Social Connection and Knowledge Brokerage in a State Government Research Network in Australia

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Abstract: The social dimensions of knowledge management are often overlooked when attempting to develop innovative approaches to preserve and balance the multiple values of protected natural landscapes. This oversight can hinder the incorporation of knowledge from research and experience, particularly tacit knowledge held by experts and experienced individuals. Building social connection between leaders, researchers and experienced staff within an organisation can address this challenge because it fosters knowledge incorporation and dissemination. However, this can be a slower, more costly and more challenging method of incorporating diverse knowledges. Organisations, particularly government organisations, need to demonstrate the value of building social connection and cohesion. Our work was designed to evaluate social connection and the development of deliberative knowledge networks. We tracked social connection during the formation of a research network within a state government organisation in Australia. The aim of the network was to improve the adoption of research knowledge into management of the alpine region in the state of New South Wales, Australia. Social Network Analysis (SNA) was used to evaluate the effectiveness of forming a research network, given it was a costly, time-consuming and challenging method for the organisation. SNA was used to visualise social connections and measure changes during the planning phase of the research network over 12 months, when scope of the alpine research program was being identified and priorities determined. The analysis revealed individuals in the network grew social connections over time (total ties, average degree and density increased) which is likely to lead to better knowledge sharing. The SNA also identified individuals with knowledge brokerage roles (betweenness scores) and those with the greatest reach and potential influence in the network (key players) who were targeted for future roles in the network. The majority of alpine information was sought from and shared with staff within the network, particularly those in two Groups/ Divisions, which may limit the innovation by the network. The results provided insight to the government research network that is invaluable in its transition from the planning phase to implementation of research priorities and adaptive management. Our approach provides evidence for the value of building social connections and knowledge brokerage to improve environmental outcomes.

Keywords: Social Network Analysis, knowledge exchange, social connection, evaluation, environmental management, alpine

1. Introduction

Effective management of environmental challenges needs more than knowledge of the environment. We must understand social interactions in human systems (Robinson, et al., 2019) because knowledge, and indeed wisdom (Easterbrook, 2012), is conceptualised and embedded in social relations (Nguyen, Young and Cooke, 2017). A diversity of knowledge and values needs to be integrated into decisions to achieve effective environmental management (Reed, 2008). However, this process can be costly, time-consuming and challenging. Therefore, organisations, particularly government organisations, need to demonstrate the value of building social connection when developing environmental management programs.

It has been assumed people with different levels of expertise could listen, understand and respond to each other's needs (Porter and Dessai, 2017). However, knowledge exchange is a complex process and the conditions that make it effective remain uncertain (Fazey, et al., 2012). Knowledge moves in dynamic, non-linear and iterative ways (Nguyen, Young and Cooke, 2017) so integrating knowledge of multiple individuals with varying expertise, backgrounds, problem-solving styles and personalities can be challenging (Cross, Borgatti and Parker, 2001). The challenges have been attributed to a lack of understanding (Cullen, 1990) caused by differences in language, background, rewards, pressures, power and needs (Briggs, 2006; Fazey, et al., 2012).

As individuals, we continuously create our world through our various experiences, memories and references (Reis, 2001; Mannheim, 1960). Conceptual models of knowledge exchange affect how we create and attempt to

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share knowledge. Fazey, et al. (2012) listed two models of knowledge exchange that create different outcomes. The first model was 'transmissive' and the second, for the purpose of this paper, the authors named 'co-created'. The traditional 'transmissive' model of knowledge exchange assumes knowledge is something explicit which can be passed between people. This model results in traditional methods of disseminating knowledge – where 'facts' are communicated to different groups. It tends to maintain the status of those involved and fails to recognise the complexities of the learning process (Fazey et al., 2012). Eden (2011) calls the traditional approach for science in government the 'loading dock' model – where results are produced and users are expected to seek them out. Failures of the model include problems with salience, credibility and legitimacy. This 'deficit model' assumes 'correct' policies will automatically follow once scientific results are provided to politicians (Lawton, 2007).

The 'co-created' model of knowledge (Fazey, et al., 2012) is a "more complex, iterative process of reflection and experiential learning" which makes implicit knowledge explicit. The model leads to approaches that emphasise co-production of knowledge and to more adaptive forms of learning. This model leads to increased agility in environmental management that produce more effective and enduring outcomes (Fazey, et al., 2012).

Leaders in (the former) Office of Environment and Heritage (OEH) in New South Wales (NSW), Australia, wanted to adopt the latter model and develop a research program using a collaborative approach with co-production of knowledge. Co-production of knowledge can be a costly, time-consuming and challenging process (Goggin, et al., 2019) so leaders in OEH needed to evaluate their investment in building social connection to improve knowledge exchange.

Knowledge exchange in government organisations can present many challenges, particularly with the flow of scientific knowledge into decision making. According to Head (2013), scientific or rigorous knowledge is "widely valued" by decision-makers in government but must "contend with business, political and professional understandings about the nature of the problems, and about what kinds of solutions are practical and feasible." There is also evidence that government decision makers do not seek evidence from published scientific literature. For example, Pullin, et al. (2004) analysed management plans for nature reserves written by statutory and non-governmental conservation organisations in the United Kingdom. They found most plans were compiled from a limited amount of the total information available. None of the plans critically evaluated the quality of evidence in support of actions. Few planners used scientific literature because they said it was too time-consuming to access and read, and too technical and difficult to interpret in the context of their decision making. In Australia, policy officers from the Victorian state government Department of Primary Industries (DPI) said they sought information from the internet (their preferred source of information), the library and from other policy documents (Dripps and Bluml, 2008) rather than from scientists or from scientific literature.

There is growing evidence that decision makers seek concise information in context from trusted sources, rather than from published literature. The information must be relevant, timely, credible and legitimate (Cook, et al., 2013). For example, policy officers from the Victorian DPI, Australia, sought information from their personal networks (formed after face-to-face meetings in working groups, technical support groups, seminars and forums) (Dripps and Bluml, 2008). Similarly, water managers and policy officers in New South Wales (NSW), Australia, reported interpersonal communication was their preferred means of accessing information (including scientific outputs) (Inca Consulting, 2011). They did not actively search for scientific information but would consider and/ or use scientific information presented to them, particularly by scientists they trusted or with whom they had built a relationship.

Therefore, a collaborative approach can help address the challenge in knowledge exchange in government (Wall, Meadow and Horganic, 2017; Goggin, et al., 2019) because it improves the creation, uptake and flow of knowledge between groups. A collaborative approach can also foster social learning and integrate knowledge from different groups so novel results can be reached that were not achieved by the groups separately (Xavier, Jacobi and Turra, 2018). Collaboration is also a key factor in successful translation and implementation of knowledge (Long, Hibbert and Braithwaite, 2016). For example, building relationships between scientists and practitioners from Australia was key to better outcomes in environmental programs and practice (Goggin, et al., 2019). Interactions between scientists and stakeholders also overcame gaps in perception and improved the use of climate science (Briley, Brown and Kalafatis, 2015). Gibbons, et al. (2008) also found successful research-policy partnerships were built around personal relationships.

Crona and Bodin (2006) found strong social networks facilitate the generation, acquisition and diffusion of knowledge and information. This aligns with work by Long, Cunningham and Braithwaite (2013) who reviewed the flow of information between groups or silos in networks (from 24 published articles), including in Australian hospitals. They found the optimal network structure to spread factual and especially tacit knowledge is cohesion (high density) not sparseness (more structural holes). The process within (the former) OEH was designed to build social connections in order to improve the flow of tacit knowledge between groups. However, there is little published research on changes in social connection in research networks in Australia (although see Long, Cunningham and Braithwaite, 2012; Cvitanovic, et al., 2017), and even less within government. Our research aimed to fill that gap and evaluate its effectiveness.

In Australia, alpine landscapes are rare, restricted to the south-east of the continent (Williams, et al., 2008) and one of six key regions that are highly vulnerable to climate change (Hennessy, et al., 2007). Some of the largest alpine landscapes in Australia are within Kosciuszko National Park (KNP) which preserves a range of special places and values that are unique in Australia and recognised internationally. The Park is a UNESCO Biosphere Reserve, preserving the only true alpine zone in mainland Australia (National Parks and Wildlife Service NSW, 2006). In addition to its natural and cultural values, KNP has significant tourism and visitor values. In 2016, there were 2.2 million visits to the Park, making it one of the ten most visited national parks in the state (Roy Morgan Research Ltd, 2017). All four ski resorts in NSW are also within the Park and these businesses and local livelihoods are vulnerable to the impacts of climate change (Sharpe, Delaney and Cunningham, 2020).

