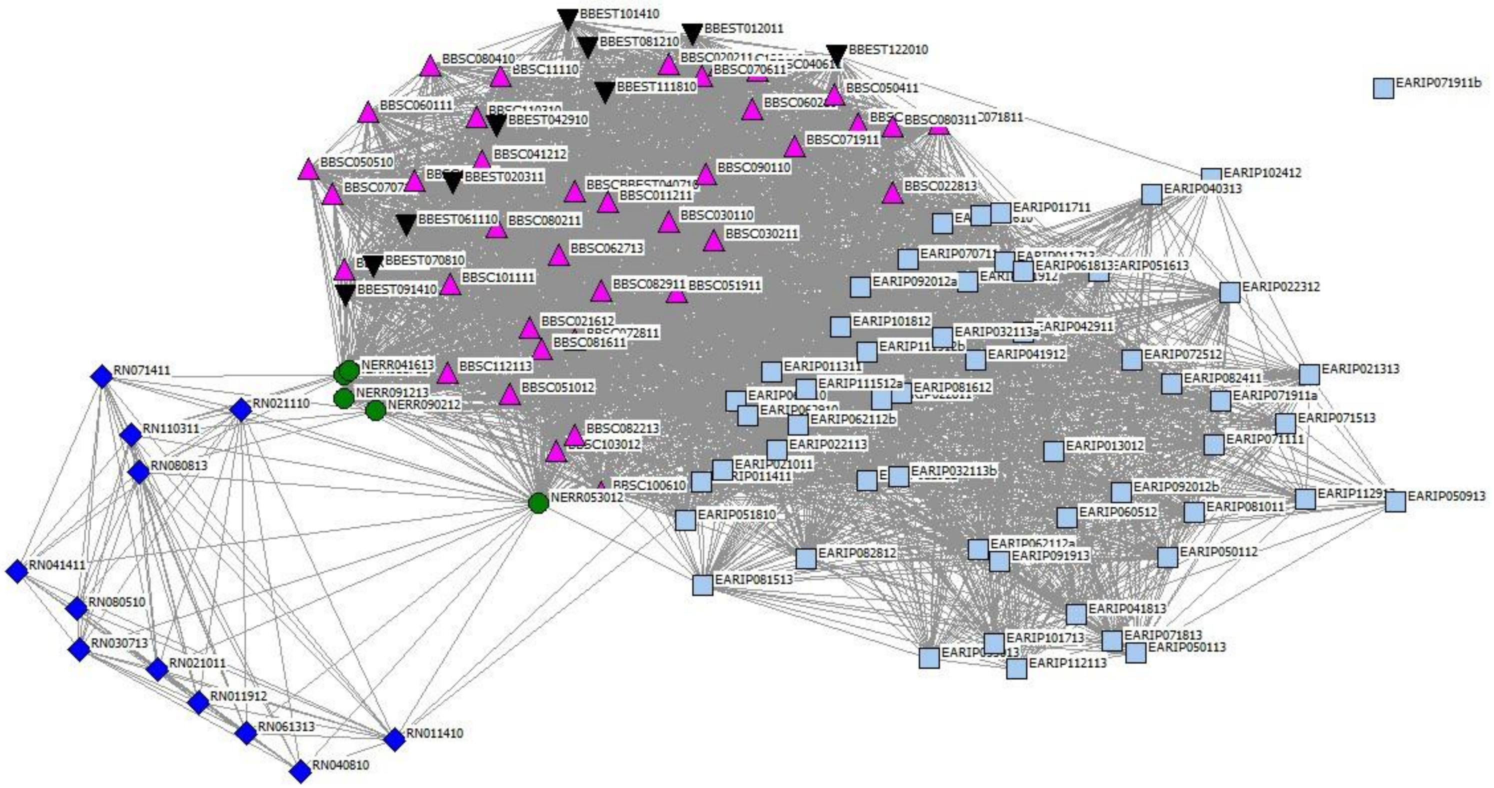

Figure 10. Network of individuals for 119 meetings during 2010-2013. Ties represent event x event adjacency matrix based on co-occurrence. This smaller subset of individuals (148 of 634) includes bridging and central actors. The network reflects connections of 50 or more edges. Key: Region N = dark blue diamonds, EARIP = light blue squares, GSA BBASC = pink up-triangles, GSA BBEST = black down-triangles, NERR Collaborative = green circles.

