Robustness and the Paradox of Bridging Organizations
The Exit Problem in Regional Water Governance Networks in Central America

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Abstract

Bridging organizations facilitate a range of governance processes, including cooperation and social learning, and are theorized to be a key component of robust governance systems. In this article, we use node removal simulations to test structural hypotheses of robustness in a regional water governance network in Central America. We investigate the response of network measures supporting core governance processes to the targeted removal of bridging organizations and other actors, which we compare to random and centrality-based simulations. The results indicate removing bridging organizations has a greater impact on the network than any other type of actor, suggesting bridging organizations are critical to the robustness of the governance system. Furthermore, network structures supporting cooperation may be less robust than structures facilitating social learning. We conclude with policy implications of the research findings as they relate to the exit problem in governance systems with a large presence of international development actors.

Keywords: bridging organizations, environmental governance, exit problem, international development, network robustness

Introduction

This article investigates whether bridging organizations contribute to the robustness of a regional water governance network in Central America. Across the world, regional governance institutions are emerging to address the challenges presented by environmental processes that occur across large spatial and temporal scales (Lockwood et al. 2010), such as climate change (Adger et al. 2009), shifts in the hydrology of aquifers and river basins (Engle and Lemos 2010), and the spread of plant diseases (McAllister et al. 2017). Regional institutions provide a platform for diverse resource users and stakeholder groups to engage in cooperation and social learning, two key social processes necessary for effective governance (Schusler et al. 2003, Lebel et al. 2006, Lubell 2013). However, the robustness of regional governance institutions depends on their continued capacity in the face of changes in institutional rules, the cast of policy actors, and biophysical processes (Folke et al. 2005, Berkes and Ross 2013).

Bridging organizations are broadly defined as actors that function as intermediaries linking other actors across sectors, types of organization, political boundaries, geographic levels, and other scales (Brown 1991, Folke et al. 2005, Berkes 2009, Crona and Parker 2012). By providing mechanisms for building trust and cooperation (Folke et al. 2005, Lubell et al. 2014), promoting social learning (Pahl-Wostl et al. 2007, Berardo and Scholz 2010), and increasing access to funding and other resources (Newman and Dale 2007, Berkes 2009), bridging organizations help facilitate governance processes that individual actors cannot address in isolation (Brown 1993, Bodin and Crona 2009, Crona and Parker 2012). Bridging organizations may also influence policy and management decisions throughout the wider governance network, given their ability to act as information brokers across diverse groups of actors (Schoon et al. 2017). For these reasons, bridging organizations are considered to be a key component of robust governance institutions (Crona and Parker 2012).

Unfortunately, in developing regions like Central America, bridging organizations often face the "exit problem" due to withdrawal of international aid, lack of political support from national institutions, or high turnover rates (Moriarty et al. 2013, Ika and Donnelly 2017). The exit problem is driven by short funding cycles, shifting organizational priorities, and overall capacity gaps in local political systems (Manyara and Jones 2007, Fee 2012). Bridging organizations can thus become a double-edged sword; regional governance institutions depend on them to support social learning and cooperation, but they may also exit the system. A core policy challenge facing social-ecological systems globally is to create bridging organizations that are capable of becoming independent, self-sustaining entities (Barrett et al. 2001, Eakin and Lemos 2006).

This paper draws on concepts and methods from network science to empirically examine how bridging organizations affect the robustness of a regional water governance network in Central America. Robustness is broadly defined as the ability of a system to continue to perform after experiencing some shock or disturbance (Anderies et al. 2004, Janssen et al. 2007, Berkes and Ross 2013), and to assess robustness in the context of governance networks we measure how key network structures respond to the removal of bridging organizations and other actors. The node removal approach provides a direct analog to the idea of a governance network receiving shocks as actors exit the system, and we focus on the effects node removal has on four network structures that facilitate cooperation and social learning: density, average local clustering coefficient, average path length, and articulation points (Prell et al. 2009, Bodin and Crona 2009, Berardo and Scholz 2010). By specifically targeting different types of actors, and comparing the results to random and centrality-based node removal, we are able to assess the contribution of bridging organizations to the robustness of the empirical governance network.

This article marks an advance in research on environmental governance, as few existing studies have used node removal simulations to examine the robustness of social networks to institutional shocks and other social-ecological changes (e.g., Baggio et al. 2016). Node removal simulations provide an opportunity to examine different scenarios of network robustness based on empirical data without experimentally removing actors in the field – an obviously infeasible research design. Furthermore, by investigating multiple structures in governance networks, we expand on previous literature highlighting how effective governance requires simultaneously facilitating multiple social processes, chiefly cooperation and social learning (Schusler et al. 2003, Bodin and Crona 2009, Berardo and Scholz 2010, Lubell 2013, Bodin 2017). We are also unaware of any existing studies of governance networks that have examined articulation points, in spite of the important information this structure can provide regarding social learning and the presence of marginalized actors (Prell et al. 2009). Lastly, through the use of empirical network data from Central America, our findings contribute to the discussion of policy strategies for addressing the exit problem in international development.

