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Public Representation in Water Management—A Network Analysis of Organization and Public Perceptions in Phoenix, Arizona

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To better accomplish their mission of an informed public, environmental education organizations often exchange ideas, share financing, and distribute overhead through collaboration. Yet it remains to be seen whether benefits of these collaborations extend to the public. We examine two possible benefits: the ability of the organizations to act as representatives of the public interest, and equitable access to environmental educational materials. We model patterns of public access to water-related education across organizations using two surveys in metropolitan Phoenix, AZ. This enables the study of interorganizational social networks and public outcomes. Results support the idea that environmental education organizations could provide a credible proxy for direct citizen participation. However, not all organizations are equivalently engaged with historically underrepresented groups like women, minority racial and ethnic groups, and those who rent their home. The implications for more inclusive environmental policy decisions are discussed.

Keywords collaboration, public information, social network analysis, urban, water resource conservation

Phoenix, AZ, and its suburbs are home to 4.2 million residents and have an area of 37,744 km^2 (U. S. Census Bureau 2010). Population growth and increasing volatility in the climate across the southwestern United States are expected to increase water scarcity and, thus, conflict related to water resources (Gober et al. 2010). The potential for conflict underscores the need to develop appropriate methods to elicit and

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include public values in both defining and selecting among a range of potential management options.

In Phoenix, as in other urban areas, a diverse array of water education providers (WEPs) has emerged. Utility providers, environmental groups, museums, and others aim to educate adults using pamphlets, media campaigns, and special events. WEPs tend to share information and funding with other organizations through interorganizational networks (Cutts, Saltz, and Elser 2008). In the following we introduce two ideas: (1) WEPs in Phoenix, and environmental education organizations more generally, have intimate knowledge of the public that could better serve policy decisions when direct citizen participation is not possible; and (2) collaboration that occurs across WEPs has a unique influence over the extent to which efforts enhance public knowledge and enhance the public's capacity to advocate for its own interest. We describe social network measurement and analysis using exponential random graphs as a method of analysis and present five hypotheses that lend insight into the feasibility of these two ideas.

Policy Value of Environmental Education Organizations

Many organizations provide environmental education with the aim of enhancing the public's capacity to participate in policy decisions and improve alignment between pro-environmental attitudes and behaviors (Dietz and Stern 2008). Environmental education has been defined as learning that increases knowledge and awareness about the environment and associated challenges, develops skills and expertise to address challenges, and encourages commitments to make informed decisions and take responsible action (UNESCO-UNEP 1978). Environmental education organizations represent a diverse array of public, nonprofit, and commercial organizations that are funded or mandated to provide public information. The efforts of these organizations are often dismissed as ineffective or trivial (Syme 2004; Noar 2006). However, the conclusion that environmental education is ineffective is based on the relatively weak effect of information over specific behavior changes measures over small time steps (Kaiser and Fuhrer 2003). As previous studies have argued, the implications of exposure to and engagement with environmental education are not limited to the measures individuals take to change behaviors or attitudes (Cutts et al. 2013). The consideration organizations give to increasing public knowledge about the environment is an important indicator of effort to understand the public interest and to enable members of the public to access additional materials as their interest and level of expertise matures.

Democratic societies place a high value on direct public participation in environmental decisions (Dietz and Stern 2008). Many water decisions, however, are made through processes in which experts determine the needs and concerns of the public (Downey and Strife 2010). This occurs despite calls for public inclusion in many federal and state policies (Guo and Acar 2005; Dietz and Stern 2008). Expert-driven water decisions have typically widened environmental inequities (Guo and Acar 2005; Downey and Strife 2010). As such, there is a need to enhance public involvement. Yet the barriers to participation for many segments of the population are high. Expecting direct public engagement that is representative of the full spectrum of interests held by the general public is impractical in many contexts. Efforts to enhance representation of diverse public interests must overcome historical and institutionalized biases, as well as underrepresentation in political office (e.g., Konisky,

Milyo, and Richardson 2008). In the United States, evidence suggests that social groups differ in their priorities for water use and in their acceptance of alternate water policies. Three commonly discussed social divisions in particular have shown consistent differences: gender, homeownership, and race/ethnicity (e.g., Zelezny, Chua, and Aldrich 2000; Kalof et al. 2002; Williams and Florez 2002). Women, renters, and those who identify as racial/ethnic minorities navigate risk and process information differently than men, homeowners, and non-Hispanic white residents. Including traditionally marginalized public stakeholders in decision making may be critical to creating sustainable solutions to local water use and quality. There is a need to improve the degree to which the interests of historically disenfranchised groups are included in water conservation and management decisions (Pretty and Smith 2004). Environmental education organizations have the potential to fill this need, but deeper consideration of their interactions with other organizations is needed.

Objectives

The first objective of this study is to explore whether environmental education organizations are a potential source of proxies for the public when direct citizen participation in policy decisions is not feasible. We analyze the extent to which organizations differ in their legitimacy as representatives of the public due to their institutional characteristics, the size and diversity of their audience, and the structure of relationships among organizations. This includes consideration of organization mission that might alter the objectives of their environmental education material. It also considers geographic scope as a delimiter of the scale at which they are likely to address the public.

