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ORIGINAL ARTICLE

Assessing collaboration, knowledge exchange, and stakeholder agency in coastal governance to enhance climate resilience

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Abstract

Coastal governance plays a central role in building the capacities for adaptation and transformation towards climate resilience in coastal social-ecological systems (SES). However, enhancing climate resilience requires effective coordination between organisations involved in coastal governance. Therefore, more information about the role and agency of organisations and the relationships between them is needed. This paper aims to improve the understanding of collaboration, knowledge exchange, and stakeholder agency for enhancing climate resilience in coastal SES, using a case study in Algoa Bay, South Africa. We apply and combine stakeholder analysis and social network analysis, which is currently underrepresented in climate change adaptation research. Results suggest that different top-down and bottom-up processes are needed to improve knowledge exchange and enhance climate resilience in the coastal governance of the Algoa Bay SES. These include improved leadership, effective knowledge transfer, integration of climate information, support for bridging organisations, and inclusivity of marginalised stakeholders. These suggestions may also be more broadly applicable and transferable to similar coastal SES. Ultimately, the results of this study shed light on network structures in coastal governance facing climate change and advance research on combining stakeholder analysis and social network analysis in climate change adaptation and environmental governance research.

Keywords Coastal governance · Climate resilience · Social network analysis · Stakeholder analysis · Knowledge exchange

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Introduction

Coastal social-ecological systems (SES) worldwide are facing significant impacts due to climate change. Sea-level rise, changed precipitation, and variations in wind and wave conditions pose major challenges to the sustainability and resilience of coastal ecosystems (Pörtner et al. 2019). To effectively address these challenges, governance systems have emerged as vital components in building the capacities for adaptation and transformation towards climate resilience in coastal SES (Celliers et al. 2020; Jozaei et al. 2022; Pörtner et al. 2019). Building on the concept of social-ecological resilience, adaptation relates to minor or incremental adjustments of the current system, while transformation refers to actions or processes that significantly alter current system structures and thus changing system properties (Walker et al. 2004; Folke 2006; Foke et al., 2010; Westley et al. 2013). For a system to retain important elements of its identity, it must adapt and be resilient in some properties and transform in others (Folke et al. 2010).

Coastal governance plays a central role in addressing environmental and climate-related challenges in coastal SES (Celliers et al. 2020). It encompasses the political

and institutional processes of coastal management and the implementation of related decisions. By creating the conditions for ordered rules and collective action, coastal governance involves actors from the government, private sector, and civil society (Adger et al. 2003; Shah and Shah 2006; Ojwang et al. 2017; Celliers et al. 2020). However, the integration of climate change adaptation into processes or structures for coastal governance has been described as challenging (Tobey et al. 2010; Frazão Santos et al. 2020; Gissi et al. 2021). Thus, it remains unclear how to enable effective coastal governance to build the capacities that are needed to enhance the resilience of coastal SES to climate change.

Governance systems can be understood as a network of stakeholders, encompassing different administrative levels, sectors, and organisational types, e.g. government agencies, non-governmental organisations, and associations from the local to the international level (Armitage et al. 2009; Weiss et al. 2012; Schlüter et al. 2020). In such governance networks, collaboration and knowledge exchange are critical for successful and effective management and decision-making, particularly in the context of climate change (Berkes 2009; Fazey et al. 2013; O'Mahony et al. 2020). While area-based management approaches, such as Integrated Coastal Zone Management, can facilitate capacity building, collaboration, and knowledge exchange for the implementation of coastal and climate policies (O'Mahony et al. 2020), an understanding of the degree of knowledge exchange on climate-related issues in coastal governance is still poor (Mabudafhasi 2002; Cárcamo et al. 2014; Thorne et al. 2017).

Furthermore, there is a need to understand the strategic and functional role, specific characteristics, and *agency* of different stakeholders to act in coastal governance networks (Charli-Joseph et al. 2018; Sayles et al. 2019; Partelow et al. 2020). Agency can be defined as 'the capacity of individual and collective actors to change the course of events or the outcome of processes' (based on Pattberg and Stripple 2008; Otto et al. 2020b). The concept of agency, as an approach to frame and analyse stakeholders, has gained particular attention over the last years, as it has been described as an important lever for transformation to coastal sustainability (e.g. Charli-Joseph et al. 2018; Haas et al. 2021) and for climate change adaptation more specifically (e.g. O'Brien and Sygna 2013; Otto et al. 2020a). The agency to act in coastal governance processes includes a combination of stakeholder properties, such as political power, or the availability of resources and access to information and knowledge. Different types of agency, in turn, can enable both bottom-up initiatives or top-down actions — and thus polycentric decision-making as a response (Schlüter et al. 2019; Lam et al. 2020).

Polycentricity, as a concept in governance, recognises the presence of multiple decision-making centres or governing authorities operating at different scales within a governance system. It allows for more adaptive and context-specific solutions to emerge, as decision-making authority and actions are distributed among various actors (Ostrom 2010). In the context of coastal governance, polycentricity can enhance the resilience of coastal SES by promoting flexible and responsive decision-making that considers the diverse interests and needs of stakeholders across different scales (Morrison et al. 2023; Tuda et al. 2021). Scale-crossing brokers, or 'bridging organisations', play a crucial role in facilitating collaboration and knowledge exchange across different scales and sectors within polycentric governance networks. These brokers bridge gaps and facilitate information flows between stakeholders working at the interface between different sectors, such as at the science-society interface (Dale et al. 2019), or between different administrative levels (Cárcamo et al. 2014). In coastal governance, scale-crossing brokers can help to connect otherwise disconnected stakeholders, e.g. by customising information from one stakeholder and providing it to a third-party organisation. Thus, assessing and understanding the role and agency of stakeholders in polycentric collaboration and knowledge networks can help to enable effective governance and therefore to enhance the resilience of SES to climate change (Bodin and Crona 2009; Prell 2011; Weiss et al. 2012).