Background: Bridging Organizations and Governance in Developing Regions

Bridging organizations have emerged as a means of addressing the complex governance challenges facing human society and natural ecosystems in an increasingly interconnected and globalized world (Berkes 2009, Crona and Parker 2012). In developing regions like Central America, bridging organizations facilitate linkages among the many different local and international actors working to manage water and other natural resources. Bridging organizations comprise a diverse set of actors, and examples from water governance in Central America include the Central American Commission of Environment and Development, National Reforestation Association of Panama, Blue Planet Network, and the Water and Sanitation Network of El Salvador. Although these actors bridge many different types of boundaries, they all work to link different types of actors involved in water governance.

Water governance in developing regions is often supported by non-governmental organizations (NGOs), donors, and other development actors. Many of these groups are increasingly adopting the ideas of bridging organizations in the design of their programs – for example, funding a consortium of local and international actors to implement a project, as opposed to a single entity – but attention is rarely given to how bridging organizations can be of value at the conclusion of development programs (Ika and Donnelly 2017). Even though the international development community aspires to catalyze lasting change, the reality remains that most governance processes begin to decline following the conclusion of individual projects, as development actors leave the area and withdraw technical and financial support (Harvey and Reed 2006, Moriarty et al. 2013). Bridging organizations provide an opportunity for development programs to devolve support for governance processes, as they fill the same niche and perform many of the same functions as development actors, such as facilitating access to resources and fostering social learning (Moriarty et al. 2005). This suggests that supporting bridging organizations should be a focus of development programs, but if bridging organizations are unable to function as permanent fixtures on the institutional landscape, their failure may further increase the scale of the exit problem.

Theory: Robustness and Structural Properties of Governance Networks

Robustness refers to the ability of a system to continue to function through periods of uncertainty and changing conditions, or after sustaining shocks and large-scale disruptions (Anderies et al. 2004). The concept of robustness has been used to frame research on systemic vulnerability across diverse settings, ranging from physical infrastructure to institutional arrangements for governing social-ecological systems (Folke et al. 2005, Janssen et al. 2007, Janssen and Anderies 2007). However, robustness often implies a tradeoff – reducing vulnerability may entail reductions in the efficiency and performance of the system (Anderies et al. 2004).

In this article, we integrate core concepts from network science with research on environmental governance to quantify the contributions of bridging organizations to the robustness of an empirical water governance network. The basic analytical approach we apply involves comparing how the structure of the network changes in response to the removal of different types of actors, and is taken from research on robustness in physical infrastructure networks like the Internet (Cohen et al. 2000), electrical grids (Simonsen et al. 2008), and water supply (Porse and Lund 2016). In this literature, analyzing network robustness typically involves measuring how different network structures respond to random and targeted removal of nodes (Bagrow et al. 2015).

Table 1: Definitions of network structures assessed in the node removal simulations, and their relationship to cooperation and social learning in governance networks.

Network Structure	Definition	Relationship to Governance
Density	The overall connectivity of a network; measured as the ratio of the observed ties to the maximum number of possible ties.	Dense networks can help build trust and facilitate cooperation (Berardo and Scholz 2010), but may also lead to homogenization and reduced adaptive capacity (Bodin and Crona 2009).
Average local clustering coefficient	The extent to which a network is comprised of dense subgroups; measured as the mean density of ties among all the partners of each node.	Clustered structures facilitate cooperation within communities of actors, but may limit the transfer of knowledge more widely through the network (Newman and Dale 2007).
Average path length	The reachability within a network; measured as the mean number of ties between any two nodes.	Short paths can facilitate the transfer of knowledge throughout the network, but may depend on a base level of trust among actors (McAllister et al. 2017).
Articulation points	The cohesion of a network; measured as the number of nodes with ties to otherwise unconnected nodes or subgroups.	Networks with few articulation points may facilitate social learning, and indicate greater inclusion of marginalized actors (Prell et al. 2009).