Like many protected areas around the world, balancing and protecting the multiple values of KNP is challenging. Managers must balance the needs of increasing numbers of visitors and development, and risks from climate change which are exacerbating threats from pests, weeds and fire. Wild horses have established in KNP and their management is emotive and controversial (Knight, 2019). In addition, a major expansion of the Snowy Mountains hydroelectric scheme will affect the Park (Normyle and Pittock, 2020). These multiple challenges need robust evidence and innovative approaches to enable adaptive management in order to continue to protect the natural, socio-economic and heritage values of the Park.

The former NSW Office of Environment and Heritage (OEH) established an Alpine Research Program to foster collaboration and improve flow of knowledge about the alpine region within the organisation. The Program was designed to inform the management of the alpine region, particularly KNP which is managed by National Parks and Wildlife Service (NPWS) on behalf of the NSW Minister for Energy and Environment. At the time of this research, NPWS was part of the former OEH and one of the seven functional areas or groups (Office of Environment and Heritage NSW, 2018). The Alpine Research Program was designed as a model for prioritising and undertaking research that informs management, particularly management of emotive and controversial issues in national parks. The theory of change (Funnell and Rogers, 2011) underpinning the Program was that building social connection would improve the generation, acquisition and exchange of knowledge between participants in the network (Crona and Bodin, 2006). Therefore, our research was designed to evaluate the effectiveness of building social connection within government to improve knowledge sharing.

Social Network Analysis (SNA) is a tool that identifies social groups, influential people and patterns of communication (Crona and Bodin, 2006). It allows quantitative analysis and qualitative insights into interactions between individuals in a network (Borgatti, Everett and Johnson, 2013; Cunningham et al., 2014). In this study, SNA was used to track changes in social connection between individuals from a state government department with expertise, experience and/or responsibilities in the alpine region of NSW, Australia. We used longitudinal SNA to track development and changes in the network over time as well as shifts in social connection between participants. SNA was also used to identify individuals with knowledge brokerage roles. The aim of the research was to evaluate the role of the social network in fostering knowledge exchange and inform management of the alpine area within a government context.

2. Materials and methods

The former Office of Environment and Heritage NSW (OEH) employed staff to provide evidence and advice to support government policy and management decisions, including decisions about protecting the environment in the state of New South Wales (NSW), Australia. At the time of this research, OEH employed about 3,000 staff in seven functional areas (OEH, 2018). The focus of this study was the interaction between Heritage Division (Heritage), National Parks and Wildlife Service (NPWS), Regional Operations Group (Regional Operations) and

Science Division (Science). The majority of OEH's functions were transferred to the NSW Department of Planning, Industry and Environment in July 2019.

In early 2017, leaders (referred to as managers within the organisation and throughout this paper) in (the former) OEH with responsibilty for the alpine region of NSW became aware that a large number of OEH staff were involved in research in the alpine region. In June 2017, an audit of alpine research in OEH found more than 30 staff were involved in over 60 research projects in the alpine region of NSW and elsewhere. However, the research was not well known nor coordinated across the organisation. Managers with responsibility for the alpine region wanted to evaluate the use of the contemporary conceptual model of knowledge exchange to improve knowledge sharing between Groups/ Divisions in the organisation. Therefore, in July 2017, leaders held a workshop with staff to discuss challenges and opportunities in the alpine region. They invited staff with expertise, experience and/or responsibilities for the alpine region. The meeting was designed to build connection between staff from different Groups/Divisions so knowledge about the alpine region would be better shared within the organisation. In turn, this would allow the use of collective expertise to develop a coordinated program of collaborative research. The research program was designed to use natural, socio-economic and heritage values to inform and guide management, so the condition of the alpine region would continue to be protected and improved.

Social Network Analysis (SNA) was used to evaluate the organisation's investment in face-to-face meetings to improve knowledge sharing. Bringing staff together for face-to-face meetings was costly in both staff time and funds (travel, accommodation, etc). It was also challenging logistically with a number of staff needing to travel up to six hours to attend. Therefore, although face-to-face meetings were preferred and additional meetings may have built better connection, the number of face-to-face meetings was restricted.

Many connections within the alpine network were invisible to managers but were crucial to sharing information; SNA was an appropriate approach because it can visualise connections between participants. Longitudinal SNA was identified as the preferred method because it allowed the exploration of changes in the number and strength of connections between individuals in the network over the three meetings (ALPINE network: July 2017, November 2017, June 2018). These three time periods and three networks are used as a proxy for knowledge sharing. In addition, SNA identified individuals from whom information about the alpine region was sought (SEEK network: November 2017, June 2018), and with whom information about the alpine region was shared (SHARE network: November 2017, June 2018).

Prior to the first meeting in July 2017, a list was made of 59 staff with experience, expertise and/or responsibilities in the alpine region. The staff were invited to a meeting in Canberra, Australian Capital Territory (ACT) to discuss issues and challenges with management of the alpine region. Thirty staff from across NSW attended. They were given a list of 59 names prior to the meeting and asked to rank their connection to each one.

A second meeting was held in November 2017 in Queanbeyan, NSW, to finalise the scope and goal of the research program (by developing a program logic). Eighteen staff attended; 16 people who attended the first meeting and two people who were new to the network. Those who attended were given a list of 61 people and asked to rank their connection to each one. The list included 59 names from the previous list (N1-N59) and two people (N60, N61) invited to the second meeting.

After the first two meetings, those who attended were asked for feedback via an online survey. As part of the feedback, respondents were asked how many new people they met at each meeting.

In March 2018, a Steering Committee was formed, followed by two Working Groups (with representatives from across the organisation) to advise and support decision-making by the Steering Committee. In June 2018, the Working Groups met to review and prioritise research listed in the 2006 KNP Plan of Management (NPWS, 2006) as well as those research questions raised by staff in the previous two meetings.

In June 2018, 26 staff attended a third meeting in Queanbeyan. Participants were given a list of 85 names which included 61 names from November 2017 (N1-N61). The additional names on the list were: two people (N75, N76) who responded by email in November 2017 (but did not attend that meeting); seven people (N66, N77, N78, N79, N80, N82, N94) nominated in November 2017 as part of the ALPINE network; 10 people invited to the meeting in June 2018 (two of them were listed in the SEEK or SHARE networks, N74, N95); four people (N62, N63, N72, N73) added from the SHARE network; and one person (N65) added from the SEEK network.

Before each meeting, those who attended were asked to rank their connection to people on the supplied lists (n=59 in July 2017; n=61 in November 2017, n=85 in June 2018) as none (0), weak (1), moderate (2) or strong (3). Therefore, responses reflect connection of individuals prior to meetings. This resulted in the potential to create a directional value-weighted matrix; individuals ranked the strength of connection according to their intuition because researchers did not define 'weak', 'moderate' or 'strong' within the survey instrument (De Brún and McAuliffe, 2018).

In November 2017 and June 2018, respondents were also asked to name three people who they sought information about the alpine region from (SEEK network) and three people who they shared information with (SHARE network).

Between July and September 2018, the Working Groups continued to prioritise research. They provided a list of research priorities with recommendations to the Steering Committee who considered their recommendations and finalised a list of research for the alpine region in November 2018. The SNA did not capture connections that changed during this period.

The three networks were treated as unique and discrete networks, i.e. ALPINE, SEEK and SHARE networks. Individuals were numbered sequentially so an individual is represented by the same number in all networks. In the analyses, individuals were assigned one of six categories (as listed in Table 1) which we defined as follows. 'Attend – response': the individual attended the meeting and provided data. 'Did not attend – email response': the individual did not attend the meeting but provided data by email. 'Not in this time period – email response': the individual was not identified as part of the network at that time but provided an email response, and their data were included in the analysis. 'Attend – no response': the individual attended the meeting but did not provide data. 'Did not attend – no response': the individual did not attend the meeting or provide data. 'Not in this time period – no response': the individual was not identified as part of the network at that time, and was analysed as missing values for that time period.

After the three meetings, the networks were bound to the total number of participants from every time period: ALPINE = 87; SEEK = 124; SHARE = 124. The total number included missing data such as non-responses and inactive nodes. Missing data was listed as null responses. The data were used to create a symmetric-directed matrix so networks could be mapped and analysed. Visualisations and analyses were run in UCINet (Borgatti, Everett and Freeman, 2002) and Netdraw (Borgatti, 2006). The visualisation layout uses geodesic distance to position the nodes so those with similar characteristics (i.e. similar properties or structural positions) were forced together.

We calculated UCINet Multiple Cohesion Measures (Borgatti, Everett and Freeman, 2002) including average degree, density, fragmentation, closure and diameter to measure changes in network efficacy over time. To identify individuals with knowledge brokerage roles for each time period, we calculated metrics including the UCINet Freeman betweenness (Freeman, 1979) which is a centrality measure that considers degree and closeness. Key players (diffuse) were identified using the key player problem 1 algorithm (Borgatti, 2006) which calculated nodes with the most and strongest connections in the network. Individual key player diffuse algorithms were run for the ALPINE, SEEK and SHARE networks. The total number of ties in the ALPINE network at each time period was calculated to estimate change over time.