This paper aims to improve the understanding of collaboration and knowledge networks, and stakeholder agency to act in coastal governance processes facing climate change. The paper examines the complexity of these issues through a case study in Algoa Bay, South Africa. By employing a combination of stakeholder analysis (SA) and social network analysis (SNA) this paper seeks to (i) assess collaborations and the flow of climate information and knowledge between organisations involved in coastal governance; (ii) identify the role of organisations in collaboration and knowledge networks through measures of centrality and agency; and (iii) propose recommendations for improving knowledge exchange within coastal governance to enhance climate resilience in coastal SES.

Some studies applying SA and SNA in the context of natural resource management, climate adaptation, and sustainability transformations exist (e.g. Lienert et al. 2013; Ahmadi et al. 2019; Lam et al. 2020). However, quantitative approaches for network analysis in environmental governance research are still recent and scarce; and the combination of SA and SNA is currently underrepresented in climate adaptation research (Cárcamo et al. 2014; Ziervogel et al. 2017). Thus, this paper advances the application and integration of SA and SNA in climate change adaptation and environmental governance research, providing valuable insights both for researchers and practitioners.

Material and methods

Climate change impacts and coastal governance in the case study area

Algoa Bay, in the Eastern Cape of South Africa, is home to the Nelson Mandela Bay Municipality (NMBM), including the cities of Gqeberha (formerly Port Elizabeth), Despatch, and Kariega. It is an integrated SES stretching from land to the ocean including important social-economic and ecological features, e.g. two economically important industrial ports, strong urban and peri-urban development along the coast, and diverse and pristine ecosystems with high species diversity (Dorrington et al. 2018). Given its prime ecological and socio-economic importance, Algoa Bay has also been described as one of the most vulnerable coastal areas in South Africa to climate change. Its location between two up-welling systems, the warm Agulhas current and the cool Benguela current, results in particularly high climate variability (van Huyssteen et al. 2013). The area is already experiencing climate-induced changes, including hotter days, more frequent and longer droughts, more intense floods, greater wind speeds, a change in the prevailing wind directions, rising sea levels, and increased (extreme) storm surges (NMBM 2015; Bornman et al. 2016). These impacts are likely to increase in magnitude and frequency over time. In addition, ongoing droughts have resulted in water shortages in the city and rising sea level is causing popular swimming beaches, public infrastructure, and development, including national roads and houses, to eventually be reclaimed by the ocean (CMR 2020a).

Coastal management in South Africa is still largely sector-based and top-down, governed by different administrative levels of government and area-based management (ABM) tools and approaches (Sowman and Malan 2018; Taljaard et al. 2019). Different institutional arrangements for such ABM tools include Integrated Coastal Management (ICM), Marine Spatial Planning (MSP), and nature protection areas, including Marine Protected Areas (MPAs). Government institutions are mandated to operationalise such management tools. For example, the national Department for Forestry, Fisheries and the Environment is responsible for leading the MSP process, and for enforcing rules and regulations governing MPAs. Such enforcement is assisted by other national government agencies including the South African National Parks and the South African National Biodiversity Institute and provincial entities like the Eastern Cape Parks and Tourism Agency.

On a local level, the NMBM Directorate 'Public Health' is responsible for environmental management in Algoa Bay. Specifically, the Sub-Directorate 'Environmental Management' (Coastal Zone Management section) is responsible for implementing the provisions of the *National Environmental Management: Integrated Coastal Management Act, 2008 (Act 24 of 2008)* in the municipal area, including the coast up to 500 m from the shoreline into the Bay. Other municipal departments (i.e. 'Sports, Recreation, Arts and Culture', 'Infrastructure and Engineering', and 'Human Settlements') have operational responsibilities within the coastal zone. In August 2015, the NMBM published its first 'Climate Change and Green Economy Action Plan'. However — and despite the above-mentioned climate-induced changes — no specific directorate in the NMBM addresses climate change adaptation issues for the Bay (CMR 2020b). In addition, management objectives on land are still separated from the ocean. This means that the NMBM — in its current state — faces considerable challenges to achieving sustainability and climate change adaptation objectives. Algoa Bay therefore presents a suitable case study to test the combination of a stakeholder analysis and social network analysis in the context of sustainable coastal management and climate change adaptation.

Stakeholder identification and questionnaire design

An initial stakeholder identification within the framework of the CICLICO (Cities and Climate Change in the Coastal Western Indian Ocean) project identified 113 organisations relevant to coastal and ocean governance of the wider Algoa Bay SES. Organisations were identified from a review of literature and online resources, Environmental Impact Assessments, and provincial and local coastal working groups, as well as by means of snowball sampling (Leventon et al. 2016). The list included different organisational types from government, parastatal (semi-state), and civil society, e.g. national to local stakeholders from government, education and research institutes, (industry) associations, businesses/industry, and advocacies. For this paper, a sub-sample of organisations was selected, including organisations, which are locally active in the Nelson Mandela Metropolitan Area, or hold specific mandates for the management of the coast and ocean. In total, 36 relevant organisations active in decision-making, tourism, nature conservation, development, research, and service provision were identified and asked to participate in a questionnaire. Due to COVID-related travel restrictions, the questionnaire was conducted online using LimeSurvey (Limesurvey GmbH 2012). The online questionnaire was answered by 20 organisations.

