LETTER

Conservation stakeholder network mapping, analysis, and weaving

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Keywords
Conservation stakeholders; social network analysis; social network interventions.

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Received
17 September 2010
Accepted
8 March 2011

Editor
Mark Lubell

doi: 10.1111/j.1755-263X.2011.00176.x

Abstract

Conservation science frequently does not lead to conservation action; collaborations between conservation practitioners and stakeholders might support greater conservation success. We describe stakeholder social network analysis (SNA) and facilitation in coastal Oregon, United States. We surveyed 47 people, who named 297 other sustainable natural resources collaborators. Network analysis found cohesive ecosystem-based groups and groups defined by organization type, collaboration between groups, actors who bridged groups, and a core-periphery network structure. Cross-boundary collaboration analysis revealed that people in the estuary group and business people were isolated. To facilitate network change, we discussed network maps and analyses with participants, elicited their ideas about new relationships to enhance their work, and introduced people who might have common interests. New participant-organized projects to emerge included: a successful grant proposal; an online participant skills directory; collaboration between the local solid waste program and the state agricultural extension office; and two participants doing ongoing interventions. SNA and facilitation may make valuable contributions to conservation outcomes.

Introduction

Conservation science frequently does not lead to conservation action (Balmford & Cowling 2006; Knight *et al.* 2008), and Knight *et al.* (2006) suggest that collaborations between scientists and empowered stakeholders is one factor that might contribute to greater conservation success. But who are the stakeholders in a conservation issue, how can scientists build partnerships with them, and is there anything conservation scientists and practitioners can do to facilitate a shift from "informed" to "empowered" stakeholders?

Social network analysis (SNA) began in the 1930s when Moreno (1934) invented the sociogram, using nodes to represent individuals and lines to represent relationships between them; its use in the social sciences has grown exponentially in recent decades (Borgatti & Foster 2003). The network perspective assumes that: (1) relationships among actors are important; (2) actors are interdependent rather than autonomous; (3) a relationship between two actors represents a flow of material or nonmaterial resources; and (4) network structures enhance or inhibit actors' ability to act (Wasserman & Faust 1994). SNA has been used in a wide variety of contexts (Borgatti *et al.* 2009), and has begun to be used in natural resources management studies (Schneider *et al.* 2003; Bodin *et al.* 2006; Crona & Bodin 2006; Isaac *et al.* 2007; Ernstson *et al.* 2008; McAllister *et al.* 2008; Ramirez-Sanchez & Pinkerton 2009).

Natural resources social network researchers have found a variety of network structures, and it is likely that no single network structure is optimum for all circumstances (Bodin *et al.* 2006; Bodin & Crona 2009). However, network structural characteristics that are hypothesized to contribute to sustainable natural resources management include: densely connected groups of people that share specific knowledge and work together productively (Bodin *et al.* 2006; Bodin & Crona 2009;

Table 1 Examples of interventions that have been applied to enhance individual and group success in networks

Sector	Interventions	Outcomes	Reference
Health	Identify and provide HIV prevention training to opinion leaders of networks of young men who have sex with men	Increased condom use by network members	Amirkhanian *et al.* (2003)
	Pay injecting drug users to distribute educational and risk reduction materials (bleach and condoms) in their networks	Reduced syringe sharing and injection frequency	Broadhead *et al.* (1998)
	Peer-nominated youth leaders facilitate antisubstance use groups	Reduced marijuana and cocaine use	Valente *et al.* (2007)
Counter-terrorism	Take action against actors who have many contacts, are involved in complex covert activities, and handle many resources	Reduced sniper activity and improvised explosive device deaths in Iraq	Bohannon (2009)
Business	Bridge isolated divisions; increase awareness of employee expertise; draw in peripheral network participants.	Increased customer satisfaction; increased new product revenue; improved operational productivity	Cross *et al.* (2006)
	Build a licensed kitchen facility for local food entrepreneurs to test products	Increased purchases from local family farms	Krebs & Holley (2004)
	Encourage self-organized collaboration networks among employees	Reduced new product development time; increased product quality	Sandow & Allen (2005)
Natural resources	Identify peripheral stakeholders who can bring in new ideas and well-connected stakeholders who can diffuse new ideas out into the network	Well-connected stakeholders selected for natural resources management committee	Prell *et al.* (2009)

Sandström & Rova 2010); a heterogeneous set of groups within the network as a whole, contributing expertise in a variety of knowledge areas (Bodin *et al*. 2006; Ernstson *et al*. 2008; Bodin & Crona 2009; Sandström & Rova 2010); bridging relationships between groups that facilitate the sharing of expert knowledge in response to emerging challenges (Bodin *et al*. 2006; Ernstson *et al*. 2008; Bodin & Crona 2009; Sandström & Rova 2010); and ties to a periphery of diverse actors that provide specialized knowledge, skills, and other resources over time as changing circumstances require (Ernstson *et al*. 2008; Bodin & Crona 2009).