3. Results

3.1 ALPINE network

In July 2017, 29 individuals ranked their connection to a list of 59 names. There were 28 responses at the meeting and one emailed response afterwards (from someone who did not attend) (Table 1). At the next meeting in November 2017, 29 individuals ranked their connection to a list of 61 names (Table 1). Those who ranked their connection included 18 individuals who attended the meeting (including two individuals who did not attend the first meeting but were added to the list in November 2017). There were also responses from nine individuals who did not attend the meeting but were on the original list of 59 people and provided data after the meeting. The remaining two individuals did not attend either meeting, were not in the network list, but were sent the list from someone in the network. In June 2018, a total of 26 individuals ranked their connection to a list of 85 names. All individuals who responded were on the supplied list (Table 1).

Response rate in the ALPINE network declined over time (Table 1). Response rate will affect results but an “adequate” response rate for a whole network analysis has not been defined (Long, Hibbert and Braithwaite, 2016). In this analysis, missing sections of the network were partly filled by respondents who nominated non-respondents so we believe response rate was adequate for our purposes.

The ALPINE network was bound to 87 internal nodes: five from Heritage (D1); 45 from NPWS (D3); 10 from Regional Operations (D3) and 27 from Science (D4). The network was visualised for July 2017 (Figure 1), November 2017 (Figure 2) and June 2018 (Figure 3). All nodes (i.e. attend, no attend, not in this time period, etc) were visualised. The node size in the visualisation reflects the total number and strength of connections, i.e. sum of the strength of nominated connections. Isolates (or inactive nodes) did not respond at that time period nor were they nominated by another node in that network. They appear on the left of the visualisations.

The total number of ties in the ALPINE network increased by 53% over time: from 784 in July 2017, to 902 in November 2017 and to 1,199 by June 2018.

Table 1: Number of participants, response rate and participation at each time period

	JUL 2017	NOV 2017	JUN 2018
Names on supplied network list	59	61	85
Attend - response	28	18	26
Not attend – email response	1	9	0
Not in this time period – email response	0	2	0
TOTAL RESPONSES	**29**	**29**	**26**
Attend - no response	2	0	0
Not attend – no response	30	34	61
Not in this time period – no response	26	24	0
TOTAL in ALPINE network	**87**	**87**	**87**
Response rate (percent)	33.3	33.3	29.8

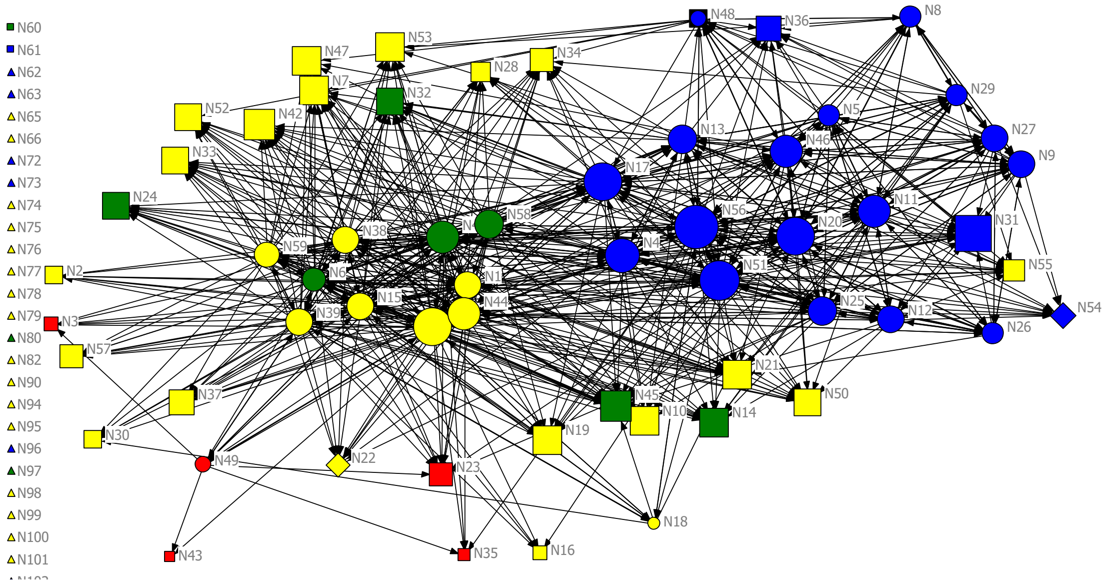

Figure 1: Visualisation of ALPINE network (July 2017). Node colour represents (former) OEH Division/ Group: Red = Heritage; Yellow = NPWS; Green = Regional Operations; Blue = Science. Shape of nodes represent attendance: circle = attended and responded; square = did not attend; square with circle = email response (did

not attend); diamond = attended with no response; triangle = not in this time period; plus = email response but not in this time period

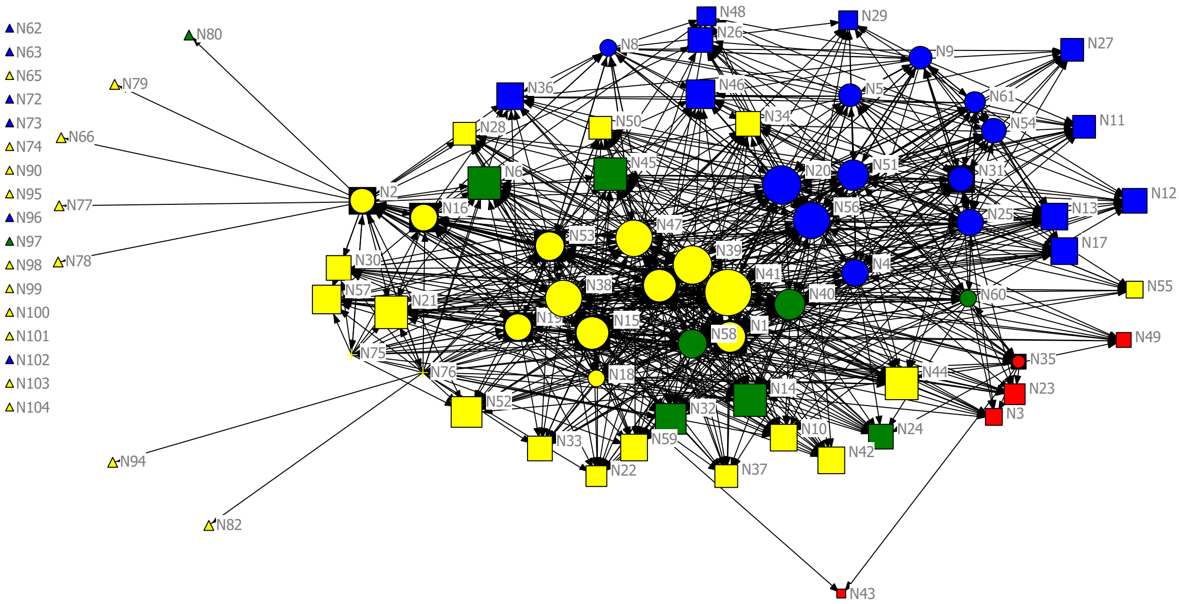

Figure 2: Visualisation of ALPINE network (November 2017). Colour of nodes represent (former) OEH Division/ Group. Red = Heritage; Yellow = NPWS; Green = Regional Operations; Blue = Science. Node shape represent attendance at the meeting: circle = attended and responded; square = did not attend; square with circle = email response (did not attend); diamond = attended with no response; triangle = not in this time period; plus = email response but not in this time period.

