Sociological Forum

Sociological Forum, Vol. 31, No. S1, September 2016
DOI: 10.1111/socf.12275

Water Policy And Governance Networks: A Pathway To Enhance Resilience Toward Climate Change

Beth Caniglia[1], Beatrice Frank[2], Bridget Kerner[3] and Tamara L. Mix[4]

Natural resources governance is key to enhancing resilience toward climate change and strengthening socioecological systems in light of future uncertainties. Overlapping jurisdictions and lack of clarity in the lines of authority reduce the efficiency of environmental policies and governance, jeopardizing the conservation and sustainable use of resources. With the forecast of longer droughts, extreme precipitation patterns, faster runoff, and slower water table recharge over the coming years, water governance becomes an impellent issue. To understand the risks posed by water scarcity and water regulations, a case study was conducted of Oklahoma state-level water policies and governance. A content analysis of water policies and a network analysis of water governance was used to determine how Oklahoma experiences features of fragmented and adaptive governance within its natural resource governance structure. Data analysis reveals that Oklahoma water governance experiences multiple forms of fragmentation while also showing features of an adaptive network. Such adaptive features make Oklahoma's water governance network more resilient than forecasted. Identifying gaps and understanding how a governance system experiences fragmentation can help policy makers develop strategies to enhance the adaptive features of water governance, thus preparing for risk and disasters related to water scarcity and climate variability.

KEY WORDS: climate change; environmental sociology; governance; networks resilience; sustainability

INTRODUCTION

With increasing environmental changes and climate uncertainty, implementing adaptive governance of natural resources is key to enhancing resilience and strengthening socioecological systems (SES) on which humans are dependent (Berkes and Folke 1994; Bodin and Crona 2009). Natural resource governance, defined as "the structures and processes by which people in societies make decisions and share power" (Folke et al. 2005:444), is a formal method to manage common pool resources. However, such resources are difficult and controversial to manage, especially when formal authority over their use is not clearly defined or when there is conflicting legislation (Anderson, Gibson, and Lehoucq 2004; Bartley et al. 2008; Bodin and Crona 2009; Crona and Hubacek 2010;

[1] Director of the Sustainable Economic & Enterprise Development (SEED), Institute and Faculty Research Director in the College of Business and Economics at Regis University, 3333 Regis Boulevard, Denver, Colorado 80221.
[2] Capital Regional District of Victoria, Regional Parks, 490 Atkins Avenue, Victoria, British Columbia V98 2Z8, Canada; e-mail: frankbea@hotmail.com.
[3] National Association of County and City Health Officials (NACCHO), 1100 17th NW Street, Washington, District of Columbia 20036-4601.
[4] Oklahoma State University, Department of Sociology 470 Murray Hall, Stillwater, Oklahoma74078-4062.

Lockwood et al. 2010). Additional complexity in natural resource governance comes from overlapping jurisdictions at local, municipal, state, regional, and federal levels (i.e., vertical scale) and across different governing institutions, such as multiple state-level environmental agencies (i.e., horizontal scale) (Hill et al. 2008). The lack of clarity in lines of authority within and across geographies and jurisdictions can reduce the efficiency of environmental policies and governance, jeopardizing the conservation and sustainable use of resources, such as water.

With the forecast of longer droughts and less frequent yet more extreme precipitation patterns due to climate variability, more runoff and less water table recharge over the coming years are expected, making water governance an impellent issue in natural resources governance (Craig 2008; Hess et al. 2016). Water governance is central for predicting water usage and availability and monitoring supply sources. According to the 2006 United Nations World Water Assessment Program (UNWWAP), the most important water problem facing the world today is not water scarcity, but rather its governance (Cook 2011).

Legal scholars (Buzbee 2003, 2005) as well as resilience scholars (Folke et al. 2005) have elaborated upon various features that impact the efficacy of water governance. Fragmented governance and adaptive governance have been documented as key components of effective natural resource management. While fragmented governance generally decreases the ability of an SES to respond to disturbances and reduces the resilience of a system, adaptive natural resource governance increases the coping capacity of an SES to respond to uncertainty and change (Folke et al. 2005). Conceptual clarity and rigorous operationalization of fragmented and adaptive governance structures is in its infancy. Through a better understanding of these dimensions of natural resource governance, practitioners and scholars can enhance the coping capacity of an SES, and thus improve governments' and institutions' preparedness toward unpredictable shocks and disturbances, especially in the domain of water governance and climate change (Berkes and Folke 1998; Berkes, Colding, and Folke 2003; Caniglia et al. 2014; Dietz, Ostrom, and Stern 2003; Gunderson and Holling 2002).

To better understand the risks posed by overlapping jurisdiction and lack of clarity in the lines of authority in water governance, we offer an overview of fragmented governance and adaptive governance. To examine fragmentation, we introduce a content analysis of Oklahoma's understudied state-level water policies. Thereafter, we analyze the features of adaptive governance within the water governance structure of Oklahoma using a network analysis approach. Through this mixed-method approach, we portray the risks posed by overlapping jurisdictions and unclear lines of authority, thereby highlighting areas of vulnerability in Oklahoma's existing water governance network. We end with a brief discussion of how this case study on water governance in Oklahoma advances the natural resource governance literature and suggest potential new lines of research in this domain.