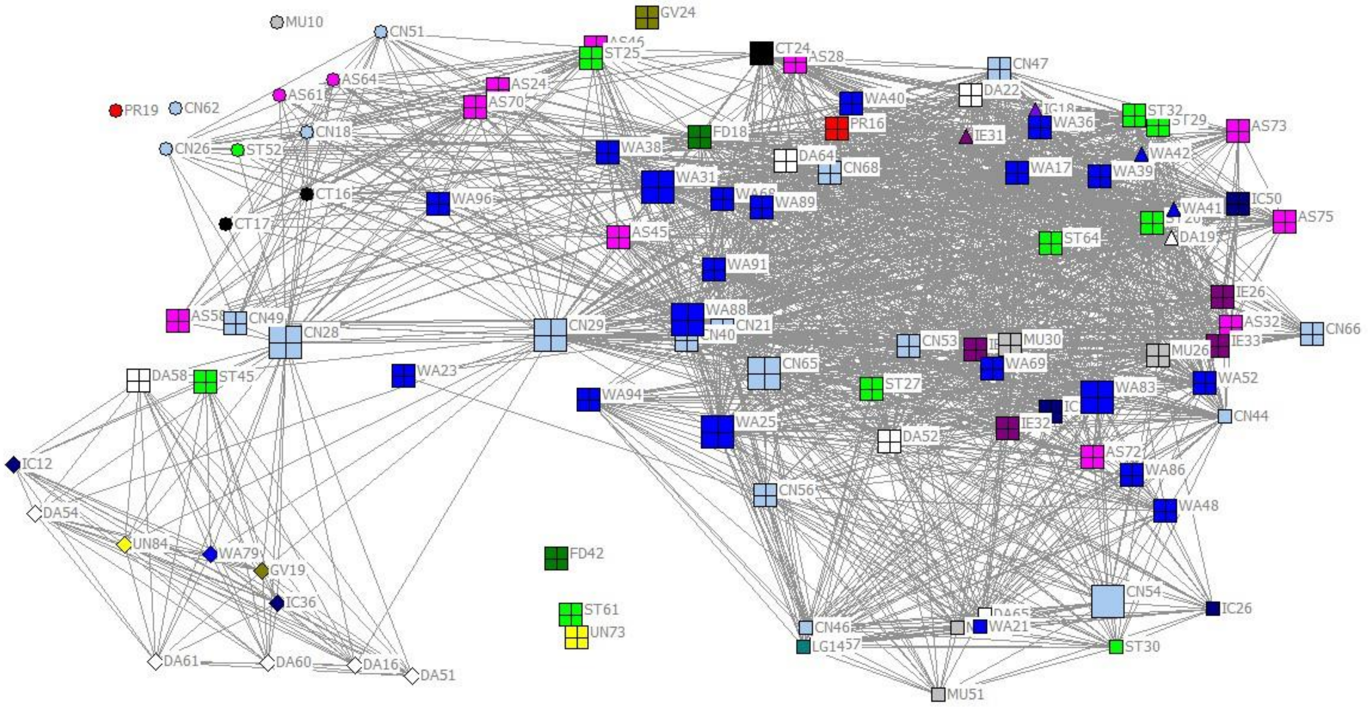

Figure 11. Network of bridging and central actors for meetings during 2010-2013 (N=148). Ties represent actor x actor adjacency matrix based on co-occurrence. The network reflects connections of 50 or more edges. Stakeholder types are indicated by color and code designation (Table 2). Group affiliation is indicated by node shape: Region N=diamond, EARIP=square, GSA BBASC=up triangle, GSA BBEST=down triangle, NERR Collaborative=circle, and individuals bridging 2 or more groups=box. Node size reflects role in network: small nodes=attended single group, medium node=bridge 2 or more groups, large node=broker in network.