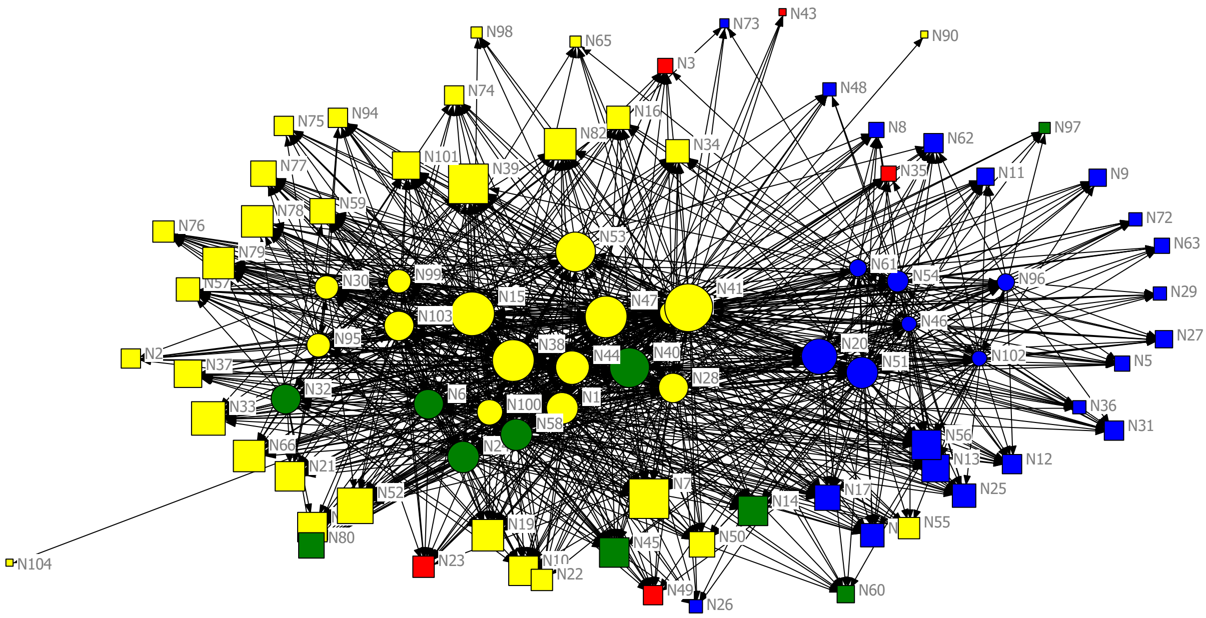

Figure 3: Visualisation of ALPINE network (June 2018). Node colour represents (former) OEH Division/ Group. Red = Heritage; Yellow = NPWS; Green = Regional Operations; Blue = Science. Shape of node represents attendance at the meeting: circle = attended and responded; square = did not attend or respond; square with circle = email response (did not attend); diamond = attended with no response; triangle = not in this time period and no response; plus = not in this time period and email response.

In July 2017, a manager from Science (N56) and one from NPWS (N41) had the highest UCINet Freeman betweenness scores (Freeman, 1979) in the ALPINE network (Table 2). The NPWS manager (N41) maintained high betweenness scores over time. By November 2017, a scientist from Science (N20) also had high betweenness scores. At this time, a different NPWS manager (N2) had the highest betweenness score at that time period and at any time period. This individual did not attend meetings, and their high score is likely to be bias – they provided data sheets to individuals (not on the supplied list) who responded. In June 2018, N2 did not complete data sheets nor pass them to others so did not maintain a high betweenness score.

Table 2: UCINet Freeman betweeness score for nodes in the ALPINE network over time, with affiliation and role of each node

TIME	NODE	DIVISION/ GROUP	ROLE	BETWEENESS
July 2017	N56	Science	Manager	117
	N41	NPWS	Manager	113
	N51	Science	Manager	92
	N17	Science	Manager	68
	N20	Science	Scientist	64
	N40	Regional Ops	Manager	62
	N44	NPWS	Manager	59
November 2017	N2	NPWS	Manager	255
	N41	NPWS	Manager	128
	N20	Science	Scientist	100
	N56	Science	Manager	99
	N1	NPWS	Manager	64
	N47	NPWS	Scientist	58
June 2018	N41	NPWS	Manager	234
	N47	NPWS	Scientist	95
	N20	Science	Scientist	70
	N40	Regional Ops	Manager	59
	N51	Science	Manager	54
	N15	NPWS	Manager	52

Multiple Cohesion Measures tracked growth of the ALPINE network over time (Table 3). The average degree increased from July 2017, when individuals had an average of nine connections, to more than 13 by June 2018. Density (total connections divided by total possible connections) increased between July 2017 and June 2018, so individuals were connected to more people over time. Fragmentation (a measure of lack of connectivity in the network) decreased between July 2017 and June 2018 reflecting better connection over time. Closure measures the degree to which 'the friend of my friend is likely to be my friend' and is calculated by dividing the number of triads (three nodes) by two. Closure of the ALPINE network was similar throughout the project. Diameter estimates the number of steps to reach everyone in the network (Cunningham, et al., 2017). Individuals in the majority of the ALPINE network could be reached in three to five steps.

Table 3: Multiple Cohesion Measure Metrics for the ALPINE network over time

METRICS	JUL 2017	NOV 2017	JUN 2018
Average degree	8.98	10.37	13.76
Density	0.11	0.12	0.16
Fragmentation	0.78	0.73	0.70
Closure	0.65	0.65	0.67
Diameter	3	5	3

In July 2017, the 17 key players in the ALPINE network included managers from NPWS (n=4), Science (n=3) and Regional Operations (n=1) (Table 4). Key players also included rangers (n=2), project officers (n=2), environmental liaison and management officers (n=2) from NPWS, as well as a scientist from Science and from Regional Operations, and a regional coordinator from Regional Operations. A combination of key players from each run could reach over half (69%) the network.

In November 2017, the 14 key players in the ALPINE network were managers from NPWS (n=6) and Science (n=3), a ranger, Discovery coordinator, Indigenous liaison officer and environmental management officer from NPWS, and scientists from Science (n=2) (Table 4). A combination of key players for each run could reach most (81%) of the network. In June 2018, there were only three key players, all of whom were from NPWS (a manager and two scientists) and they could reach the entire network.

Table 4: Key player (diffuse) in the ALPINE network at each time period (Time) for each key player query run (Run). A combination of any three key players from each run can reach the listed percentage of nodes in the network

TIME	RUN	KEY PLAYER	KEY PLAYER	KEY PLAYER	NODES REACHED (%)
Jul 2017	1	N40 (Manager, Regional Ops)	N61 (Scientist, Science)	N75 (Manager, NPWS)	69
	2	N40 (Manager, Regional Ops)	N62 (Manager, Science)	N74 (Manager, NPWS)	69
	3	N40 (Manager, Regional Ops)	N77 (Ranger, NPWS)	N80 (Regional coordinator, Regional Ops)	69
	4	N40 (Manager, Regional Ops)	N78 (Ranger, NPWS)	N94 (Project officer, NPWS)	69
	5	N40 (Manager, Regional Ops)	N94 (Project officer, NPWS)	N96 (Manager, Science)	69
	6	N40 (Manager, Regional Ops)	N95 (Environmental liaison officer, NPWS)	N97 (Scientist, Regional Ops)	69
	7	N41 (Manager, NPWS)	N65 (Manager, NPWS)	N82 (Manager, NPWS)	69
	8	N41 (Manager, NPWS)	N76 (Environmental management officer, NPWS)	N95 (Environmental liaison officer, NPWS)	69
	9	N41 (Manager, NPWS)	N77 (Ranger, NPWS)	N79 (Project officer, NPWS)	69
	10	N41 (Manager, NPWS)	N82 (Manager, NPWS)	N94 (Project officer, NPWS)	69
Nov 2017	1	N104 (Ranger, NPWS)	N2 (Manager, NPWS)	N56 (Manager, Science)	81
	2	N2 (Manager, NPWS)	N39 (Manager, NPWS)	N99 (Discovery coordinator, NPWS)	81
	3	N2 (Manager, NPWS)	N56 (Manager, Science)	N65 (Manager, NPWS)	81
	4	N2 (Manager, NPWS)	N56 (Manager, Science)	N98 (Indigenous liaison officer, NPWS)	81
	5	N39 (Manager, NPWS)	N73 (Scientist, Science)	N76 (Environmental management officer, NPWS)	81
	6	N41 (Manager, NPWS)	N72 (Manager, Science)	N76 (Environmental management officer, NPWS)	81
	7	N41 (Manager, NPWS)	N76 (Environmental management officer, NPWS)	N96 (Manager, Science)	81
	8	N56 (Manager, Science)	N63 (Scientist, Science)	N76 (Environmental management officer, NPWS)	81
	9	N56 (Manager, Science)	N74 (Manager, NPWS)	N76 (Environmental management officer, NPWS)	81

TIME	RUN	KEY PLAYER	KEY PLAYER	KEY PLAYER	NODES REACHED (%)
Jun 2018	1	N18 (Scientist, NPWS)	N41 (Manager, NPWS)	N47 (Scientist, NPWS)	100

3.2 SEEK networks

Total individuals from all time periods in the SEEK network was 124 (Table 5) with 91 nodes from four OEH Divisions/ Groups (five from Heritage, 46 from NPWS, 10 from Regional Operations, 30 from Science) and 33 nodes from 11 external organisations (Table 6). Response rate increased between November 2017 and June 2018 (Table 5).

