# Perceptions of Social Network Influence: Key Players' Insights Into Power, Conflict, and Collaboration at the Bonneville Salt Flats

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## Abstract

Conflict among stakeholders is a familiar challenge to natural resource managers and researchers. Fostering trust and collaboration among diverse stakeholder groups is, therefore, a primary goal for natural resource conservation. One tool often used to understand stakeholder relationships and to foster collaborative conservation is social network analysis (SNA), a method that identifies patterns in social relationships among members of a population using networks and graph theory (Scott 2017). Through an explanatory sequential mixed-methods approach, this study applied SNA to better understand social dynamics among six stakeholder groups associated with Utah's Bonneville Salt Flats (Bonneville; USA). We sought to (1) build social network models (i.e., *sociograms*) depicting Bonneville-related social interactions among stakeholders, (2) identify potentially influential individuals (i.e., key players) in Bonneville's stakeholder network; and engage these key players in (3) 'member-checking' social interaction trends gathered during the data collection year, and (4) discussing perceptions of their network's influential social dynamics. Sharing SNA data and sociograms through semi-structured qualitative interviews with key players verified four seasons' worth of social interaction trends within and among Bonneville stakeholder groups. These conversations also evoked key players' reflection on social power dynamics, social network evolution, the influence of research into the Bonneville social network, and introspection about social connections therein. These emergent themes support applying SNA and qualitative interviews with key players in natural resource social networks to yield valuable information for managers who seek to foster collaboration while avoiding or abating resource-related conflict among stakeholder groups.

## Introduction

Conflict and tension among natural resource users is a common occurrence. Whether related to water rights, land access, recreational activities, or other topics, natural resource management scholarship has no shortage of examples of stakeholders' competing interests. Land managers are often both in the position of arbitrating disputes among stakeholders as well as sometimes facing scrutiny over the resource-related decisions they have

made (Loomis 2002). This position is also the target of scholarship seeking to avoid, abate, or resolve conflict related to natural resources (Daniels and Walker 2012).

In the last several decades, the idea that stakeholders can and should influence environmental decision-making has gained traction, and various forms of stakeholder analysis have sought to improve collaboration among groups with vested interests in specific natural resources (Prell et al., 2009). Crucial for successful natural resource conservation, stakeholder group collaboration

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**Table 1** Conservation goals and the SNA metrics useful for attaining them, with definitions

| Conservation diffusion goal | Relevant centrality* metric | Definition of metric |
| --- | --- | --- |
| Rapid diffusion of conservation information | Closeness | The average shortest distance from a node to every other node. The more central a node is, the lower its total distance to all other nodes. |
| Diffusion between disconnected groups (e.g., information or initiatives) | Betweenness | The degree to which nodes stand between each other. More information passes through nodes with higher betweenness, and thus such nodes may exert more control over the network. |
| Widespread, long-term diffusion of information or complex initiatives | Eigenvector | The influence of a node in a network based on its connections to other high-scoring nodes. |
| Rapid diffusion of complex knowledge or initiatives | Degree | The number of direct connections any node has with other nodes |

*Adapted from* Mbaru and Barnes (2017); * *Centrality refers to indicators that identify important nodes within a sociogram, e.g., the most influential person(s) in a social network*

may benefit from applying social network analysis (SNA), a research method that identifies patterns in social relationships among members of a population using networks and graph theory (Scott 2017). One important aspect of SNA entails identifying potentially influential people—herein referred to as *key players* (Borgatti 2006)—in social networks because of their potential influence in their networks.

Mbaru and Barnes (2017) suggest that key players in social networks are likely to be best positioned to help implement four distinct conservation objectives: (1) rapid diffusion of conservation information, (2) diffusion between disconnected groups, (3) rapid diffusion of complex knowledge or initiatives, or (4) widespread diffusion of conservation information or complex initiatives over a longer period. These authors further suggest that achieving these objectives is attributable to specific SNA metrics (Table 1). Identifying and engaging key players is therefore potentially valuable for the sustainable management of natural resources.

## Research Problem, Purpose, and Questions (RQs)

Seeking to both draw from and contribute to scholarship that helps avoid, abate, or resolve natural resource-related conflicts, we employed SNA and qualitative interviews to illuminate social interactions among stakeholder groups associated with a unique American landscape, the Bonneville Salt Flats ('Bonneville,' US). For over 100 years, natural processes and human activities have converged at Bonneville—an environment that is culturally cherished for the esthetics of its vast, white salt crust and therefore its value as a premier location for breaking land speed records (Kipnis and Bowen, 2018). For decades, concern for Bonneville has centered on the idea that mineral extraction has been compromising

conservation and the resultant suitability of the salt flats for specific forms of recreation, such as land speed racing.[1]

Ultimately, Bonneville represents a vast body of interconnected human and natural elements and processes that change or learn as they interact through reciprocal linkages (as per Levin et al., 2013; Biggs et al., 2015). To help reveal such reciprocities, this study was part of a larger multidisciplinary effort to research various social and ecological phenomena associated with Bonneville, including seeking reasons for the objective decrease in the salt crust. We used SNA to identify Bonneville's key players with whom we conducted qualitative interviews to explore their perceptions of the influence of their network on overall social dynamics, with possible implications for natural resource management.

This study's primary contributions to SNA and natural resource management scholarship are twofold. Although numerous studies employ SNA to identify key players, this study is one of few to engage those influential people in clarifying their social network. We specifically interviewed Bonneville's key players to (a) member-check their social network structure and seasonal interaction trends and (b) solicit their insight and introspection about their social network, including how social dynamics may affect the larger social-ecological system. To this end, our study addressed three primary research questions: (1) *"What is the structure of the Bonneville stakeholder social network?"* (2) *"Who are the potentially influential people (i.e., key players) in Bonneville's social network?"* (3) *"How do Bonneville's key players perceive that their social network structure may influence social dynamics in the larger social-ecological system?"* The goal of this line of inquiry was to (a) explore the utility of using key players as surrogates for their stakeholder groups and (b) to reveal potential implications

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[1] The land speed racing community has a long history of use at Bonneville. Beginning with the first motorcars over a century ago, Bonneville's vast expanse of hard, flat salt has seen speed records increase with each passing decade's technological innovations. Top speeds are now 400–700+ miles per hour depending on vehicle type.

for better managing Bonneville and other natural resources as complex, social-ecological systems.

## Background

### Social Network Analysis and Network Theory

Social network analysis (SNA) endeavors to understand interactions among individuals by quantitatively and graphically mapping their connective relationships in the form of sociograms. Sociograms depict social relationships in terms of *nodes* representing individual people (i.e., *actors*) or groups and the *edges* (i.e., *links* or *ties*) that connect nodes to form a network of relationships. Sociograms can thus be studied to understand the general characteristics of a social network as well as the qualities of specific relationships by enumerating actors' connections and therefore potential influence on other actors. SNA can also be used to examine both the availability and exchange of resources, such as information or other social goods (Wellman and Berkowitz 1988).

Although using SNA to reveal network structure and to graphically portray social relationships are not novel pursuits, contemporary network visualization software helps ease the analysis of complex social structures (Makagon et al., 2012). Additionally, statistical analysis of social networks helps define specific problems as well as to explore the behavior (e.g., function, role, or influence) of specific individuals in the network. For these reasons, it has become more feasible for the conservation community (i.e., scholars and practitioners) to demonstrate how harnessing social networks can contribute to achieving desirable social and environmental outcomes (Groce et al., 2019).

