Social network analysis of a landscape-scale conservation initiative in South Africa

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Assessment of social relations, including social network analysis, is central to understanding collaborative processes for environmental decision-making and action. The capacity of network role players to learn and adapt appropriately to uncertainty and change is a critical determinant of the resilience of social-ecological systems. Poor social network structure can predispose failure. In this study, we used social network analysis to explore learning capacity and network resilience in a multi-authority conservation initiative on the West Coast of South Africa (Dassenberg Coastal Catchment Partnership). Our analysis focused on structural variables for network learning and resilience, namely connectivity, heterogeneity, and centrality. The governance network was found to be structurally connected, with the interaction between heterogeneous organisations and sectors, and centralised around a core group of actors. The network had good structural features to enable learning. However, the high level of centrality, and dependence on a small number of core actors, rendered the network potentially vulnerable to dealing with complex challenges. We recommend that core actors (1) reflect on their core functions and whether the network can absorb these functions if they were to leave and (2) tap into the knowledge potential of actors on the network periphery or invite new actors to the network when dealing with complex challenges. This may require the network to diverge into decentralised subgroups to deal with complex issues. We further suggest that the Dassenberg Coastal Catchment Partnership network incorporate social network research with qualitative monitoring into a long-term plan to monitor the movement and influence of actors as the initiative evolves.

Significance:

- This study illustrates how social network analysis can help researchers, public-sector organisations, and donor agencies to monitor the structural features of governance networks that enable or disable learning and resilience within landscape-scale conservation initiatives.
- Our results illustrate how social network analysis can assist public-sector actors to reflect on their roles and whether there is redundant competency within the network to maintain its resilience.

Introduction

The challenges associated with navigating complex social-ecological systems require governance regimes to be collaborative and adaptive.[1,2] Collaborative governance is an arrangement in which one or more public-sector agencies engage non-state actors in collective decision-making processes.[3] This takes place through formally organised forums, focusing on decisions, made by consensus, that affect public policy and management. Adaptive governance is a flexible, learning-based, collaborative approach in which state and non-state actors engage in decision-making, at multiple interconnected levels.[4] Operationalised through adaptive co-management, adaptive governance promotes resilient social-ecological systems by encouraging adaptation and transformation, whilst maintaining core functions.

Importantly, these governance regimes need to promote cross-scale networks of interaction and learning between multiple sectors of society, e.g. government departments, the private sector and civil society groups.[5,6] While learning typically takes place within an individual[7], learning required for environmental governance must occur at larger social scales, e.g. organisations and institutions[6,8]. Cross-scale, co-learning is crucial for adaptive governance because it taps into the stored social memory of networks[9,10], enhancing the adaptive capacity of governance regimes by providing options for response through periods of change and uncertainty[10,11]. Decision-making in governance networks is therefore assumed to be only as effective as the relational links that facilitate communication between actors within and between networks.[2]

Analysing social relations has therefore come to the forefront of assessing collaborative governance arrangements.[12,13] Social network analysis (SNA) is an approach that examines patterns of interaction and communication between actors and entities. Through this approach, data are systematically analysed, using mathematical tools derived from graph theory, to assess the configuration of social ties between actors.[14] The distribution of these configurations is theorised to have implications for the resilience and learning capacity of governance regimes.[10,12,15,16] While network structure alone does not fully explain the success or failure of a governance regime, poor structure can predispose failure.[2,16,17] Therefore analysing social network structures can assist governance regimes in uncovering factors hindering success.

Resilience in social networks has been described by Newig et al.[15(p.6)] as 'the capacity of the network to remain intact in its core functions when subject to pressure or sudden change'. Resilient governance networks therefore need redundancy of both competencies and network relations, as these make the network less vulnerable to sudden change.[15] Therefore, for co-management to promote resilience in social-ecological systems, governance networks should not rely solely on one administrative entity but should seek redundancy in core functions amongst diverse entities.[17]

While there are no panaceas, different structural properties can enable and/or disable networks.[16,18] For example, networks exhibiting a high degree of centralisation are linked to a greater likelihood of building consensus and coordinating collective action.[17,19] On the other hand, high degrees of centralisation in networks that lack actor heterogeneity have also been found to inhibit the capacity of long-term planning and the ability to manage complex tasks in future stages.[16,20] A high degree of centralisation can be beneficial, depending on the life stage of the initiative.[17,21] By taking a social network perspective, it is possible to examine the structural configurations of governance networks, to gain insight into how the relational structure may enable or hinder the network, potentially identifying opportunities for improvement.[13,22] These measures are, however, context dependent and interpretations regarding their influence should be based on several social network measures to obtain a comprehensive understanding.[23]