The second objective of this study is to determine whether WEPs alter their legitimacy as representatives of the public by working together. Cooperation is increasingly common between organizations that seek to enhance public engagement in natural resource management through education (Dietz and Stern 2008; Bodin and Crona 2009). While cooperative relationships form between organizations as a way to enhance their collective efficacy, the outcomes are a result of pressures to perform effectively both as individual organizations and as a collective. When organizations are connected, a network forms. Interorganizational networks can be defined as a form of social network in which three or more organizations share a resource in an effort to reach both individual and shared goals (Provan and Kenis 2008). The type of resource being shared defines the network. Therefore, there can be many types of networks linking the same set of organizations. As organizations strive toward common goals, their shared success is often influenced by the nature of ties (what is transmitted between organizations), the number of ties (the density of exchanges), and how exchanges are distributed (reviewed in Provan and Lemaire 2012). Thus, the arrangement of ties that connect organizations can also influence the suitability of all environmental organizations as legitimate representatives of the public. Social network analysis can be used to elicit, visualize, and analyze the influence of social relations and structure (Wasserman and Faust 1994). Research in social network analysis has demonstrated that frequencies and patterns in information transfer among network members (also called actors or nodes) can have substantial impacts on both the network members and the influence of the network over the services provided cumulatively. While social networks, or interactions, among

sources of environmental education organizations are a widely observed phenomenon, they have not been widely studied.

Two important interorganizational relationships are shared information and cooperation to make the best use of funding. Above others, these two sets of ties can lower the costs of transactions and maximize the ability of organizations to reach shared goals by working together (Provan and Milward 2001; Provan and Lemaire 2012). Information and funding resources move between organizations very differently. Information is an inexhaustible resource (Provan and Kenis 2008). Funding, unlike information, is a restricted resource. Therefore, their influence is likely to differ.

The outcome of interest is a third network: the public access network. The public access network is formed through the educational material use patterns of the public, rather than by direct interactions among organizations. It represents the pathways that the public uses to gain access to additional resources as a relationship between organizations. Ties are created between organizations when members of the public use materials from two WEPs concurrently (Figure 1). In this network, each tie is weighted by the extent to which the public recognizes pairs of organizations as good sources of water education materials. By predicting the strength of ties in the public access network, we can understand how the properties of organizations and their relationships to one another affect the public. We can also better estimate whether environmental education builds the capacity for the public to gain access to new educational opportunities in equitable ways.

The methods that follow use data from two surveys: one administered to the public and one administered to environmental educators in the Phoenix, AZ, metropolitan region. Public access serves as the dependent variable in an analysis of network-based effects on environmental education outcomes. We measure the

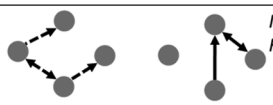
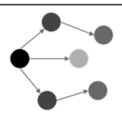
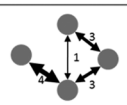
Hypothesis		Data	ERGM term(s)
1. Characteristics of the public users		*Pct. Female* *Pct. Ethnic and/or racial minority* *Pct. Renting home*	node covariates
2. Characteristics of organizations		*Institution* *Geographic scope*	node factors & node match
3&4. Interorganizational network ties		*Information sharing* network ties (0/1) *Funding exchange* network ties (0/1)	edge covariate
5. Roles in the interorganizational networks		*Block assignment* (using regular equivalence) assigned based on ties to other organizations in the information and funding networks	node factor
Y. Dependent network		*Public access - weighted network* representing the frequency of public survey respondents that report receiving information from two organizations.	edges

Figure 1. Illustration of how each factor is conceptualized in analysis using exponential random graphs (ERGMs).

changes in public access as influenced by characteristics of organizations, their audience, and two sets of connections, or networks, among organizations (information sharing, funding), using exponential random graph models (ERGMs).

The Exponential Random Graph Approach

Testing network-based predictions requires constructing a statistical model that allows for data that violates assumptions of independence. To accommodate this challenge, exponential random graph models (ERGMs) can be used to model inferential relationships (Cranmer and Desmarais 2011). ERGMs assess the likelihood that specific network configurations will occur (Lusher, Koskinen, and Robins 2012). Therefore, when network ties appear more frequently than expected by chance, the structure has a positive and significant probability of being present within that network (Robins et al. 2007). The observed network and characteristics of both ties and organizations can be compared to other hypothetical networks of similar tie numbers and weights using simulation techniques (Cranmer and Desmarais 2011). In a count-based ERGM, like the one we perform, the conditional probabilities reported in the model represent the likelihood that an additional member of the public will access information from a new organization, given current use patterns (Krivitsky 2013). There are many parameters relevant to the overall structure of the network, the network-based attributes of organizations, and the characteristics of the organizations that can be included in the models (Morris, Handcock, and Hunter 2008). These are explained next in relation to the hypotheses tested in this study.

Hypothesis 1. The Fixed Characteristics of Each Organization Will Alter Their Use by the Public

The fixed characteristics of organizations are likely to influence their legitimacy as representatives of the public interest. Notably, the institutional form and geographic scope of organizations are likely to matter (Pretty and Smith 2004; Guo and Acar 2005; Crona and Hubacek 2010). Institutional form—whether the environmental education is delivered by a government agency, water utility provider, or other organization—may indicate differences in mission and the purpose of water education. For example, in many evaluations of networks related to environmental challenges, success has been associated with ties that span multiple geographic, ideological, and expertise boundaries (e.g., Schneider et al. 2003; Ernstson, Sörlin, and Elmqvist 2008; Crona and Hubacek 2010; Muñoz-Erickson et al. 2010). This is because there are inherent differences in the culture and mission of the organization that influence their ability to generate and sustain trust among the public (Provan and Kenis 2008). It is not practical, for example, for WEPs associated with a city utility to focus effort and attention on neighboring municipalities without coordination. This constraint is likely to persist even in the most strategically focused network.