Most SNA research is done by academic network scientists, but there is a history of applied SNA as well. Interventions based on SNA, and the outcomes they produced, have been reported in applied fields such as public health, counterterrorism, and business (Table 1), but we are aware of only one in natural resources management (Prell *et al*. 2009), suggesting there may be a research–implementation gap (Knight *et al*. 2008) in natural resources SNA. Many SNA-based interventions have been top-down: using opinion leaders to diffuse health information and behavior (Broadhead *et al*. 1998; Amirkhanian *et al*. 2003; Valente *et al*. 2007); directing action against covert operators (Bohannon 2009); reorganizing business operations (Cross *et al*. 2006); or inviting well-connected stakeholders to participate in a resource management committee (Prell *et al*. 2009). Others have supported self-organized (Ostrom 2009) network initiatives, such as employees forming product development or quality assurance networks (Sandow & Allen 2005) or entrepreneurs developing local food products (Krebs & Holley 2004).

Our goal was to investigate the applicability of applied SNA for conservation by first assessing the structural characteristics of a conservation stakeholder network and then communicating our results directly to the stakeholders, encouraging them to consider new initiatives that might enhance their conservation success, a process we call "network weaving." We explored conservation stakeholder network analysis and weaving in Lincoln County on the Oregon coast, United States. Our initial results suggest that applied SNA can make valuable contributions to conservation practice. Network participants used network maps and analyses to identify collaboration gaps and took actions to begin working with others they had overlooked in the past.

Methods

Study area

Lincoln County has a population of about 50,000 and an area of about 250,000 hectares. Conservation issues there include loss of mature forests, declining salmon runs, degraded wetlands and estuaries, depleted rock fisheries, and potential impacts of climate change, sea level rise, and ocean wave energy development. Timber harvest was a major activity and source of jobs in coastal Oregon from the post-WWII era until the 1990s, when the effects of industrial forestry on salmon, the Pacific spotted owl (*Strix occidentalis*), and other species led to a series of lawsuits by conservation organizations, which ultimately resulted in implementation of the Northwest Forest Plan and significant reduction of logging on public lands (REO 2006). Salmon fishing was economically important for most of the 20th century, until the cumulative effects of overfishing and freshwater and estuarine habitat degradation and loss due to forestry, agriculture, road construction, and other human activities reduced salmon populations and several were listed as endangered or threatened under the U.S. Endangered Species Act (Lichatowich 1999). Most of Oregon's larger estuaries are degraded and associated wetlands diked and filled (Jennings *et al*. 2003). To our knowledge, there is no single program operating in Lincoln County to coordinate sustainable natural resources management from the mountains to the sea.

Our conservation stakeholder network analysis began with surveying a sample of the people working on sustainable natural resources issues in Lincoln County, then diagramming ("mapping") and analyzing their answers, looking for patterns among the reported relationships. Network interventions were then based upon presenting the resulting network information to network participants and encouraging them to consider new self-organized collaborations.

Network survey and mapping

We did a "snowball" sampling survey (Doreian & Woodard 1992) of people in Lincoln County working on sustainable natural resources issues, starting with one person with lengthy conservation experience in the county, then doing follow-up surveys with people he named, and so on. As the number of people named increased we concentrated on follow-up surveys with people that had been named frequently, because our survey resources were limited. We invited 111 people to take the survey by using either a paper questionnaire, survey website, or telephone or face-to-face interview, and 47 people completed the survey, for a 42% response rate. Respondents named another 421 people, for a total of 468 network participants from 229 different organizations. Our survey, mapping, and analysis were for individuals, not organizations, because conservation stakeholder relationships are between people even though they work for organizations.

Our network survey questionnaire is given in Appendix S1. We asked respondents a variety of "network questions" about their relationships to others; due to space constraints we report results for only the most frequently answered question: "Please list key individuals with whom you have collaborated on sustainable natural resource projects or issues during the past two years." We mapped the network of reported collaborations using the NetDraw program (Borgatti 2002) Spring Embedding layout function, which used an algorithm that attempted to position linked nodes near to one another. We then moved some nodes by hand to make the map easier to read.

Network analysis

We calculated collaboration network descriptive statistics and assessed structural characteristics regarding cohesive subgroups, collaboration among different groups, bridging actors, and peripheral actors using the UCINET program (Borgatti *et al*. 2002). Using survey responses and information gathered from the internet, we assigned actors to groups based on their primary ecosystem of interest: terrestrial, freshwater, estuary, marine, or multiple. We also made groupings by the type of organization for which the actor worked: business, education, NGO, local government, state government, or federal government. We tested for cohesion within and collaboration among focal ecosystem and organization groups using the UCINET E-I Index function, which subtracted the proportion of ties internal to groups from the proportion external to groups, potentially giving index values ranging from -1 (entirely internal) to 1 (entirely external). A 10,000-iteration permutation test then indicated whether the observed index value differed from expected given the number of groups and ties. We also used a spreadsheet to tabulate the proportion of ties respondents reported within their ecosystem and organization groups and to other groups, an assessment of "cross-boundary exchange" or collaboration (Cross *et al*. 2002; Sandström & Rova 2010).