Table 5: Number of individuals in the SEEK and SHARE networks and response rate over time

RESPONSE TYPE	SEEK Nov 2017	SEEK Jun 2018	SHARE Nov 2017	SHARE Nov 2018
Attend - response	18	28	18	28
Did not attend – no response	58	96	58	96
Not in this time period – no response	48	0	48	0
TOTAL	**124**	**124**	**124**	**124**
Response rate (%)	**14.5**	**22.6**	**14.5**	**22.6**

Table 6: Number of individuals in each category for the SEEK and SHARE networks over time. An individual may have been nominated several times in the same network but is counted once for each time period in this table

CATEGORY (ATTRIBUTE)	SEEK Nov 2017	SEEK Jun 2018	SHARE Nov 2017	SHARE Jun 2018
OEH Heritage (D1)	1	1	1	
OEH National Parks & Wildlife Service (NPWS) (D2)	21	18	22	21
OEH Regional Operations (D3)	6	7	5	5
OEH Science (D4)	12	8	14	9
TOTAL OEH INDIVIDUALS NOMINATED	**40**	**34**	**42**	**35**
ACT Govt (D5)		1	1	1
NSW Govt (D6)	2		2	1
University (D7)	3	3	1	1
Traditional Custodian (D8)	2	1		
Committee (D9)		1	1	2
Zoo (D10)		1		1
Resorts (D11)	3		2	
Consultant (D12)	2			
Business/ company (D13, D15)	1			1
Research organisation (D14)		1		1
Research group/ network/ association (D16)		1		1
Education centre (D17)				1
TOTAL EXTERNAL INDIVIDUALS NOMINATED (% of total individuals nominated)	**13 (24.5%)**	**9 (20.9%)**	**7 (14.3%)**	**10 (22.2%)**

Table 7: Frequently nominated individuals (four times or more) in the SEEK and SHARE networks over time, in decreasing order of nominations. Individuals who increased their nominations over time are heavily shaded. Those who maintained the number of nominations over time are in a lighter shade.

NODE	ROLE (Group/ Division)	SEEK Nov 2017	SEEK Jun 2018	SHARE Nov 2017	SHARE Nov 2018	TOTAL
N47	Scientist (NPWS)	5	6	4	5	20
N41	Manager (NPWS)	2	4	9	5	20
N32	Scientist (Regional Ops)	4	4	2	2	12
N58	Scientist (Regional Ops)	3	6	3		12
N38	Manager (NPWS)		3		5	8
N15	Manager (NPWS)		2	2	4	8
N66	Ranger (NPWS)		2		5	7
N10	Scientist (NPWS)	4	3			7
N20	Scientist (Science)	2	2		2	6
N51	Manager (Science)	2		4		6
N53	Scientist (NPWS)	2	2			4
N21	Scientist (NPWS)	2	2			4
N25	Manager (Science)			4		4

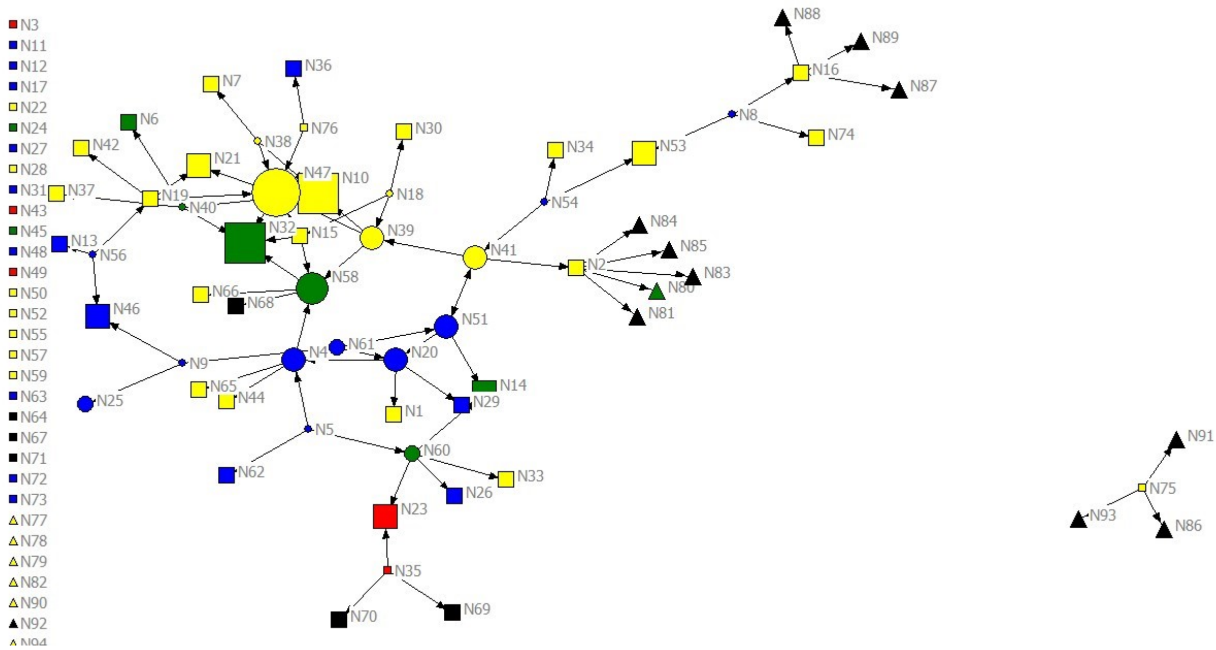

Figure 4: Visualisation of SEEK network for November 2017. Node colour represents OEH Division/ Group or organisation. Red = Heritage; Yellow = NPWS; Green = Regional Operations; Blue = Science; Black = non OEH. Node shape represents attendance: circle = attended; square = did not attend; triangle = not in this time period. Arrow direction indicates whom the node seeks information from

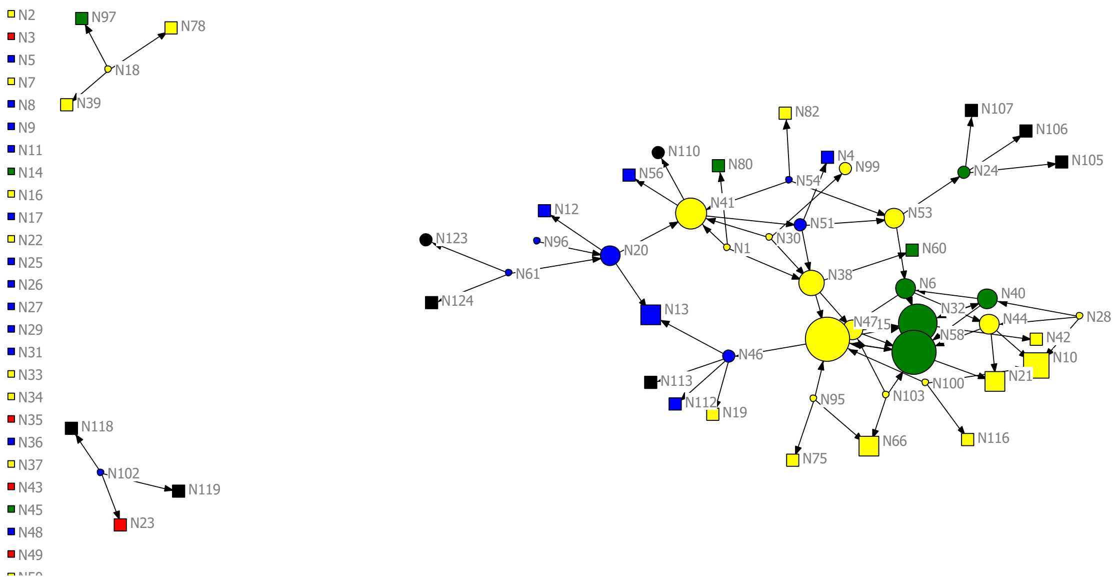

Figure 5: Visualisation of SEEK network for June 2018. Node colour represents OEH Division/ Group or organisation. Red = Heritage; Yellow = NPWS; Green = Regional Operations; Blue = Science; Black = non OEH. Shape of node represents attendance: circle = attended and responded; square = did not attend or respond. The direction of the arrow indicates whom the node seeks information from

Most multiple cohesion measures for the SEEK network remained similar between November 2017 and June 2018 (Table 7). Different participants provided data at each time so similarities may reflect varied responses from different individuals. Fewer people attended the meeting in November 2017 than in June 2018 which may also affect the result.

The average degree for the SEEK network remained similar and density did not change between November 2017 and June 2018 (Table 8) so people in the network did not seek information from more or different people over time. Indeed, the fragmentation of the SEEK network decreased and closure increased, suggesting more individuals sought information from similar individuals over time. It also suggests that in triads, where originally person A knew both B and C but B and C may not have known each other that by June 2018, it was more likely B and C knew each other (see Granovetter, 1973). However, the diameter of the SEEK network increased so more steps were required to access all nodes in most of the network.