To represent the diversity of organizations in metropolitan Phoenix we include two sets of nominal terms (node factors) in the ERGM models (Table 1). This term accounts for categorical identifiers and adds multiple network statistics to the model, one for each unique value. To evaluate whether or not organizations of a similar type were more likely to be connected in the public access network, we included a second term called "node match." Using this term, we identify whether ties are more likely,

Table 1. Summary of organizations included in each survey

	Organizations ($n = 35$), count	Proportion of public survey respondents ($n = 749$), mean (*SD*)
Geographic scope		
Private	1	
City	5	
Region	7	
State	13	
Federal	8	
Other	1	
Institutional form		
Water supply (public and private)	8	
Nonsupply government	7	
Environmental nongovernmental organization	6	
Education/research	11	
Consortium	1	
Mass communication	1	
Other	1	
Popularity		0.21 (0.26)
Female audience		0.49 (0.13)
Non-Hispanic white audience		0.80 (0.15)
Home owners		0.78 (0.17)

Note. Organizations in the organizational survey that were not included in the public survey were collapsed to a singular "other" for analysis.

less likely, or equally likely between two organizations that share a categorical attribute compared to two organizations that do not share the attribute.

Hypothesis 2. The Configuration of the Public Access Network Will Not Isolate Organizations Serving Culturally Specific Audiences

If some organizations provide culturally appropriate entry points for public access to environmental education, they may be used by a smaller audience that is predominantly one gender, racial or ethnic identity, or homeownership status. For these groups, more general resources may not be appropriate, at least at first. Users of these sources should then begin to recognize a wider range of information sources as they seek additional information. Alternatively, if organizations serve a narrow cultural group and are not interacting with larger, more mainstream organizations, it would indicate that information-seeking effort by their audiences does not improve the capacity for public engagement in water decisions.

To represent the diversity of the public served by individual organizations, we include four continuous terms, or "node covariates" in the ERGM models (Table 1). Like the "node factor" term, this is used to determine the level of

similarity shared by two organizations. We control for the popularity of organizations separately from the frequency with which they were reported as an information source by women, racial and ethnic minorities, and renters. Positive values indicate that the larger the appeal of the organization to traditionally underrepresented groups, the more likely it is that the information source will be used. If this relationship holds, then popular environmental education sources are legitimate representatives of the public interest broadly.

Hypotheses 3 and 4. The Presence of (3) an Information Sharing Tie or (4) a Funding Tie Will Influence Tie Strength in the Public Access Network

Like others in the public sector, environmental education organizations may participate in networks because this lowers transaction costs and maximizes single-organization measures of success (Provan and Milward 2001; Provan and Lemaire 2012). Organizations may benefit from being better able to meet the expectations of those they serve (Provan and Milward 2001; Guo and Acar 2005; Provan and Lemaire 2013). Alternatively, enthusiasm for collective efficiency could lead to free-riding and a tendency to institutionalize suboptimal choices (Provan and Lemaire 2012). There is a need to balance the efficiency with which information diffuses through a network with a capacity for creativity (Provan and Lemaire 2012). This can be assessed by examining the direct influence of interorganizational funding and information exchange networks on the public access network.

If a funding or information tie increases public access of information from two WEPs, this would indicate that working together limits the collective legitimacy of the network because coordination does not expand the size of the public audience. Instead, cooperative effort may increase efficiency by avoiding delivery the same educational material to the same audience. A negative relationship between shared information or funding would be one indication that this is occurring. The public will identify a network that is the inverse of the interorganizational network.

Hypothesis 5. Ties Strength in the Public Access Network Will Vary Based on the Roles an Organization Fills in the Interorganizational Information and Funding Networks

Interorganizational networks may alter the legitimacy of individual organizations as public representatives by creating roles that differ in their levels of public engagement. Role assignments identify classes of organizations that occupy the same social position, play the same role, or have the same function in the network. Beyond simply the presence of a funding or information tie, we expect information and funding exchanges to improve the degree to which public recognition of funding receivers improves recognition of funding distributors. Both funding receivers and distributors might be more highly recognized than organizations that do not pool funding. This idea has been supported in other cases of network-based environmental governance. Ernstson et al. (2008), for example, found that connectivity among organizations was managed by one set of organizations and informing the community by a second set.

Role partitions can be calculated in a number of ways, but we focus on regular equivalence, or tie-based identities, based on the idea that multiple organizations can serve the same function in the network (Wassermann and Faust 1994). The number

of distinct roles for organizations to fill is determined by the arrangement of ties. Regularly equivalent organizations are not perfectly substitutable. Instead of sharing the same ties, they share the same pattern of ties. This is illustrated in Figure 1. Many roles may be differentiated based on the tie arrangements. Most simply, there can be two roles: connected and unconnected. As the arrangements of ties become more complex, other social roles may emerge. We expect core roles in the funding network to be associated with higher levels of public access, and peripheral, but well-connected, roles in the information sharing network to lead to higher levels of public access.