FRAGMENTED GOVERNANCE

Understanding the ways fragmentation applies to certain governance structures and acknowledging that some forms of fragmentation are more prevalent than others can help practitioners increase the resilience of a governance structure. Fragmented governance is "the allocation of responsibility for governance among multiple actors and/or agencies, with relatively little or no coordination" (Hill et al. 2008:316).

Different types of fragmentation exist at different levels of the governance structure, from territorial to biophysical to jurisdictional fragmentation (Bakker and Cook 2011; Cash et al. 2006; Cook 2011; Dietz et al. 2003; Ostrom 2010). While territorial fragmentation refers to disjointed governance caused by geopolitical boundaries, biophysical fragmentation focuses on the contradictory and/or uncoordinated governance of watersheds and ecosystems due to geopolitical boundaries. Jurisdictional fragmentation can be defined as "the fragmentation created by the interaction of political and legal institutions that hold or assign authority to a territory" (Cook 2011:26). As such, jurisdictional fragmentation has a negative impact on natural resource governance because "too many separate actors and actions can become dysfunctional" which leads to inefficiencies or inaction in solving resource issues (Cook 2011:33). Such fragmentation occurs when multiple actors and/or agencies share management of a natural resource. A lack of understanding about which individual, agency, or institution is responsible for regulating a particular aspect of a resource can cause confusion and conflict, leading to overaction, inefficiency, and/or inaction in solving resource management issues (Buzbee 2005; Cook 2011). This uncertainty experienced by agencies, industries, or citizens over who is the leading authority in charge of managing a common resource creates governance gaps and bottlenecks, making the governance of a resource controversial and inefficient.

One way to observe jurisdictional fragmentation is to analyze institutional documents such as "constitutions, statutes, regulations, common law rules, international treaties, and policies" (Cook 2011:28). The outcome of jurisdictional fragmentation is a "governance gap," meaning that there is uncertainty between agencies or actors as to who has jurisdiction over a resource (Cook 2011). The "governance gap" can lead to multiple problems, the first of which is inaction because "where social ill is juxtaposed against multiple potential regulators all will be tempted to ignore that social ill and free ride on the anticipated actions of others" (Buzbee 2003:21). In addition to agency inaction, another issue that arises is overaction. Overaction occurs when multiple agencies attempt to take control of and address a resource situation without a clear understanding of which agency is actually responsible. Thus, when governance becomes fragmented it ineffectively regulates that which it is trying to govern. Despite being ineffective, it is often not clear that fragmentation is occurring until it is either determined through analysis or exposed through a shock or disturbance to the system. This is connected to resilience because vulnerabilities within a system are often not exposed until that system experiences a shock or disturbance and is incapable of responding to or adapting to the shock. Such an approach also offers flexibility in response to changing

regulations and environments (Brunner et al. 2005; Folke et al. 2005; Gunderson 1999; Gunderson and Light 2006; Lee 1999; Scholz and Stiftel 2005; Walters 1986). As climate variability is likely to worsen in unpredictable ways, it is now more important than ever to analyze natural resource governance structures so that governance systems can become prepared before the system is exposed to a shock or disturbance (Caniglia et al. 2014).

Multiple levels of natural resource governance can create complexities because of overlapping jurisdictions through both vertical and horizontal scales. Vertical scales refer to the different hierarchical levels of government such as federal, state, municipal, and so forth. Horizontal scales refer to the different governing institutions across the same level of government, such as multiple state-level environmental agencies (Hill et al. 2008). These complexities created within natural resource governance highlight the need for more research on the ways in which common pool resources are governed.

Scholars argue that fragmentation within a governance system causes mainly negative outcomes. As already stressed, the overlap and redundancies caused by fragmented governance creates confusion regarding the roles of different governing agencies. Fragmentation reduces the ability of the system to respond when disturbances occur, decreasing the resilience of an SES (Folke et al. 2005). Nevertheless, fragmentation is also capable of providing positive outcomes by favoring diversity and innovation, and by enhancing the functionality of a governance structure (Cook 2011). Teisman and Edelenbos (2011) state that a certain amount of fragmentation is necessary when governing different landscapes and ecosystems within and across nation-states. Fragmented governance, indeed, keeps governance structures from having too much centralized power and is generally seen as a necessary attribute of democratic governments. Thus, the presence of fragmentation in a government structure in and of itself does not necessarily lead to inefficient governance; rather, the degree of fragmentation and how well-coordinated the governance structure is determines the severity of this phenomenon on the resiliency of the system. Scholars have suggested several solutions to reduce undesirably high levels of fragmented governance, such as the centralization of resource management under the federal government. However, a severely centralized governance structure can produce negative outcomes, similar to that of a severely fragmented governance structure (Buzbee 2003). Other approaches that reduce fragmentation have been suggested, from fostering integration and open communication between the different actors or agencies trying to regulate a resource, to adaptive governance strategies. Such approaches are believed to reduce fragmentation between different governing agencies and governing entities and thus build resilience in governance structures (Buzbee 2003).