A particular area of governance to which SNA can be applied is landscape-scale approaches to conservation. Landscape-scale conservation is an ecosystem-based management approach promoting connectivity, integrity, and heterogeneity while simultaneously attempting to reconcile trade-offs between conservation and development.[2,24] Spanning traditional protected area boundaries and land uses, landscape-scale conservation recognises the potential contribution of other systems – such as farmlands or urban areas – towards achieving conservation targets. These integrated landscape-scale conservation initiatives represent social-ecological systems that are heterogeneous and multifunctional, encompassing multiple ecosystems services, land uses, stakeholders, organisations, and institutions.[24] The inherent multiplicity of stakeholders, ecosystems, land uses, organisations and institutions poses challenges for governance. Effective co-learning is necessary for navigating complexity and achieving desirable coordinated action.[8] However, many environmental governance systems lack the mechanisms or capacity for co-learning and often repeat past mistakes.[8,25] SNA allows us to explore the structural configuration of social relationships within governance regimes to gain insight into the network's capacity to foster collaboration and adaptation.

In this study, we used SNA to explore the structural aspects that facilitate learning and network resilience for a landscape conservation initiative in the West Coast of South Africa: the Dassenberg Coastal Catchment Partnership (DCCP). We selected three network variables (connectivity, heterogeneity, and centrality) to assess capacity for learning and network resilience.

Overview of selected network variables

While each of the three selected measures – connectivity, heterogeneity, and centrality – has advantages and disadvantages for learning and network resilience (Table 1), they may also affect one another.[23] Furthermore there are no standard criteria or 'cut-off-values' for any of these measures to be considered high or low. Interpretations are context dependent and should be based on a comprehensive understanding of all the selected network measures.[23]

Network connectivity

Connectivity within social networks is a function of the number of social ties between actors or nodes within the network.[26,27] The basic assumption is that the more relational ties there are, the greater the potential for building social capital within a network.[26] Social capital refers to relations of trust and reciprocity, with common rules, norms and sanctions present.[10] Social capital thus results in feelings of belonging, trust, and group identity.[2] This promotes the transfer of information, leading to learning that supports greater legitimacy for co-management and improved management practices.[22] Structurally, cohesive networks lack clearly distinguishable subgroups, as they are connected through many strong and redundant ties.[13] These ties have also been referred to as bonding ties and linked to bonding social capital.[16,28] Bonding social capital plays a key role in building trust and developing a shared understanding and group identity. Ties that link subgroups are referred to as bridging ties and promote bridging social capital.[13,16] These ties are especially important for enabling access to new information and facilitating the diffusion of innovation.[28]

Suggested measures for network connectivity include network density and reachability.[27,29] Network density is defined as the extent to which actors in the network are connected to one another, providing pathways for information transfer between actors.[27] Small networks generally exhibit high network density as it is easier to maintain relationships and transfer information within small groups.[15] Large networks are likely to exhibit less density because of the quadratically growing number of possible relations. Thus small networks (between 8 and 15 actors) have been found to be more effective for co-learning[30], although learning may still effectively occur in large networks that exhibit small cohesive subgroups through core-periphery structures[13,15].

Reachability refers to the capacity of all actors within a network to have access to each other.[27] It becomes important to consider in large networks, because information can become distorted when transmitted by many actors. Highly connected networks have many relational ties between actors and tend to exhibit high density and high reachability. Networks with high density and reachability are cohesive and potentially resilient to the loss of nodes as there is likely redundancy found within the social ties of actors who can fulfil similar roles.[17,27] While having a high level of connectivity is preferable, networks must foster ties with heterogeneous actors to reduce the risk of knowledge becoming insular.[20,31] It is therefore important to consider the interdependent nature of network connectivity and heterogeneity when assessing learning capacity and network resilience.

Network heterogeneity

According to human communication theory, information transfer and knowledge development mostly occur amongst like-minded or similar individuals.[7] Homophily is the degree to which two actors have similar attributes.[15,32] Homophily can be advantageous in that information can be transferred more quickly, as actors have similar experiences and understanding. Complex social-ecological challenges, however, require governance networks with a certain level of heterogeneity.[5,33,34] Diversity of organisations and sectors in a network reflects cross-boundary and cross-scale interactions, indicating access to diverse knowledge and resources, as well as the potential for diversity of practices and experimentation in the landscape.[2,10] Therefore, by incorporating heterogeneous actors from different sectors, organisations and institutions, governance networks will have options available for responding to change and disturbance, thereby improving the potential for learning and innovation and overall social-ecological systems resilience.