The questionnaire was divided into two parts: (i) stakeholder information and (ii) assessment of collaborations for coastal governance (collaboration network), as well as assessment of the exchange of information and knowledge

regarding climate change adaptation within coastal governance (knowledge network). Participants were asked to represent their organisation (as opposed to personal representation), to assess collaborations and knowledge exchange from an organisational level. For a common understanding among participants, the terms collaboration and climate information and knowledge were explained. *Collaboration* was defined as the exchange of resources, information and knowledge, or working towards common objectives within coastal governance. *Climate information and knowledge* were defined as any kind of data, information, and knowledge that can support climate change adaptation, such as climate change projections, or flood lines, reports on climate impacts, and adaptation options.

For the collaboration network, participants were asked to identify organisations they collaborate with and assess the frequency of collaboration (weekly, monthly, or yearly). For assessing knowledge exchange, participants were asked to indicate the direction of information flow (receive, provide, exchange) and the frequency of exchange (weekly, monthly, or yearly). Even though the frequency of collaborations does not necessarily translate into stronger/better relationships between organisations, it was used to simplify the comparison with the knowledge network, as well as to simplify the online assessment for survey participants. For an easier assessment of collaborations and knowledge exchange, a list of the 36 organisations relevant to the coastal governance of Algoa Bay was provided with the option to add other organisations or stakeholders with whom they frequently interact. Participants were also asked if there are any formal agreements to share climate information and knowledge with other organisations.

Stakeholder analysis: organisational archetypes based on agency

In a previous assessment (see Celliers et al. 2023), organisations were categorised and grouped into organisational archetypes according to their agency to act in coastal governance processes. Agency, in this context, was measured by dimensions of scale, power, and resources (based on Celliers et al. 2012). Scale is described as the level at which an organisation operates, including spatial and functional parameters, e.g. operational scale and organisational mandate to achieve management objectives in Algoa Bay. Power is considered as a function of executive and legislative power, political relevance, enforcement role, and moral suasion to influence policy issues. Resources, in this context, is composed of varying amounts of capital, including financial and human capital, as well as infrastructure in the form of equipment and other physical assets (Celliers et al. 2023).

Each of the three dimensions covers a range of organisational characteristics (referred to as indicators) that are important for achieving management objectives of coastal governance at the intersection with climate change adaptation in Algoa Bay. Organisations were scored for eleven indicators by three experts knowledgeable within the coastal domain in Algoa Bay (see Table A1 for a full list of indicators). The normalised scores (between 0 and 1) for each indicator were then aggregated per dimension, and the arithmetic mean across all indicators was referred to as the agency of the organisation. An agency of 1 would be an institution that has physical presence in Algoa Bay with a high institutional mandate and constituency, which is highly resourced and has the highest power.

Subsequently, a hierarchical cluster analysis (HCA) was performed using 'complete-linkage clustering' to identify clusters of organisations that have a similar scoring for indicators internally, but are distinct from other clusters externally, using the maximum Euclidian distance (dissimilarity). We chose to use a dissimilarity clustering approach because we were seeking to identify distinct archetypes. The HCA resulted in five distinct groupings of organisations with similar characteristics (agglomerative coefficient of 0.893). Each group was then evaluated by their organisational types, scoring for the three dimensions and categorised into organisational archetypes. More details on the methodology can be found in Celliers et al. (2023).

The descriptions of the organisational archetypes based on their medium scores for the different indicators are presented in Table 1. The remaining archetype 'on-the-margin' presented a small group of organisations without authority and without being physically based or operating in Algoa Bay. As none of the stakeholders in this study belongs to this archetype, it is not presented here.

Social network analysis

In preparation for the network analysis, two adjacency matrices were created from the questionnaire for the collaboration and knowledge network, respectively. The frequency of interactions (collaboration, knowledge exchange) was translated into a numerical value between 1 and 3, with 1 indicating lower frequency (yearly) and 3 indicating higher frequency (weekly). If two individual stakeholders assessed the common frequency of interaction between their organisations differently, the higher value was chosen. Even though we acknowledge a potential over-interpretation, this approach was chosen, as an average would display false relations (Lam et al. 2020). The adjacency matrices were then imported to the statistical computing environment RStudio (R Core Team 2021) and analysed using the *igraph* package. Network-level cohesion measures were calculated for both networks, including the number of nodes and edges, network

Table 1 Description of organisational archetypes of organisations involved in coastal governance in the Algoa Bay SES, described by the three dimensions of agency, namely scale, resources, and power (adapted from Celliers et al. 2023)