Study Site

The Phoenix, AZ, metropolitan region of the United States presents a useful case study to examine the role of interorganizational coalitions in building the capacity for inclusive democratic practices through water education campaigns. Currently, population growth and climate change are creating an increasingly complicated set of trade-offs between water supply, water quality, urban temperatures, and energy consumption (Gober et al. 2010). The expanding urban heat island has changed the temperature profile of the region. Grass and high water use mitigate temperature change (Gober et al. 2009). Climate change will also have an impact on water. Most climate models predict that the southwestern United States will become drier, with precipitation occurring in fewer, more extreme events (Brazel and Gober 2007).

Additional stressors on water supply come from policies that shape water availability and equity. The state has adopted a policy designed to reduce groundwater withdrawal near Phoenix, while an interstate compact grants Arizona junior rights to Colorado River water. Decisions have traditionally marginalized female, racial and ethnic minority, and home renter perspectives. For example, Latino communities are exposed to toxins leached from gravel pits and landfills in a nearby riverbed and have been excluded from decisions to restore riparian habitat in their neighborhoods using treated effluent (Brittle 1998). Current drought management plans explicitly call for a flat 5% reduction in residential water use across all users (e.g., City of Glendale 2004), a strategy that typically results in larger water restrictions among poorer residents (Gilbert 2007). These policies have the capacity to alter what Phoenix looks like, determine whether or not it has enough water for all residents, and influence which residents bear the brunt of the social, economic, and/or environmental consequences associated with choices about water use and management. Thus, it is critical to understand whether the network interactions of organizations—specifically WEPs—intervene in these inequities in positive or negative ways.

How Phoenix plans for the water impacts of growth and climate change depends on the priorities of the local policy community as well as residents. Both groups have the ability to make decisions or take action related to water resources. Residential development has shifted the scale of water conservation decisions; reducing total water consumption now requires altering the decisions of residents with control over smaller individual landholdings.

Methods

To address the hypotheses presented in this article, we collected data using two survey instruments. To construct the public access network, and data on public user

characteristics, we completed a mail survey using a random sampling technique stratified across six neighborhoods that differed in their demographic characteristics. The method used to select neighborhoods and to assure both homeowners and renters are included among respondents followed the protocol described in Cutts et al. (2013). Following the Tailored Design Method (Dillman 2007), we conducted a four-wave mailing. This included sending informational letters and two survey packets with both English and Spanish versions of the full survey instrument and a stamped return envelope. Respondents were asked to answer a series of questions that included awareness of 35 organizations (see Table 1) and one space to list additional sources of water-related information, as well as questions about the respondent's demographic information (sex, race/ethnicity, and homeownership status).

A survey of WEPs was also conducted. This used professional e-mail addresses to recruit individual respondents into an Internet survey. We attempted to contact each professional four times, using both professional e-mail addresses and telephone numbers. The sample frame included the highest-ranking environmental education or outreach professional at each organization, defining the study region as the U.S. Census 2000 Phoenix Metropolitan Statistical Area. Each individual was asked to recall, from a list provided, the number of other water education providers with which they shared information and/or funding resources. The survey asked representatives from each organization to report whether or not they had exchanged information about water outreach programs with other organizations. It also asked whether they had given and/or received funding from other organizations following methods validated by Marsden (1990). The network frame initially included 61 organizations, all of which were listed on the survey instrument.

Public Access

The dependent variable is the public access network. To construct a network of organizations from the survey, reports of two information sources being used together constituted a tie between organizations. The tie was then weighted by the number of surveys on which both organizations were listed together (Figure 1).

Organization Characteristics

To operationalize the characteristics of the organization that might influence the public access network, we use the geographic scope and institutional form. These are considered directly to assess whether the category influences the probability of tie formation. We also include a measure of the likelihood that ties between organizations of the same category will occur more frequently than expected by chance (Hypothesis 1). Organization-level characteristics were assigned using interview and document analysis following methods described in Cutts et al. (2008) and Cutts (2013).

Public Characteristics

To operationalize audience cultural identities, we include measures of the total population that uses the organization as an information source, and the percentages of the organizations' current users who identify as women, members of the dominant

racial and ethnic group (in this case, identified non-Hispanic white), and homeowners rather than renters. We include the current network of public access as a covariate, defining the ties based on the number of public survey respondents currently relying on two WEPs (Hypothesis 2). This is illustrated in Figure 1.

Interorganizational Network Measurement

To measure the impacts of interorganizational ties on public access, we included the presence and direction of (Hypothesis 3) funding ties and (Hypothesis 4) information-sharing ties. Information and funding partnership networks were constructed from an Internet survey administered to WEP representatives.

Organization-Level Network Measurements

To measure the impacts of interorganizational network roles on public access, we included the role of each organization in both the information network and the funding network (Hypothesis 5). Two roles were identified in the funding network: core and unconnected. Four roles were identified in the information network: core; not central, with more ties in than out (peripheral in $>$ out); not central, with equivalent numbers of ties in and out (peripheral in $=$ out); and very few ties (sparse).

Data Analysis Methods

Data management and analyses were completed using the R programming language (R Core Team 2013). Using the statnet package, we were able to load data, make organization-level network measurements, and complete exponential graph random models (Handcock et al. 2013). Role classifications were calculated in statnet using the catrege method to compute role assignments and partition the vertex set of a graph into classes (Butts 2014). Before analysis, organizations that did not appear on the public survey were combined and included as a single ''other'' organization for analysis.