Heterogeneity in networks, however, can come with challenges due to the diverging priorities, perceptions, terminologies and needs among diverse actors.[2,17] Therefore, when managing networks for knowledge diversity, the focus should not be simply to bring heterogeneous people together. Rather, the focus should be on bringing a set of diverse actors together with knowledge relevant to the issue at hand, and bridging their differences through collective learning processes and the development of social capital.[2,35] While actors should represent different disciplines, perspectives and contexts, there should be some consensus toward a common goal.[24] While these actors may differ in opinion, such variations are likely to generate more ideas and creative solutions.[7] The challenge is to balance knowledge diversity, to increase the potential for acquiring new knowledge, with knowledge overlap to enable effective coordination and communication.[22,35] When managed effectively, diversity increases the opportunities for creativity, innovation and resilience.[5,33] When managed inappropriately, it can lead to inefficiency, dissatisfaction, major conflict and even collapse of decision-making and coordinating action.[2]

Network centralisation

Network centralisation considers the distribution of social ties between actors within a network, as well as the structural importance of actors depending on where within the network they are located. A highly centralised network is characterised by one or few central actors which are tied to the majority of actors within the network.[26] Actors found in central positions are high ranking as they have a significantly higher-than-average number of ties and are considered well connected and influential within the network.[21,27] Centralised networks have been positively correlated with collective action, due to the potential of central actors to act as information hubs, prioritise and share information, and coordinate activities.[17] These networks are also seen as more accountable, as central actors can be held responsible to some degree.[27]

While centralised networks are good for information transfer and collective action, they are less appropriate for dealing with complex problems.[13,20] The over-reliance on central actors can reduce the diversity of representative information and lead to insular thinking.[13,31] Furthermore, centralised networks are vulnerable to the loss of, or dysfunctionality of, central actors. Actors that occupy these positions can have a positive and negative impact on governance outcomes. There are several metrics of centrality, including whole network measures and actor-level centrality measures.

Table 1: Advantages and disadvantages of network structural properties

Network structural properties	Advantage	Disadvantage
Connectivity	Increased information exchange and learning Trust and group identity Diffusion of innovation Less vulnerable to the loss of key actors	Highly connected, low heterogeneous networks are susceptible to insular thinking
Heterogeneity	Access to diverse knowledge Exposure to alternative practices Increased opportunities for creativity and innovation	When managed incorrectly it can lead to inefficiency and dissatisfaction for decision-making and coordinating action
Centrality	Enhances coordination and collective action Perceived as more accountable	Less effective for complex problems Central actors can impede information and resource flows The loss of central actors can lead to vulnerability and network fragmentation

Case study

The Dassenberg Coastal Catchment Partnership (DCCP) is a landscape-scale environmental stewardship initiative, falling within the Cape Floristic Biome in the West Coast region of South Africa (Figure 1). With a total area of 34 000 ha, landownership consists of 39% state owned, 29% privately owned, 20% community owned, and 12% land owned by the City of Cape Town Municipality (Figure 1).[36] With assistance from the Global Environmental Facility, the City of Cape Town Municipality – Biodiversity Management Department (CCT-BM) and CapeNature aim to proclaim 12 000 ha of the DCCP area under some form of protected area status.

Together the CCT-BM and CapeNature are driving the project by providing knowledge and resources for protected area expansion and implementation of biodiversity conservation. The CCT-BM is a relatively small department within the local municipality responsible for managing the green spaces and nature reserve that fall within the City of Cape Town municipal domain.[37] CapeNature is a provincial conservation organisation responsible for management of provincial nature reserves within the Western Cape Province.[38] The funding obtained from the Global Environmental Facility was utilised for various staff appointments such as a landscape coordinator, legal consultants, and conservation planning facilitators as well as for capacity development and various biodiversity management implementation costs.

The DCCP was identified as having conservation significance in terms of biodiversity protection and climate change mitigation.[36] It contains the most extensive, ecologically functioning portion of endangered lowland fynbos habitats in the Western Cape, with up to 60% of the plant species only occurring within a 50-km radius. The area hosts a coastal aquifer and recharge zone which is responsible for supplying neighbouring communities with 40% of their fresh water. The coastal aquifer is a critical natural resource considering that climate change predictions for the Western Cape suggest that the area will become increasingly water stressed, as was evidenced by the 2017/2018 ‘day zero’ drought in Cape Town.[39] Furthermore the cost of replacing the water that this critical ecological infrastructure provides is estimated to be billions of rands. Ecological infrastructure is the nature-based equivalent of built infrastructure, providing society with services such as naturally filtered fresh water.[40] It can support, sustain, or even substitute built infrastructure.