Table 8: Multiple Cohesion Measures for SEEK and SHARE networks over time

METRICS	SEEK Nov 2017	SEEK Jun 2018	SHARE Nov 2017	SHARE Jun 2018
Average degree	0.597	0.589	1.129	1.113
Density	0.005	0.005	0.009	0.009
Fragmentation	0.985	0.972	0.844	0.857
Closure	0.083	0.155	0.127	0.128
Diameter	6	7	8	7

The composition and number of key players in the SEEK network changed over time (Table 9). In November 2017, there were three key players which increased to five key players by June 2018. In November 2017, there were more key players from Science (n=2) than NPWS (n=1), but by June 2018, most key players were from NPWS (n=4) with only one from Science. In November 2017, key players were managers from Science (n=1) and NPWS (n=1), and a scientist from Science. By June 2018, four of the five key players were scientists from NPWS (n=3) and Science (n=1) with one NPWS manager.

Table 9: Key players (diffuse) from SEEK networks over time; and percent of nodes reached by a combination of key players for each key player query run (Run)

TIME	RUN	KEY PLAYER	KEY PLAYER	KEY PLAYER	NODES REACHED (%)
Nov 2017	1	N41 (Manager, NPWS)	N5 (Manager, Science)	N8 (Scientist, Science)	22
Jun 2018	1	N1 (Scientist, NPWS)	N4 (Scientist, Science)	N53 (Scientist, NPWS)	20
	2	N30 (Manager, NPWS)	N47 (Scientist, NPWS)	N53 (Scientist, NPWS)	20

3.3 SHARE networks

There were 124 individuals in the SHARE network (Table 5) with 91 nodes from (the former) OEH (5 nodes from Heritage, 46 from NPWS, 10 from Regional Operations, 30 from Science) and 33 nodes from 10 external categories (Table 6). Attendance and response rate increased over time (Table 5). SHARE networks for November 2017 and June 2018 were visualised in Figures 6 and 7 respectively.

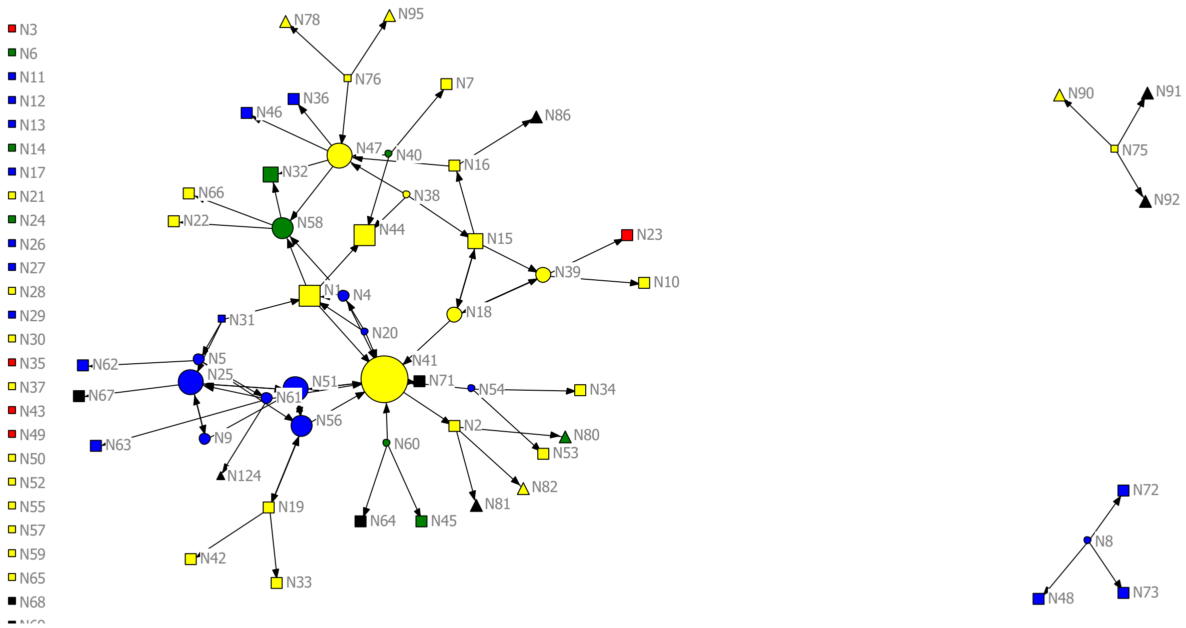

Figure 6: Visualisation of SHARE network for November 2017. Isolates listed on the left of the visualisation. Node colour represents OEH Division/ Group or organisation. Red = Heritage; Yellow = NPWS; Green = Regional Operations; Blue = Science; Black = non OEH. Node shape represents attendance: circle = attended; square = did not attend; triangle = not in this time period. Arrow direction indicates whom the node shares information with.

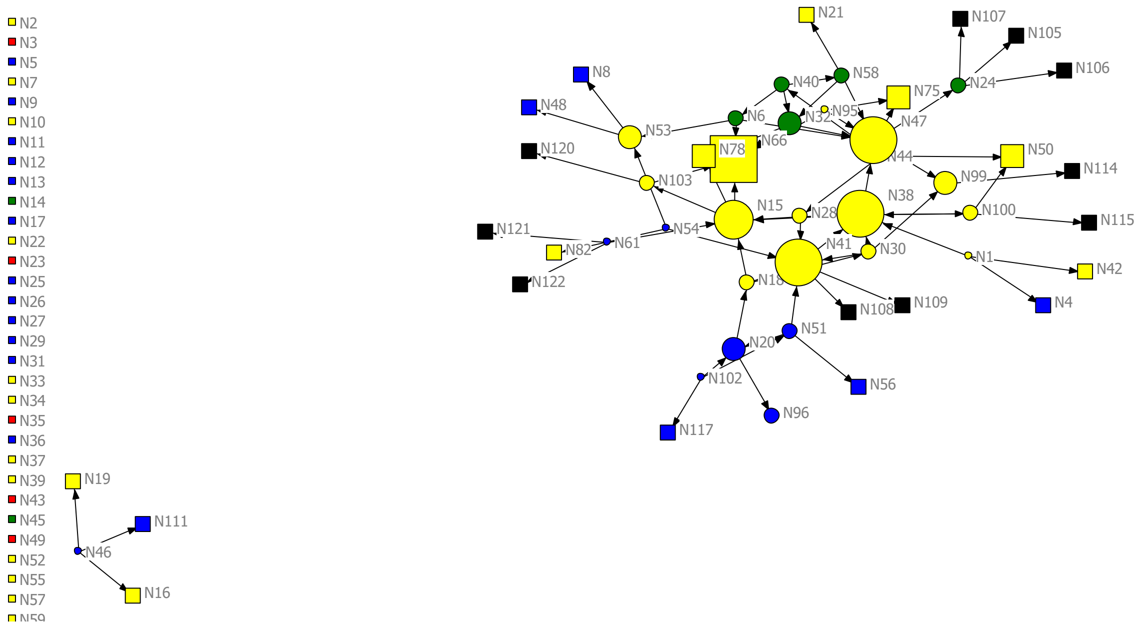

Figure 7: Visualisation of SHARE network for June 2018. Isolates are listed on the left. Node colour represents OEH Division/ Group or organisation. Red = OEH Heritage; Yellow = OEH NPWS; Green = OEH Regional Operations; Blue = OEH Science; Black = non OEH. Node shape represents attendance where circles = attended; square = did not attend. Arrow direction indicates whom the node shares information with

Multiple cohesion measures for the SHARE network were similar or the same over time (Table 8). Results may have been affected by the declining response rate. Different participants also provided data each time so the lack of difference may reflect varied responses by different individuals. Density and closure did not change, and decreases in average degree and diameter, and increases in fragmentation were small, indicating participants shared information with similar numbers of people over time.

The composition of key players in the SHARE network changed, and their number and reach declined between November 2017 and June 2018 (Table 9). In November 2017, four of the seven key players were from NPWS, with the rest from Science. By June 2018, an NPWS scientist (N47) remained one of the five key players with others being replaced by scientists (n=2) and a manager from Science, and a different NPWS manager (N38).

Table 10: Key players (diffuse) in the SHARE network over time; and percent of nodes reached for each key player query run (Run)

TIME	RUN	KEY PLAYER	KEY PLAYER	KEY PLAYER	NODES REACHED (%)
Nov 2017	1	N41 (Manager, NPWS)	N47 (Scientist, NPWS)	N72 (Manager, Science)	36.4
	2	N41 (Manager, NPWS)	N47 (Scientist, NPWS)	N73 (Scientist, Science)	36.4
	3	N41 (Manager, NPWS)	N47 (Scientist, NPWS)	N75 (Environmental management officer, NPWS)	36.4
	4	N41 (Manager, NPWS)	N47 (Scientist, NPWS)	N8 (Scientist, Science)	36.4
	5	N41 (Manager, NPWS)	N47 (Scientist, NPWS)	N90 (Project officer, NPWS)	36.4
Jun 2018	1	N102 (Scientist, Science)	N38 (Manager, NPWS)	N47 (Scientist, NPWS)	31.4
	2	N20 (Scientist, Science)	N38 (Manager, NPWS)	N47 (Scientist, NPWS)	31.4
	3	N38 (NPWS)	N47 (Scientist, NPWS)	N51 (Manager, Science)	31.4

3.4 Survey results

A total of 22 people (73%) provided feedback about the meeting on 25 July 2017. Respondents were from Heritage (1), NPWS (6), Regional Operations (1) and Science (10). Four respondents did not nominate a Division/ Group. The opportunity to meet colleagues from across the organisation was considered the best part of the meeting. All respondents said they met at least one new person. Half those who attended (50%, n=11) met 1-5 new people at the meeting, eight respondents (36%) met 6-10 new people, and three respondents (14%) met more than 10 new people. Respondents said they would have liked more time to network during the meeting.