ERGM models were constructed using the individual package ergm (Handcock et al. 2008, 2013; Hunter et al. 2008) and the extension for count data, ergm.count (Krivitsky 2013). This extension was needed in order to accommodate the weighted ties in the public access network. We measured the degree to which a public survey respondent's access expands the diversity of organizations that the respondent interacts with as the respondent seeks out more educational material. To test this, we constructed and compared the explanatory ability of five exponential random graph models (ERGMs) that included different combinations or parameters from interorganizational networks, organizational characteristics, and audience demographic variables. The model that offers the best fit is the one that demonstrates the lowest Akaike information criterion (AIC) and Bayesian information criterion (BIC) values. The results appear in Table 2.

Results and Discussion

Results indicate that the network structure of interorganizational relationships in metropolitan Phoenix does not obstruct the public's access to information resources. Network roles have shaped the ways in which each organization targets interactions

Table 2. Exponential random graph models for public awareness network

Model	1	2	3	4	5
Geographic scope (nodefactor)					
Household/private (baseline)	—	—	—	—	
City	−14.32 (3.34)***	−14.33 (3.39)***	−92.28 (25.45)***	−15.16 (3.40)***	−95.25 (27.65)***
Region	−15.00 (3.03)***	−15.23 (3.07)***	−88.61 (21.78)***	−16.00 (3.13)***	−90.88 (22.86)***
State	−16.04 (3.24)***	−16.12 (3.27)***	−88.62 (22.02)***	−17.05 (3.33)***	−91.47 (23.23)***
United States	−15.33 (3.24)***	−15.40 (3.26)***	−85.52 (21.56)***	−16.36 (3.33)***	−88.13 (22.79)***
Other	−12.32 (3.24)***	−12.39 (3.27)***	−88.13 (22.28)***	−13.39 (3.32)***	−91.23 (23.59)***
Institutional form (nodefactor)					
Water supply (baseline)	—	—	—	—	
Nonsupply government agency	2.60 (0.63)***	2.82 (0.65)***	1.11 (1.75)	2.92 (0.69)***	0.95 (1.92)
Environmental group	1.00 (0.70)	1.08 (0.72)	4.89 (2.40)*	1.41 (0.76)	4.96 (2.56)
Educational/research group	−2.23 (0.64)***	−2.14 (0.67)**	−7.49 (1.91)***	−2.16 (0.64)***	−7.98 (1.20)***
Consortium	0.59 (0.98)	0.73 (1.04)	13.40 (12.02)	0.85 (1.00)	13.83 (12.34)
Mass communication outlet	3.79 (1.04)***	3.90 (1.06)***	7.39 (11.80)	4.24 (1.10)***	7.23 (13.12)
Other	—	—	—	—	
Geographic scope (nodematch)				0.11 (0.42)	0.03 (0.85)
Institutional form (nodematch)				0.94 (0.54)	0.37 (1.37)
Popularity of organization (nodecov)	6.13 (1.23)***	6.49 (1.29)***	3.49 (3.58)	6.40 (1.27)***	2.09 (4.19)
Female users (nodecov)	8.78 (2.35)***	8.38 (2.39)***	68.08 (14.02)***	9.04 (2.36)***	70.75 (14.78)***
Hispanic and/or non-White users (nodecov)	−22.32 (4.28)***	−22.33 (4.40)***	−89.06 (19.76)***	−22.99 (4.33)***	−90.91 (20.14)***
Renters (nodecov)	14.10 (2.65)***	13.91 (2.83)***	34.69 (9.61)***	14.26 (2.67)***	34.32 (9.72)***
Information network (edgecov)		0.23 (0.40)			−1.04 (1.05)
Funding network (edgecov)		−2.41 (0.97)*			1.58 (2.98)

(*Continued*)

Table 2. Continued

Model	1	2	3	4	5
Role-information (nodefactor)					
Core (baseline)			—		
Peripheral in = out			13.99 (3.14)***		14.54 (3.26)***
Peripheral in > out			5.55 (2.05)**		5.65 (2.13)**
Sparse			2.93 (1.32)*		3.24 (1.42)*
Role-funding (nodefactor)					
Core (baseline)			—		
Unconnected			−10.02 (1.96)***		−10.47 (2.11)
Public access network (edges)	5.05 (1.55)**	4.99 (1.55)**	15.61 (23.2)	5.41 (1.59)***	15.97 (25.79)
Akaike information criterion	303.88	300.60	95.12	304.40	101.9
Bayesian information criterion	374.09	379.60	182.90	383.39	207.2

Note. For each variable, the estimate is given on the first line, followed by the standard error in parentheses. The ergm term used in the model specification is noted next to each variable title. Significance: $^{***}p < .001$; $^{**}.001 < p \leq .01$; $^{*}p \leq .05$.

with the public and the demographics of the public with whom organizations interact. Therefore, organizations differ in the degree to which they are trusted by groups like women, renters, and minority races/ethnicities. This can be interpreted as an indicator of cultural sensitivity and awareness by WEPs. Though not a perfect proxy, this organization-level specialization could be used to identify appropriate proxies when direct citizen participation in decisions is not feasible.