Organisational archetype	Description
Get-it-done	This archetype represents organisations with the highest agency, based on the highest scoring for available resources, operational scale, and power. Organisations have the ability to act locally and to implement decisions on local issues in a relatively short period of time. Management actions are directly related to ocean and coastal governance, and the impact of such actions will be experienced by many stakeholders in the system. These organisations have direct authority over implementation and a significant control of policy-implementation processes. Organisations from this archetype must be included in participatory processes related to developing the knowledge-base for local decision-making such as climate change adaptation or biodiversity conservation
Vocal-and-insistent	This is an internally diverse archetype of organisations including local NGOs, civil society advocacy groups which typically score low on all measures of agency. Their physical presence in Algoa Bay makes them relevant stakeholders and their collective interest and agency makes their contribution in participatory processes important and bordering on critical. Even though their operational scales may be small, i.e. conservancy of an area within the larger Algoa Bay area, they are important for latent/dormant power, and the vulnerability of their members. Even though organisations score low on power, enough motivation and concern can have high influence in the form of moral suasion, e.g. fishing companies, community-based organisations. This archetype can easily be split into smaller sub-groupings
Plans-and-planning	This archetype presents a relatively diverse group of mainly government institutions, which are mostly thematically or sectorial focussed, i.e. transport, minerals and energy, and environment. Organisations of this archetype have substantial power, which is mostly enacted through national policy and legislation. Their role is clear with regards to medium- to long-term strategic planning in the ocean and coastal governance domain and there are no locally based organisations in this archetype. Organisations are well-resourced in terms of human capacity and access to data and information. While they are scoring relatively high for agency overall, they have substantially less agency compared to the archetype 'get-it-done'
Little-by-little	This archetype includes organisations from research and education, which are low in power, but present and active in Algoa Bay. They are relatively well-resourced and operate at the Bay-scale. There are overlaps with other groups ('vocal-and-insistent' in particular) but this group is very relevant to focussed activities in the ocean and coastal space of Algoa Bay. With their relative high level of resources and their local presence and agency, they are important and relevant actors for local decision-making

Table 2 Network cohesion measures to describe and compare the collaboration and knowledge network (Freeman 1979; Vance-Borland and Holley 2011; Prell 2011; descriptions based on Cárcamo et al. 2014)

Measures	Description	Collaboration network	Knowledge network
Number of nodes	Number of organisations in the network	41	38
Number of edges	Number of connections in the network	302	259
Network density	Number of actual connections divided by the possible number of connections	0.37	0.18
Average path length	Average number of steps between any two actors	2.15	2.58
Network diameter	Longest number of steps between any two actors	6	6
Degree centrality	Extend to which one actor is holding all the links in the network	0.46	0.45
Betweenness centrality	Measure of the number of times that actors in the network lie on a path between other actors	0.15	0.22
Eigenvector centrality	Measure of the influence of a node in a network based on the influence of adjacent nodes	0.51	0.65

density, average path length, diameter, degree, betweenness, and eigenvector (see Table 2 for descriptions and results).

For analysing the centrality of organisations within the network, three different centrality measures were calculated at the node level, including *betweenness*, *closeness*, and *eigenvector* using the statistical computing environment RStudio (R Core Team 2021). Other centrality measures such as *strengths* and *degree* were omitted due to their redundancy with *eigenvector* centrality (see correlation plot of different centrality measures in Fig. A1). *Betweenness* indicates the number of times an organisation in the network lies on a shortest path between other organisations that are otherwise disconnected (Freeman 1979; Cumming 2011). Organisations with high betweenness centrality are referred to as 'bridging organisations', 'scale-crossing brokers', or 'boundary organisations' (Freeman 1979; Dale et al. 2019). *Closeness* indicates the independence of an organisation from all other organisations in the network. It is highest for organisations that have the shortest paths to other organisations in the network (Freeman 1979; Cumming 2011; Prell

2011). *Eigenvector* indicates the influence of an organisation based on the interconnectedness and influence of an adjacent organisation in a network. It considers the number of connections of the adjacent organisation and can be interpreted as the future influence of an organisation (Freeman 1979; Prell 2011). For the knowledge network, the *in-* and *out-degree* of organisations were additionally calculated, to indicate the degree to which organisations receive (in-degree) or provide (out-degree) information.

Subsequently, mean centrality values were calculated for the organisational archetypes. As there was a significant difference in whether organisations participated in the survey or not (two-tailed *t*-test, p-value < 0.005), mean centrality values were only calculated for organisations that participated in the survey. Pairwise *t*-tests were carried out to analyse different centrality values between archetypes and '*p*-adjusted' was calculated using the 'Bonferroni' adjustment method to correct for multiple comparisons.

Results

The online questionnaire was answered by 20 organisations at local ($n = 7$), provincial ($n = 2$), national ($n = 10$), and international ($n = 1$) level. Different sectors, e.g. government, education/research, businesses, (industry) association, and advocacy, were represented. The resulting networks consisted of 41 and 38 organisations for the collaboration and knowledge network, respectively. For brevity, the participating organisations are referred to via abbreviations corresponding to their organisational type (see Table A2 for a full list of organisations). According to the stakeholder analysis, organisations were categorised and described by four different organisational archetypes (see Table 1). The archetype *plans-and-planning* represented mainly national organisations, *vocal-and-insistent* includes national and international organisations, and *get-it-done* and *little-by-little* represent mainly local and some national (mainly national scientific) organisations.

Different network-level cohesion measures describing the stakeholder networks are displayed in Table 2. Results indicate that there are a higher number of total connections, higher frequency of interaction, and higher interconnectedness of organisations (measured by strength centrality) in the collaboration network compared to the knowledge network. This is also supported by a higher network density (Table 2) and a significantly higher closeness between organisations in the collaboration network. Consequently, general collaboration between organisations involved in coastal governance of the Algoa Bay SES is more established than the exchange of information and knowledge regarding climate change adaptation.