Krupa et al., (2018), also suggest that social SNA is an efficient, objective, and transparent approach to identifying stakeholders in highly contested natural resource management issues. Applied as a tool to help navigate resource-related disputes and stakeholder conflict, SNA thus has the power to help strategically identify key players who may be able to connect to one or more stakeholder groups of which they are integral members. These individuals may be indispensable for disseminating consistent information and encouraging participation in management-related activities across a social network. SNA's utility to illuminate social influences on decision making (Groce et al., 2019) builds on Prell's (2006) declaration that stakeholders should, indeed, influence that decision making. In this manner, SNA and associated stakeholder analysis can be used to fairly represent diverse interests, avoid exacerbating conflicts, and ensure that certain groups are not marginalized (Prell 2006).

Social network theory (SNT; Prell et al., 2009) focuses on the roles that social relationships perform in conveying information, channeling personal or media influence, and facilitating attitudinal or behavioral change (Liu et al., 2017). Fundamental to SNT is the notion that social structure is significant because it can quantify interactional relationships and patterns (Sih et al., 2009). Social interactions potentially influence how new information or behaviors are transmitted throughout groups; one's behavior, that is, can both affect and be affected by the behavior of others (Makagon et al., 2012). SNT also suggests that a network's most central actors—through whom many social interactions can occur—at least partially facilitate the co-creation of stakeholder knowledge. Understanding the genesis or propagation of knowledge and behaviors, therefore, has many potential applications in natural resource management, wherein managers must oversee both ecological and human social aspects of a resource.

Furthermore, Mills et al., (2014) suggest that potential contributions of SNA to conservation planning include (a) identifying stakeholders and their roles in social networks and characterizing relationships between them; (b) designing and facilitating strategic networking to strengthen linkages between local and regional conservation initiatives; and (c) prioritizing conservation actions using measures of social connectivity alongside ecological data. These authors thus propose that SNA has the potential to be a valuable tool to support decision-making in conservation planning. This implication is also consistent with Ostrom and Nagendra (2006), who found that resource users are more likely to follow rules and to monitor others when they are engaged in resource use rule-making, as opposed to when an authoritative entity simply imposes rules.

### Social-Ecological Systems

Along with their associated human actors (e.g., social networks) and institutions (e.g., businesses and government agencies), social-ecological systems (SESs) represent 'bio-geo-physical units' that are demarcated by spatial or functional boundaries embedded ecosystems and their contextual problems (Glaser et al., 2012). Adding to the complexity of SESs are the numerous reciprocities among social and ecological actors and their actions. This ultimately means that SESs are fraught with uncertainties and non-linear relationships (Werner and McNamara 2007), requiring most SES research to target smaller, nested systems with a priori boundaries that help focus inquiry and analysis (Schluter et al., 2014).

Such reduction is not antithetical to SES thinking. It is typically neither desirable nor feasible to study entire ecological or social systems—independently or jointly—at a single scale or resolution (Scholes et al., 2013). Selecting a unit of analysis to justify and logically frame the scale of inquiry is therefore necessary (Berkes et al., 2003). Accordingly, our study sought to illuminate one small

component of social complexity within an SES: key players' perceptions of social network influence on social dynamics, which may reverberate through the larger SES that Bonneville represents. To do this, we first employed SNA to identify key players in Bonneville's social network.

## Study Location

The social network data herein pertains to stakeholders associated with one of the United States' most iconic western landscapes historically unaddressed by social science (Zajchowski et al., 2020). Part of the state of Utah's enormous West Desert, Bonneville is approximately 125 miles west of Salt Lake City bordering Interstate 80. This unique landscape is characterized by a 30,000-acre salt pan representing mineral remnants from the Pleistocene epoch's Lake Bonneville (Turk 1973). At its largest historic expanse, Lake Bonneville was approximately the size of modern-day Lake Michigan, with a maximum depth of over 1000 feet (Hunt et al., 1953). Topographically isolated between 13,000 and 15,000 years ago (Baxter 2018), Lake Bonneville developed into a terminal basin from which water escaped only through evaporation. The mineral content of that historically immense volume of long-since-evaporated water is responsible for the accumulation of salt on the playa floor and in subsurface brine aquifers.

The United States Bureau of Land Management (BLM) oversees Bonneville as a Special Recreation Management Area. Specifically, Bonneville is managed for (1) dispersed and unconstrained recreation including automotive land speed racing, rocketry, foot races, cycling, and diverse artwork; as well as for (2) corporate mineral extraction of (a) potash—used for manufacturing synthetic fertilizer; and (b) culinary and industrial salt. These recreational and extractive relationships with Bonneville were established over 100 years ago (Mason and Kipp 1997). In recent decades, however, impacts to the natural processes that form and sustain Bonneville's characteristic salt crust have fueled tension among several stakeholder groups. The large land speed racing community, for example, is concerned about the future viability of Bonneville's salt crust for facilitating record-breaking speeds. Specifically, adequate thickness, dryness, and length of racecourses are necessary for safe acceleration to—and deceleration from—speeds of hundreds of miles per hour. Responding to ongoing concerns of diminishing salt, the BLM completed an Environmental Assessment in 2012 (EA #UT-020-2006-002, August 2012) and issued a Decision Record that required a nearby mineral extraction operation to continue Salt Laydown—a project begun in 1997 to balance the sodium chloride extracted from groundwater brine with brine returned to the flats during the winter season ('Salt Laydown'; White, 2013)—for the life of its extraction lease (DR September 2012).

Although Bonneville's stakeholder groups share a desire for sustainable use of the salt flats, they also recognize that the complexity of its overall system requires robust research to inform management and decision-making. Toward this end, both the long history of scientific investigation and stakeholder engagement at Bonneville have long-provided input for federal land management. This history was expected to provide fertile ground for studying stakeholder interactions through analysis of Bonneville's social network.

Along with others involved in social network scholarship, we suggest that it is important to validate the structure and function of a quantitative social network. Therefore, we solicited insight from the key players identified through SNA regarding the accuracy of our data through semi-structured interviews. These interviews revealed insightful perceptions regarding the influence of Bonneville's social network on social dynamics associated with this iconic natural resource.

## Methods

We used an explanatory sequential mixed-methods approach (Creswell and Plano-Clark 2017) with an additional exploratory component to reveal important structural characteristics of the Bonneville stakeholder community. Data collection consisted of (1) four seasonal quantitative surveys to gather social network data from Bonneville stakeholders to (a) reveal social network structure and (b) to identify key players in the Bonneville community; and (2) qualitative interviews with key players to (a) member check the study's quantitative SNA findings; and (b) investigate key players' perceptions of the social network's influence at Bonneville.

### Participant Sampling

We identified initial participants by their recorded attendance at a Bonneville summit hosted by the University of Utah in the fall of 2015. Each of these participants was identified with a Bonneville-related stakeholder group[2], including community members from (1) Academic/Scientific research, (2) Land Speed Racing, (3) Land Management, (4) the city of Wendover and greater Tooele County, Utah, and (5) the Media. The Mining and Industry community—a sixth group—also shows up in this study

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[2] Stakeholders referred to in this study are members of one of several a priori groups associated with the Bonneville Salt Flats. Deeper, theory-based stakeholder definition, identification, or selection was not the focus of this study.

through referrals and post-SNA interviews, despite non-participation in SNA surveys.