We assessed bridging actors using the UCINET G&F Brokerage Roles function, which found for each actor the number of times they connected two actors, each from a different focal ecosystem or organization group, who were not otherwise connected. We assessed the presence of peripheral actors using the UCINET Core/Periphery Categorical function, which ran 500 iterations of a genetic algorithm to assign each actor to either the core or periphery of the collaboration network.

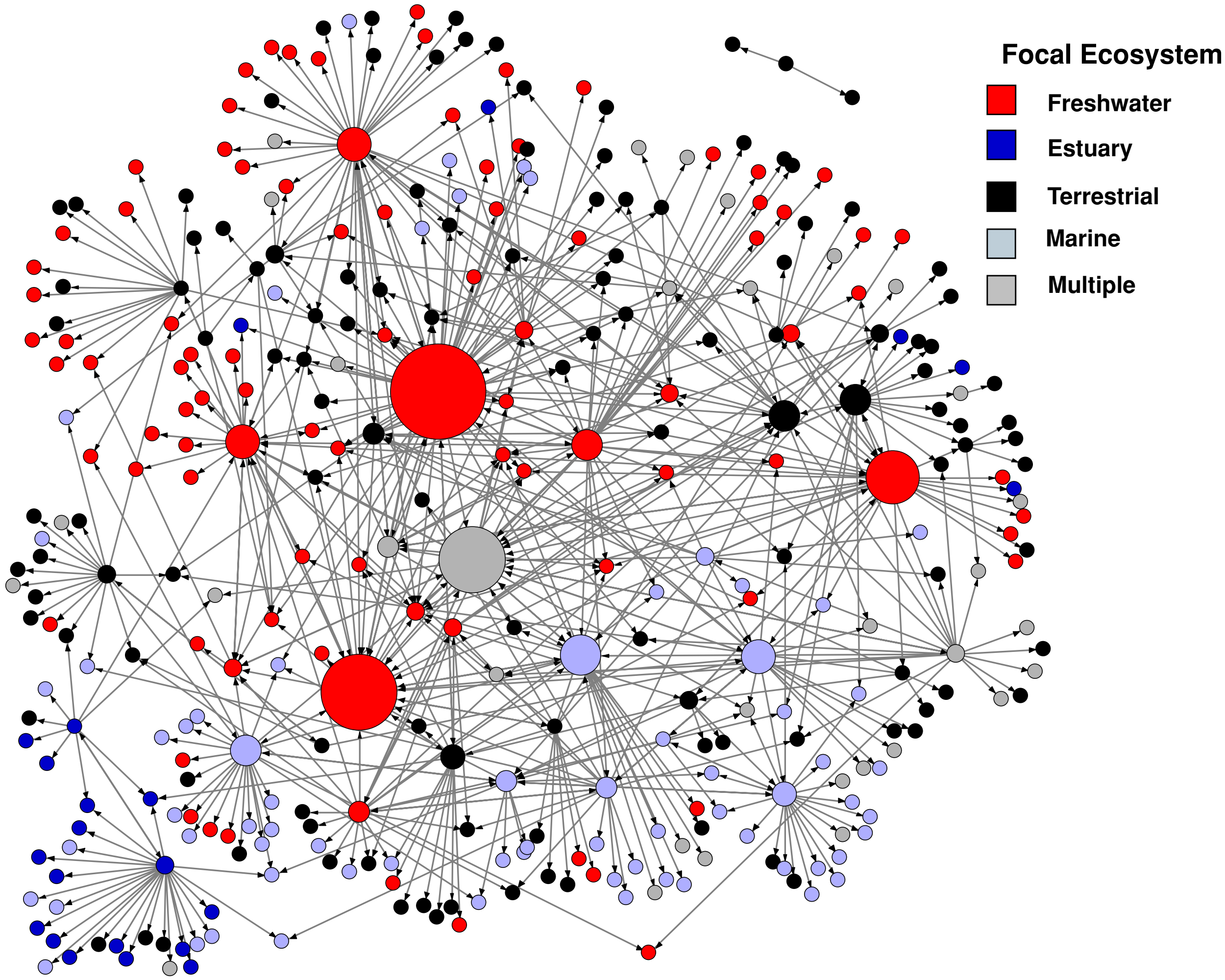

Figure 1 The collaboration network, showing answers to the question "Who are the key individuals with whom you have collaborated on sustainable natural resource projects or issues during the past two years?" Nodes are colored by the person's primary ecosystem of concern, and sized proportional to bridging score: the number of times an actor connects two other actors, each from a different ecosystem group, who are not otherwise connected. Arrows point to the person that was named.