The DCCP initiative is reacting to several drivers including multilateral treaties such as the Convention on Biological Diversity Aichi target 11[41], and national policies such as the National Protected Area Expansion Strategy[42] and the National Climate Change Adaptation Strategy[43]. The focus is on using an ecosystem-based approach to address multiple threats and promote conservation of biodiversity to secure critical ecological infrastructure and increase ecosystem resilience to climate change.[36]

Due to the high cost of land acquisition and declining budgets of conservation agencies, landscape conservation was promoted through biodiversity stewardship agreements with private and communal landowners.[36] Biodiversity stewardship arrangements range from non-

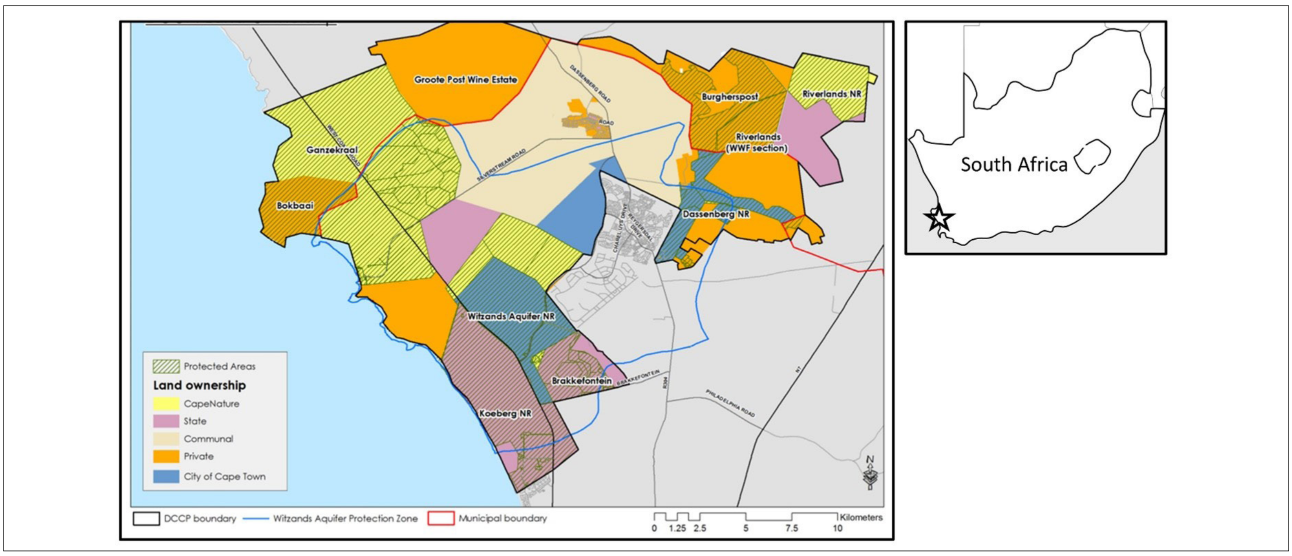

Figure 1: Map of the Dassenberg Coastal Catchment Partnership (DCCP) indicating landownership and represented in the context of South Africa.

binding to long-term, formally declared protected areas.[44] Depending on the contract between landowners and conservation agencies, the agreements contain incentives ranging from technical advice and biodiversity supportive management (e.g. alien clearing and ecological fire management), to tax incentives for the highest levels of protected area status. The protected area expansion project is focused on promoting and coordinating cost-effective and efficient co-management for a network of protected areas at a landscape scale.

Methods

When embarking on a SNA it is important to define the boundary of the network studied.[13,14] As is typical of governance networks elsewhere[3,17], the DCCP network comprises actors that represent governmental, non-governmental and private organisations and citizen groups. Based on Sandström and Rova[21], we defined the governance network boundary to be those actors who actively represented their organisations in designing the rules for co-management within the DCCP. We therefore conducted a social network survey, using a technique similar to that described in Plummer et al.[45], with managers and key individuals who were identified as being actively involved in the governance of the DCCP.

Through participation in planning workshops during September and October of 2017, we identified 15 managers who were actively involved in the governance of the DCCP. Of these, 10 actors accepted our invitation to participate in a social network survey. Ethics approval for this study was granted by the Human Research Ethics Committee of Nelson Mandela University (REF: H17-SCI-NRM-007) and informed consent was obtained from all participants.