A total of 10 people gave feedback (of the 18 who attended) on the workshop in November 2017. Respondents were from NPWS (3), Regional Operations (2) and Science (5). They said the best part of the workshop was meeting colleagues and participating in the discussion. Everyone who responded said they met new people, with most respondents (80%, n=8) saying they met 1-5 new people, and the rest (20%, n=2) meeting 6-10 new people.

4. Discussion

Our analysis demonstrated the value of exploring and evaluating social dimensions of knowledge management when planning a collaborative research program. Social Network Analysis (SNA) visualised the informal knowledge network of staff involved with the alpine region in an Australian state government organisation which was invisible without the analysis. The visualisations were crucial for beginning a conversation about knowledge sharing across the organisation. The SNA also helped evaluate the knowledge network by revealing its structure supported long-term planning and knowledge sharing. The analysis also identified people with knowledge brokerage roles who were crucial in bridging the divide between different cultures. These insights will be invaluable in transitioning the network from planning, scoping and prioritising, to implementing a coordinated program of collaborative research.

4.1 ALPINE network

Although it is assumed that knowledge flows freely within organisations, this is often not the case. Information can get stuck or siloed in different segments of society and within parts of organisations (Cunningham, Jacobs and Measham, 2021). There can also be a striking contrast between a person's position in the formal hierarchy and in the informal knowledge network (Cross, Parker and Borgatti, 2002). For the first time, our analysis visualised connections in the ALPINE network so members could see their position in the informal structure, and links and/or divisions between groups. We found that showing the visualisations to people in the network stimulated discussion about how to improve knowledge sharing. This was an unexpected benefit of the analysis.

As expected, the ALPINE network illustrated homophily which means similar actors were attracted together and have more contact with each other (Wood, et al., 2014). Homophily is common in social networks (McPherson, Smith-Lovin and Cook, 2001). In July 2017, Science staff, in particular, were clustered together (Figure 1) and, in June 2018, NPWS staff were drawn together (Figure 3). People who are similar often have mutual understanding which reduces cognitive distance so they can better share complex information that relies on tacit knowledge (Prell, Hubacek and Reed, 2009; Wood, et al., 2014). Homophily also has a role in innovation. For example, innovation is initiated by interpersonal discussions between close colleagues which are most influential when there is uncertainty (Wood, et al., 2014). Cvitanovic, et al. (2015) highlighted the need for institutional innovation by decision-making agencies and research institutions to overcome barriers in knowledge exchange in Australian adaptive resource management. They noted that innovation is required to legitimise, recognise and reward knowledge exchange activities by research scientists. Therefore, the work by (the former) Office of Environment and Heritage (OEH) in New South Wales (NSW), Australia, is to be applauded for recognising and legitimising knowledge exchange activities by establishing the ALPINE network. The stated aim was to use the network to create a collaborative research program to inform management by OEH of the alpine region.

Homogeneity between groups can also enhance transfer of tacit knowledge (Cross, Borgatti and Parker, 2001). Before our research, NPWS and Regional Operations were more homogenous than Science (Figure 1) which suggests better knowledge transfer within clusters than between. High levels of homogeneity can also reduce diversity and limit access to distant resources (Krackhardt and Stern, 1988 in Crona and Bodin, 2006). Therefore, the ALPINE network needs to be monitored into the future to track homogeneity, and its impact on access to resources.

The visualisations also showed individuals who disrupted the pattern of homophily. For example, an individual from NPWS appeared within the Science cluster (N55), and two individuals from Regional Operations (N40, N58) appeared within the NPWS cluster (Figures 1, 2, 3). Their positions in the network probably result from secondments and transfers, illustrating the importance of movement in an organisation to build social connection, disrupt homophily and improve the knowledge flow across boundaries. Dowd, et al. (2014) found individuals in Australian primary industries who sought ties with people "outside their peer groups, geographical locations and industry boundaries" were more likely to be transformational adaptors and undertake purposeful action that created significant structural or functional change. Therefore, to find novel solutions to the challenging environmental issues within the alpine region, leaders of the state government knowledge network must consider ideas from individuals who disrupt patterns of homophily.

Those who attended meetings became more central and grew connections over time (Figures 1, 2 and 3). Hoffman, Lubell and Hills (2015) also found participation in outreach events correlated with network centrality, i.e. the more outreach activities a person attended, the more knowledge sharing relationships they had. This supports results from both the SNA and the surveys because respondents who attended meetings reported they met new people in the network and valued the opportunity to do so. It is pertinent that Obstfeld (2005) found social knowledge (not technical knowledge) was a significant predictor of involvement in innovation. Therefore, it is likely that innovation was fostered during the planning phase of the alpine research program – as leaders hoped.

Individuals with high degree centrality can help mobilise a network and bring others together (Prell, Hubacek and Reed, 2009), suggesting those with high centrality in the alpine research network in June 2018 would be effective members of a Steering Committee to progress the work. However, highly central individuals can also be more influenced by and embedded in their own group (Prell, Hubacek and Reed, 2009) and less influenced by other groups. Therefore, future research on the ALPINE network should monitor behaviour of people identified as central individuals to ensure they foster knowledge sharing and do not function as road blocks.

Goggin, et al. (2015) found state government scientists in NSW, Australia, had extensive knowledge networks. We also found the ALPINE network had connections to external sources of information with 19-25% of individuals in the SEEK network and 14-22% of individuals in the SHARE network nominated from external organisations (Table 6). As mentioned above, Dowd, et al. (2014) found those with far-reaching knowledge networks were more likely to make transformational change in Australian primary industries. Therefore, staff with more external contacts may be more likely to implement novel strategies and options. Innovation in organisations is also fostered by creating new social connections between people, their resources and ideas that combine in new ways (Obstfeld, 2005). Therefore, continuing to encourage novel and existing ties in this homogenous network is likely to allow the emergence of innovative strategies and options to address management challenges in the alpine region.

In general, NPWS staff became better connected in the ALPINE network over time, while Science staff became less connected (Figures 1, 2, 3). It is likely more staff in NPWS have expertise, experience and/or responsibilities for the alpine region than other groups because staff work directly with park management and are based adjacent to the alpine region. It is also possible that NPWS staff renewed and strengthened existing social connection with each other but failed to build new trusted connections beyond their group. Haynes, et al. (2011) found researchers who influenced public health policy in Australia had a personal relationship with policy makers, i.e. they were trusted. Goggin, et al. (2019) also found trusted connections improved knowledge exchange in Australian environmental programs. At the time of this research, the network was still in the planning phase, and yet to transition to implementing research priorities. Research suggests (Goggin et al., 2019; Cvitanovic, McDonald and Hobday, 2016) that new trusted connections between groups will form in the next phase of the program as staff from across the organisation work together to co-design and undertake projects. Of more concern, is that Heritage staff remained disconnected to the network throughout our research. This disconnection needs to be addressed to ensure social and heritage issues are included in a future alpine research program.

The analysis revealed the ALPINE network is likely to support its goal of developing a coordinated program of collaborative research that informs management. The network was decentralised which is conducive to long-term planning and collective problem-solving (Prell, Hubacek and Reed, 2009). The density (or cohesion) of the ALPINE network also increased over time (Table 4). Strong networks with high density (or cohesion) have the optimal structure to generate, acquire and spread knowledge, particularly factual, tacit knowledge (Long, Cunningham and Braithwaite, 2013; Crona and Bodin, 2006). Since the network became more dense (cohesive) over time, it is likely that tacit knowledge could be shared more efficiently through the network as people built connections. Dense networks are also effective for implementing action (Wineman, Kabo and Davis, 2009) which will be required as the network transitions from planning a program of research to undertaking it.

The SNA indicated the ALPINE network improved knowledge transfer over time. The network remained dynamic during the 12 months of the analysis, with people joining and others becoming inactive. This suggests the network continued to form and storm but was yet to 'norm' so it could better perform (Tuckman and Jensen, 1977). The network became less fragmented over time, indicating there was better connection between individuals and it was less vulnerable to change (Borgatti, Everett and Freeman, 2002; Prell, Hubacek and Reed, 2009). The average degree of the ALPINE network also increased (Table 3) indicating each individual was connected to more people. These measures bode well for the future of the alpine research network.