Network interventions

Network interventions attempt to make networks more effective by increasing the quantity and quality of relationships among network participants (Cross *et al.* 2006). We had four meetings with 8–40 people, and 18 with 1–6 people, introduced people to one another, discussed network maps and metrics, and encouraged participants to think of, and undertake, new small projects among people that had not normally worked together in order to foster relationships that might enhance their conservation success. We followed up with people in the new projects, providing support and encouraging action outcomes. We invited network participants to begin doing network interventions themselves, and provided training and coaching to those who accepted the invitation.

Results

Network mapping

Of the 468 people that were either respondents or were named in response to one or more network questions, 390 were part of the collaboration network. We lacked sufficient information to assign a focal ecosystem to 46 people, so excluded them from mapping and analysis. There were 610 ties among the remaining 344 actors in the collaboration network (Figure 1). We also mapped the collaboration network with nodes symbolized according to the type of organization for which the actor worked (Figure 2). Three actors formed an isolated triad because the respondent was not named by any other respondents and both of the collaborators they named were not named by any other respondents.

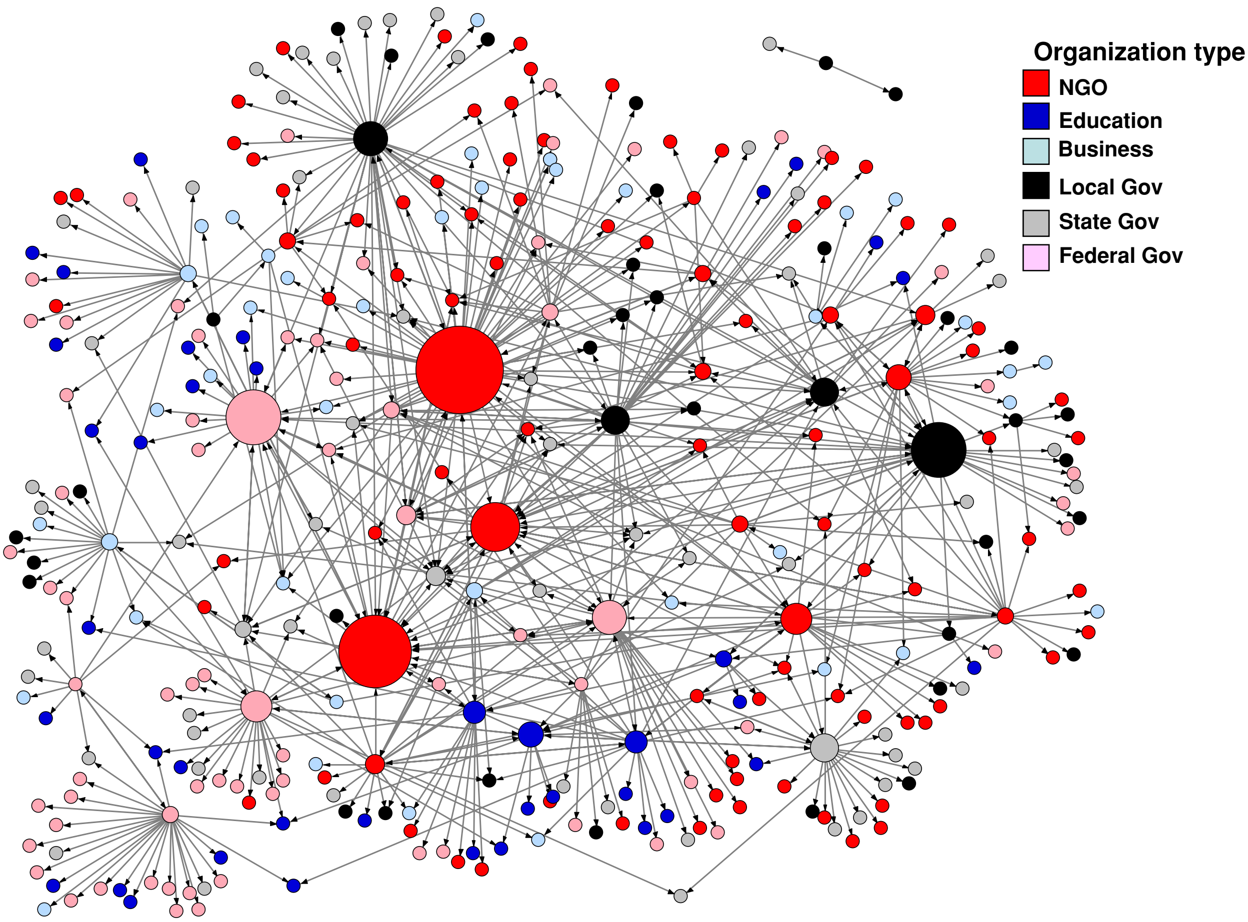

Figure 2 The collaboration network, showing answers to the question "Who are the key individuals with whom you have collaborated on sustainable natural resource projects or issues during the past two years?" Nodes are colored by the type of organization for which the person works, and sized proportional to bridging score: the number of times an actor connects two other actors, each from a different organization type, who are not otherwise connected. Arrows point to the person that was named.