ADAPTIVE GOVERNANCE

The development of adaptive governance can be traced back to the concept of adaptive management (Gunderson and Light 2006; Holling 1978). In the natural sciences, adaptive management enhances ecological resiliency by including uncertainties, and the complex functioning and feedback loops of ecological systems in

resource management (Gunderson and Light 2006). Adaptive governance emerges from this concept and is used as an interactive "framework" to portray the different aspects that build up multilevel governance. Specifically, this framework helps to pinpoint how the different levels of social, institutional, economic, and ecological governance interact to foster resiliency, especially in SES (Brunner et al. 2005; Folke et al. 2005; Gunderson 1999; Gunderson and Light 2006; Lee 1999; Scholz and Stiftel 2005; Walters 1986). An SES that experiences adaptive governance "draws upon various knowledge systems and experiences for the development of a common understanding and policies" (Folke et al. 2005:441). Adaptive governance addresses specific social dimensions of complex SES that tend to mitigate the impacts of shocks or disturbances (Gunderson 1999; Gunderson and Light 2006; Lee 1993; Walters 1997). As Garmestani and Benson (2013:3) argue, if institutions cannot work toward resilience through adaptive governance, then they should not be considered "appropriate for managing social-ecological systems."

So how do we measure adaptive versus fragmented governance? While most published studies have used ethnographic and anecdotal cases to illustrate dimensions of adaptive governance, the following measures are consistently considered primary indicators of adaptive governance: social memory, learning, trust, adaptive capacity, heterogeneity, and redundancy (Bodin, Crona, and Ernstson 2006; Buzbee 2005; Comacho 2009; Folke et al. 2005). We approach the measurement of fragmentation through qualitative content analysis (QCA), coding passages that describe jurisdiction, whether territorial or institutional. We then use network analysis to examine the overall structure of Oklahoma's water governance system and interpret this structure using network concepts that best approximate the aforementioned measures of adaptive governance (i.e., learning, trust, etc.).

WATER GOVERNANCE: AN OKLAHOMA CASE STUDY

The state of Oklahoma continually suffers as a result of a limited water supply. Oklahoma has a history of drought, a reliance on agriculture, and a growing population, all of which impact water availability. As argued by Hess et al. (2016), "the addition of climate change to the sources of stress for freshwater-supply systems not only enhances the risk of supply shortages but also increases the uncertainty of future water availability projections." Accordingly, Oklahoma is predicted to experience more severe droughts and other environmental changes related to water availability in the future as the impacts of climate change become more intense (Hess et al. 2016; Oklahoma Climatological Survey 2011). Recently, Oklahoma has attempted to improve its management of water resources through the Oklahoma Comprehensive Water Plan developed by the Oklahoma Water Resources Board, described in more detail below. Despite an effort to address limited water supply, more research is needed to understand Oklahoma's water governance structure in order to address vulnerabilities that might exist and be exacerbated by climate change.

In the state of Oklahoma, water has been referred to as Oklahoma's "most precious resource" because of its limited quantity (Wertz and Layden 2013:1). Throughout its history, Oklahoma has experienced periods of drought. Records

show that major drought occurred in Oklahoma in the 1890s, 1910s, 1930s, 1950s, 1960s, and more recently 2010s. Not only did these droughts impact the ecological systems in Oklahoma by reducing the amount of topsoil and agricultural productivity, but social systems suffered as well. The social impacts of these environmental disturbances over time led to both decreased economic activity and a major exodus from the plains region (Worster 1979). The most recent drought in Oklahoma not only cost an estimated $1.7 billion in agricultural losses, but it also exposed the vulnerability of industries to water shortages (Liuzzo et al. 2010; McLeman et al. 2008; Zhang and Nearing 2005). However, droughts have not been the only impact of Oklahoma's severe climate variability. Between January 2000 to July 2012, Oklahoma has experienced 33 federally declared major weather-related disasters that have impacted inhabitants, civil infrastructure, natural resource–related businesses, and rural economies (Liuzzo et al. 2010; McLeman et al. 2008; Zhang and Nearing 2005). In addition to agricultural losses and industrial vulnerability, the indirect costs of drought have impacted both social and ecological systems with the increase of wildfires across Oklahoma, which have destroyed both homes and landscapes (Liuzzo et al. 2010; McLeman et al. 2008; Zhang and Nearing 2005). Not only is Oklahoma expected to continue to experience instability in weather patterns, but climate change is also predicted to severely impact the climate variability of this region leading to more severe weather patterns.