Following this strategy for environmental governance networks, we selected four network measures the empirical literature suggests facilitate cooperation and social learning: density, average local clustering coefficient, average path length, and articulation points (Table 1). Our choice of network structures reflects the assumption that social learning and cooperation are two key processes in environmental governance. Social learning is critical to working within the complexity of dynamic social-ecological systems (Pahl-Wostl et al. 2007), while the need for collective-action among many interdependent actors requires cooperation (Ostrom 1990). Our approach assumes that governance must balance cooperation and social learning simultaneously, and both are supported by different network structures; cooperation is facilitated by closed network structures like density and clustering, while social learning is facilitated by more open network structures including short paths and bridging (Bodin and Crona 2009, Berardo and Scholz 2010). However, the benefits of these network structures may depend on characteristics of the social system, including power dynamics (Morrison et al. 2017) and other variables related to institutional fit (Bodin 2017).

Using a regional water governance network from Central America, we test the hypothesis that bridging organizations contribute to key network structures supporting cooperation and social learning. Specifically, we expect bridging organizations are able to facilitate cooperation through contributing ties that increase the density of relationships among groups of actors, and support social learning by spanning otherwise unconnected subgroups in the network. We find evidence in support of this hypothesis if the loss of bridging organizations from the network results in large impacts to density, average local clustering coefficient, average path length, and articulation points.

Data Collection and Network Construction

This study draws on empirical network data from Central America, where nodes represent organizations and ties indicate collaboration on water governance activities, such as water service provision, watershed restoration, and water policy and planning. We gathered the data through a key word "Google" search, in English and Spanish, of geographic terms (e.g., Central America, Mesoamerica, Honduras) and contextual terms (e.g., water governance, water resources development, integrated water resources management) designed to identify actors contributing to water governance processes in the region. We reviewed the first fifty results for each set of search terms, and recorded all unique actors. We then examined each actor's website, and removed all actors determined to be outside the boundaries of the network. Actors were only included if they were engaged in water governance activities in Central America during at least part of the time period spanning 2010 through 2014.

Next, we established undirected ties in the network – all ties associated with an actor selected for removal are also removed during the node removal simulations – by recording all of the self-reported partners on each actor's website. Simply having a hyperlink or being mentioned on the website does not constitute a tie; partners had to be clearly designated as collaborators on shared projects or other work activities. We then expanded the dataset through four rounds of snowball sampling – reviewing the partners' websites and recording all of their ties to other actors – after which point no new actors were uncovered. Through this process we identified over 2,000 unique water governance actors in Central America, however, we removed all actors with only one tie in order to focus on the core structures at the heart of the network. After removal, the network contains 624 actors and is composed of a single component with no unconnected actors or clusters of actors (Figure 1). Portions of the online information were reviewed by key informants, known to one of the authors as a result of previous participatory research conducted in the region.

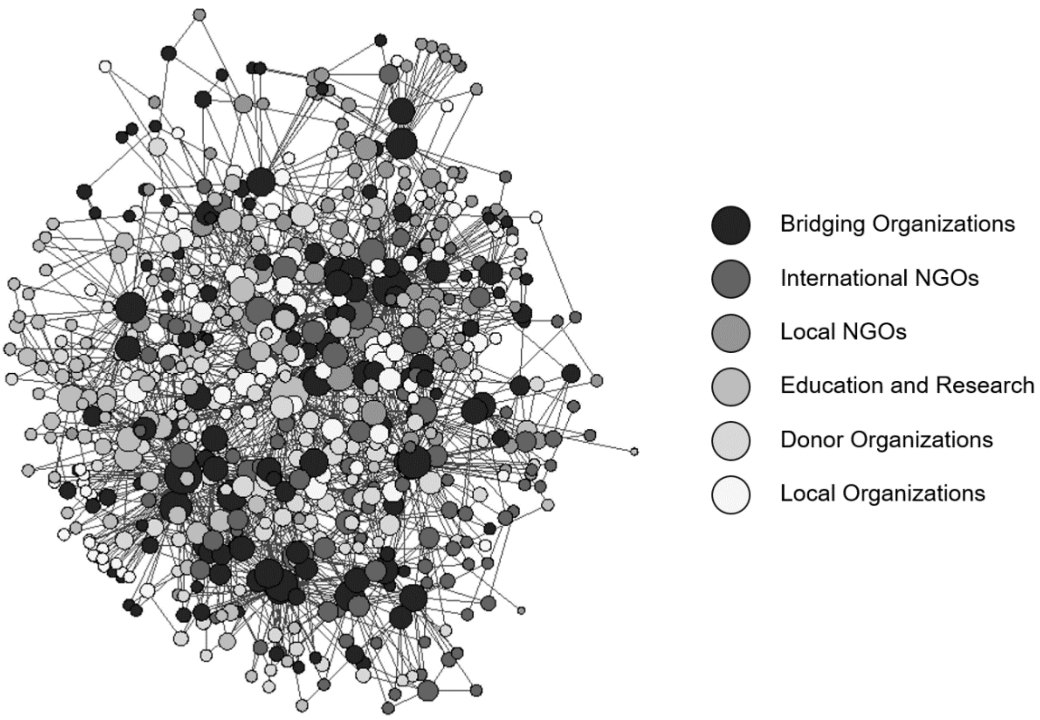

Figure 1: Network of water governance actors in Central America, with nodes shaded by actor type and sized by degree centrality. The position of the actors was determined using a spring-embedded layout.