Network analysis

Network density is the observed number of ties in a network as a proportion of the total possible number of ties given the number of nodes, and was 0.005 in the collaboration network (Table 2). On average, actors had less than two ties (average degree), fewer than 6% of which were reciprocal (named by both nodes). The greatest number of steps between any two nodes in the network (diameter) was 8, and the average number of steps between any two nodes was 3.4. Betweenness centralization is a measure of the variation in the number of times actors in the network lie on paths between other actors. A betweenness centralization value of zero would indicate that all

Table 2 Collaboration network descriptive statistics. Size: total number of nodes. Density: observed number of ties as a proportion of the total possible number of ties given network size. Average degree: average number of ties for all nodes in the network. Reciprocity: proportion of observed ties that are named by both nodes. Diameter: greatest number of "steps" between any two nodes in the network. Average path length: average number of steps between any two nodes in the network. Betweenness centralization: a measure of the variation in the number of times actors in the network lie on the path between two other actors; a value of one indicates that all paths pass through a single actor

Size	Density	Average degree	Reciprocity	Diameter	Average path length	Betweenness centralization
344	0.0051	1.759	0.0577	8	3.417	0.0294

Table 3 External-Internal (E-I) Index results for the collaboration network with groups defined by focal ecosystem or organization type, and using 10,000 permutations in UCINET

	Observed			Permutation			
	External	Internal	E-I	E-I Min.	E-I Ave.	E-I Max.	$P \leq$ Obs.
Ecosystem	0.535	0.465	0.070	0.266	0.480	0.682	0.000
Organization	0.701	0.299	0.402	0.458	0.628	0.766	0.000

nodes lie on the same number of paths, and a value of 1 would indicate that all paths pass through a single actor; the value for the collaboration network was 0.03.

The External–Internal (E-I) Index function for the collaboration network with groups defined by focal ecosystem found an observed value of 0.07 (Table 3), meaning that the proportion of ties within groups was slightly less than the proportion of ties between groups. None of the permutation-derived E-I values was as low as observed ($P \leq 0.000$), evidence that while about half the ties crossed groups indicating cross-group collaboration, the proportion of internal ties was higher than expected by chance, indicating within-group cohesion. Similarly, the observed E-I Index value of 0.402 ($P \leq 0.000$) for groups defined by organization type indicated that while approximately 70% of ties were external, this was still lower than expected by chance, again indicating within-group cohesion. Cross-boundary collaboration rates (Table 4) revealed more details of between-group collaborations,

Table 4 Within- and cross-boundary collaboration rates between groups defined by focal ecosystems and organization types. Values on the diagonal are the proportion of all collaboration ties respondents in a group named that were with others in the same group. Other row-wise values are the proportion of ties respondents named to others in a different group than their own

	Named					
Respondents	FW	Ter.	Est.	Mar.	Mult.	
Freshwater	0.47	0.33	0.02	0.10	0.08	
Terrestrial	0.32	0.49	0.02	0.08	0.09	
Estuary	0.03	0.14	0.53	0.25	0.05	
Marine	0.2	0.14	0	0.52	0.14	
Multiple	0.37	0.37	0	0.09	0.17	
	Bus.	Edu.	NGO	Local	State	Fed.
Business	0.18	0.15	0.16	0.16	0.15	0.20
Education	0.09	0.30	0.30	0.07	0.09	0.15
NGO	0.13	0.05	0.16	0.12	0.42	0.12
Local gov.	0.04	0.06	0.33	0.14	0.24	0.18
State gov.	0.04	0.07	0.41	0.07	0.33	0.07
Federal gov.	0.06	0.14	0.20	0.08	0.22	0.31

Table 5 Bridging scores of the highest scoring actors in the Lincoln County collaboration network according to groupings by focal ecosystem type and organization type, and the average score for all actors. Actor ID is composed of the ecosystem of primary interest to the actor or the type of organization for which the actor worked, and a unique number to distinguish them from others in the group. Bridging scores are the number of cases in which an actor has ties to two actors, each in a different group, who are not otherwise connected

Focal ecosystem		Organization type	
Actor ID	Bridging score	Actor ID	Bridging score
Freshwater19	263	NGO22	272
Freshwater103	204	NGO120	217
Multiple24	169	Federal200	152
Freshwater29	123	Local90	149
Marine29	85	NGO68	136
Freshwater67	68	Local116	80
Freshwater9	66	Federal19	71
Marine13	66	NGO17	64
Terrestrial76	57	Federal53	64
Freshwater78	55	State169	58
Network average	4.7	Network average	5.2

showing that for groups defined by focal ecosystems, people in the freshwater and terrestrial groups were the most frequent receivers of named ties, and people in the estuary group were the least frequent receivers. For groups defined by organization types, people working for NGOs and state government were the most frequently named collaborators, while people working for businesses, educational institutions, and local government were named less often.