Collaboration network for coastal governance

In the collaboration network, the interactions between organisations were assessed regarding coastal governance (e.g. the exchange of resources, information and knowledge, or working towards common objectives). Figure 1a and b show the collaboration network consisting of 41 organisations displayed as nodes and the existence and frequency of collaboration indicated by finer (yearly) or thicker (weekly) edges. Whereas organisations in the centre of the network hold many connections to other organisations — and therefore are more central — organisations further away from the centre have fewer connections.

Additionally, mean values for the centrality measures by organisational archetype are displayed in Fig. 2. Even though there was no significant difference between archetypes (pairwise *t*-test, p-adjusted > 0.2, Table A3), results show some distinct trends (Fig. 2). In the collaboration network, organisations with high eigenvector centrality are mainly characterised by the archetypes *little-by-little* and *get-it-done*, and represent mostly organisations involved in the development sector from local and provincial level. The Nelson Mandela University, which is also under the five most central organisations in terms of strength and eigenvector, is involved in research and education. Even though *plans-and-planning* scored high for eigenvector, none of the organisations from this archetype was under the most central organisations. For betweenness and closeness centrality, mainly organisations from the archetype *vocal-and-insistent* and *little-by-little* that are active in environmental and conservation management scored high. However, also here, development organisation from the archetype *little-by-little* and *get-it-done* played a significant role.

Knowledge network for climate change adaptation within coastal governance

In the knowledge network, the exchange of information and knowledge related to climate change adaptation within coastal governance was assessed. Results from the open-ended questions show that several formal agreements to share climate information and knowledge (and other environmental data) exist, e.g. Memorandum of Understanding (MoU), research permits, and data-sharing agreements. However, such agreements almost exclusively exist between organisations at the national level, such as scientific and research institutions, nature conservation organisations, and national government. Only the Nelson Mandela University mentioned a MoU with the local-level NMBM. The type of climate information ranged from environmental data (e.g. sea-surface temperature, currents, nutrient levels, water quality, biodiversity data), sea-level rise and flood lines, to sector-related climate change adaptation information, seasonal forecasts, and climate projections.