Survey Responses

By treating public access to WEPs as a network connecting organizations to each other, we were able to evaluate the factors driving differences in the quality, quantity, or nature of educational opportunities that are available. The public survey was completed by 749 respondents. Of these, 79.0% of survey respondents owned their home, 51.3% were female, and 77.5% identified their race and ethnicity as non-Hispanic White. The use patterns differed among organizations (Table 1). On average, respondents to the public survey indicated receiving information from approximately 4.75 ± 3.6 organizations. This ranged from 2.5% (low) to 80.1% (high). The network of public access (Y network) is valued and undirected. The tie weights are the number of individual respondents that reported accessing educational materials through two organizations. There are a total of 489 ties and a mean of 55.89 ties per organization ($SD = 17.49$). The network centralization score is 0.0001, indicating that no organization appears on all lists.

Representatives from 45 organizations provided responses to the organizational survey. This included representatives of 35 organizations on which we collected data in the public survey, as well as data from several other municipal water providers. There are 289 observed ties in the information network and 34 in the funding network. Mean number of ties is 13.67 ($SD = 0.25$) and 3.61 ($SD = 0.03$), respectively. The information network indicates a higher level of centralization, or reliance on a few key organizations to maintain connectivity (0.35, as opposed to 0.11 in the funding network).

Exponential Random Graph Model (ERGM) Results

Table 2 presents the results of the ERGMs. AIC, BIC, and goodness of fit simulations indicate that Model 3 is the best fit to the data. This model omits funding and information ties as direct predictors of additional public access, but includes variables associated with the role organizations play in the funding and information networks. Related to our hypotheses, we find that:

1. Fixed characteristics of organizations moderate network effects, with variation being explained by any shift in geographic scope groups as well as particular institutional forms.
2. Organizations serving larger proportions of historically disenfranchised groups (women and renters) are more likely to have higher tie weights. The opposite relationship holds for race/ethnicity, with organizations serving disenfranchised populations being less likely to be linked. This is a critical challenge to delivering on democratic principles of inclusive public engagement.
3. The presence of an information-sharing tie does not decrease tie strength in the public access network.

4. The presence of a funding tie does not increase tie strength in the public access network.
5. Information and funding network roles predict differences in tie strength in the public access network.

Related to the first objective of this article, ERGM results in Model 3 lend significant insight into the promise and pitfalls of relying on environmental education organizations as proxy representatives of the public interest. Model 3 supports the idea that the network activity structures organizations' roles with respect to their suitability as proxies for public interest in water decision-making. Organizations performing different network-based roles have different probabilities of being identified as information sources by the public. Core information sharers have a lower chance of interacting with the public, as do organizations unconnected from the funding network.

The second objective of this study was to determine whether WEPs alter their legitimacy as representatives of the public by working together. Results indicate that organizations serving culturally specific audiences are not isolated (Hypothesis 2). The extent to which women, racial and/or ethnic minorities, and homeowners currently use a WEP as an information source does matter, suggesting that the organizations that are deemed culturally appropriate by nonmajority groups are also most trusted across the populace. Interorganizational relationships, indicated by the presence of a tie, are not significantly related to the probability that the public will access information from one of the organizations involved in that tie. Interorganizational relationships are not significantly related to the probability that the public will access information from one of the organizations in that tie. As members of the public seek out more water education, they are more likely to seek out information from sources currently used in higher proportions by nonmajority groups. That is, no matter how members of the public initially enter into the network of available water education, they are equally likely to access additional sources that improve the breadth of learning opportunity provided to them.

The WEPs upon which the public currently relies do not significantly alter the probability of accessing educational materials from new sources in models that control for organizational role in funding and information sharing (Hypotheses 3 and 4). This means that interorganizational relationships structure public access to additional information in ways that cannot be overcome by effort by the public alone. However, there is evidence that the public benefits from interorganizational interactions through the creation of roles based on network relations (Hypothesis 5).

A demonstrated benefit of interorganizational networks is task differentiation across organizations. As in other studies, this appears to occur by separating roles of organizations through network links, with central members generating material and more peripheral members reaching out to the public (Lubell et al. 2012). Our results provide evidence that this is occurring through intentional partitioning of "the public" that leverages each organization's specialized approach to environmental education. This may be an advantage to the public if, as our results suggest, it enhances information access among audiences who may benefit from initial WEPs that appeal to culturally specific interests. As a cooperative outcome, differentiation is an alternative to adopting a uniform, one-size-fits-all approach to public education that inadvertently privileges the dominant social group (Guo and Acar 2005; Downey and Strife 2010). By joining together, organizations are more efficient by

concentrating on their individual strengths, allowing the coalition to achieve diversity and organizations to achieve efficiency.

In conclusion, consideration of whether coalitions between organizations provide greater benefit to the public than organizations working independently is important. Declining state funding has made public will an ever more important mechanism for initiating action to protect freshwater ecosystems and for maintaining drinking water supply and quality (Dietz and Stern 2008). The results of this study indicate that relationships between organizations do shape public access to materials designed to educate citizens about local water issues by creating network-based roles (Hypothesis 5) but not through ties directly (Hypotheses 3 and 4). This suggests that intentionally restructuring relationships could better support opportunities for more inclusive public engagement through water education. While this study does not speculate on an optimal network configuration, it provides a case study of how effectiveness at the organization, network, and community level interacts. This study further recognizes that "the public" is comprised of diverse stakeholders who do not participate in interorganizational networks but are presumed to benefit from a network's coordinated efforts. When, as in this case, the organizations themselves are not marginalized, these outlets offer the most credible representatives of these public interests in policymaking spheres or act most effectively to build capacity for key underrepresented social groups to participate in environmental decisions. A network approach and ERGMs allow us to evaluate whether public access (and opportunity for engagement) is improved or limited by cooperation across WEPs. One potential limitation of the study is the inability to include all members of the WEP network in the public survey. Due to concern for respondent exhaustion, we elected to exclude organizations that focused exclusively on either children or policy audiences. While this presents a potential limitation, the inclusion of an all-encompassing "other" enables us to isolate the potential influence of these organizations.