The participants were interviewed individually and asked to identify actors from the original list of 15 with whom they (1) exchanged information and (2) coordinated action on behalf of the DCCP initiative. Information sharing included collating monitoring and evaluation data, as well as one-on-one and group engagements that promote collective decision-making and action. Examples of coordinated actions included invasive alien plant control, conservation compliance and law enforcement operations, and stakeholder engagement. The actors were then also asked to nominate any other actors, not included on the list, with whom they shared information and coordinated action on behalf of the DCCP initiative. These nominees were also invited to participate in the study and were asked the same series of questions. Consistent with a snowball sampling technique[46], sampling was halted when no new important actors were nominated.

Through this process, a total of 34 actors were identified of which 25 (74%) agreed to participate in the study. All interviews took place between February and November 2018. Each of the 34 actors was assigned a node identity number. The data were then captured as an adjacency matrix in an Excel™ spreadsheet, with 34 columns and 34 rows. Every confirmed relationship between actors was marked as a 1, with no relationship equal to 0 (Supplementary table 1). The organisation and sector affiliations for each actor were noted. The data sets were analysed and visualised using social network software, UCINET 6 and Net Draw.[14] To compensate for missing data (the actors who did not participate), it was necessary to symmetrise the adjacency matrix, using average actor responses as recommended by Borgatti et al.[14] In the network, each node represents an actor, with the relationships between actors visualised as a link between the nodes.

Connectivity was assessed using measures for density and reachability.[27,29] To assess reachability, network diameter and the number of components within the network were considered. Heterogeneity was assessed through node diversity and network homophily measures.[21,32] Network centrality was assessed through the degree of network centralisation, a core-periphery structure, degree centrality and betweenness centrality.[2,13,47] See Table 2 for more details of network measures.

The effect of the loss of key actors on network resilience was explored through node removal experiments. This procedure was performed by removing the nodes with the five highest degree centrality scores from the network one by one to determine how many relational ties for which these nodes were responsible.[47] This procedure indicated the extent to which the loss of central actors would fragment the network. All the results were used to interpret the learning capacity and resilience of the DCCP network.

Results

Table 3 displays results from our analysis for network connectivity, heterogeneity and overall network centralisation. Core-periphery centrality results are displayed in Figure 2. Individual centrality measures can be found in Figure 2 and Table 4.

A total of 34 nodes with 454 ties were captured. This resulted in a density of 0.406, with network reachability consisting of one component with a diameter of three. In terms of heterogeneity, the actors represented 17 organisations from six sectors: local, provincial and national government; non-governmental organisations (NGOs); private landowners; and a local

Table 2: Methods for measuring connectivity, heterogeneity, and centrality

Variable	Measure	Description
Connectivity	Density	Number of social ties divided by the maximum number of possible ties.[27]
	Reachability	Network diameter – the maximum path length/ number of steps to connect any two actors. Number of components – a component is an independent network within a larger network.[29]
Heterogeneity	Node heterogeneity	The number of participating organisations and sectors.[21]
	Homophily	Number of ties between and within mutually exclusive groups, divided by the total number of ties. E-I output range -1 to 1, whereby -1 indicates complete homophily and 1 indicates complete heterogeneity.[32]
Centrality	Network centralisation	Measures the extent to which all networks are centralised around one or a few actors.[13]
	Core-periphery	Identifies which actors sit within the core and which sit on the periphery of the network.[13,45] Core actors are highly connected to other highly connected actors and act as hubs for information transfer and coordination. Peripheral actors are those connected only to core actors, with no or few direct connections to other peripheral actors. Peripheral actors are likely to act as bridges to other networks, thus having access to different information.[10,45]
	Degree centrality	An actor-level centrality measure that assesses the number of direct social ties for each node.[26]
	Betweenness centrality	An actor-level centrality measure that looks at the number of times a node falls along the shortest path between other nodes.[14] These actors are critical connection points and play bridging roles, used to disperse information and innovation or mobilise resources. These actors can highlight vulnerabilities as they may impede information or cause fragmentation to the network if they leave.[26]

community property association (Table 3) (see Supplementary table 2 for details on the identified organisations). The homophily score indicated a weak-to-moderate level of heterogeneity between participating sectors (E-I=0.395) and a moderate level of heterogeneity between participating organisations (E-I=0.553).