When groups were defined by five focal ecosystems, the average bridging score of actors in the collaboration network was 4.7 (Table 5), meaning that actors lay between two other actors, each from a different ecosystem group, 4.7 times on average. The maximum bridging score was 263, and 6 of the top 10 scores went to people in the freshwater group. With groups defined by six organization types, average bridging score was 5.2, and people working for NGOs had 4 of the top 10 scores. We mapped node size proportional to bridging score for ecosystem groupings (Figure 1) and organization groupings (Figure 2) to provide visual representations.

The UCINET Core/Periphery Categorical function placed 104 of the 344 collaboration network actors in the core and 240 in the periphery (Figure 3). Among the 47 respondents, 42 (89%) were in the core and 5 (11%) in the periphery. Simply responding to the survey was not enough for an actor to be placed in the core category; respondents that named few collaborative relationships were placed in the periphery category. Within the core,

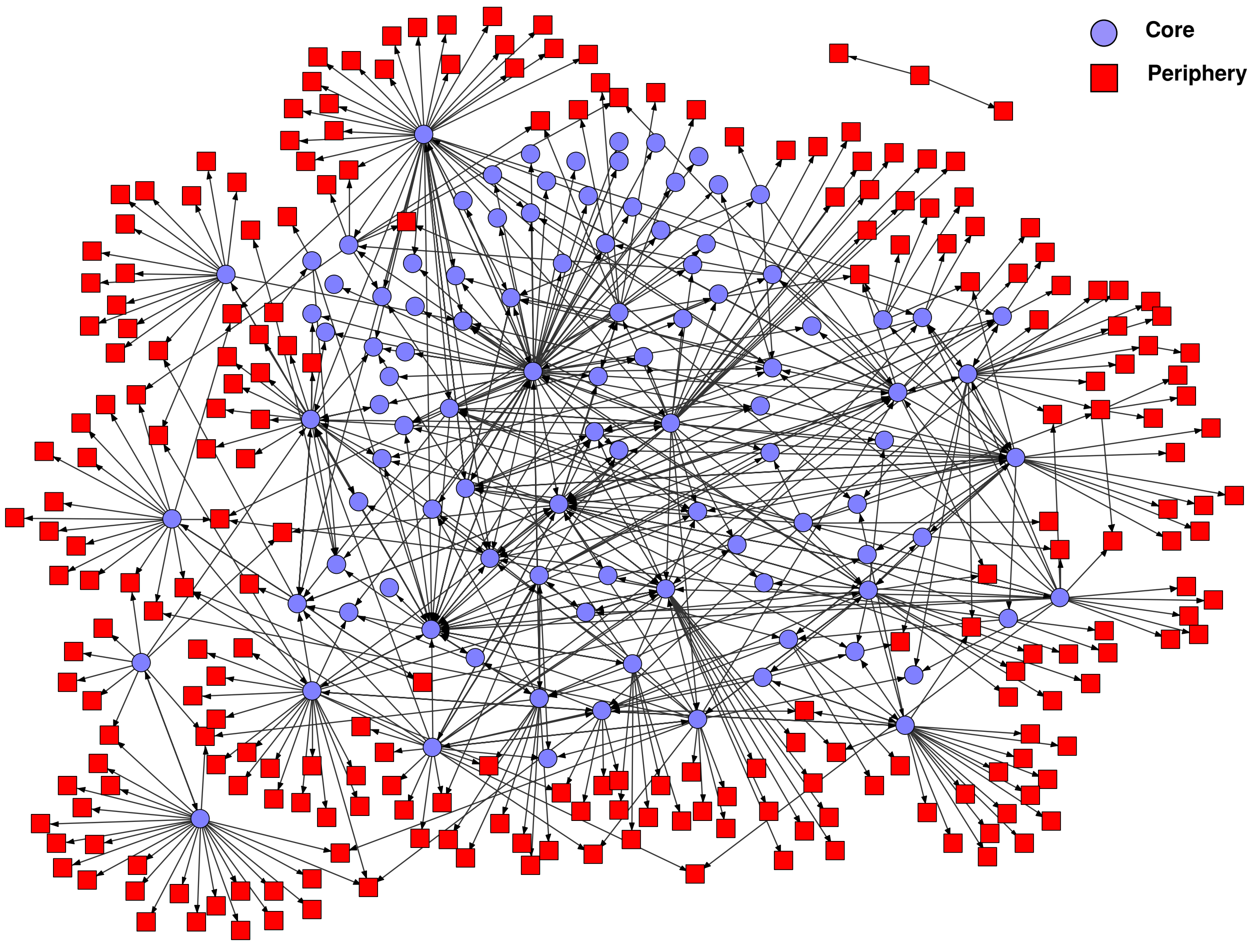

Figure 3 A collaboration network core-periphery model, produced in UCINET using a 500-iteration genetic algorithm.