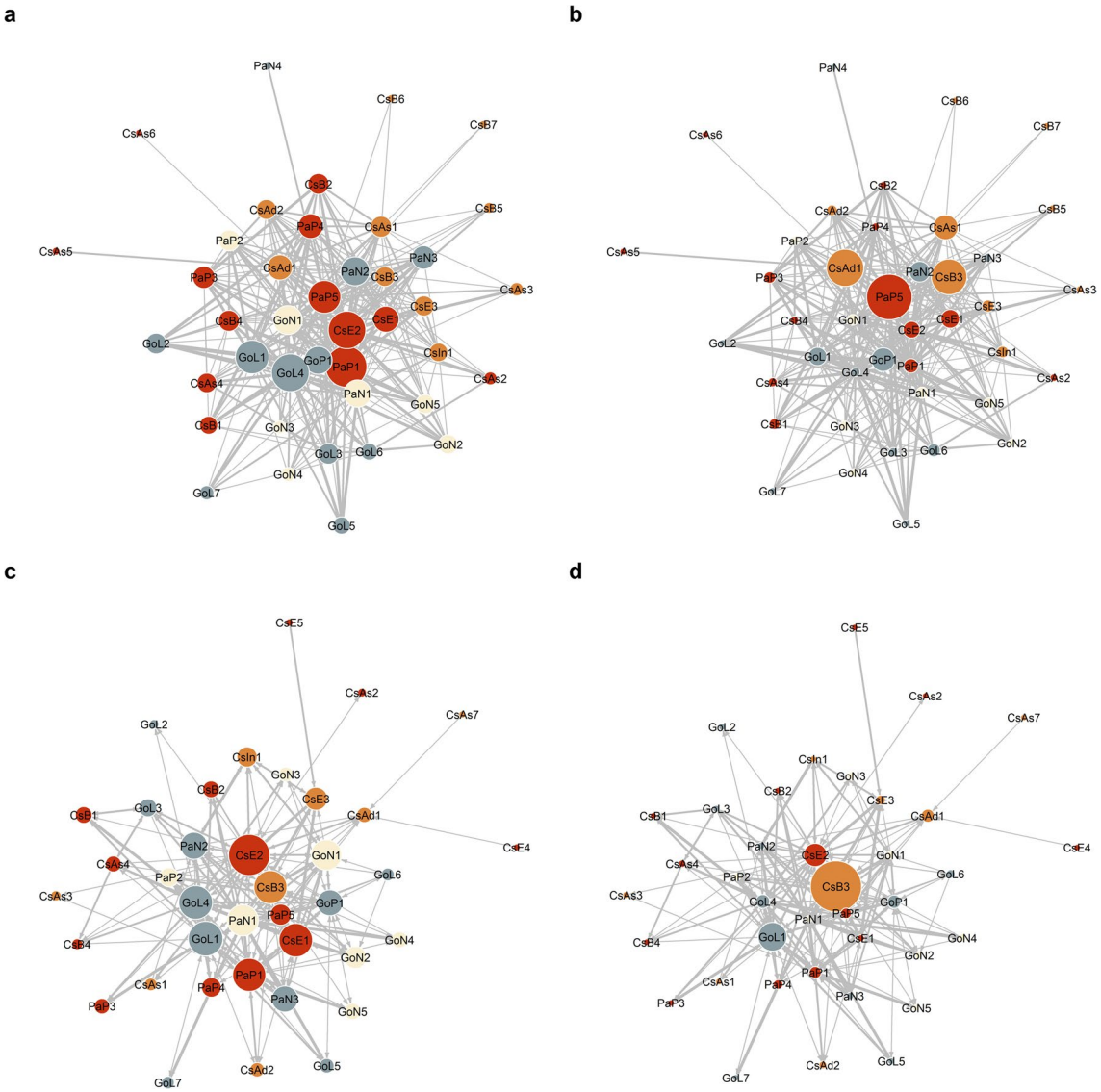

Fig. 1 **a**, **b** Collaboration networks with node size indicating the centrality of organisations for eigenvector (**a**) and betweenness (**b**). **c**, **d** Knowledge networks with node size indicating the centrality of organisations for eigenvector (**c**) and betweenness (**d**). Colours indicate organisational archetypes: beige, *get-it-done*; red, *little-by-little*; grey, *plans-and-planning*; orange, *vocal-and-insistent*. Labels are abbreviations of organisations and a full list of organisations can be found in Table A2

Figure 1c and d show the knowledge network consisting of 38 organisations. Here edges show the existence and frequency of exchange, as well as the direction of information flows (receive, provide, exchange) indicated by finer (yearly) or thicker (weekly) edges and the direction of arrows, respectively. The values calculated for betweenness, closeness, and eigenvector for both networks can be found in Table A2.

For the knowledge network, mean values for the four centrality measures were not significantly different between archetypes (pairwise *t*-test, *p*-adjusted > 0.4, Table A6) and trends were similar to the collaboration network (see Fig. 2). However, there was a significant difference for closeness between the collaboration and knowledge network (two-tailed *t*-test, $p < 0.001$). The three archetypes *plans-and-planning*, *get-it-done*, and *vocal-and-insistent* showed similar values, whereas in the collaboration network, *vocal-and-insistent* scored higher for closeness than the other archetypes. Whereas organisations with high eigenvector in the collaboration network were mainly involved in the sector of development, organisations from research and education and service provision were more central in the knowledge network. For three of the four centrality measures, one consulting organisation (CsB3) clearly exceeded the scoring of other organisations for the archetype *vocal-and-insistent* and most other archetypes (Fig. 2b, d, f), highlighting its overall importance within the knowledge network.