In an effort to address Oklahoma's current and impending water issues, the Oklahoma Water Resources Board recently completed the Oklahoma Comprehensive Water Plan (OCWP). The plan was initiated in 2006 and completed in 2012, though the plan provided an outlook for water use in Oklahoma through 2060 (OWRB 2012). Since the completion in 2012, the OCWP is still evolving as revisions, updates, and additions have continued. This plan is an attempt to assess Oklahoma's water resources, help resource managers, and inform policy makers on multiple scales how to determine and implement appropriate water use strategies. Comprehensively, this plan has provided an unprecedented amount of research and community input into recommendations for water policy. The outcome of the plan was a report that highlighted the critical needs of Oklahoma's water system and identified priority recommendations and initiatives. Some of the top recommendations were water project and infrastructure funding, regional planning groups, water supply reliability, water quality and quantity monitoring, and state/tribal water consultation and resolution (OWCP 2012). Despite these valuable recommendations, the policies recommended by the OCWP are not guaranteed to be adopted into law. It is unclear what, if any, policy changes have occurred as a result of the OCWP. The impacts of climate change, the history of Oklahoma's relationship with water, and the recent acknowledgment of the need to prepare for future water availability all contribute to the growing need to increase the preparedness and resilience of Oklahoma's water governance. Certainly, the OCWP did not examine the jurisdictional, territorial or institutional overlaps that characterize fragmented governance. Therefore, we conducted a content analysis of Oklahoma's state-level codes to explicitly examine these dimensions of Oklahoma's water governance system. The content analysis further separated water governance into a set of distinct subsectors of the broader water governance system. The results of the content analysis

represent our operationalization of fragmentation. Thereafter, to address the question of how adaptive Oklahoma's water governance system is, we conducted a network analysis that makes the underpinning structure of this system ostensible and provides empirical ground for the conclusions and recommendations we make at the end of this article.

Little research has been conducted on Oklahoma's water governance and its structure. From the limited existing literature found on this topic, it becomes quickly clear that water governance is multifaceted and overlaps between jurisdictions in this state. Oklahoma water laws, for example, are described as being complex due to the dual rights system, the lack of connection between streams and groundwater aquifer regulations, and the existence of laws that allows groundwater mining (Allison 2012). The efficacy of water governance is further challenged by water right conflicts with Native Americans (Helton 1998) and by the diverse planning efforts and laws applied to regulate water use and management (Langston 2011; OWRB 2015). Additionally, freshwater-supply systems may be at increased risk as droughts become longer and more frequent (Hess et al. 2016), and thus "conflicts in water management are only likely to increase as climate change alters the expected availability of water in many areas of the county" (Craig 2008:1).

As clearly described by Jantzen (2001:9), "regulation of the environment in the State of Oklahoma is divided by, and shared among, federal agencies, state agencies, tribal governments, county governments, and municipalities." The 2010 Water Town Hall Final Report further stresses that "Oklahoma has several agencies that have a role in water resources management. These agencies are not located in close proximity to each other and information comes in different formats... resource management is fragmented and inconsistent because of insufficient interagency coordination, jurisdictional conflicts, and regulatory gaps" (The Oklahoma Academy 2010:11). We imply that the web of statutes, regulations, standards, and requirements enforced at different levels of jurisdictional power makes water governance highly fragmented in Oklahoma. We thus base our analysis on the following hypotheses:

H1: Oklahoma's water governance experiences a low degree of adaptive capacity.

H2: Oklahoma's water governance experiences a low degree of heterogeneity.

H3: Oklahoma's water governance experiences a low degree of redundancy.

H4: Oklahoma's water governance experiences a low degree of social memory.

H5: Oklahoma's water governance experiences a low degree of learning.

H6: Oklahoma's water governance experiences a low degree of trust.

The hypotheses focused our analyses on defining if and what kind of fragmentation and adaptive governance structures are present in Oklahoma's water governance network. The methods utilized to examine Oklahoma's state water laws can

be replicated in other geographical areas to assess the potential degree of jurisdictional fragmentation and adaptive capacity, identify existing gaps, and develop strategies to enhance the adaptive features of water governance in preparation for hazards related to water scarcity and climate variability.

METHODS

A mixed-method research design was used to analyze water regulations and regulating agency networks in Oklahoma (Williams and Shepherd 2015). A content analysis of Oklahoma's water policies was conducted to provide explanatory information on the fragmentation of water policies and to identify the policy domains needed to perform a network analysis of state water governance. The data set was selected from the most recent publicly available edition of The Oklahoma Administrative Code (OAC). The OAC is published every five years and contains all state-level environmental regulations, statutes, laws, and ordinances in Oklahoma. Data for the analysis were retrieved from the Oklahoma Secretary of State online edition of the OAC of 2011 (http://www.oar.state.ok.us/oar/code). The online edition of the OAC is updated every year to include supplemental changes that occur during the five-year full edition publications. Thus, our data set was implemented with the online supplemental information and changes provided in 2012, 2013, and 2014.

The following state agencies were found to have jurisdiction over at least one water policy in the state: Oklahoma Water Resources Board (OWRB), Department of Environmental Quality (DEQ), Oklahoma Department of Agriculture, Food, and Forestry (ODAFF), Oklahoma Scenic Rivers Commission (OSRC), Corporation Commission (CC), Oklahoma Conservation Commission (OCC), Department of Wildlife Conservation (DWC), Department of Mines (DM), and Grand River Dam Authority (GRDA).