71% were from Lincoln County, 27% were from elsewhere in Oregon, and 2% were from outside of Oregon. While a majority (53%) of peripheral actors were from Lincoln County, 40% were from elsewhere in Oregon, and 7% were from outside Oregon.

Network interventions

New self-organized projects that emerged from the conversations we had with network participants included:

(1) A successful grant proposal supporting new collaboration between a freshwater youth volunteers organization and a terrestrial county trails group.
(2) Work on an internet-based directory of people in the county working on sustainable natural resources, including their interests and skills.
(3) New collaboration between people from the county solid waste program and the state agricultural extension office to start a yard cleanup program for the elderly and disabled.

In addition, two network participants began doing network interventions with us. They met with people from the county sustainability action committee, a conservation voters group, and a community forest organization, and organized a brainstorming session with people in the network to discuss ways to increase conservation volunteerism in the county.

Discussion

Why pay attention to social networks? One reason is that the complex ecosystems we are concerned with require an equally complex set of people engaged in questions of their long-term management. Engaging stakeholders across the diverse sectors that impact ecosystems is challenging, but may be a key to conservation success

(Cowling & Wilhelm-Rechmann 2007; Pressey & Bottrill 2009). Because impacts spread across multiple ecosystems, conservationists working in terrestrial, freshwater, estuarine, coastal, and marine ecosystems are potential allies for conservation (Sloan *et al*. 2007), but building and maintaining cross-ecosystem collaborations is also challenging. The complexity becomes three-dimensional when levels of governance are considered, because while state or federal levels may set conservation policy, laws, and regulations, much conservation action is local (Pierce *et al*. 2005).

Social network maps and analyses are valuable diagnostic tools in making sense of the complex stakeholder environment. Network analysis can reveal if relevant stakeholder groups are missing or underrepresented, the degree of integration across sectors and levels, and gaps that might need to be filled. Network maps can also help network participants identify new partners, ideas, and resources they need for effective planning and management. At the Hewlett-Packard site in Corvallis, Oregon, attention to knowledge-sharing networks significantly reduced the amount of time and money needed to solve problems in product development, quality, and invention (Sandow & Allen 2005; Senge 2006). Applied conservation could benefit from a tool that reduces problem-solving time.

Network mapping

Network maps were our primary means of presenting our results to network participants, and we produced many others besides those we include here. Although some people had no interest in them or were skeptical of their value, many people in the Lincoln County network were intrigued by the "bird's-eye-view" the network maps provided, enabling them to see for the first time a snapshot, admittedly imperfect, of the complex web of relationships among them (although we did not show names). Maps were useful for us in identifying people to invite to meetings to discuss potential new projects, and in one-on-one discussions with network participants about their position in the network; network tabular data and metrics could not easily provide that level of detail.

Network analysis

Collaboration network density, average degree, reciprocity, and betweenness centralizaton values were all low, in part because only 17% of the named individuals in our snowball survey provided relationship data. Many network metrics were developed for complete networks, in which relationships between all actors are known, and results from sampled networks should be viewed with extreme caution (Ö. Bodin, pers. com.). Thus a priority for our future work will be to continue collecting relationship data from network participants. However, complete network data require establishing a boundary to the group being studied, whereas there are not well-defined boundaries to actual social networks (Doreian & Woodard 1992) such as natural resources stakeholders. One consequence of bounding the network may be to exclude the periphery (Doreian & Woodard 1992), which would be counterproductive in attempting to assess the presence of a diverse periphery that might contribute to sustainable natural resources management. We did not predetermine who constituted the Lincoln County natural resources collaboration network, but relied on respondents to name their collaborators. In the end, respondents made up 17% of all named network participants, but they named nonrespondents frequently enough to identify a core-periphery structure in which 60% of the network core is people who did not take the survey.

Our E-I Index results provided evidence that three of the network characteristics we investigated were present in Lincoln County: cohesive groups of people that collaborate on focal ecosystems, a diverse set of those groups, and collaboration between groups. According to our cross-boundary tabulation collaboration was not evenly distributed between groups. Most striking among the focal ecosystem grouping was the estuary group, which reported almost half of their collaborations to be with people in other ecosystem groups while people in those groups acknowledged little or no collaboration with people in the estuary group. Cross *et al*. (2002) found that interventions to bridge administrative, functional, and other boundaries within a business was one of the most effective strategic uses of SNA. Estuaries are important ecosystems (Schneider *et al*. 2003) for coastal conservation, and enhancing cross-ecosystem collaborations with people working for estuary conservation might increase overall conservation success in Lincoln County. We also found collaboration gaps when groups were defined by organization type, most notably for people working in business.