We used participant referral sampling (i.e., snowball sampling) to identify and engage other individuals. Next, we distributed the individual-level SNA online survey with the Qualtrics Research Suite four times during 2018. Using a modified Dillman (Hoddinott and Bass 1986) approach, this step of the sampling process captured a full year of Bonneville-related social interactions among participants. Initial telephone solicitation of 20 stakeholders for SNA survey participation yielded referrals to 74 additional Bonneville-affiliated individuals, for a total of 94 total names that survey participants could select to identify with whom they interacted each quarter.

## Instrumentation

The surveys contained three questions about significant Bonneville-related interactions—i.e., conversations, meetings, email, or phone calls lasting approximately two minutes or longer—that each participant had with other individuals during the previous three months. Each survey requested that participants (1) select from a list of names with whom they had contact regarding Bonneville during the previous three months; and (2) quantify interactions with each individual in terms of (a) total number, (b) average duration in minutes, and (c) average importance on a seven-point Likert-type scale (1 = "very low" to 7 = "very high").

## Data Formatting and Analysis

We used Excel (Microsoft, 2019) to clean and restructure Qualtrics data for compatibility with *Gephi 0.9.2* (Bastian et al., 2009), an open-source software package used for network visualization and analysis. We then used IBM's SPSS (version 26) to perform multiple imputation of missing interaction values attributed to survey incompletion (Huisman 2000; Rubin 1987). These imputed values comprised 82 interaction counts, 107 interaction durations, and 71 ratings of interaction importance. The total number of imputed data values (260) comprised approximately 16% of the total data. With imputation complete, we proceeded to calculate *edge weight* for Bonneville-related social interactions. As the product of *frequency, duration*, and *importance of conversations* (i.e., number of interactions, average interaction length as a percentage of one hour, and rating of 1–7 on Likert-type scale), this edge weight represents the relative 'value' of Bonneville-related social interactions between actor pairs for semi-quantitatively comparing these interactions at both individual and group levels. Edge weight was also used to calculate *weighted degree*, wherein the edge weight is multiplied by an actor's *total degree*—a measure of the number of direct connections an actor has

with other actors—regardless of their group affiliation. Weighted degree is thus useful for comparing the relative influence that certain actors may have in a social network compared to others.

After calculating edge weights, we imported the restructured data as an *edge table* into Gephi. This table contained all reported interactions as well as weighted edge values representing the three measures of each of those interactions.

## Sociograms and Network Structure (RQ1)

With the final, completed dataset, we used Gephi to construct (a) an unweighted and undirected sociogram at the actor level, (b) a model that shows the structural results of removing potentially influential actors, and (c) a weighted and directed sociogram at the group level. The sociograms revealed the network structure at the individual and group levels (Fig. 1). Analytically, we used Gephi's Force-Atlas algorithm, which treats the distance between any two actor nodes as a function of the strength of the edge connecting them. Often used with weighted network data to show the attractive forces within groups, Force Atlas arranged the Bonneville network into communities with strong relationships that emerged as a product of repeated interactions among actors during the data collection year despite being unweighted by interaction frequency, duration, or importance. These relationships are therefore reinforced by multiple reports of pairwise interactions between individuals. When one actor reports an interaction with another actor, an edge relationship is established; if that second actor also names the first, the strength of that edge is thus doubled, allowing Gephi to easily render overall group cohesion.

## Identifying Key Players (RQ2)

We used three *centrality* scores—i.e., closeness, betweenness, and eigenvector—in addition to both (a) weighted and (b) total *degree* scores from SNA data to identify key players. Table 1 contains definitions and justification for using these measures, as per Mbaru and Barnes (2017). Next, we selected the two actors from each of the six a priori stakeholder groups who had the highest degree and centrality scores.

## Social Network Influence on Bonneville Social Dynamics (RQ3)

Eleven of the twelve key players participated in qualitative interviews. We provided them with individual- and group-level sociograms produced in Gephi, noting that they were identified individually by a numbered, anonymous node in the social network (Fig. 1). We then conducted audio-recorded, semi-structured telephone interviews (Seidman 2013) with these participants to

**Fig. 1** This undirected and unweighted sociogram shows pairwise social interactions that SNA respondents reported during data collection year. Each circle (i.e., *node*) represents a Bonneville stakeholder identified by an anonymous number; each connecting line (i.e., *edge*) represents one or more interactions between two nodes. Key players are identifiable by the numerous edges emanating from their nodes (i.e., nodes 138, 222, 450, 324, 396, 330, 342, 297, 207, 156, 213, and 159)
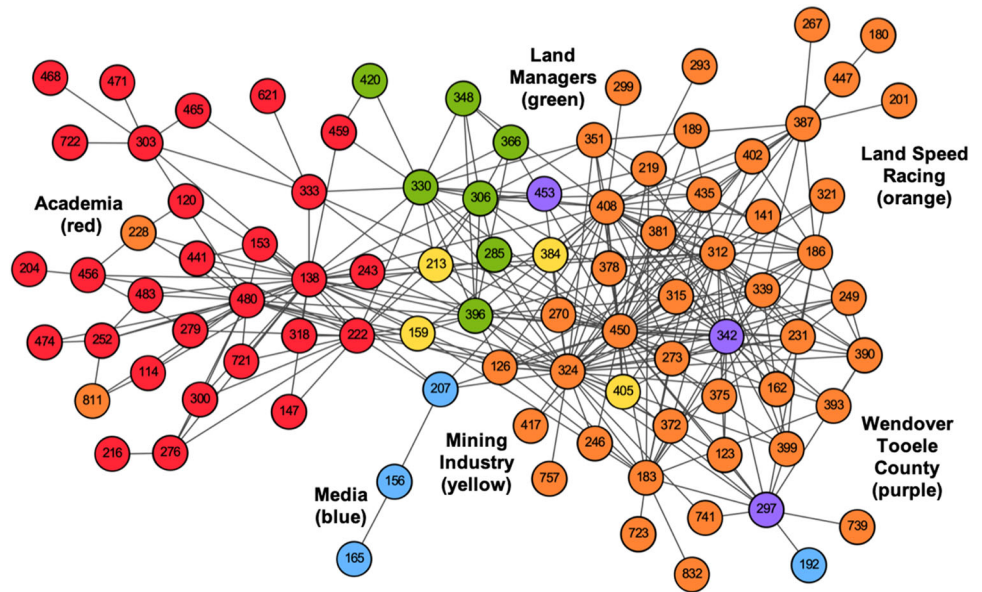


corroborate (a) relative positioning of Bonneville's stakeholder groups in reference to one another, and (b) social interaction trends in terms of seasonal frequency, duration, and importance of interactions for the data collection year (i.e., member-checking; Creswell 1994). During the first part of each interview, we displayed and verbally described the structural characteristics of the sociograms in terms of the meaning of the colors, numbers, lines, and layout of nodes and clusters. We then verbally described seasonal, group-level interaction trends for each participant's community. We also shared a graphic of each participant's highlighted connections, such as those shown in Fig. 2 to help them understand their position and connections within the sociogram. In the second half of each interview, we solicited their insights into how the social network potentially influences social dynamics related to Bonneville. These conversations confirmed seasonal interaction trends, SNA structure, and helped identify inductive emergent themes (Creswell and Plano-Clark 2017) related to RQ3 through open coding. Following the selection of quotations to represent these themes, we solicited participants' permission to use their quotations herein; all eleven individuals granted permission with the understanding that although identified with their stakeholder group, they would remain anonymous.