Content Analysis

The content analysis focused on Oklahoma's state-level water policies. Policies included in the data set were limited to regulations, statutes, laws, or ordinances that control the use of water in Oklahoma, regulate water rights, determine water quality, and/or control pollutants entering or impacting bodies of water. Documents containing water policies were uploaded from the OAC website into the qualitative data analysis software (QDAS) program NVivo 9 (QSR International 2012). A single policy was used as the unit of analysis; however, some policies contained two or more codes within the same policy. In this case, the separate instances of the codes were isolated into different coding categories. The codes identified from the QCA were then organized and analyzed to determine whether any patterns and themes within the data portrayed water policy fragmentation.

Open thematic coding was used to code Oklahoma's state-level water policies. Overlapping themes were coded and combined to determine if underlying subthemes existed within the data. The existence of duplication, which we term "overlap," of regulatory jurisdiction between two or more agencies was considered

as an indicator of governance fragmentation. After the initial coding, the identified categories were analyzed in NVivo to ascertain that each code was related to the correct policy domain. To ensure that the concepts and themes identified from the data were present and replicable, another researcher was asked to code a sample of the data set. The rate of intercoder reliability for the sample was 90%.

Network Analysis

The network analysis was conducted to evaluate features of adaptive governance within different agencies and for different policy interactions. A set of structural features was explored to determine if the network was adaptive or nonadaptive: adaptive capacity, heterogeneity, redundancy, social memory, learning, and trust (Bodin et al. 2006). These features were evaluated through the measurement of four structural characteristics of the network: density, centrality, reachability, and betweenness (Bodin et al. 2006). Different sets of these measurements have been used to explore fragmented and/or adaptive natural resources governance (Bodin and Prell 2011; Luthe, Wyss, and Schuckert 2012; Sandy et al. 2011). An integrated approach considering all the structural features constituting a governance network has never before been applied. Hence, we have used density, centrality, reachability, and betweenness to evaluate the adaptive capacity, heterogeneity, redundancy, social memory, learning, and trust of Oklahoma's water governance network.

A two-mode assimilation network was created to determine the density and centrality of the water governance system in Oklahoma. Density helps examine the existing connections and ties between agencies and policies, while centrality offers the ability to determine the presence of adaptive features in Oklahoma's water governance. Reachability represents the number of social ties needed to connect any one actor/agency with any other actor/agency in the network, and betweenness is used to determine the amount of actors/agencies that form a bridge between two unconnected events or actors/agencies within the network (Borgatti, Everett, and Freeman 2002). The nine agencies regulating water were used as row variables and the policy domains identified through the content analysis represented the column variables in the two-mode assimilation network. Each box within the matrix was labeled as "0" (no affiliation between agency and policy) or "1" (affiliation between agency and policy). Additionally, the software program Ucinet 6 was used to develop a one-mode affiliation matrix between agencies to evaluate the reachability and betweenness of the network (Borgatti et al. 2002). Unlike the first network, this symmetrical matrix operates with the numbers representing the connections between agencies and events. A sociogram was also produced to provide a visualization of the relationships and ties that exist between agencies and policy areas.

RESULTS

Content Analysis: Types and Degrees of Fragmentation

Sixteen domains were identified through the content analysis for Oklahoma water-related policies: dams (*1), reservoirs (*2), fire protection (*3), fish and

wildlife (*4), mining (*5), oil and gas (*6), hydroelectric power (*7), scenic rivers (*8), wastewater (*9), water rights (*10), ground water (*11), well water (*12), surface water (*13), storm water (*14), stream water (*15), and lakes (*16). Through these domains, five overlapping themes were identified: federal overlap, state overlap, local overlap, multiscale overlap, and miscellaneous overlap. Federal, state, local, and multiscale overlap referred to intersecting jurisdictions by two or more water regulating agencies/policies. The miscellaneous overlap included codes that could not be categorized into the other subthemes and were not prominent enough to be separated in an independent category.

Federal overlap was consistently found throughout the data and caused high degrees of fragmentation within Oklahoma's water policies. State and federal scales of governance were often named concurrently as responsible parties to govern the same violation. When responsibilities were split between different institutions, fragmentation became especially evident. The CC policy 165:10-7-18, for example, states: "Discharge of deleterious substances to streams or other surface waters is prohibited except by order of the Commission; unless permitted by a valid National Pollutant Discharge Elimination System (NPDES) Permit issued by U.S. Environmental Protection Agency (EPA)." By giving authority to both the EPA and the CC, this policy causes jurisdictional overlap and redundancy. Another form of federal overlap occurred when no specific agency had jurisdiction on a matter or when policies were left to open interpretation. In such cases, individuals were required to apply best professional judgment. Such vertical fragmentation between the federal- and state-level policies reduces Oklahoma's natural resource governance resilience toward future shock and disturbances.