Bridging scores quantified how many times actors were the link for collaboration between groups. Some actors did a great deal of bridging; even among the top 10 there was a five-fold difference in scores. Bridging actors play an important role in facilitating the exchange of diverse ideas and skills (Prell *et al*. 2009), and likely contribute to greater capacity for innovative problem-solving (Bodin & Crona 2009) in the Lincoln County network.

Similarly, the presence of a large and geographically diverse periphery, the fourth network characteristic we were assessing, was evidence of links to people with resources that might support the work of the actors in the network core. There were two types of links to peripheral actors present: horizontal links to people in the county whose contributions might include local ecological knowledge (Ernstson *et al*. 2008), and vertical links to people outside the county and state that might provide external ideas or decision-making authority (Bodin & Crona 2009) or other resources.

We found that the four network characteristics of within-group cohesion, across-group collaboration, bridging actors, and peripheral actors were present in the Lincoln County collaboration network. However, we could not assess whether the amount or quality of the various characteristics were sufficient for supporting sustainable natural resources management in Lincoln County. In part that was because we had no objective measure of the success of such management, and in part because little is known about the interactions among varying levels of these and other characteristics and the outcomes for resource management under different scenarios (Bodin & Crona 2009).

Network interventions

Relationships require time and energy to maintain (Cross *et al*. 2002) and having too many can be a drawback (Bodin & Crona 2009). The goal of network weaving is not to increase connectivity between everyone in the network, but rather to use network maps and data to help people strategically identify specific others with whom a new relationship might be mutually beneficial. Although only 17% of people named in the collaboration network responded to the survey, the resulting network map enabled us to begin linking people. Discussing network maps with actors, eliciting their ideas about new relationships that might enhance their work, and introducing people to one another, as we did, are among the most basic of network interventions (Krebs & Holley 2004). Yet they fostered the emergence of four self-organized projects that network participants believed would contribute to their goals. Empowerment of stakeholders has been suggested as a way of improving collaborative resource management (Ernstson *et al*. 2008) and conservation implementation (Knight *et al*. 2006); we observed that many of the network participants involved in new projects they designed found it empowering.

Network analysis identified bridging individuals that may be desirable collaborators for conservation work, the "low-hanging fruit" that could readily be identified by other stakeholder assessment techniques (Cowling & Wilhem-Rechmann 2007) besides SNA. But the most central actors do not necessarily represent the interests of everyone (McAllister *et al*. 2008), and social network maps can validate the roles and contributions of everyone in the network (Sandow & Allen 2005). While central actors with many ties to others play a strong role, Granovetter (1983) describes the "strength of weak ties" to peripheral actors that can provide innovative ideas or other resources that are not present among the central actors. Network weaving assumes that everyone in the network has something to contribute, and supports self-organized interventions that can often be more effective than top-down directed action (Sandow & Allen 2005; Ostrom 2009). Strong relational ties are voluntary, and actors are likely to resist top-down attempts to impose them (Bodin & Crona 2009).

Although we had a 42% survey response rate, receiving relationship data from only 17% of the people who were named as participating in the collaboration network was a limitation for our current analysis. Additional data collection is needed to increase our confidence that the structures that emerged with the current limited data sample are a realistic depiction of the network. We also lacked empirical measures of ecosystem conditions to compare to the current collaboration network structures, and to future network structures if we are able to sustain network interventions, to attempt to assess the relationship between ecosystem conditions and conservation stakeholder network structures. Lack of funding to support a paid network weaver position limited the number of interventions we were able to facilitate. Enthusiastic volunteers are invaluable but difficult to sustain for the long term; a paid facilitator would enable more consistent action to develop new relationships for enhancing conservation outcomes. Our follow-up work will attempt to overcome these limitations.

Luke & Harris (2007) assert that SNA has been underutilized in public health research and practice, and we believe it has strong potential as a tool for exploring the relationships between stakeholder network structures and the implementation of conservation actions. Our work suggests that SNA and network weaving may make valuable contributions to conservation outcomes. Conservation biologists rarely have the power to implement conservation actions themselves, and they may wish to consider incorporating SNA into their work and applying the insights gained to weave their conservation stakeholder networks into ones that are more innovative, resilient, and effective.

Acknowledgments

Anne Yemaya and Aaron Vance-Borland helped with survey data collection. Morena Mills, Jorge Alvarez-Romero, Bethany Cutts, Mark Lubell and an anonymous reviewer provided comments on earlier drafts, which greatly improved this article.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. The social network survey questionnaire.

Please note: Wiley-Blackwell is not responsible for the content or functionality of any supporting materials supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

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