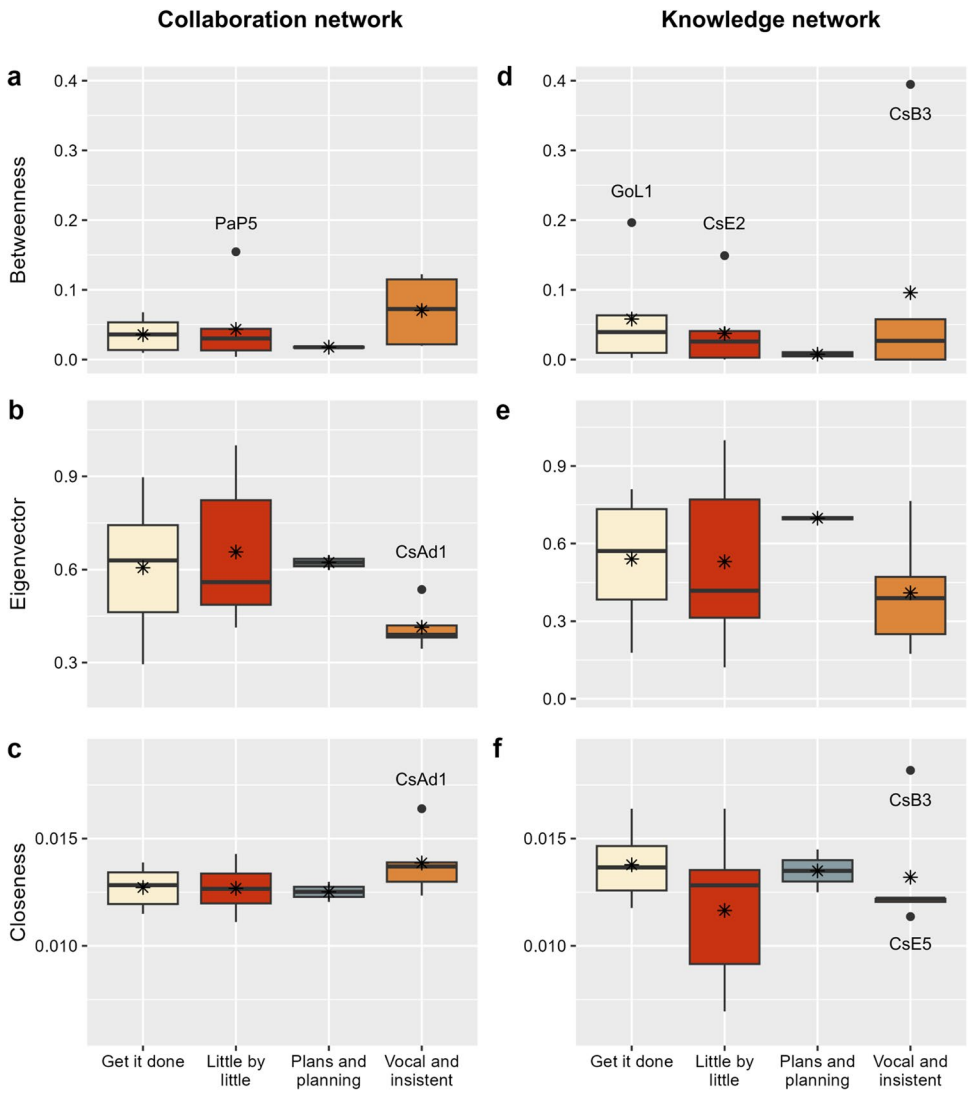

Fig. 2 Boxplots for centrality measures of the collaboration network (left column) and knowledge network (right column) by organisational archetypes for betweenness (**a**, **d**), eigenvector (**b**, **e**), and closeness (**c**, **f**) ($n = 6,7,2,5$ from left to right). Boxes show the 75th percentiles of distribution, with horizontal lines indicating the median. Mean values are symbolised by stars and outliers are shown as dots outside of the boxes, including abbreviations of the outlier organisations

Roles of organisations and organisational archetypes in the networks

The centrality measures together with the descriptions of organisations provided by the stakeholder analysis reveal different roles of organisations within the networks. While some organisations are highly connected to many other organisations, and therefore often show a higher influence, other organisations act as information providers, or bridging organisations.

Organisations with high interconnectedness and influence

Collaboration between organisations in coastal governance is mostly driven by a high interconnectedness and influence of development organisations. These organisations are mainly associated with the archetypes *little-by-little* and *get-it-done* (Fig. 2a, c), and include organisations such as Eastern Cape Development Corporation (PaP1), Coega Development Corporation (PaP5), and the NMBM directorates 'Human Settlements' and 'Economic Development, Tourism and Agriculture' (GoL1) (Fig. 1a, b). Such organisations and archetypes show the highest rating for operational scale, e.g. physical presence, representation, and organisational mandate to achieve management objectives in Algoa Bay (Table A1). As mentioned in the archetype descriptions (Table 1), the archetype *get-it-done* also shows a high availability of resources and power, and the archetype *little-by-little* is well-resourced and operates at the local scale but is low in power. Activities related to coastal management in the Bay, therefore, are mainly driven by local economic development, as the archetype *get-it-done* has more authority over the implementation and significant control of policy-implementation processes directly related to coastal governance.

In the knowledge network, the archetypes *little-by-little* and *get-it-done* also score as the top five for influence and

interconnectedness. Also, the NMBM directorates 'Human Settlements' and 'Economic Development, Tourism and Agriculture' (GoL4, GoL1) (*get-it-done*) play a significant role for knowledge exchange (Table A4). However, the Nelson Mandela University (NMU/CsE2) (*little-by-little*) shows a much greater role in terms of interconnectedness and influence compared to the collaboration network, and South African Environmental Observation Network (SAEON, CsE1) (*little-by-little)* ranks higher for eigenvector centrality compared to the collaboration network, indicating their potential for playing a more central role for knowledge exchange in the future. NMU and SAEON are the main research entities in the Bay.

Organisations acting as bridging organisations

In the collaboration network, environmental and conservation organisations from the archetype *vocal-and-insistent* such as the Wildlife and Environment Society of South Africa (WESSA/CsAd1) Southern African Foundation for the Conservation of Coastal Birds (SANCCOB/CsAs1), and Anchor Environmental Consultants (CsB3), were identified as bridging organisations (Fig. 2a). WESSA and SANOCBB are involved in environmental education and have recently established a group called 'Algoa Bay Ocean Stewardship', including members from sea-based enterprises, environmental NGOs, parastatal organisations, and community researchers advocating for environmental protection and ocean activism in the Bay. All of these are linked to the archetype *vocal-and-insistent* representing NGOs, or civil society advocacy groups, which score low on all measures of agency, but physical presence and high moral suasion. WESSA also scored high for eigenvector centrality, which indicates their potential future influence in the network.

In the knowledge network, the importance of bridging organisations was even more pronounced. Results reveal that knowledge exchange is based on fewer organisations, but significant influence and bridging character. Here, different organisations and organisational archetypes play a significant role. The archetypes *vocal-and-insistent* and *get-it-done* score under the top five for betweenness and therefore show the greatest importance for bridging between other organisations. In particular, one consulting company (CsB3) takes a central position, both in terms of bridging between organisations, as well as exchanging information independently in the network (Fig. 2b, d).

Organisations acting as information providers

Based on the out-degree of organisations, only a few organisations act as information and knowledge providers (Table A4). These include SAWS, NMU, and NMBM1 (Directorate 'Economic Development, Tourism and Agriculture'), which are all governmental agencies. Whereas different archetypes show a high interconnectedness in the knowledge network, the archetype *plans-and-planning* plays a significant role in terms of knowledge provision, based on out-degree (Fig. A1) and their significant influence (Fig. 2d). Organisations included in this archetype are mainly government institutions with substantial power, enacted through national policy and legislation, as well as strategic planning and access to data and information. In contrast to collaboration, knowledge exchange for climate change adaptation seems to be more dependent on organisations from the archetype *plans-and-planning*.