Lastly, we classified nodes into six types of actors: bridging organizations, international NGOs, local NGOs, research and education, donors, and local organizations (e.g., community-based organizations, government agencies). We exogenously determined whether or not actors were considered bridging organizations through reviewing their mission statements online. In order for an actor to be classified as a bridging organization, it had to have the explicit aim of working as an intermediary spanning between actors from different sectors, geographic and administrative levels, or types of organization. For example, the website for the Blue Planet Network states the group "connects funders, NGOs, the public and communities in need to improve the planning, selection, management and monitoring of water and sanitation programs." In this regard, the focus of the analysis here is on bridging organizations generally, and we do not distinguish between specific forms of bridging that may be occurring.

Analytical Methods

Our analysis compares three types of node removal simulations: random, degree centrality, and actor type. Random removal serves as a measure of baseline robustness, where all the actors in the network have the same probability of being removed. Removal by degree centrality occurs through sequentially removing the actors with the most ties and represents a form of worst-case scenario from a structural perspective; actors with more ties may or may not contribute more to governance activities and outcomes, but our data do not allow us to assess this directly. Removal by actor type involves specifically targeting different classes of actors, such as bridging organizations. We expect different types of actors to contribute different structures to the overall governance network, as each type of actor has its own unique objectives, decision-making process, and resources, all of which help shape patterns of collaboration with other actors in the network. With this analytical framing, we are able to assess both the robustness of the empirical governance network to the removal of different types of actors, as well as compare the removal of each actor type against the baseline robustness and structural worst-case scenario.

For this study, we developed an R package for social network analysis using the R Environment for Statistical Computing (R Development Core Team 2014) that allows us to remove nodes randomly, by degree centrality, and by actor type. In each of the simulations, the analytical approach consists of removing increasing numbers of nodes from the network, and measuring network statistics after each increase in the level of node removal. In order to capture variance in the responses of the network measures, multiple random samples at the same level of node removal are necessary. For example, if we simulate the random removal of two nodes from a twenty-node network, there are nearly two-hundred unique pairs of nodes that could be selected. In the case of node removal by actor type, random samples occur within each class of actor. For node removal by degree centrality, random samples are necessary when multiple nodes have the same number of ties.

The limit to the range of the simulations – the maximum number of nodes that can be removed – is dictated by the node class containing the fewest nodes. While there is no computational limit for random and degree centrality simulations, in the absence of compelling theoretical reasons for doing so, results should not be compared across simulations beyond the limit imposed by the structure of the dataset. Once all the nodes of a particular class have been removed, that node class no longer has an impact on the structure of the network at higher levels of removal. Therefore, if results are to be compared across simulations, the maximum number of nodes removed in each simulation should correspond to the number of nodes in the smallest node class. With 84 nodes, representing 13% of the total nodes in the network, local NGOs are the smallest node class in the empirical dataset.

Increasing in 1% intervals, we progressively remove up to 13% of the actors in the empirical network in each of the random, degree centrality, and actor type simulations. At each 1% increase in the level of removal we take nearly 7,000 random samples and calculate density, average local clustering coefficient, average path length, and articulation points, for each sample. While computationally more expensive, increasing the number of random draws helps capture the variance in the four network measures across the range of the simulations. We apply a generalized additive model (GAM) smoother[1] to the results in order to compare the differences in the expected values of the network measures across the simulations. The smoother does not assume a given response shape, which further allows us to assess the behavior of each network measure across the simulation types.

[1] Formalized by Hastie and Tibshirani (1986), GAMs use multiple smoothing functions to estimate the relationship between dependent and independent variables. With GAMs it is not necessary to know the relationship between variables from the outset, which enables the observation of any hidden patterns or structures within the data.

Lastly, we examine an additional four network measures – average degree, betweenness centrality, constraining ties, and diversity – to validate our exogenous classification of bridging organizations. These node-level measures are calculated for each actor, and we report the average value for each type of actor (e.g., bridging organizations, international NGOs) in order to assess the extent to which different actor types contribute to bridging structures in the network. These measures are not included in the node removal simulations.