Table 3: Results of social network analysis for the Dassenberg Coastal Catchment Partnership governance network

Network metrics		Structural properties
Density	0.406	Connectivity
Diameter	3	
Components	1	
Number of organisations	17	Heterogeneity
Number of sectors	6	
Homophily E-I – Sector	0.395	
Homophily E-I – Organisation	0.553	
Network centralisation %	50.19	Centralisation

The core group of actors participating in the governance of the DCCP were dominated by actors from CCT-BM and CapeNature but also included representatives from two NGOs (the Cape West Coast Biosphere Reserve and The Nature Conservancy – Water Fund), a private conservancy, and the local community property association (Table 4).

Degree and betweenness centrality measures were used to identify highly connected and influential actors within the DCCP co-management network (Figure 2 and Table 4). Actors 3, 15, 10, 4 and 2 had the top five highest degree centrality results, with Actors 3, 2 and 15 having notably high betweenness centrality scores. The node removal experiment indicated that the actors with the five highest degree centrality scores (Node ID 3, 15, 10, 4 and 2) were responsible for 50% of the relational ties of the network. Only by removing Node 2 were two peripheral actors isolated. This result was supported by the network centralisation score of 50.19% (Table 3).

Discussion

Our findings suggest that the DCCP governance network was structurally cohesive, with 40% of all social ties present, no fragmentation, and a maximum path length of three. The level of connectivity was thus conducive for information transfer and learning[13,20], also suggesting potential for group identity and social capital within the network[29]. Heterogeneity measures showed diverse interactions between organisations and sectors, indicating cross-boundary and cross-scale information exchange. This finding shows that the network had access to diverse knowledge and resources, which would potentially reduce the likelihood of insular thinking.[5,16] Furthermore, connected, heterogeneous networks have been found to exhibit increased experimentation[21,33] which can potentially enhance their resilience and increase their capacity to deal with complex challenges.

The DCCP network was moderately centralised, as indicated by the network centralisation score (50.19%). Centralised governance networks have been found to be effective for knowledge sharing and solving simple challenges, and favourable for coordination.[19,48] Highly centralised networks are held together by one node, and the loss of that node can lead to fragmentation and potentially the end of collaboration.[27,29,48] However, our results distinguished a well-connected core group from loosely connected peripheral actors, typically observed in governance settings.[47] Degree centrality results indicate that the network was centralised around five core actors. These actors were responsible for 50% of the relational ties within the network (Table 4). As to be expected, these actors represented CapeNature and CCT-BM. These organisations were important, not only for driving the initiative[36] but also as bridging organisations responsible for strategically linking actors and providing arenas for the potential development of trust and shared understanding, and for facilitating conflict resolution and cross-scale collaboration.[49]

Actors 2, 3 and 15 were identified as important coordination points within the network, due to their betweenness centrality results. Actors 3 and 15 were landscape and stewardship coordinators for CapeNature and CCT-BM, respectively, and Actor 2 was CapeNature's regional manager for the area. Their positions within the network suggest that these three actors played a potentially important role as knowledge brokers[47] and boundary spanners[2], as they were responsible for channelling information and mobilising joint action between sectors, between organisations, and across scales. A SNA study by Angst et al.[47], based on three actor networks around the water governance sector in Switzerland, identified central coordinators and peripheral connectors as key actor positions in governance networks. Central coordinators, such as Actors 3 and 15, were found to connect actors at the centre of the network and, as found in Angst et al.[47], they were key for regularly facilitating coordinated action. Actor 2 played a role both as a central and as a peripheral connector. Peripheral connectors were noted as an important bridging role for integrating otherwise unconnected actors, thus facilitating access to new knowledge.[47] Corresponding to Angst et al.[47], we found that the central coordinators were occupied by public-sector actors who were involved in day-to-day operations. Peripheral coordinators, on the other hand, are often not involved in day-to-day