Betweeness explores the brokerage role of individuals. Actors with high betweenness have the most holistic view of a problem (Prell, Hubacek and Reed, 2009) so it is encouraging that, in July 2017, a manager from Science and one from NPWS had the highest betweenness scores (Table 2). The NPWS manager stayed involved in the ALPINE network for the 12 months and maintained a high betweenness score reflecting their diverse links throughout the network and continued role in knowledge brokering. In contrast, the Science manager moved to a different role in the organisation and no longer had responsibility for the alpine region; the change is reflected in the decline of their betweenness score. Long, Cunningham and Braithwaite (2013) found brokerage can mediate and resolve conflict, make knowledge more accessible and create environments where collaboration flourishes. However, there are different types of brokerage behaviour; mediation brokers help coordinate and transfer information between individuals while separation brokers maintain an advantageous disconnect between them (Grosser, et al., 2019). There are also challenges in measuring efficacy of knowledge brokers (Cvitanovic, et al., 2017). We recommend brokerage behaviour is investigated in the future to ensure knowledge brokers are functioning as mediators in the alpine research network. We also recommend further research into measuring the efficacy of knowledge brokers.

Key players may have the greatest reach and potential influence in a network (Cunningham, et al., 2017). The composition of key players in the ALPINE network changed over time, shifting from staff in NPWS, Regional Operations and Science (in July 2017), to those in NPWS and Science (in Nov 2017) and then to NPWS staff only (in June 2018). A manager from NPWS (N41) maintained their position as a key player throughout the 12 months with two scientists from NPWS (N18, N47) emerging as key players by June 2018. The changing composition reflects the shifting dynamics of the ALPINE network and changing dominance from Science staff to NPWS staff. It may also indicate better integration of social science into the network because one of the new key players was a social scientist. This is an encouraging development for the network because socio-economic research is often overlooked when determining research priorities but is critical to improving environmental outcomes (Robinson, et al., 2019).

The number of key players needed to reach most nodes in the network decreased over time. Initially, 17 key players were needed to reach 69% of the network but one year later, only three key players were needed to reach the entire network (Table 4). This suggests there may be some resiliency or redundancy in the network after 12 months. The composition of the ALPINE network will be reviewed as a result of this analysis to avoid duplication.

4.2 SEEK and SHARE networks

There was little change in multiple cohesion measures of the SEEK or SHARE networks over time (average degree, density, fragmentation and diameter stayed similar) (Table 7). The greatest shift was increasing closure of the SEEK network suggesting more individuals sought information from similar individuals. This suggests there is more work to be done to build connections in the network. Increasing the number of meetings could have improved these measures, but face-to-face meetings were costly and had to be limited.

Knowledge brokers are often suggested as a way to bridge the divide between different cultures. They can help build relationships of trust and facilitate transactions between actors who lack access to or trust in one another (Long, Cunningham and Braithwaite, 2013; van Kammen, de Savigny and Sewankambo, 2006). Most people in the state government research network sought information about the alpine region from scientists (Table 7).

Some scientists from NPWS (N47) and Regional Operations (N32, N58) (Figure 4, 5) remained important sources of alpine information over time. However, no scientists from universities or research organisations were nominated more than once (Table 7), suggesting the network could improve links to external sources. People also sought information from managers, particularly in NPWS (N38, N41). These individuals functioned as bridges between groups, and probably gained social capital from their role (Long, Hibbert and Braithwaite, 2013).

One manager from NPWS (N41) held a pivotal role in the network. This individual remained a source of alpine information, was frequently nominated as someone who people shared information with, and was identified as a key player throughout the analysis. In addition, an NPWS scientist (N47) was also identified as a key player in the ALPINE network in June 2018 (Table 4) and frequently nominated in the SHARE network in November 2017 and June 2018 (Table 7). Therefore, the NPWS manager (N41) and NPWS scientist (N47) hold influential positions in the network. There are risks with having a few key players in a network. Prestigious and successful individuals can spread unproven or ineffective ideas and practices in a knowledge network (Hoffman, Lubell and Hills, 2015; Henrich, 2001). Therefore, influential individuals particularly when they are "embedded" in a group (Prell, Hubacek and Reed, 2009) need to seek knowledge from different and diverse stakeholders. Access to information increases the ability to facilitate action that differs from social norms, and plan and implement novel strategies and options (Dowd, et al., 2014). So, although it is important to integrate existing knowledge in the network, it is also vital that key players widen their knowledge network to new sources. The influence of these key players needs to be harnessed in the research network by inviting them to join Steering Committee for the research program. Their knowledge brokerage behaviour also needs to be monitored (Long, Cunningham and Braithwaite, 2013) to ensure they are fostering knowledge flow and not hindering it.

The reach of key players remained similar over time in both the SEEK and SHARE networks. However, key players in the SHARE network had more reach than those in the SEEK network. This suggests people share with fewer well-connected individuals and seek information from a broader network. This is encouraging for the alpine research network because individuals are drawing information from diverse sources which is being consolidated by sharing it with a few key individuals. Weak ties are also important for innovation (Granovetter, 1973). However, as discussed above, there are risks associated with only a few key individuals in a knowledge network.

Individuals in the ALPINE network sought and shared information with a majority of NPWS staff over time, with fewer (but similar numbers of) staff from Regional Operations nominated in both networks over time. In contrast, the number of Heritage and Science staff nominated in both networks declined over time, suggesting Heritage and Science Divisions became less connected to the network. This suggests the expertise of Science and Heritage staff is not well known. It is also likely that staff in the network continue to seek and share information with existing connections, and have not yet formed trusted connections in other Groups/ Divisions as a result of the meetings. Therefore, the organisation must continue to foster connection between staff from different groups (particularly with Heritage Division) and build social connection, so their relevant expertise is highlighted within these groups and in turn can inform the development of the research program. In these instances, there may need to be organisational intervention to encourage additional collaboration between these groups (Cross, et al., 2001).

Information about the alpine region was often shared with managers, particularly in November 2017 when most individuals (seven of 11, 64%) who were nominated frequently in the SHARE network were managers (Table 7). By June 2018, more than half (four of seven, 57%) the individuals nominated frequently were managers, with most from NPWS. No Science or Regional Operations staff were nominated more than twice, and no Heritage staff were nominated, suggesting the network was contracting. It may also reflect that Science staff helped coordinate the network at the start, but later many of them stepped away because few of them have experience or responsibilities for the alpine region. Regardless of the cause, it highlights a gap in knowledge sources informing the alpine program, and it is recommended that connections beyond NPWS to Regional Operations, Heritage and Science Divisions are encouraged. A research program will only be considered legitimate if it is developed through a process that considers the values and perspectives of all relevant actors (Cook, et al., 2013).

5. Conclusion

Leaders and managers need to integrate a diversity of knowledge and values into their decision making for effective environmental management (Jacobs, et al., 2016, Easterbrook, 2012). This challenge is particularly difficult for managers within government organisations because social connections are invisible and the role of staff as knowledge brokers may not be recognised (Fliervoet et al., 2016; Cross, et al., 2001). We found Social Network Analysis (SNA) allowed invisible connections to be uncovered; to analyse and visualise the dynamics of this government research network. Longitudinal SNA enabled us to measure growth in social connections and identify individuals with knowledge brokerage roles. The results of the analysis will be invaluable in transitioning the network from the planning to the implementation phase, and ensuring it creates a collaborative program of research that is considered legitimate and also addresses the multiple challenges in the alpine region.

Our analysis highlighted risks and opportunities for the network if it is to achieve its aim of fostering knowledge exchange. It revealed the government research network is building more and stronger connections between participants. The network also had connections through both the SEEK and SHARE network to external sources of information which are likely to be sources of novel ideas. However, individuals continued to seek and share information with existing (trusted) connections, particularly from one group which could limit new innovative solutions to the challenging management issues in national parks in NSW. The behaviour of key players also needs to be studied to ensure they are fostering, not hindering, knowledge exchange. Additional research on measuring the efficacy of knowledge brokers is also recommended Future planning will draw on the influential individuals identified as key players in the ALPINE, SEEK and SHARE networks, while continuing to track their roles and undertake research to understand their knowledge brokerage behaviours and effectivness.

In conclusion, our analysis provided insight to manage the research network so it integrates diverse sources of knowledge into environmental management of a unique Australian region. Our results suggest that with ongoing collaboration, a deepening of shared knowledge, and appropriate adaptation policies, the network may achieve its goal of building a coordinated program of collaborative research that informs management and improves condition of the natural, socio-economic and heritage values of the alpine region.

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