Descriptive Statistics and Results of Node Removal Simulations

Descriptive network statistics assessing bridging structures (Table 2) help unravel the unique positioning of different types of actors in the regional water governance network from Central America, and justify our focus on bridging organizations as key governance actors. Bridging organizations are more active in the network; they are both more prevalent and have the highest average degree, indicating they tend to have more ties than other types of actors. Bridging organizations also have the highest betweenness centrality scores, indicating they are more frequently located on the shortest path between other actors in the network. The relatively low value on constraining ties indicates bridging organizations tend to have fewer ties to actors who are themselves strongly interconnected, which is in line with Burt's (2009) definition of bridging ties. Bridging organizations also tend to have more diverse partners, and frequently span between different types of actors in the network. These descriptive statistics shed light on the positioning of bridging organizations in the empirical governance network, however, they do not indicate how robust governance processes are to the exit of actors from the system.

Table 2: Descriptive network statistics capturing bridging structures by actor type.

Actor Type	Nodes	Average Degree	Average Betweenness Centrality	Average Constraining Ties	Average Diversity*
Local organizations	106	4.0	348	0.382	2.42
Research and education	93	5.1	945	0.370	2.12
Donors	102	3.9	400	0.355	2.36
Local NGOs	84	4.2	505	0.391	2.19
International NGOs	99	5.2	604	0.343	2.41
Bridging organizations	140	9.4	1673	0.286	2.59

* The maximum diversity score is six, representing the six types of actor in the empirical network.

The impacts of removing bridging organizations from the regional governance network, and their relationship to baseline robustness (random removal) and the structural worst-case scenario (removal by degree centrality), are provided in Figure 2. The x-axis displays the level of node removal in the simulations, and the y-axis indicates the response of each of the four network measures across the simulations. Only the line representing the GAM smoother is displayed, as including the tens-of-thousands of individual data points results in a cluttered and uninterpretable graph. The narrow range of the standard error bars, on account of the large number of samples, makes them indiscernible from the smoother lines.