## Results

SNA survey participants selected individuals with whom they had Bonneville-related social interactions during the data collection year. In total, 37 unique individuals supplied

survey responses that characterized 556 Bonneville-related interactions during the data collection year.

### Bonneville Social Network Structure (RQ1)

The sociogram in Fig. 1 shows Gephi's automated clustering of six a priori stakeholder groups in this study. Whether regarding internal or external communication, the Academic and Land Speed Racing communities reported the highest number of Bonneville-related social interactions. The abundance of these interactions is influenced by these two communities (a) having many individuals and (b) the highest level of SNA survey participation in the study. Showing few actor nodes, Industry, Media, and Wendover/Tooele stakeholders are least represented in the sociogram.

The final tally of stakeholders represented in the social network totaled 91 individuals who engaged in 375 person-to-person social interactions related to Bonneville. By percentage, 49.5% of these individuals represented the Land Speed community (orange nodes), 30.8% represented Academia (red nodes), 7.8% represented Land Managers (green nodes), 4.4% represented Mining/Industry (yellow nodes), 4.4% represented Media (blue nodes), and 3.3% represented the local Wendover-Tooele community (purple nodes). See Table 2.

### Identification of Key Players in Bonneville Stakeholder Communities (RQ2)

The individual-level sociogram in Fig. 1 visibly revealed influential hubs of important activity attributable to specific individuals. From each of the six stakeholder groups,
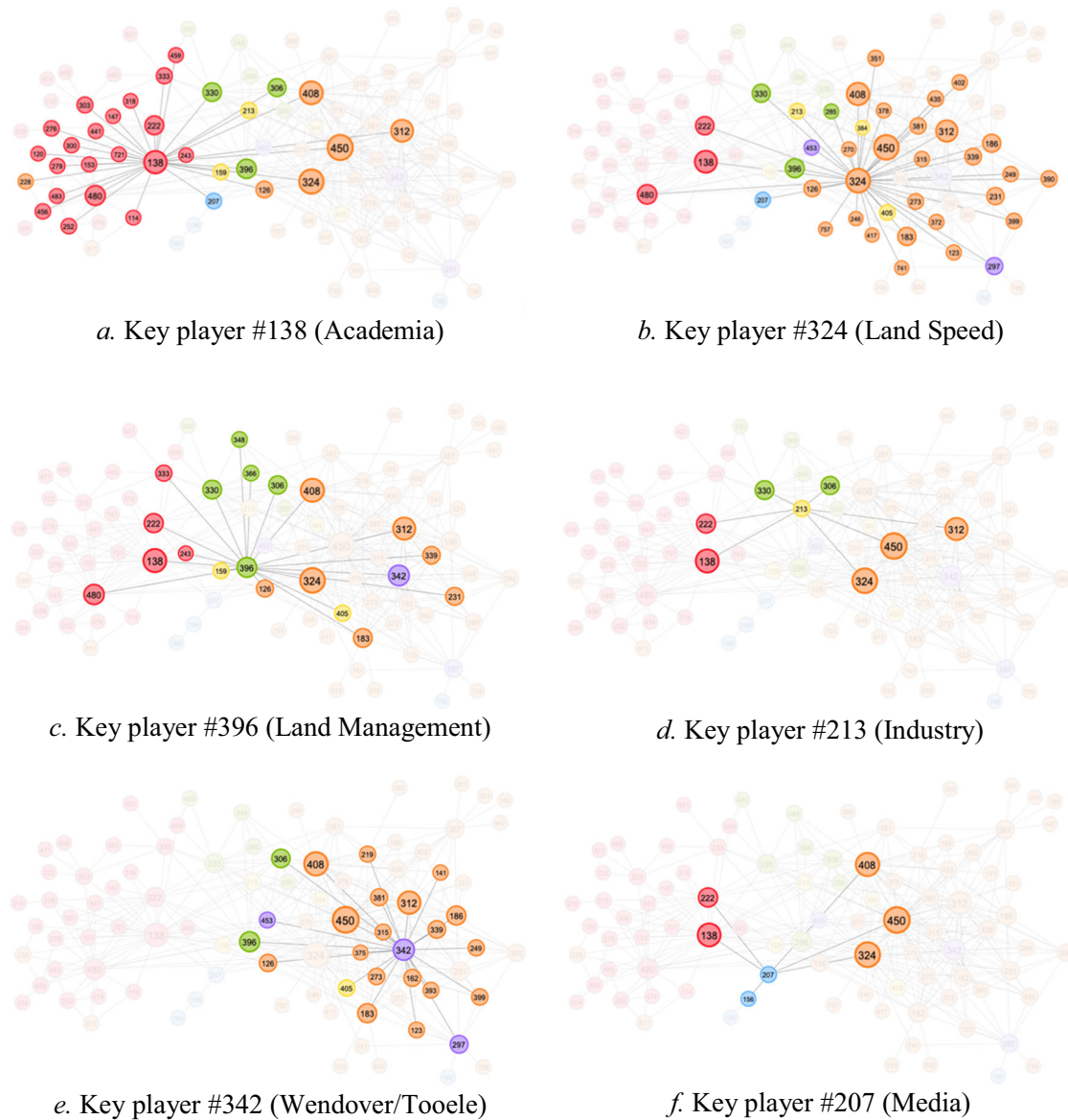
*a.* Key player #138 (Academia)

*b.* Key player #324 (Land Speed)

*c.* Key player #396 (Land Management)

*d.* Key player #213 (Industry)

*e.* Key player #342 (Wendover/Tooele)

*f.* Key player #207 (Media)

**Fig. 2** Highest-scoring key players, their placement, and connections in the social network. These six images represent only half of the key players who participated in this study; the remaining five key players helped 'hold' the network together, as well

we identified the two individuals with the highest total degree and centrality scores as "key players". These twelve individuals' scores signify their importance for connectivity internally within their own stakeholder groups as well as externally with other stakeholder groups (see Table 3).

The graphs in Fig. 2 highlight key players' placement and connections in the unweighted sociogram. These graphs help visualize key players' connectedness and influence in Bonneville's social network as well as their ability and/or authority to assess social interaction trends in the SNA data. The cohesion that key players provide in the network can be seen when they are removed from the unweighted sociogram, which results in disconnected

groups, isolated nodes, and thus decreased network connectivity (see Fig. 3).

## Aggregated group-level sociogram

Figure 4 displays the weighted and directed sociogram of social network interaction trends at the stakeholder group level. The numbers in this graph represent the subjective relative value or significance of interactions with edge weights—as the product of frequency, duration, and importance of social interactions—for internal (inside nodes) and external (at arrowheads) communication. For example, the arrow noted with "1.17" represents key players from Wendover/Tooele reporting interactions with the

Media community; Media did not report those interactions, hence no arrowhead in the other direction. 'Loops' on nodes represent internal interactions quantified by in-node values (e.g., 0.55 for Media represents interactions reported within the Media community). These numeric values speak only to the relative 'weights' of reported interactions; accordingly, higher weights represent combinations of more numerous, more lengthy, and/or more important interactions. Table 4 provides in-, out-, total, and weighted degree values related to the group-level sociogram.