DISCUSSION

In this case study, diverse stakeholder types worked within groups successfully despite different agendas. For example, conservation groups concern for environmental integrity was integral in the written reports of the GSA BBASC, Region N, and EARIP groups (GSA BBASC, 2011; EAHCP and Gulley, 2012; TWDB, 2012). Municipalities are under enormous pressure from citizens and industry to provide cheap and potable water. Farmers and ranchers compete for scarce water resources, and state and federal natural resource managers frequently answer to political climates. Within the context of social and ecological resilience, stakeholder diversity is perceived to increase adaptive capacity (Bodin et al., 2006). Perhaps because all of these disparate stakeholders were so actively involved, this watershed has successfully addressed issues of endangered species management, environmental integrity, and water planning for an increasingly urbanized future. In other studies, stakeholder diversity has contributed to a broad collective knowledge base, and more robust capacity for innovative management for marine protected areas (Alexander and Armitage, 2015) inland watersheds (Floress et al., 2011), and a national park (Prell et al., 2009).

Network density, as a reflection of the number of ties within a network, facilitates the spread of information within groups and contributing to greater trust (Prell et al., 2009).Watershed management groups in the Nueces and GSA watersheds form cohesive functioning groups with diverse stakeholders and access to outside knowledge. Each group had a central, cohesive core of actors that served the groups as a durable presence and source of social memory. Density measurements in this study were consistent with other natural resource studies and suggest that these networks facilitate social memory and provide the buffering capacity of redundancy useful when dealing with uncertainty and risk (Bodin et al., 2006; Sandström and Rova, 2010). In this study, the four groups formed for the purpose of developing policy (Region N, EARIP, GSA BBASC and GSA BBEST) successfully negotiated consensus agreements within required time periods. We observed trust development over time within both the EARIP and GSA BBASC groups, both in the tenor of the conversation and the efficiency with which meetings operated (Ragland et al., in press). This compares positively to other watersheds in Texas where either distance (the Rio Grande BBASC committee eventually split into upstream and downstream units) or other factors (dominance of single stakeholder type in watershed management) derailed management and planning efforts (Roach, 2013).

Our access to stakeholder information gave us a rich view of stakeholder types that were central actors in the network and those that played significant bridging and brokering roles. Central actors had more ties within the network due to greater co-occurrence and their durable presence in the networks likely generated greater information dissemination, coordination, and greater capacity for trust (Bodin et al., 2006; Prell et al., 2009). All of these factors are crucial to social capital development (Uphoff, 2000). Bridging actors were integral components of all groups, increasing the potential to innovate.

Over time, these networks shared key individuals and learning advantages. At the beginning of the EARIP process, stakeholders were exposed to collaborative learning principles through workshops conducted by Steve Daniels and Greg Walker (for a description of this type of training see Daniels and Walker (2001)). A number of stakeholders that participated in the EARIP process were also later involved in the GSA BBASC. Valuable skills from the collaborative learning workshop likely transferred and contributed to successful navigation of the SB3 process. As well, those involved within the EARIP process likely had established relationships through affiliation which may have led to a level of trust useful for the SB3 process. At the very least, they had familiarity working together.

Two brokers within the watershed functioned to better connect Region N stakeholders to the rest of the network. Other brokers had broader connections that spanned all groups. Brokers, in the network sense, are more likely to have access to diverse information and resources useful to themselves, and they function to increase heterogeneity within the network (Barnes-Mauthe et al., 2015).