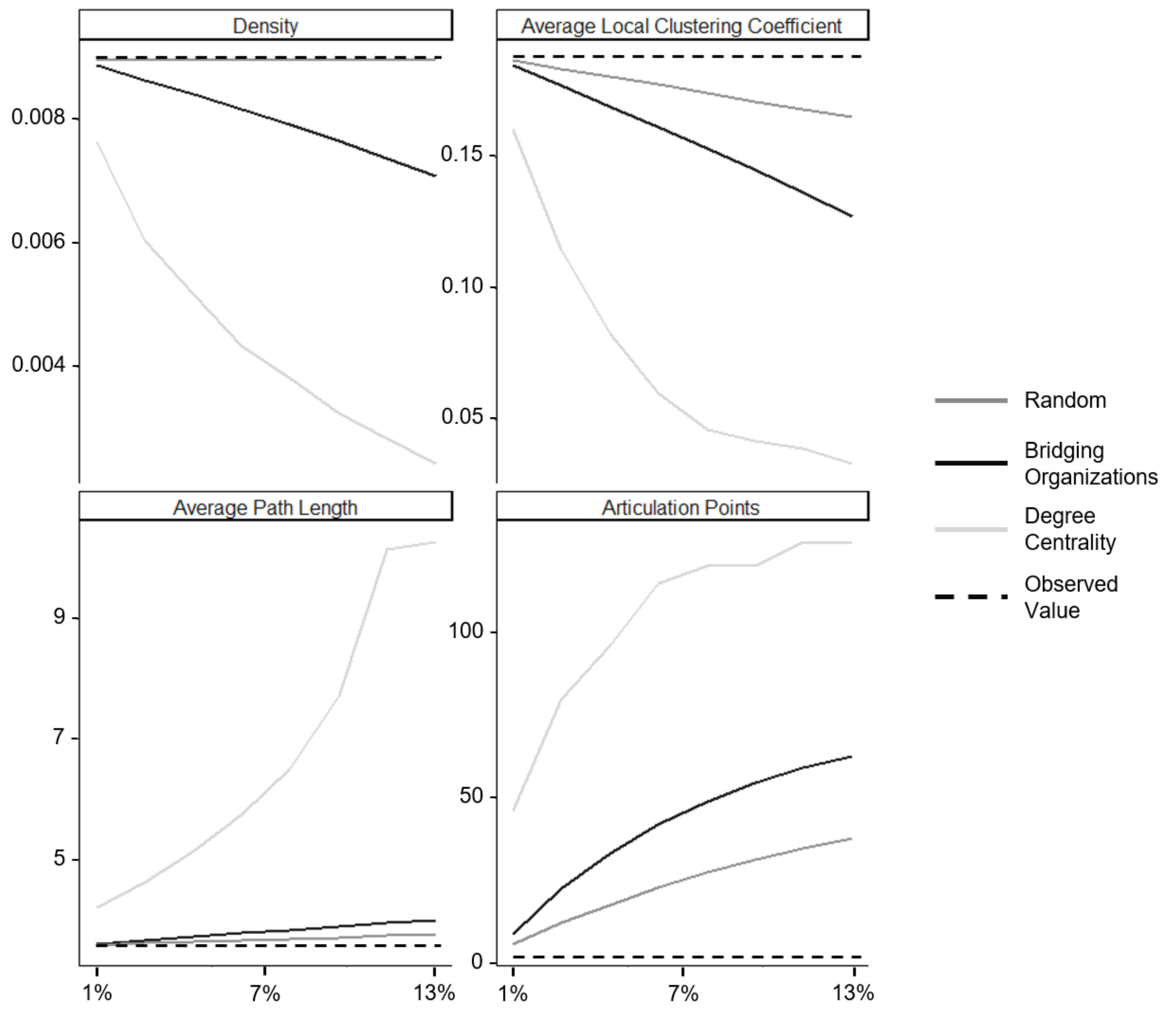

Figure 2: Results from random, degree centrality, and bridging organization node removal simulations for density, average local clustering coefficient, average path length, and articulation points. The dashed black line represents the observed value in the full network prior to node removal.

The results for density and average local clustering coefficient suggest structures supporting cooperation in the empirical network are relatively robust to the random removal of actors over the range of the simulations, but vulnerable to the exit of bridging organizations. In the case of random removal, the expected value for density across the range of the simulation is unchanged from the observed value (0.009) prior to the removal of actors. Targeting bridging organizations, however, results in a linear decrease in density as more actors are removed. With regard to the average local clustering coefficient, the statistic decreases linearly from the observed value (0.188) in response to both random removal and targeting bridging organizations, but the magnitude of the decrease is significantly larger for bridging organizations. Removing the highest-degree actors from the network results in the most dramatic decrease in density, which is expected given the definition of density only takes into account the number of nodes and ties. That removal by degree centrality also results in the largest decrease in average local clustering coefficient indicates actors with more ties also tend to be located in relatively dense subgroups.

The results for average path length and articulation points indicate structures supporting social learning are relatively robust in the empirical governance network, and perhaps more so than structures facilitating cooperation. In the case of both random removal and targeted removal of bridging organizations, the expected value of average path length increases linearly above the observed value (3.58) over the range of the simulations. The loss of bridging organizations results in a larger response, but the increase is slight in both cases. With regard to articulation points, the measure appears to grow logistically from the observed value (2) for both random removal and removal of bridging organizations, but the exit of bridging organizations again results in a larger impact on the measure than random removal. The decreasing marginal response of articulation points suggests that the network is most vulnerable to the initial removal of bridging organizations, which can fragment large, but loosely connected, subgroups of actors from the rest of the network. The response of average path length and articulation points to the targeted removal of high-degree actors is much larger than either random removal or the removal of bridging organizations, indicating actors with many ties are more likely to be located on the shortest path between other actors in the network, and to be connected to more isolated actors and subgroups of actors on the periphery of the network.