Although the Industry/Mining community did not participate in the SNA and therefore reported no interactions, most other groups did report interacting with Industry/Mining individuals. Academia reported interacting with all groups except Wendover/Tooele and Media, despite Media reporting interactions with Academia. Land Speed interacted with all groups, although

Media did not report interactions with Land Speed. Land Managers reported interacting with all groups except Media. Land Speed and Wendover/Tooele reported interacting with Media, though Media itself only reported interactions with Academia. All stakeholder groups except Industry/Mining (which did not participate in the SNA survey) reported internal Bonneville-related social interactions, as noted by in-group edge weight values inside each node in Fig. 4 (e.g., 0.55 for Media represents the average product of frequency, duration, and importance of Bonneville-related social interactions reported within the Media group). Edge weights for external communication are represented by the values adjacent to arrowheads for group-to-group, Bonneville-related social interactions (e.g., 1.63 represents the edge weight of interactions that Media reported with Academia).

Land Speed's degree count represents the most Bonneville-related connectivity with other groups ($D_{total} = 10$) while Academia boasts the highest weighted degree ($D_{wtd} = 55.8$) (see Table 4). Most unweighted degree values are similar across groups, but once weighted by the product of frequency, duration, and importance, those degree values increased substantially.

## Perceptions of Social Network Influence on Bonneville Social Dynamics (RQ3)

During semi-structured interviews, participants (i.e., key players) validated the sociogram in Fig. 1 and the social interaction trends that it depicts. Although offering minor suggestions to possibly make it more accurate, participants did not dispute the sociogram's general depiction of the social

**Table 2** Network structure metrics for individual-level sociogram of Bonneville stakeholders across data collection year

| Metric | |
|---|---|
| Number of participants | 37 |
| Nodes (Actors) | 91 |
| Edges (Interactions) | 375 |
| Average degree (per actor) | 4.12 |
| Ave. weighted degree | 30.7 |
| Network diameter | 6 |
| Graph density | 0.046 |
| Modularity | 0.617 |
| Ave. path length | 2.59 |

**Table 3** Centrality and degree scores for star actors in the Bonneville social network

| Stakeholder group | Actor/Key player ID | Centrality | | | Degree | |
|---|---|---|---|---|---|---|
| | | Closeness | Betweenness | Eigenvector | Weighted* | Total |
| Academia | 138 | 0.59 | 1289 | 1.0 | 987 | 46 |
| | 222 | 0.48 | 131 | 0.54 | 480 | 24 |
| Land Speed Racing | 450 | 0.71 | 157 | 0.51 | 10 | 44 |
| | 324 | 0.68 | 803 | 0.42 | 331 | 43 |
| Land Management | 396 | 0.51 | 350 | 0.80 | 292 | 25 |
| | 330 | 0.47 | 109 | 0.61 | 167 | 22 |
| Wendover/ Tooele County | 342 | 0.54 | 190 | 0.37 | 336 | 28 |
| | 297 | 0.48 | 72 | 0.15 | 171 | 14 |
| Media | 207 | 0.37 | 86 | 0.14 | 11 | 6 |
| | 156 | 0.28 | 0.00 | 00 | 0.19 | 2 |
| Mining/Industry | 213 | 0.00 | 0.00 | 53 | 36 | 7 |
| | 159 | 0.00 | 0.00 | 0.46 | 32 | 6 |

*Note*: Mining/Industry stakeholders did not participate in SNA but were identified by other stakeholders.
*Weighted degree based on edge weights. Edge Weight = (# of Interactions) × (Avg. Duration of Interactions as a percentage of one hour) × (Importance on a scale of 1–7).

**Fig. 3** The Bonneville social network with key players removed, resulting in network fragmentation. Compare with Fig. 1
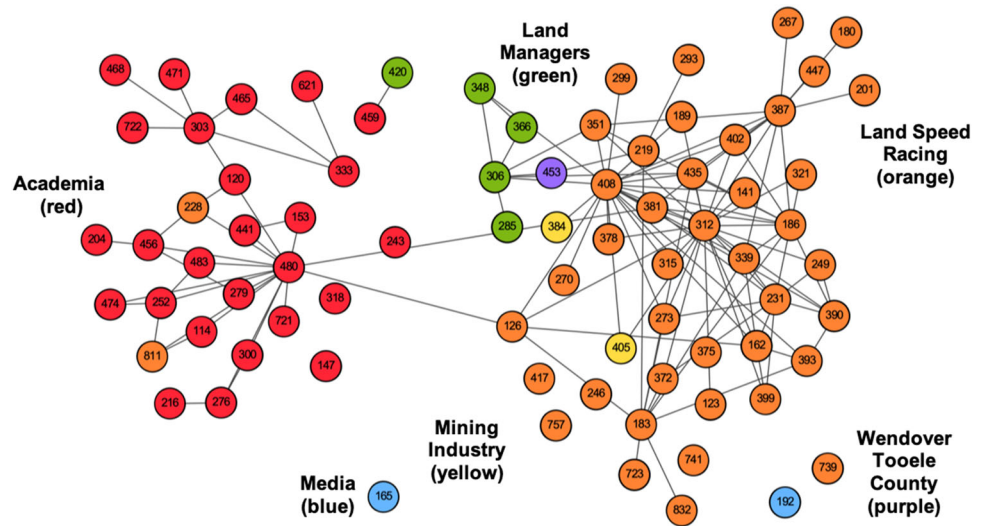


**Fig. 4** This group-level sociogram shows *directed* and *weighted* (i.e., the product of *frequency, duration,* and *importance*) Bonneville-related social interactions (i.e., arrows as *edges*) among stakeholder communities represented by colored *nodes*. Arrows between nodes represent interactions reported by each group with another group. Within-group interactions represented by in-node values and loops on nodes
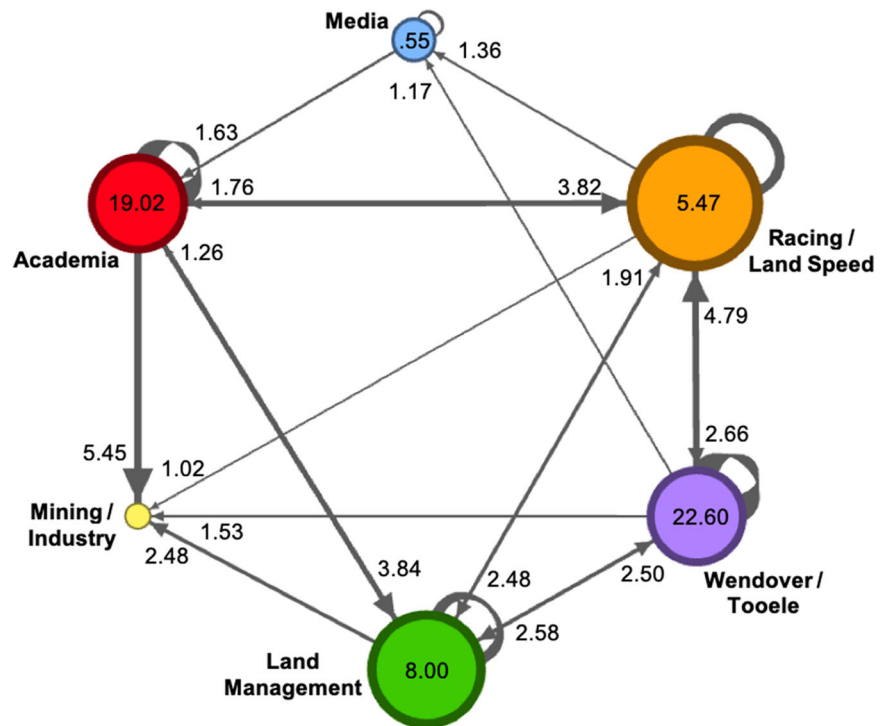


network in terms of relative group size, groups' relation to one another, or general connectivity. We then addressed RQ3: *How do key players perceive the influence of their social network structure on Bonneville's social dynamics?* Participants shared four primary themes regarding (1) the influence of power and authority; (2) social network evolution; (3) the influence of research on the social network and the larger SES; and (4) self-reflection. These themes are represented in the subheading statements below with representative quotes and interpretation.