No single individual was the most central actor in any given year or in all groups. Such redundancy improved the chances that the loss and gain of specific individuals did not damage network integrity. Regional water authorities and conservation organizations played central roles within these networks as leaders, bridges, and brokers. Where their function was historically to manage the water rights that they owned, the mission of regional water authorities has shifted towards planning for the future and it is not surprising that they would be active and important stakeholders (www.sara-tx.org/about-sara). The key roles played by conservation organizations are more puzzling. The adage that conservationists are rabble rousers, in this study, gives way to the reality of this stakeholder group as well-connected members of the watershed community. In fact, most are paid staff advocating for natural resources. Over time in this watershed, the role of the Sierra Club and the San Marcos River Foundation has shifted from litigation to central and leadership roles in these water groups. Endangered species within the watershed are powerful drivers for protection, and will continue to keep federal and conservation organization stakes in the ongoing conversation about water management (Bernacchi and Ragland, in press).

Group networks overlapped from the Edwards Aquifer to the coastal plains, indicating exchange of social capital throughout the watersheds. Overall, confluence of overlapping geographic jurisdiction and shared resource appear to be the overriding factor behind co-occurrences. The greatest overlap between groups was between the GSA BBASC and GSA BBEST, two groups that worked towards a common goal during the same time period. Moreover, the NERR Collaborative was an outgrowth in time and purpose of the work plan developed by the GSA BBASC. As mentioned above, a number of EARIP members were later involved in the GSA BBASC process. Region N members attended NERR Collaborative meetings, such that these meetings likely provided a nexus for interchange of ideas. The NERR Collaborative meetings did not lead to development of policy recommendations, and were thus an opportunity for lower-stakes dialog and exploration of new ideas common to all participants (Ragland et al., in press).

The groups examined within this study are likely to function into the future of this watershed. While some individuals may shift, these dense networks are likely to persist and continue to overlap. The large number of centrally involved actors suggests that social memory will remain an asset in policy development. As well, regional water authorities and conservation groups that currently function as brokers will likely continue to work towards their long-term goals of managing this watershed towards a resilient future.

CONCLUSIONS

Water will remain a critical natural resource issue, if not the most pressing issue into the future. Management of this precious resource requires creativity, patience, and communication among diverse individuals and groups over time. Network structural features that contribute to social capital within these watersheds include stakeholder diversity, network density, redundancy of actors in bridging and brokering roles, and connectivity across groups. Successful management is a continuum of responsive, legitimate actions that neither privilege a few, nor exclude others. Social capital provides a lens to examine the nuances of groups and individuals working on water issues in the Texas Coastal Bend.

Successful watershed management is likely to continue due to the diversity of stakeholders involved, redundancy of important actors within dense and cohesive networks, and social capital resulting from the watershed network. Science based processes that address common issues, such as the NERR Collaborative, provide opportunities for increased interaction among water groups. Successful watershed management may be enhanced by providing more opportunities similar to this science-based collaborative effort which addressed specific data needs outlined by the GSA

BBASC to adaptively manage the GSA watershed. The NERR Collaborative also provided networking opportunities for stakeholders across the watershed to participate in share ideas and examine issues of concern in a lower-stakes environment.

This study provides insight into the structural network factors that contribute to social capital useful for successful watershed management into the future. Network analysis revealed pathways for information exchange and innovation, bonded group networks in which diverse stakeholders are able to reach consensus decisions, key individuals that bridge the gaps between and within groups, and structural characteristics of successful natural water management.

Affiliation network analysis in this study provided a useful overview of watershed management, within the context of knowledge about the purpose and accomplishments of water groups. Our analysis shed light on stakeholder groups contributing influential actors as well as groups that may benefit from greater outside influence. The density of the networks and the great number of bridging individuals who are actively engaged in watershed management bodes well for the future of these watersheds.