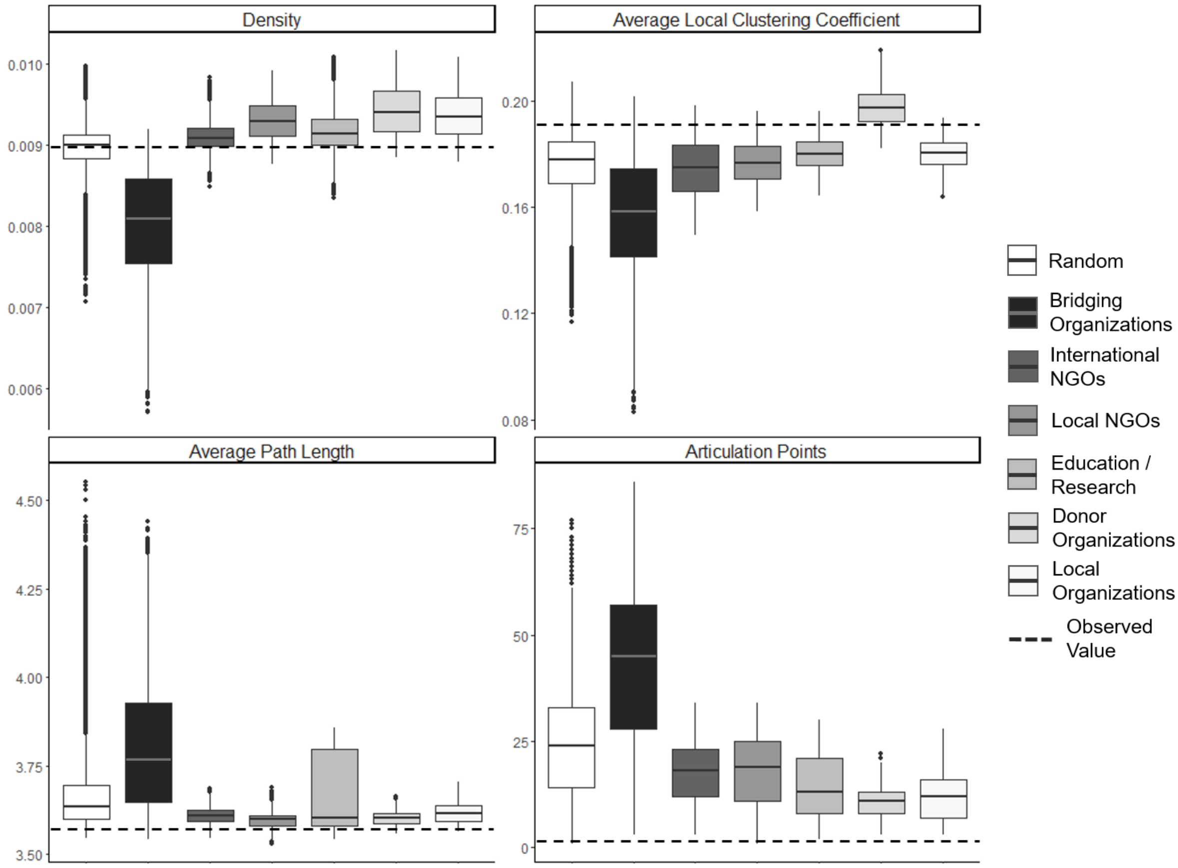

Figure 3: Results from random and actor type node removal simulations. Each boxplot contains all the results from removing 1% up to 13% of the actors in the network, and provides for comparison of the full range of response of the four network measures across the simulations. The dashed black line represents the observed value in the full network prior to node removal.

The results from targeting each of the six different actor types for removal are displayed in Figure 3, which includes the results from random removal as a baseline comparison. The y-axis displays the changes in the network structures that result from removing 1% up to 13% of the actors in the network, and the spread of the boxplots vertically captures the overall range of response.

With regard to network structures supporting cooperation, targeting bridging organizations results in an overall larger response in density and average local clustering coefficient than removing any other type of actor in the network. In the case of density, removing all other actor types results in a slight increase in the mean density above the observed value in the full network, which is indicative of the large number of ties bridging organizations bring to the network. With the exception of donor organizations, removing all other actor types results in an overall decrease in the average local clustering coefficient. The increase in the measure as donors are removed indicates these organizations do not generally partner with other actors in the network who are themselves strongly interconnected. For the two network structures associated with social learning, average path length and articulation points, removing all actor types results in an increase in the measures above their observed values in the full network. However, the loss of bridging organizations has a much greater impact on these structures than removing any other type of actor.

Discussion and Conclusions

The loss of bridging organizations from the regional water governance network in Central America results in a larger shock to structures supporting cooperation and social learning than any other actor type, indicating bridging organizations are key actors in the network. However, these results also illustrate a possible paradox of robustness in the network: structures facilitating cooperation and social learning are strongly supported by bridging organizations, which in turn makes the network more vulnerable to their exit. The results further suggest network structures supporting cooperation may be less robust than structures supporting social learning, which is in line with studies demonstrating the relative difficulty of establishing cooperation versus coordinating the distribution of knowledge and other resources (Sandström and Carlsson 2008, Berardo and Scholz 2010, McAllister et al. 2017).

The removal of bridging organizations decreases density and the average local clustering coefficient, which suggests bridging organizations are well-positioned to support cooperation within subgroups in regional governance networks. At the same time, the increase in articulation points fragments the network by isolating loosely connected subgroups, and indicates bridging organizations may help facilitate social learning by spanning subgroups. However, we recognize the benefits of any particular network structure are not monotonically increasing, and governance networks are assumed to be more effective when they maintain a balance between intermediate levels of clustering and bridging (Bodin and Crona 2009). Too much clustering in subgroups can result in an “us-and-them” mentality and impede the flow of information and other resources, yet subgroups are a natural part of governance networks that span multiple sectors and geographic boundaries, such as regional governance networks, and may indicate cooperation among communities in the network. For this reason, bridging across subgroups in the wider governance network is critical for social learning at the regional level, and may also help facilitate the creation of inter-group trust and social capital (Crona and Parker 2012).