## Both formal and informal authority at Bonneville have power in the social system

Several participants began their response to RQ3 with commentary on the position of the stakeholder groups relative to one another in the sociogram:

> "It makes sense to me that hovering in the middle are the land managers and the members of [the mining] industry because ultimately these are the individuals

**Table 4** Aggregated, directed, and weighted structural characteristics for group-level BSF social network (Data Collection Periods 1–4)

| Stakeholder group | Degree | | | Weighted degree | | |
| --- | --- | --- | --- | --- | --- | --- |
| | In-degree | Out-degree | Total | In-degree | Out-degree | Total |
| Academia | 4 | 4 | 8 | 23.67 | 32.13 | 55.8 |
| Land Speed Racing | 4 | 6 | 10 | 15.99 | 14.75 | 30.74 |
| Land Management | 4 | 5 | 9 | 16.9 | 16.15 | 33.05 |
| Industry/Mining | 4 | 0 | 4 | 10.48 | 0 | 10.48 |
| Wendover/Tooele | 3 | 5 | 8 | 27.76 | 32.67 | 60.43 |
| Media | 3 | 2 | 5 | 3.08 | 2.18 | 5.26 |

that have the authority under which activities occur at Bonneville."

-and-

"Racing and research have become connected through a number of key nodes as we see in the [social network] model… Ultimately, those interactions pass between and through and around the Land Managers and the mining industry."

These quotes and others illustrate the intermediary role that some community members serve at Bonneville in between other communities, some of which wield considerable legal authority—such as federal land managers—to allow or disallow certain activities at Bonneville. These quotes thus demonstrate key players' recognition of power dynamics regarding the use and management of Bonneville and the significance of the positioning of those powers in its social network.

One participant from Land Management commented on the influence of non-managerial stakeholder communities on the system. Specifically, this person suggested that the Academic and Land Speed communities provide much of the knowledge that informs Bonneville's management:

"Looking at the [social network] model… I think that the interactions that have the most potential to influence a change in the management of Bonneville [are the ones in] the research [i.e., Academic] community. We also change management based on what we hear from the [Land Speed] racers. In terms of how we communicate with the public—it depends pretty heavily on what we hear from the scientists [and racers] and both of those have helped us change over time with how we communicate about the salt flats."

This quote acknowledges that certain groups (i.e., the racing and academic communities) can affect the SES when

their influence is channeled through an authorized entity such as the BLM. Furthermore, this individual suggests that quantitative information derived from interactions with the Academic and Land Speed communities informs land managers' communication with the public; this, in turn, may affect the way that the public interacts with the resource. The cumulative impact of tens of thousands of visitors upon a resource thus represents a large-scale physical effect of seemingly distant social interactions among stakeholder groups.

This sentiment seems echoed by the following statement, wherein a Media participant suggests their own community's impact on Bonneville:

"To a degree, the media will affect public perception, and if public perception to some degree affects function and management [of Bonneville]… then I guess there would be influence there."

This quotation suggests that the media—through due diligence to report on salient Bonneville storylines—hypothetically affects public perception, and therefore possibly how the public interacts with Bonneville. Just as knowledge constructed by the Academic and Land Speed communities to inform management, Media also has the power to broadcast influential information to the public, who—while they could be considered stakeholders—are not directly or heavily involved in most of the social and ecological phenomena at Bonneville (e.g., mining or racing activities). Nonetheless, the power of that information may influence how the public regards and interacts with Bonneville.

The previous quotation's sentiment is expressed more dramatically by another participant. This person suggested that the media—although underrepresented in the sociogram—drew from the lived experiences of the Land Speed community in telling stories to "light the match" that culminated in the blaze of research of which this study is a part:

"The blue interactions [i.e., Media actors] are severely deficient in this model. There's no doubt in my mind

that the media community is underrepresented, and it is not shown to be as powerful [as it actually is]… To be honest, frankly, you and I would not be talking [about the Bonneville social network] if it had not been for the media… [who] blanketed the country [with news of the salt decline] and [shined] an absolutely glaring spotlight on the [salt crust decline] problem… You can't care about something you don't know about!"

The last part of this quote further suggests the power of the media to inspire awareness and concern for Bonneville, which may result in support for certain conservation initiatives. More pointedly, this actor is suggesting that the Land Speed community's rallying cry—broadcasted by the media—spurred the most recent endeavors to study and invest in the conservation of Bonneville's salt crust.

## Bonneville's social network has evolved over time and will continue to evolve

Several participants briefly suggested that the social network we measured may be different than it was in the past or would be in the future. One participant, however, suggested examples of how groups and interests related to Bonneville change and interact differently over time:

"The communication structure has changed a little bit over the years… with the emergence of [specific individuals] from the racing community that became the point of contact between mining and racing…. The [communication with the] BLM stays consistent… Academic [communication] is going to be declining [as the current studies wrap up]… We'll see how the Salt Laydown goes… you'll probably see the frequency of all discussions go up… and you'll have other players—the State [of Utah] USGS and DNR—managing that [salt laydown] project…"

The nature of any complex system is to generally change over time and also for its various parts to adapt, changing in relationship to one another (Bodin and Crona 2009). Social network dynamism thus entails individuals and communities continuously changing in size, makeup, purpose, goals, etc. in response to the varying forces drawing them together. As suggested in the previous quotation, Academia is periodically called upon to study Bonneville—such as through this SNA study—and academic actors become temporarily prominent, subsequently receding when their work is completed. Although Academia will probably never completely disappear from the social network, its influence during such research cycles is perhaps different from

perennially connected stakeholder groups; this influence relates to the next emergent theme.

## The Bonneville social network is potentially affected by studying it

While providing a nod toward the evolution of the Bonneville social network over time, an academic participant suggested that this study and its encompassing SES research have the potential to generate internal bias and network influence:

"Before the NSF grant [to study the salt crust], Academia would not be in the model… and if you include the [principal investigators] of a study, they're going to be highly represented [in the sociogram]… we included a social scientist and his graduate students on the grant… then it occurred to me that we engaged the [Academic] community [in SNA and interviews] and documented it…There's something kind of funny and profound and laughable and truly fascinating about all that…"

This person thus suggested two things: (1) that, by including academia in the sociogram we are measuring the influence of our own research, and (2) that the very nature of research into Bonneville's social network may have an impact on Bonneville as a system. Both points speak to the reciprocity of social and ecological interactions in a complex SES. Our SNA study, as suggested by this participant, yielded network data that may reflexively impact the network—either directly or indirectly through the Land Management community who, as suggested previously, draws from the knowledge of Academia to inform some management actions. This is a noteworthy point because one of the intended applications of academic research is, indeed, to inform policy-making in whatever field that research is performed. So, too, might this study's qualitative interviews help inform policy because of the things that we specifically asked key players to consider about their social network and its influence on Bonneville (i.e., RQ3).