CHAPTER V

CONCLUSIONS AND FINAL THOUGHTS

In this dissertation, I used social capital as a framework to focus on the nexus of society and natural resources in TX Coastal Bend. But, I will digress and first examine how I came to this point. There is ample evidence that top-down management rarely works well. As I pointed out in Chapter IV, frustration with management of the watershed led to litigation and controversy. Over time, the response by the legislature was to broaden the input into water governance by increasing stakeholder involvement. This has been a trend in general in the last few decades (Depoe et al., 2004; Innes and Booher, 2004). This brings natural resource management to a societal scale, and the need to examine how society functions to accomplish management goals. Social capital, as theory, is a framework that looks at how individuals function at a societal level: the connections, engagement, subsequent rules and norms, shared ideas, trust, reciprocity, and the vital component of learning. Latour (2010) puts this societal action into perspective: “just at the time when people despair at realizing that they might, in the end, have “no future”, we suddenly have many prospects.” I suggest through this dissertation that social capital provides the framework for looking at the many prospects before us, of the networks and the social learning and the potential to work together.

In the USA, natural resource management is an incredibly complex process involving multiple levels of structured government, stakeholders, and citizens. The idea that any one of these components can responsively address changing global conditions is absurd. This leaves us with the dilemma of finding innovative ways to manage an increasing fragile and susceptible system that includes endangered whooping cranes and increasingly scarce fresh water. These are resources that are neither plentiful, nor do they afford a great deal of room for error in their management. Every decision has the potential for catastrophic effect. As we struggle to effectively engage a broader group of minds and means, social capital offers a framework of understanding. It addresses the networks that lead to access to ideas and influence. It provides the rhetoric to discuss shared ideas and norms that can be examined as either beneficial to robust decision-making or exclusionary. It provides the cognitive context that is essential for legitimizing complex policy. And finally, it recognizes that stasis is unrealistic.

Social capital is not a new idea, and it aligns with other ideas about adaptive management, collaboration, community-based management, and resilience, bringing each of these worthy ideas under a single umbrella to look at similarities and differences. Resilience differs from the other three concepts as it refers to the nature of the natural system rather than as a means of addressing the issues. Resilience has been described as the ability of a system to adapt and absorb disturbances to retain function and identity (Folke et al., 2005; Tompkins and Adger, 2004). The means to achieve resilience in social ecological systems includes adaptive management, collaborative learning, and community-based management (Daniels and Walker, 2012; Measham and Lumbasi, 2013; Williams et al., 2009). Throughout the discussion of these concepts are emphasis on stakeholder or community involvement, learning, systems thinking, flexibility, and purpose. First, stakeholder and or community involvement is essential for success because these are the publics that must accept policy decisions or derail them. Learning is a key theme for adaptive management, with adaptive management stressing that it is an iterative process, not ‘trial and error’ of making purposive decisions (Williams et al., 2009). As well, collaborative learning focuses entirely on how engagement and shared learning facilitates successful management by promoting systems thinking (Daniels and Walker, 2001). Community-based management brings concepts of local engagement, learning, and how people are tied together and work together (Berkes, 2006; Measham and Lumbasi, 2013). In the previous chapters, I have used social capital as a focal point because it encompasses social learning, networks, diversity of voice, engagement, shared values, reciprocity, and trust all to a single place.

Chapters II – IV focused on the capacity that exists within communities to become involved in ongoing management of conservation-reliant species, that social learning is a means to build further capacity and deepen understanding, that time and patience do strengthen social capital, and that we can find evidence of social capital that already functions at multiple scales. A social capital approach has the potential to tap social resources previously unrecognized, build capacity through modeling and active social learning, and recognize resources where they exist as a source of valuable social knowledge.

Chapter II examined social capital active at the community scale. Bonding and bridging networks founded in previous community action served as potential resource for involvement in whooping crane management. Bonding ties within the community led to common knowledge that has facilitated trust, reciprocity and shared values and the ability to work together successfully. This is a community that cares and is actively engaged. The context of structural social capital dimensions, the networks, engagement, and existing institutions are essential to the social capacity for stewardship. Community members share values and ideas about whooping cranes and whooping crane recovery, establishing the context within which social capital may save both time and money that might normally be invested by management in outreach and education.