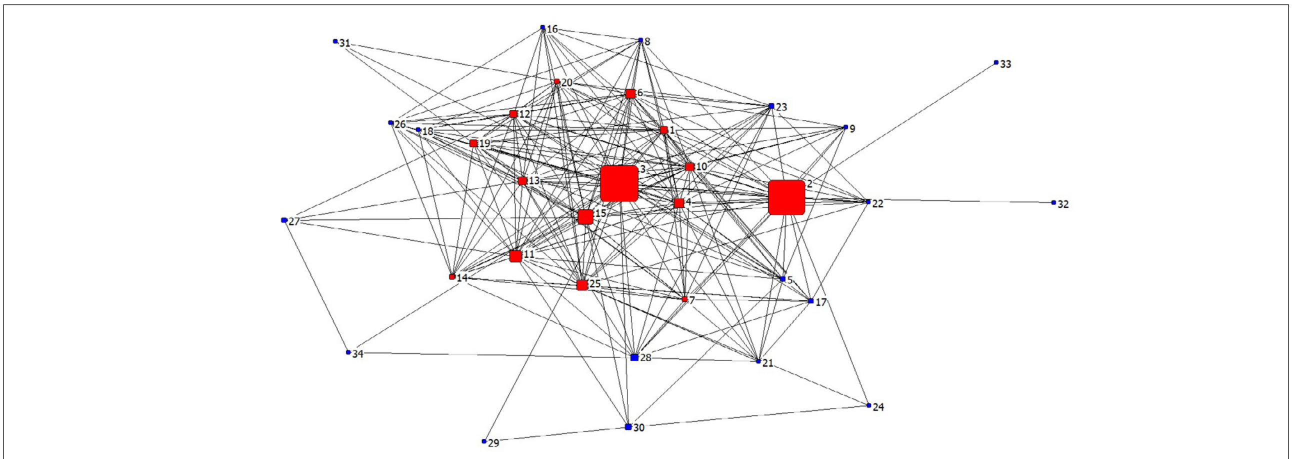

Figure 2: Dassenberg Coastal Catchment Partnership governance network. Red nodes show the core actors and blue nodes show the peripheral actors. Node size indicates betweenness centrality. The numbers identify each actor as listed in Table 3.

Table 4: List of actors with identified attributes and degree and betweenness centrality scores. Actors in bold were not available for participation.

Node	Organisation	Role	Sector	Centrality		Node	Organisation	Role	Sector	Centrality	
				Degree	Between					Degree	Between
1	Bokbaai NR	Reserve manager	PS	50	10.231	18	Eskom-Koeberg NR	Reserve manager	NatG	41	1.034
2	CN	Regional Manager	PG	87	84.663	19	MCPA	Mamre - Community property association	Community association	58	8.451
3	CN	Landscape coordinator	PG	134.5	88.629	20	TNC	Water fund manager	NGO	48	1.655
4	CN	Science management coordinator	PG	87.5	14.244	21	SANParks	Buffer Zone Coordinator	NatG	25	1.044
5	**CN**	**Conservation extension services**	**PG**	**23**	**4.023**	**22**	**WCDM**	**Environmental Management**	**LG**	**23**	**0.559**
6	CN	Community Conservation	PG	73	13.97	23	DEA	LANDCare	PG	38.5	2.579
7	**CN**	**Conservation planning**	**PG**	**21.5**	**1.818**	**24**	**Swartland Municipality**	**Town planning**	**LG**	**7**	**1.038**
8	**CN**	**Reserve Manager - Riverland's**	**PG**	**26**	**1.266**	25	CWCBR	Conservation manger	NGO	69.5	17.755
9	CN	Marketing and Tourism	PG	26	0.637	26	CCT-BM	Reserve supervisor	LG	32	1.101
10	CN	Reserve Manager - Ganzekraal	PG	96	12.594	27	Nirvana Conservancy	Reserve manager	PS	8	1.5
11	CCT-BM	PA expansion manager	LG	80.5	19.473	28	WWF	Land Programme	NGO	29.5	8.756
12	CCT-BM	Area manager	LG	77.5	9.779	29	CN	PA expansion and stewardship manager	PG	12	0
13	CCT-BM	Biodiversity coordinator	LG	77.5	12.813	30	CN	Legal dept.	PG	24.5	5.032
14	CCT-BM	Biodiversity Management - senior manager	LG	47	3.245	**31**	**CN**	**Small grants management**	**PG**	**11**	**0**
15	CCT-BM	Stewardship coordinator	LG	102.5	28.297	**32**	**CN**	**Financial department**	**PG**	**3.5**	**0**
16	Burgherspost conservancy	Reserve manager	PS	33	1.012	**33**	**DPWI**	**Property management**	**PG**	**2**	**0**
17	DEA&DP	Integrated Coastal Management	PG	28	2.085	**34**	**CPFPA**	**General Manager**	**NGO**	**6**	**0.716**

Organisation: CN, CapeNature; CCT-BM, City of Cape Town – Biodiversity Management; DEA&DP, Department of Environmental Affairs and Development Planning; MCPA, Mamre Community Property Association; TNC, The Nature Conservancy; SANParks, South African National Parks; WCDM, West Cost District Municipality; DEA, Department of Agriculture; CWCBR, Cape West Coast Biosphere Reserve; WWF, World Wildlife Fund; DPWI, Department of Public Works and Infrastructure; CPFPA, Cape Peninsula Fire Protection Association
Sector: PS, private Sector; LG, local government; PG, provincial government, NatG, national government; NGO, non-governmental organisation

operations and are often linked to external networks and knowledge.[47] Angst et al.[47] found that peripheral connectors were likely to be actors representing organisations at a higher jurisdictional level. However, in our study this was not necessarily so. The peripheral actor was part of one of the organisations responsible for central coordination, while also performing a higher jurisdictional role.