## Reflecting on the social network has an effect on perceptions of its influence

Upon examining the individual and group-level sociograms, some of the key players pondered their connections to other actors and their role in the Bonneville network. Thus, seeing the graphic SNA data evoked interest in interacting more widely and perhaps more intentionally within the network. The following statement from an Academic participant goes deeper into the idea that this study itself might have affected

the social network in question, and by extension, the overall SES.

> "Looking at all those nodes in [the social network] and my place within it, there's clearly a lot of people that I should talk to because I'm not as connected to many of those nodes as I would like to be."

This participant is thus suggesting that despite knowing that there are many individuals in the Bonneville stakeholder community, seeing them illustrated in the sociogram makes it clear that there are many other people with whom they should probably engage more regularly. This also suggests the potential utility of sociograms as navigable maps of stakeholders that could help improve network communication. Although we include this quotation here as evidence regarding perceptions of the social network, it could also be construed as supporting the previous emergent theme that the Bonneville social network is potentially affected by studying it. That is, if one's changed perceptions motivated them to differently engage in interactions with other actors, such changes could potentially lead to different interaction patterns and network structures.

More philosophically, one actor pointed out seemingly paradoxical representations of stakeholder communities and their relative power to influence Bonneville's social-ecological system:

> "Well… thinking about the density of lines [representing interactions, i.e., edges in the sociogram] between different communities relative their actual impact or power within the landscape. Extractive industries are not well represented [in the model] and yet financially and resource-wise and ecologically—they are doing a lot [in terms of systemic influence]. The racers show the strongest presence, with the most lines [i.e., edges in the sociogram], but does it mean that they get to have—that they should have?—the power, you know, to determine what happens in the system?"

This participant is speaking explicitly to the sociogram's imprecise portrayal of the power of the mining industry. While this statement might be perceived as evidence for the previous theme regarding power, we suggest that it more pointedly addresses the sociogram's potential to provoke critical thinking about the relative power of certain stakeholder groups to influence social and ecological phenomena at Bonneville.

Despite the thoughtfulness that interview participants demonstrated during these qualitative interviews, one of them suggested that it is easy to get wrapped up in one's own group and its perspectives and interests:

> "I think all of the departments probably have to step out of their comfort zones more to get a valid picture [of the whole Bonneville system]."

While succinctly stated in this case, numerous other less explicit statements suggested similar sentiments—that as part of a specific community, stakeholders are nonetheless bound into relationships with other communities as well, which makes them all a part of the Bonneville community at large.

Overall, key players offered valuable perceptions of the influence that the social network may have on both the ecology and management of Bonneville as a complex SES. They also demonstrated how discussing sociograms of Bonneville's social network could provoke conversation around numerous themes that are worthy of broader and deeper consideration.

## Discussion

This social network study endeavored to illustrate and understand the social network connections among stakeholder groups associated with Utah's Bonneville Salt Flats. Because social network structure can significantly impact how actors interact and ultimately behave, understanding social networks has implications for managing natural resource challenges (Groce et al., 2019). Accordingly, we identified and engaged key players in the Bonneville social network through semi-structured interviews to discuss their perceptions of (a) sociogram accuracy, (b) the influence of social network structure on Bonneville's overall social dynamics, and (c) how social dynamics might influence the ecology and management of the greater social-ecological system that Bonneville represents. The remainder of this discussion will unpack our major findings and their corresponding implications for natural resource management before addressing the study's limitations, additional considerations, and directions for future research.

### Major Findings and Implications

Member-checking the social network data and sociograms with key players was a valuable exercise. They deemed the sociograms representative of general in- and out-group social connections, despite some imprecision regarding the size of the overall Bonneville social network and its stakeholder groups. We also member-checked seasonal, group-level interaction trends with key players—i.e., mean frequency, duration, and importance of in- and out-group communication—and solicited their perceptions of our data's accuracy. Overwhelmingly, they attested to the general accuracy of those trends and were often able to

explain the driving forces behind them. These explanations primarily included specific events (e.g., meetings) and the seasonal timing of racing-activity-related communication within and among stakeholder groups.

Following the discussion of the sociograms, we invited key players to share their perceptions of how the structure of their social network might influence social dynamics and ultimately the larger social-ecological system that Bonneville represents. Henceforth, we present an overall synthesis of the four themes described in the Results section and their implications for natural resource management.

### The influence of power and authority

Several key players were intrigued by the positioning of the BLM as mediator and moderator between the larger communities of Academia and Land Speed Racing, both of which contain numerous members. Though small in relative stature, the Mining Industry is necessarily connected to the BLM and additionally finds itself between Academia and Racing, despite its very different relationships with these two groups. Taken together, the sociogram presents not only the positioning of these groups but also the potential push-and-pull of information or other resources that these groups partially control. As some key players pointed out, this illustration of power dynamics has the potential to provide insight into SES functioning.

### Social network evolution

Bonneville's social network has and always will change in terms of (a) both gaining and losing stakeholder groups periodically for various reasons; (b) which groups or individuals have the power to inform or make decisions; and (c) both strengths and weaknesses of internal and external network ties (i.e., the increase or decrease in individual or group interactions). Recognizing and anticipating these fluxes is an important part of entering into collaboration for natural resource stewardship (McCool et al., 2015). As expressed by one respondent, "getting out of one's comfort zone" is important for gaining perspective—an implication that is applicable for natural resource managers as well as other stakeholder groups. This echoes Prell's (2006) declaration that stakeholders should, indeed, influence decisions regarding natural resource management.

### The influence of social network research

Although scientists have studied the Bonneville Salt Flats in different ways over the last century, this SNA study was one of the first to address Bonneville's social dimensions. As empirical inquiry at Bonneville becomes more common, the academic community will likely continue to be prominent in the Bonneville social network, especially during times of study or in the event of unforeseen social or ecological occurrences that warrant scientific opinion on the resource. This is a salient point for other academic researchers engaged in natural resource management studies. Specifically, when an academic community is not already part of a specific natural resource-related social network, care should be taken to consider the extent to which academics should be included in SNA because of their potential—and perhaps unique—network influence.

As noted in many texts, though (e.g., Esch, et al., 2018; Meffe et al., 1998; Sexton 1998), natural resource management is reliant on the best available science—much of which is generated and interpreted by non-agency researchers, such as those at institutions of higher education. Thus, the prevalence importance of researcher-agency relationships reinforces the idea that researchers (e.g., academics) are indeed part of a resource's social network and therefore have a connective influence on the network, albeit to varying degrees. Furthermore, actively building and maintaining relationships among managers and researchers through discussions, meetings, workshops, or field days can increase the likelihood that research outcomes will inform policy decisions (Gibbons, et al., 2008).

### The value of self-reflection

An unexpected finding in this study was the fascination that several key players expressed regarding the SNA. Although some were not surprised by what they saw in the sociogram, they were nonetheless intrigued by what it might mean for the relative relationships among Bonneville's stakeholders. Their responses suggest that sharing the sociogram more widely—i.e., with the entire social network—might inspire a more extensive discussion of how Bonneville's stakeholders are connected. This is similar to the earlier quotation regarding how "you can't care about something you don't know about".

Key players' genuine interest in discussing the implications of social network structure suggested that there is value in making an intangible concept into a tangible one. A common endeavor for natural resource, historic, and cultural interpretation professionals, relating tangible concepts to intangible ones is recognized as a powerful tool for synthesizing knowledge and potentially changing behavior (e.g., Beck et al., 2002). Key players' positive response to our sharing graphic network data suggests that if other Bonneville actors could see these sociograms, they might better understand and appreciate their role in their social network. If this is the case, sharing stakeholder sociograms for other natural resources might contribute to more meaningful collaboration and consensus among diverse parties regarding management actions.