Chapter III looks at the ‘how to’ aspect of social capital in natural resource management. We used collaborative modeling to facilitate social learning and build social capital to further the goals of ongoing freshwater inflows management in the bays and estuaries of the Texas Coastal Bend. Social learning led to better understanding of the system and allowed participants to develop a common conceptual framework and associated vocabulary needed to better address complex social - ecological issues. Collaborative modeling fostered legitimacy of learned and shared ideas. Rather than a simple ‘let’s brainstorm’ ideas about the system, participants gained a deep understanding of how the estuarine system functions and what challenges and knowledge gaps exist. The three-year collaborative modeling process built social capital through engagement, reinforcing existing ties within the greater watershed network, and building new ties.

Knowledge is an essential component of social capital discussions. It is the common knowledge or social memory that provides the foundation for sound natural resource management (Ishihara and Pascual, 2009; Pretty, 2003; Sandström and Rova, 2010). Knowledge serves as important capital that can be exchanged through network ties. Within the three case studies, better knowledge of the cranes, especially if shared garnered through social learning, would be an asset to whooping crane management. It did serve as a hallmark of success for the collaborative modeling project, and provided information that may lead to better recommendations in the next stages of the SB3 process. From these three studies, it is clear that knowledge should be added to the dimensions of social capital presented in Chapter II. Unlike other dimensions, knowledge has structural qualities as well as cognitive qualities of understanding and context.

The fourth chapter examined social capital in action. I examined affiliation networks of multiple water groups within the Texas Coastal Bend over a 10-year period. Social capital was evident from the ideas and innovation of successful processes of regional planning, protection of threatened and endangered species, and initial recommendations for freshwater inflows. Stakeholder diversity in the groups likely contributed to the robust decisions reached within each group. Network density increased in periods when groups were moving towards consensus. Within the group networks and the watershed network, social capital exists in the key individuals that provide leadership and connection, that broker relations between disparate groups and that weave the complexity together in a coherent and functional manner. With the context that chapters II and III provided, this chapter illustrates how social capital in action can facilitate successful natural resource management.

The premise of this dissertation is that social capital provides a theoretical framework to examine natural resource management. The second chapter used a holistic approach to community level social capital, analyzing rich interview data as to the structural and cognitive dimensions of social capital. The question that remains from this study is: why has crane management to this point not involved the public more? The cranes share resources with and are a source of livelihood and pride in the community. Potential community social capital lies in the ability to mobilize human capital as well as tap into leadership and knowledge of the area and crane habits. The next step then is to recognize and capitalize on this potential resource for conservation.

The study on collaborative modeling as a means of active social learning demonstrated both a tool and result useful to watershed management. The modeling process facilitated shared learning, trust building, and the context for developing next steps. As well, it reinforced knowledge and relations useful for addressing ongoing issues.

The network study of water groups in this region revealed insight as to how successful policy-making might be encouraged. Network measures of density were dependent on the point in which each process was moving towards resolution. Centrality measures pointed to actors that were central within specific groups as well as across groups. This aided identification of key brokers within the overall network. Brokers did not have the highest centrality measures, but they did connect groups not otherwise connected, which may be useful to resilient responses in this watershed (Prell et al., 2009). When planning processes, identification of existing brokers, especially in the regional water and non-governmental organization sectors may contribute to potential success. As well, including previously involved individuals appears to perpetuate valuable collaborative skills developed in previous groups.

Next steps involve communicating with management agencies, so they are able to capitalize on community social resources as funds for natural resource management are always scarce. As well, social learning processes used in management, including collaborative modeling, may be compared in terms of their effectiveness by using Bloom's taxonomy as an evaluation tool. This may help design better processes and tools to promote shared knowledge as an instrument of social capital. Social capital is a complex concept with multiple dimensions, but because of that complexity, it provides a robust framework from which to examine how to better manage natural resources.

I am not breaking ground that has not been broken by studies of collaborative learning, adaptive management, community-based management, and resilience, but rather offering social capital as a framework to bring these conversations together with a common language. Social capital provides to the tools to examine and compose a future that may not look like anything before, but builds on the networks and connections, shared ideas, and innovation through new ideas. As Latour (2010) so aptly stated, this is a future that is "slowly composed instead of being taken for granted and imposed on all."

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