These findings support the hypothesis that bridging organizations, and their sustainability in the institutional landscape, are critical to the robustness of structures supporting cooperation and social learning in regional governance networks. However, the structural contributions of other types of actors may also be considerable, and the exit of traditional development actors has always been a concern for the robustness of governance systems in Central America and other developing regions. After bridging organizations, removing international and local NGOs produced the next largest decrease in the average local clustering coefficient and articulation points, which indicates these actors also contribute substantially to structures supporting cooperation and social learning in the empirical network. The descriptive statistics further indicate international NGOs may directly contribute bridging ties, given their relatively high levels of betweenness centrality and average diversity. Education and research organizations possess an even higher betweenness centrality score than international NGOs, suggesting they are particularly important conduits for facilitating knowledge distribution and social learning throughout the water governance network in Central America, although their contribution to structures supporting cooperation are minimal.

The removal of donors and local organizations produced the smallest effects across all four network structures, indicating they contribute the least to structures supporting cooperation and social learning in the empirical governance network. Removing donors actually led to increases in density and local clustering, which indicates they have relatively few partners in the network, and the few partners they do have are not strongly interconnected. This is in line with the primary function of donor organizations, which is to fund development programs, not engage in implementation. However, that donors usually aspire to build relationships among their project partners indicates they may not be achieving success in this regard in Central America. The diminished structural contribution of local organizations is indicative of the fact that the primary focus of their activities is at a different scale; they typically collaborate with NGOs and bridging organizations in order to obtain knowledge of best practices and other resources for supporting local development projects. In this regard, a key function of bridging organizations and higher-level development actors lies in facilitating access to these benefits to local organizations, who are often key actors within their geographically-defined subgroups in regional governance networks. We recognize the data collection method also favors higher-level organizations – they are more likely to have websites – but even if interviews or surveys were feasible we still would not expect local organizations to occupy critical positions in the regional network.

Collectively, these findings suggest two core policy recommendations for enhancing the robustness of regional governance networks and addressing the exit problem in international development. First, while the regional water governance network in Central America is relatively robust to the random removal of actors, the network is especially vulnerable to the loss of even a small number of bridging organizations, suggesting they should be targeted for strategic support. Furthermore, bridging organizations tend to collaborate with a greater diversity of actors, and a core component of institutional capacity-building involves "building more effective and dynamic relationships between different stakeholders behaving in often unpredictable ways" (Ika and Donnelly 2017, p. 45). While these structural and functional contributions of bridging organizations may buffer governance networks against the exit of international development actors, in the event that bridging organizations depend on these actors for operational support they may still be susceptible to the exit problem. International development actors may initially consider prioritizing strategic funding to bridging organizations for training and support, but over the long term as international actors "work themselves out of a job" they should be working with local political institutions to develop homegrown support for bridging organizations (Breslin 2013).

Second, network structures supporting cooperation appear to be less robust than structures facilitating social learning in the empirical governance network, and these structures are predominantly contributed by bridging organizations and NGOs. Strengthening cooperation among diverse actors in Central America, especially with independent and self-sustaining bridging organizations, would further strengthen the robustness of the empirical network to the exit of international development actors. However, bridging organizations may be viewed negatively by some communities in highly polarized societies. This is particularly true in Central America, where the history of political strife and violent conflict permeates most debates over natural resource policy and planning, and actors that attempt to broker cooperation across ideological divides often face reproach from all sides. In these situations, local knowledge is critical as power asymmetries, conflict, and other characteristics of the social and political system may suggest particular ways of working with specific actors to build the social capital and trust necessary for achieving lasting cooperation (Pretty and Ward 2001, Hileman et al. 2016, Ika and Donnelly 2017, Morrison et al. 2017).

While this study makes a number of theoretical and methodological contributions to the empirical literature on environmental governance, a number of challenges remain that must be addressed in future research. One of the biggest challenges is the difficulty of tying network structures to outcomes in the empirical context; though we find evidence that the structure of the regional water governance network in Central America is relatively robust, this does not mean that the network is necessarily improving biophysical or sociopolitical outcomes. Explicitly examining different forms of collaboration (e.g., project planning, funding, implementation) and bridging ties (e.g., sectoral, geographic level, mandated/voluntary) would further enrich research on robustness in governance networks. Lastly, the empirical governance network we analyze is a cross-section, and there is a pressing need to develop data collection tools for monitoring the evolution of governance networks over time. This would allow us to develop a deeper understanding of network resilience, or how governance networks reorganize after sustaining institutional shocks resulting from the exit of actors.

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