Such a prospect is consistent with the findings of Kothari et al., (2014), whose SNA participants in a health care setting indicated through qualitative inquiry that deliberately examining their sociograms helped them to see how their social network(s) might benefit from intentional, strategic development. Such strategies might include targeting key players to promote behavior change, catalyzing interactions within existing relationships, or deliberately changing network structure altogether (as per Valente 2012).

Encouragingly, the act of engaging stakeholders in reflexive mental tasks—such as how we asked key players to think about social network structure and social interaction patterns—may hold great promise for the sustainable and collaborative management and governance of natural resources. By further sharing this study or similar ones, we may find that other stakeholders are receptive to their potential efficacy in negotiating and promoting various conservation goals. Especially considering how ideas—e.g., regarding social-ecological complexity itself—might be transferred among actors in a social network, even a little knowledge might provide fuel for the deeper, broader, social-ecological thinking that Allen and Garmenstani (2015) suggest may bolster adaptive governance of natural resources. This imperative is supported by Krupa et al., (2018), who recommend that high-level governmental and policy organizations should consider using complexity tools such as SNA when engaged in policymaking to identify where to direct communication with particular groups.

## Limitations and Considerations

Despite this study's achievements, it also experienced certain limitations and liabilities. Primarily, missing data due to some nonparticipation was undeniably a shortcoming of this study. Non-response prevented our sociograms from accurately representing the size of the actual Bonneville stakeholder network. In addition to a huge Land Speed community that was only partially represented, the Industry/Mining, Media, and Wendover/Tooele communities were vastly underrepresented. Also, as pointed out by one interview participant, the inclusion of the Academic community in the SNA surveys could be construed as inviting bias into the study. Although Academia was undoubtedly a legitimate stakeholder group with an interest in Bonneville, it is true that in the past, Academia would not have shown up as strongly as it did during the data collection year; this evidences the evolving nature of social networks.

Furthermore, because our data was limited, we acknowledge that this study may be missing the valuable input of several other possible key players in the Bonneville social network. Despite its limitations, our data (e.g., sociograms) revealed many individuals in the network through whom numerous social interactions occurred during the data collection year. Although we selected the 12 individuals with the highest centrality scores as key players—done primarily for reasons of economy—there are undoubtedly different or additional individuals from each stakeholder group who hold the Bonneville social network together. Identifying and interviewing those individuals may have led to somewhat different results and implications—perhaps even in terms of how they perceive the influence of their social network on Bonneville as an SES. Despite this limitation, we nonetheless suspect that revealing key players to themselves—and the personal power that they may wield due to their position in their social network—could be a valuable act of social transparency with stabilizing effects on an SES.

Lastly, this social network research was conducted decades after the first concerns were voiced about salt decline at Bonneville, and more than twenty years after efforts began to return 'waste' salt from mining to the part of the flats where land speed racing occurs (Bowen et al., 2018). Since these efforts to mitigate objective salt loss at Bonneville and the social interactions necessary to make that project happen, the social network described in this study is likely to be quite different from the one that existed decades ago. Again, such differences speak to the evolution of social networks due to changing social, ecological, and social-ecological factors.

## Future Research

Numerous potential lines of future research have been inspired by this study. A few possibilities for such research might include (a) investigating how sharing sociograms with stakeholder communities provides fuel for collaborative knowledge-building, (b) similarly, deliberately engaging key players to assess the relative accuracy or inaccuracy of sociograms generated by SNA, (c) the potential for another, more thorough social network analysis to include other possible stakeholder groups at Bonneville, and (d) further research into academia's role in natural resource-related social networks. Although we shared sociograms and engaged in member-checking with this study, we primarily did so to leverage the limited SNA data that resulted from low survey responses rates. Nonetheless, the results from engaging key players in these ways were promising. We thus propose that these methods should be more intentionally built into future research—during the conceptualization stage when possible—to take maximum advantage of their potential.

A methodological consideration for future research would be to simply focus on group-level SNA instead of individual-level interactions with specific actors. This approach would entail simply surveying participants' interactions with other stakeholder groups and thus would avoid the individual identification of group members. As a more

succinct and more anonymous approach, group-level analysis may potentially reduce suspicion and uneasiness—concerns expressed by some individuals during sampling—about sharing personal or sensitive information. As an abbreviated approach, a group-level survey could be quickly and easily completed without having to recall specific details about social interactions. As such, it could be administered more frequently than quarterly, as this study did. Focusing on the group-level social structure would represent a larger-scale analysis, but it could still serve as a source of inspiration for considering social-ecological complexity and the influence of a social network within a specific SES. One downside to group-level analysis, however, would be the inability to accurately identify key players.

## Closing Implications

This study's contributions to social network analysis scholarship in a natural resource management context are primarily twofold. Although numerous natural resource governance studies (e.g., Bodin and Prell 2011; Crona and Hubacek 2010) have employed SNA to identify key players, this is one of few to (a) engage those individuals in member-checking the network structure and interaction trends or (b) solicit their perceptions regarding the influence of their social network structure on social or social-ecological dynamics. The insights that this study's respondents provided upon seeing their network illustrated suggest that sociograms can stimulate knowledge-building and cooperation among stakeholders—a novel use of sociograms that represents a potentially valuable tool for natural resource managers who often find themselves mediating resource-related disputes. We thus suggest that natural resource management can benefit from better understanding how stakeholders how their social network structure influences social dynamics or the overall social-ecological system of which a social network is a fundamental part. This study's illumination of key players' insight and their genuine interest in the research process suggest that larger conversations about natural resource management are in the best interest of resource conservation.

Even more simply, our findings add to the growing idea that SNA can contribute to transparent participatory planning related to natural resources (e.g., Schröter et al 2018). Our work herein also relates to the potential for stakeholder collaboration to fairly represent diverse interests, avoid exacerbated conflicts, and ensure that certain groups are not marginalized (Prell 2006). Adding these lines of inquiry to SNA scholarship advances exploration of the role of stakeholder perceptions of complexity at both the social network scale and at the overall social-ecological system scale. Our efforts to probe such perceptions revealed that key stakeholders had valuable things to tell us about (1) the influence of power and authority, (2) social network evolution, (3) the influence of research on social networks, and (4) their own self-reflection regarding a natural resource and the people who use it. We thus conclude that SNA combined with qualitative interviews focusing on social networks can yield valuable information for natural resource managers who seek to avoid or abate resource-related conflict among stakeholder groups.

This study was part of a larger research endeavor to illuminate the complexity of Bonneville's social and ecological realities and to derive management implications from those findings. That clarification has been and will continue to be a challenging task—just as it would be for any natural resources fraught with the uncertainties, reciprocities, and non-linear interactions that characterize complex systems. No one familiar with the Bonneville Salt Flats, however, wants its unique landscape to suffer decline or be unsuitable for human use—especially recreation. Because of its complexity, managing Bonneville for many uses requires robust research to inform management and decision-making. We leveraged our SNA findings to engage key stakeholders in genuinely compelling conversations that offered insight into Bonneville's social dynamics as well as the social network's influence on Bonneville's management and ecology. While there is still much to be done about improving stakeholder collaboration and trust, we feel this study provides at least a partial foundation for confidently moving forward.

## Compliance with ethical standards

**Conflict of Interest** The authors declare no competing interests.

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