Centralised networks have often been found to be less effective for solving complex challenges[17,27] and are more vulnerable to the loss of core actors[27,48]. Networks that cross scales and are heterogeneous were, however, noted as less vulnerable to these losses.[17] Overall, network connectivity and centrality will aid decision-making by potentially lowering transaction costs and fostering learning through information transfer[17,35], whilst diversity can promote access to other knowledge at multiple scales.[50,51] The level of centralisation was also likely a function of the age of the network, which was newly initiated at the time of data collection. Higher levels of centralisation are often required at the start of collaborative governance initiatives to mobilise and coordinate actors.[13,17,19] However, when engaging to resolve more complex issues, a less centralised network may be more favourable in the long term.[11,12,52] Deliberate strategies may therefore be needed to evolve the network for various requirements.[22,28] For instance, core actors may need to either engage more closely with peripheral actors or expand beyond the reach of this network and involve new actors.

Finally, we need to acknowledge an important limitation of this study. We established the existence of relationships within the governance network of the DCCP through SNA, but did not attempt to analyse the quality of those relationships. While beyond the scope of this research, the study would have benefitted from complementary qualitative enquiry methods to further establish the quality of the established relationships. Research has found that qualitative enquiry complements SNA by indicating how the network's structural properties link to human, social and physical capital.[2,12,45] The value of our analysis lies in (1) highlighting network structural features that are hypothesised to enable or hinder learning capacity and resilience and (2) identifying opportunities for potential improvement through network governance.[13,15,17]

Another limitation was that – following the definition of Sandström and Rova[21] – we engaged only with those actors who actively represented their organisations in designing the rules for co-management within DCCP. In effect, we favoured actors from formally organised groups, and omitted marginalised, landless stakeholders who were not represented by a recognised organisation. This precluded analysis of unequal capacity and unequal power relations – issues that are critical in the context of southern Africa.[53]

Conclusion

The DCCP network was found to have good potential for learning as it was connected, heterogeneous and centralised around a core group of actors. The network was found to be potentially resilient to the loss of its core actors due to the many redundant social ties. This is, however, dependent on the ability of other network actors to absorb such potential capacity loss and maintain core functionality. The DCCP core actors should therefore reflect on these capabilities and deliberate whether the network can absorb these functions or if mentorship would be needed to ensure network resilience. We recommend that the DCCP core actors also recognise the potential knowledge contribution of its peripheral actors and facilitate co-learning processes to address complex challenges within the landscape. This may require the network to diverge into decentralised task teams. We also recommend that new actors (including those not represented by organisations) with relevant, complementary knowledge, be invited into these sub-networks when needed.

Furthermore, we recommend that SNA be used to track changes in the DCCP network structure over time, to monitor the movement and influence of actors and the evolution of the governance network. Monitoring can enable the identification of structural advantages and disadvantages for the network's capacity for resilience and to learn. Supporting this with qualitative enquiry methods can further establish an evidence base to understand the causality of the network structural properties for learning and resilience. For example, interviews with the DCCP actors could establish the level of redundancy within the network to ascertain where vulnerability lies in terms of capacity and relational links. Given the relative newness of landscape-scale conservation initiatives, like the DCCP, we believe that this type of monitoring can provide useful information to guide governing networks towards more sustainable practices. We argue that learning capacity and network resilience are important components of adaptive governance, and thus underpin the likelihood of improved long-term success for landscape-scale conservation. It should therefore be a primary consideration for these types of initiatives to monitor and manage their networks accordingly to improve governance processes.

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Competing interests

We have no competing interests to declare.

Authors' contributions

S.M.-J. was responsible for the investigation, data analysis, conceptualisation, and writing and revising of the original manuscript. P.N. was responsible for supervision of early drafts and reviewing and editing. D.J.R. was responsible for funding acquisition, reviewing, and editing. B.C. was responsible for reviewing and editing. All authors agreed to the submission of the manuscript.

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