State policy has been defined as splintered and confusing in Oklahoma (Jantzen 2001). In accordance to these previous findings, state-level water governance in Oklahoma had high levels of overlap. Horizontal fragmentation was evident between the DEQ and the OWRB. The DEQ policy 252:515-7-3, for examples, states: "All monitoring wells, borings, and/or piezometers shall be constructed and/or plugged in accordance with the applicable requirements of the Oklahoma Water Resources Board at OAC 785:35." Because these two different agencies regulate and often share responsibilities over the same resources, redundancy exists in Oklahoma's water governance. State overlap was further enhanced by lack of clarity in the lines of authorities. Based on the OCC policy 155:25-1-2, a project needs to be funneled through three different agencies (i.e., DEQ, OWRB, and OCC) to be approved or rejected. Such jurisdictional confusion is generated by the overlap of authorities over policies. Redundancy and jurisdictional confusion disrupt policy efficiency, clearly generating fragmentation and thus impacting the efficiency of Oklahoma's water governance.

Strong vertical overlap was documented between state and local water policies. Based on the OSRC policy 630:1-1-6, the state can adopt local laws. While it is upon the state to decide whether to endorse local policies, it is compulsory to allow local governments to intervene in the event that the OSRC holds a hearing. Such law provides both the local government and the state government veto power over the generation of state minimum standards. Local overlap also occurred when state-level policy attempted to govern an issue of noncompliance with local

regulations. The DEQ policy 252:623-19-2, for example, states that a person who violates a law at the local level without knowing it, is defensible through state-level law. Such policy calls into question the jurisdiction of local laws and the ability to hold individuals responsible at the local scale. Like federal overlap, such vertical overlap causes fragmentation between governance scales and reduces Oklahoma's SES resilience.

Interestingly, multiscale overlap was the most frequent form of fragmentation found in Oklahoma's water policies. Often, an alignment between federal-, state-, and local-level policies was encouraged. Nevertheless, it was unclear if conflicts existed across scales and which agency was primarily in charge when a water governance issue arose. The OSRC policy 630:1-1-2, for example, states that "the Oklahoma Scenic Rivers Commission shall work in cooperation with all other interested or concerned state and federal agencies to the extent to which they may be officially interested." Ambiguity in language and vagueness of water polices across scales was another key feature causing fragmentation. Based on the DEQ policy 252:623-5-1, users need to "provide and operate the most stringent waste water treatment equipment necessary to maintain compliance with categorical pretreatment standards." This policy does not specify which regulation is the most "stringent" (i.e., federal, state, or local), leaving freedom in interpretation about which law to implement. Unclear regulations generate confusion in the lines of authority, lead to jurisdictional complications in the event of contrasting agencies and/or laws and foster strong fragmentation across federal, state, and local policies.

Miscellaneous overlap was infrequent in Oklahoma's water policies. This category mostly included overlap between water compacts and organizations with federal, state, or local governance. Based on the OWRB policy 785:20-1-4, for example, water is regulated through the regional compacts, the Scenic Rivers Act, the OWRB, and an individual's water rights. Despite its presence, miscellaneous overlap was not a propeller of fragmentation in Oklahoma's water governance.

Network Analysis: Types and Degrees of Adaptive Capacity

A two-mode affiliation network matrix was generated to determine the density and centrality of water governance in Oklahoma (Table I). The density of Oklahoma's water governance network entailed 49% of all possible ties within the network. An ideal, fully connected network would have a density of 100%. Thus, the network was moderately connected, with agencies linked to the events or policy domains in the network. Different degrees of centrality were documented for the agencies considered in the study. The OWRB, with a 100% of centrality, was the only agency connected to all events or policies in the network. High degrees of centrality were recorded also for DEQ (88%), DM (63%), and ODAFF (63%). All the other agencies were peripheral in the network with less than half of the possible ties to events and policies.

A one-mode affiliation network transformation was made to measure the reachability and betweenness of Oklahoma's water governance network (Table II). A high reachability was found between agencies governing water in Oklahoma.

Table I. Two-Mode Affiliation Network Matrix of Oklahoma's Water Governance

Policy Domains	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Water Agency																
DWC	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
OWRB	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
OSRC	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
DM	0	0	0	1	1	1	0	0	0	1	1	1	1	1	0	1
ODAFF	0	0	0	1	0	0	0	1	1	0	1	1	1	1	1	1
GRDA	1	1	0	0	0	0	1	0	0	1	0	0	0	0	0	1
DEQ	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
CC	0	0	0	0	0	1	0	0	0	0	1	1	1	0	1	1
OCC	0	0	0	1	1	0	0	0	0	1	1	1	0	1	1	0

CC, Corporation Commission; DEQ, Department of Environmental Quality; DM, Department of Mines; DWC, Department of Wildlife Conservation; GRDA, Grand River Dam Authority; OCC, Oklahoma Conservation Commission; ODAFF, Oklahoma Department of Agriculture, Food, and Forestry; OSRC, Oklahoma Scenic Rivers Commission; OWRB, Oklahoma Water Resources Board.