There is evidence to suggest that environmental education organizations may provide good proxies for the public when direct citizen participation in decision-making is not feasible—if the organizations are widely recognized by the public (or a subset therein). However, individual organizations are not substitutable for one another. Both organizational characteristics and roles created by interorganizational network interactions affect an organization's relationships with the public and traditionally underrepresented groups. The network of WEPs in metropolitan Phoenix is not currently configured in a way that limits its collective legitimacy. This result would suggest that networks could be strategically managed to increase their collective ability to simultaneously build public capacity for participation in the policy process and serve as legitimate proxies in their absence.

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References

Bodin, Ö., and B. I. Crona. 2009. The role of social networks in natural resource governance: What relational patterns make a difference? *Global Environmental Change* 19(3):366–74. doi:10.1016/j.gloenvcha.2009.05.002

Brazel, A., and P. Gober. 2007. Urban-scale climate change effects on water use. *Southwest Hydrology* 6:10–11.

Brittle, S. 1998. The Rio Salado Project: The rest of the story. *Environmental Justice Explorer* 5:1–6.

Butts, C. T. 2014. SNA: Tools for social network analysis. R package version 2.3–2. http://cran.r-project.org/web/packages/sna/sna.pdf

City of Glendale. 2004. City of Glendale drought management plan. Glendale, AZ. https://www.glendaleaz.com/waterconservation/documents/DMP_200604.pdf

Cranmer, S. J., and B. A. Desmarais. 2011. Inferential network analysis with exponential random graph models. *Political Analysis* 19(1):66–86. doi:10.1093/pan/mpq037

Crona, B., and K. Hubacek. 2010. The right connections: How do social networks lubricate the machinery of natural resource governance. *Ecology and Society* 15. http://www.ecologyandsociety.org/vol15/iss4/art18/

Cutts, B. B. 2013. Spatial interactions between organizations and the symbolic landscapes created by their public information campaigns. *Water Policy* 15(1):61–78. doi:10.2166/wp.2012.059

Cutts, B. B., N. Moore, A. Fox-Gowda, A. C. Knox, and A. Kinzig. 2013. Testing neighborhood, information seeking, and attitudes as explanations of environmental knowledge using random forest and conditional inference models. *Professional Geographer* 65(4):561–79. doi:10.1080/00330124.2012.724347

Cutts, B., C. Saltz, and M. Elser. 2008. Insights into the interactions between educational messages: Looking across multiple organizations addressing water issues in Maricopa County, Arizona. *Applied Environmental Education & Communication* 7(1–2):40–50. doi:10.1080/15330150802194904

Dietz, T., and P. C. Stern, eds. 2008. *Public participation in environmental assessment and decision making*. Washington, DC: National Academies Press.

Dillman, D. A. 2007. *Mail and Internet surveys: The tailored design method*, 2nd ed. Hoboken, NJ: John Wiley & Sons.

Downey, L., and S. Strife. 2010. Inequality, democracy, and the environment. *Organization & Environment* 23(2):155–88.

Ernstson, H., S. Sörlin, and T. Elmqvist. 2008. Social movements and ecosystem services—The role of social network structure in protecting and managing urban green areas in Stockholm. *Ecology and Society* 13(2): art. 39. http://www.ecologyandsociety.org/vol13/iss2/art39/

Gilbert, A. 2007. Water for all: How to combine public management with commercial practice for the benefit of the poor? *Urban Studies* 44:1559–79. doi:10.1080/00420980701373461

Gober, P., A. Brazel, R. Quay, S. Myint, S. Grossman-Clarke, A. Miller, and S. Rossi. 2009. Using watered landscapes to manipulate urban heat island effects: How much water will it take to cool Phoenix? *Journal of the American Planning Association* 76:109–21. doi:10.1080/01944360903433113

Gober, P., C. W. Kirkwood, R. C. Balling, A. W. Ellis, and S. Deitrick. 2010. Water planning under climatic uncertainty in Phoenix: Why we need a new paradigm. *Annals of the Association of American Geographers* 100(2):356–72. doi:10.1080/00045601003595420

Guo, C., and M. Acar. 2005. Understanding collaboration among nonprofit organizations: Combining resource dependency, institutional, and network perspectives. *Nonprofit and Voluntary Sector Quarterly* 34(3):340–61. doi:10.1177/0899764005275411

Handcock, M., D. R. Hunter, C. T. Butts, S. Goodreau, P. Krivitsky, and M. Morris. 2013. Statnet: Software tools for the statistical analysis of network data. The Statnet Project (http://www.statnet.org). R package version 3.1–0, CRAN.R-project.org/package = statnet.