Most agencies had a one-tie linkage with other agencies and the average number of ties for the overall network was eight. Accordingly, low levels of betweenness were documented. Only four of the nine agencies in the network (i.e., ODAFF, OWRB, DEQ, and DM) acted as brokerage actors between other sets of unconnected actors.

A sociogram of the Oklahoma's water governance network shows that in Oklahoma few agencies are centrally connected to the majority of the events (i.e., OWRB, DEQ, ODAFF, and DM) (Fig. 1). Other agencies have a peripheral position within the network and have almost no autonomy within the network.

DISCUSSION

Oklahoma's water governance is more resilient than forecasted in the 2010 Water Town Hall Final Report (The Oklahoma Academy 2010:11). The measures of density, reachability, and centrality show that Oklahoma's water governance network has adaptive capacity features (H1). While the documented density limits the ability of agencies to innovate or change, the moderate structural centrality enables better coordination of responses to disturbances and a high degree of reachability to facilitate collective action. Such an unexpected feature in Oklahoma's water governance network is key, as it enables the state to respond to a certain degree of uncertainty and change.

With a low degree of betweenness and a moderate density, Oklahoma's water governance network experiences a low degree of heterogeneity (H2). While low degrees of betweenness make the network disconnected enough to retain some diversity, its density leaves few opportunities for unconnected actors to contribute new ideas to the network. Heterogeneity is an important feature of a network as it leads to innovative problem solving (Bodin et al. 2006). If all of the actors are homogeneous, the network may lack flexibility, originality, and creativity when addressing an issue. The inability to find new solutions to respond to uncertainty

Table II. One-Mode Affiliation Network Matrix of Oklahoma's Water Governance Network

Agency	DWC	OWRB	OSRC	DM	ODAFF	GRDA	DEQ	CC	OCC
DWC	1	1	0	1	1	0	1	0	1
OWRB	1	16	2	10	10	5	14	6	7
OSRC	0	2	2	1	1	0	2	0	1
DM	1	10	1	10	7	2	10	5	6
ODAFF	1	10	1	7	10	1	10	5	5
GRDA	0	5	0	2	1	5	3	1	1
DEQ	1	14	2	10	10	3	14	6	7
CC	0	6	0	5	5	1	6	6	3
OCC	1	7	1	6	5	1	7	3	7

CC, Corporation Commission; DEQ, Department of Environmental Quality; DM, Department of Mines; DWC, Department of Wildlife Conservation; GRDA, Grand River Dam Authority; OCC, Oklahoma Conservation Commission; ODAFF, Oklahoma Department of Agriculture, Food, and Forestry; OSRC, Oklahoma Scenic Rivers Commission; OWRB, Oklahoma Water Resources Board.

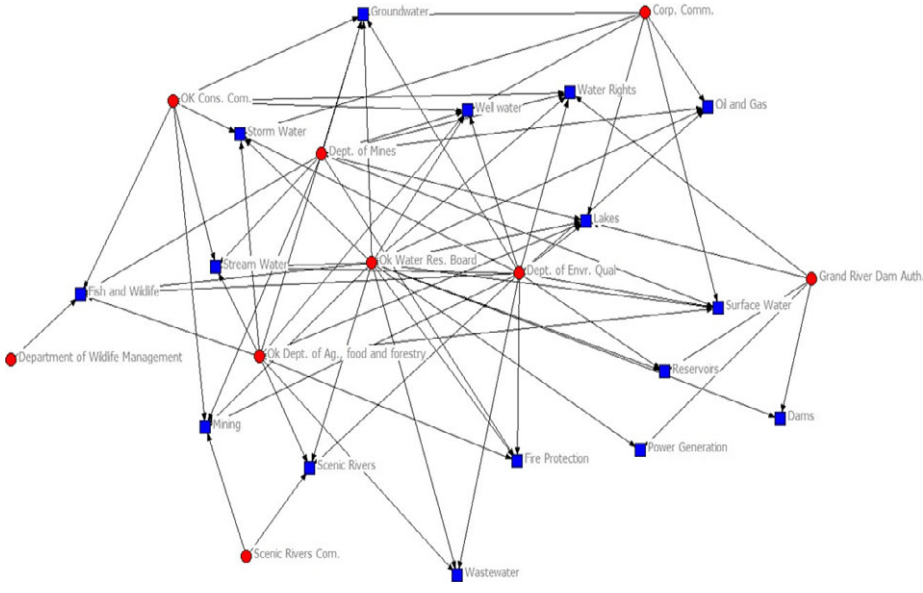

Fig. 1. Oklahoma's water governance network.

and change can deeply affect the system's resilience and thus the ability of Oklahoma to adapt to new environmental and political conditions.

An optimal amount of redundancy was documented for the Oklahoma's water governance network (H3). The network density and betweenness highlighted that water governance in the state is less likely to be impacted if a social tie is broken. Redundancy is an important and sensitive feature of a network. Too much redundancy in a governance structure contributes to detrimental fragmentation. Nevertheless, if a network lacks redundancy, the governance structure can become vulnerable by losing social ties. A balance is thus required, as redundancy provides a network the ability to replace agencies once they are removed.