Handcock, M. S., D. R. Hunter, C. T. Butts, S. M. Goodreau, and M. Morris. 2008. Statnet: Software tools for the representation, visualization, analysis and simulation of network data. 2008. *Journal of Statistical Software* 24(1):1548–7660. http://www.jstatsoft.org/v24/i01

Hunter, D. R., M. S. Handcock, C. T. Butts, S. M. Goodreau, and M. Morris. 2008. ergm: A package to fit, simulate and diagnose exponential-family models for networks. *Journal of Statistical Software* 24(3):nihpa54860.

Kaiser, F. G., and U. Fuhrer. 2003. Ecological behavior's dependency on different forms of knowledge. *Applied Psychology* 52:598–613. doi:10.1111/1464-0597.00153

Kalof, L., T. Dietz, G. Guagnano, and P. C. Stern. 2002. Race, gender and environmentalism: The atypical values and beliefs of white men. *Race, Gender & Class* 9(2):112–30.

Konisky, D. M., J. Milyo, and L. E. Richardson. 2008. Environmental policy attitudes: issues, geographical scale, and political trust. *Social Science Quarterly* 89(5):1066–85. doi:10.1111/j.1540-6237.2008.00574.x

Krivitsky, P. 2013. Ergm.count: Fit, simulate and diagnose exponential-family models for networks with count edges. The Statnet Project. http://www.statnet.org. R package version 3.1–0, CRAN.R-project.org/package = ergm.count.

Lubell, M., J. Scholz, R. Berardo, and G. Robins. 2012. Testing policy theory with statistical models of networks. *Policy Studies Journal* 40(3):351–74. doi:10.1111/j.1541-0072.2012.00457.x

Lusher, D., J. Koskinen, and G. Robins, eds. 2012. *Exponential random graph models for social networks: Theory, methods, and applications*. New York: Cambridge University Press.

Marsden, P. V. 1990. Network data and measurement. *Annual Review of Sociology* 16:435–63. doi:10.1146/annurev.soc.16.1.435

Morris, M., M. S. Handcock, and D. R. Hunter. 2008. Specification of exponential-family random graph models: Terms and computational aspects. *Journal of Statistical Software* 24(4):1548–7660. http://www.jstatsoft.org/v24/i04/paper

Muñoz-Erickson, T. A., B. B. Cutts, E. K. Larson, K. J. Darby, M. Neff, A. Wutich, and B. Bolin. 2010. Spanning boundaries in an Arizona watershed partnership: information networks as tools for entrenchment or ties for collaboration? *Ecology and Society* 15. http://www.ecologyandsociety.org/vol15/iss3/art22/

Noar, S. M. 2006. A 10-year retrospective of research in health mass media campaigns: Where do we go from here? *Journal of Health Communication* 11:21–42. doi:10.1080/10810730500461059

Pretty, J., and D. Smith. 2004. Social capital in biodiversity conservation and management. *Conservation Biology* 18(3):631–38. doi:10.1111/j.1523-1739.2004.00126.x

Provan, K. G., and P. Kenis. 2008. Modes of network governance: structure, management, and effectiveness. *Journal of Public Administration Research and Theory* 18(2):229–52. doi:10.1093/jopart/mum015

Provan, K. G., and R. H. Lemaire. 2012. Core concepts and key ideas for understanding public sector organizational networks: Using research to inform scholarship and practice. *Public Administration Review* 72(5):638–48. doi:10.1111/j.1540-6210.2012.02595.x

Provan, K. G., and H. B. Milward. 2001. Do networks really work? A framework for evaluating public-sector organizational networks. *Public Administration Review* 61:414–23. doi:10.1111/0033-3352.00045

R Core Team. 2013. *R: a language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. http://www.R-project.org/

Robins, G., P. Pattison, Y. Kalish, and D. Lusher. 2007. An introduction to exponential random graph (p^*) models for social networks. *Social Networks* 29(2):173–91. doi:10.1016/j.socnet.2006.08.002

Schneider, M., J. Scholz, M. Lubell, D. Mindruta, and M. Edwardsen. 2003. Building consensual institutions: Networks and the National Estuary Program. *American Journal of Political Science* 47(1):143–58. doi:10.1111/1540-5907.00010

Syme, S. 2004. Social determinants of health: The community as an empowered partner. *Preventing Chronic Disease* 1:A02.

UNESCO-UNEP. 1978. *Final report: Intergovernmental Conference on Environmental. Education*. UNESCO ED/MD/49. Paris, France. http://unesdoc.unesco.org/images/0003/000327/032763eo.pdf

U. S. Census Bureau. 2010. Selected social characteristics in the United States: Phoenix–Mesa–Glendale Metro Area. http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_11_5YR_DP02&prodType=table (accessed January 25, 2013).

Wasserman, S., and K. Faust. 1994. *Social network analysis: Methods and application*. New York: Cambridge University Press.

Williams, B. L, and Y. Florez. 2002. Do Mexican Americans perceive environmental issues differently than Caucasians: A study of cross-ethnic variation in perceptions related to water in Tucson. *Environmental Health Perspectives* 110(suppl. 2):303–10.

Zelezny, L. C., P. P. Chua, and C. Aldrich. 2000. New ways of thinking about environmentalism: Elaborating on gender differences in environmentalism. *Journal of Social Issues* 56(3):443–57. doi:10.1111/0022-4537.00177