Social memory is needed in an adaptive network as agencies can rely on collective memory to find appropriate solutions to natural resource issues in periods of change (Bodin et al. 2006; Folke et al. 2005). The documented density and reachability of Oklahoma's water governance shows the presence of social memory within this network (H4). The high degree of reachability in the network enables agencies to experience social memory, while density provides connections between agencies in the network. Thus, both features enhance the potential for social memory to occur (Bodin et al. 2006) and strengthen the resiliency of Oklahoma's water governance network.

Oklahoma's water governance network experiences a low capacity for learning, as demonstrated by scarce betweenness, strong reachability, and moderate centrality (H5). A high degree of betweenness is needed in a network to maintain flows of information between actors. Reachability allows information to travel across the network. If a communication can reach multiple agencies, strong collaborations can be created between institutions and actors. Finally, more centralization within a network leads to more cohesive decision making. Without the ability to learn and share from previous experiences, a government's capacity to respond to changes decreases (Armitage 2007; Bodin et al. 2006; Holling 1978). Learning, indeed, is essential for a governance network to develop resilience and to acquire the necessary knowledge to address environmental uncertainties (Newig, Günther, and Pahl-Wostl 2010).

Trust, the last feature explored for the Oklahoma's water governance network, is strong with a low degree of betweenness and a moderate density (H6). Density enhances trust by creating the potential for collective identity, which favors connections and supportiveness. A low degree of betweenness is key for the development of trust as distance between actors can result in feelings of uncertainty and low collaborations between different agencies. Trust facilitates interactions between resource managers and government actors to solve problems and strengthen the ability of a network to cope with change and uncertainty (Armitage 2008).

CONCLUSIONS

This research expands upon the concepts of resilience and natural resource governance by providing current data on the resilience and vulnerabilities of Oklahoma's water governance structure. Natural resource governance systems can enhance the resilience of an SES through adaptive governance strategies, which allow for flexibility and open communication among different actors within the governance structure. A natural resource governance system can reduce the resilience of an SES by increasing the fragmentation and "governance gaps" present in the governance system. The mixed-methods research design builds upon the existing literatures on resilience and natural resource governance, as well as fills several gaps in the literature. The content analysis helps to fill a gap in the literature on policy research in Oklahoma, offering a depth of analysis that has not yet been achieved. We add considerably to the empirical rigor of conceptualizing and measuring fragmentation, which should push us toward the development of stronger models that

enable better identification of threatening forms of fragmentation. The content analysis established the presence of the theme "overlap," which provided four areas of fragmentation in Oklahoma's water policies. This fragmentation at the local, state, federal, and multiscale levels is causing reduced resilience in Oklahoma's water governance.

Network analysis as a methodology for analyzing natural resource governance is new and contains much unexplored potential. The network analysis builds on the content analysis data by illustrating the connections between water regulating agencies and areas of overlapping policies—measuring four structural characteristics and identifying the presence of three of the six features of an adaptive natural resource governance network. Results provide a picture of Oklahoma's water governance network that is more adaptive and resilient than originally expected. Altogether, this research on Oklahoma's water governance reveals areas where Oklahoma should concentrate resilience-building efforts.

The contributions of this research include the exploration of Oklahoma's water governance through the analysis of current policy and networks to better understand Oklahoma's ability to respond to inevitable socioecological uncertainties. Ultimately, this research contributes to the identification of ways in which Oklahoma can build resilience. The three research questions were addressed by QCA and Network analysis. The content analysis of Oklahoma's water policies revealed that Oklahoma experiences many features of fragmented governance in its water governance policies. The network analysis revealed that Oklahoma is more adaptive than was predicted; however, some changes would need to be made in order to increase the adaptions of Oklahoma's water governance network. Future research should determine if Oklahoma's local-level water laws experience fragmentation, and if so how. Additional research may also address how Oklahoma regulates other natural resources in order to determine if fragmentation exists equally across all of Oklahoma's natural resources or if some natural resources experience more fragmentation than others. The future of Oklahoma's water governance relies upon the development of resilience within natural resource governance systems, which will help SES prepare for disturbances.

Increasing climate variability portends important challenges to natural resource governance around the world. Areas located in an arid climate, such as the American Southwest, "provide a model of future conditions in which climate change could lead to more severe and prolonged droughts that threaten shortages in water-supply" (Hess et al. 2016: forthcoming). The ability to clearly conceptualize and measure the extent to which existing governance systems are fragmented and/or adaptive will provide important information to local authorities regarding potential vulnerabilities within their governance systems. Using approaches applied in this article will pinpoint areas of fragmentation that enhance risk—particularly under new, more extreme climate conditions. Additionally, we provided strategies highlighting characteristics of governance systems that increase adaptability. This combination of approaches helps make ostensible the features of fragmentation and adaptability that are frequently overlooked in traditional natural resource management evaluations.

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