Discussion

Implications for the Algoa Bay case study

The network assessments provide an overview of the status of collaboration and knowledge exchange in the Algoa Bay SES. Despite the overall establishment of collaboration in Algoa Bay, results suggest a notable lack of cross-level and cross-sectoral connections in both networks. For example, organisations with strategic or operational mandates appeared to be remote within the collaboration network. Organisations mandated to support or undertake coastal management, including the Department for Fisheries, Forestry and the Environment (*plans-and-planning*) and South African National Parks at the national level, and the NMBM directorate 'Public Health' (both *get-it-done*) at the local level, did not show a high centrality. While the national-level Department for Fisheries, Forestry and the Environment has no major presence in the Bay, South African National Parks is very active on an operational scale, e.g. regarding coastal monitoring and security. Similarly, results from the knowledge network suggest that information and knowledge flow for climate change adaptation is rather reliant on top-down processes but does not sufficiently reach the local level. Supporting this, we found that formal agreements to share climate information and knowledge only exist either within specific sectors at the national level, or regarding a specific objective, e.g. between organisations working in the marine sector, or between environmental conservation organisations. In contrast, there was no formal agreement to share information and knowledge across organisations from the marine and terrestrial sector, nor between national and local organisations, e.g. *plans-and-planning* and *get-it-done*.

This reflects a disconnect between strategic planning and operational realities of coastal managers and a lack of local-level control over policy-implementation processes for coastal governance. Such a disconnect is often highlighted in coastal management literature (e.g. Celliers et al. 2015; Colenbrander et al. 2015; Elrick-Barr and Smith 2021). Given this lack of cross-level and cross-sectoral connections,

and thus a lack of polycentric governance, there is a need to establish formal agreements for sharing climate information and knowledge across sectors and administrative levels, e.g. between the South African Earth Observation Network and the NMBM. Recommendations for addressing cross-level and cross-sectoral collaboration and knowledge exchange are provided in the next section on capacity building and knowledge integration in coastal governance.

The limited knowledge exchange compared to general collaboration in Algoa Bay may also be attributed to the absence of climate change legislation and improved support from governmental organisations, such as from the archetype *plans-and-planning* in this study. Similar results were found in another study in the Algoa Bay SES, focusing on identifying leverage points to enhance governance performance for climate change adaptation (Rölfer et al. 2022). The study finds that more support from the provincial government as well as the priority given to climate change in the Integrated Development Plan can leverage change towards improved governance performance for climate change adaptation. Additionally, the recently adopted *Climate Change Bill* (Republic of South Africa 2022) may also create top-down conditions that lead to stronger networks and collaboration between organisations. The Climate Change Bill aims at enabling 'the development of an effective climate change response and a long-term, just transition to a low-carbon and climate-resilient economy and society for South Africa in the context of sustainable development'.

Findings also suggest the need for a more integrated approach to climate change adaptation in coastal planning and management frameworks, such as ICZM and MSP. The recently started process for marine spatial planning in South Africa and the wider Western Indian Ocean region offers an opportunity for the national government to mainstream climate change knowledge more centrally into coastal planning. Based on the high centrality of the Nelson Mandela University in both networks, results suggest that the university plays a significant role here, e.g. through the recently established Algoa Bay MSP Project (Reed and Lombard 2017; e.g. Dorrington et al. 2018), which connects various stakeholders with an interest in coastal development and planning. The NMU and especially the Institute for Coastal Marine Research has a longstanding MoU with the NMBM for applied and transdisciplinary research that requires close interaction with local stakeholders from the municipality and civil society.

On the other hand, there is also potential for bottom-up initiatives that can enhance climate resilience by individual stakeholder action. For example, 'local champions' have been highlighted as an important driver of change within other coastal municipalities in South Africa. Local champions, in this context, are individuals who push forward climate action within their roles, even though they are not mandated or formally directed. There are good examples of bottom-up climate change information exchange from other metropolitan cities in South Africa, which have prioritised climate change through local champions (Roberts 2010; Carmin et al. 2012; Pasquini et al. 2015). Whereas the City of Cape Town and the eThekwini municipality in Durban have dedicated climate change units or directorates, the NMBM is lacking such bundled and coordinated activities in their municipality. Consequently, there may be a lack of experience within organisations in the NMBM in dealing with climate-related impacts compared to coastal management, which has been implemented by the ICM Act more than a decade ago and specifically calls for establishing multi-level collaborations as part of the Act (Celliers et al. 2013). The Climate Change Bill, once enacted, may have the same effect, to enhance information flow and collaboration regarding climate change adaptation in coastal governance. However, there is a need for further capacity building and knowledge integration into coastal governance, which needs to be addressed at several levels.

Capacity building and knowledge integration in coastal governance

Strengthening coastal governance in the face of climate change requires a multi-faceted approach that encompasses changes at multiple levels in the governance system. Based on the results of this study, we propose four key recommendations to enhance the resilience of coastal SES to climate change.

Firstly, there is a need for **improved leadership to support knowledge transfer and climate action**. The presence of strong leadership is one of the primary pillars for strengthening coastal governance and climate adaptation plans. This entails political will and commitment from provincial and district governments to support climate actions and knowledge transfer to lesser-resourced local municipalities (Reddy et al. 2021). Such top-down processes can create a favourable environment for climate resilience initiatives. Actions from governmental institutions may include addressing funding issues, offering training focusing on stakeholders with lower agency and capacities, and improving the overall availability and accessibility of climate information (Rölfer et al. 2022). While these suggestions have also been included in the recently adopted Climate Change Bill, effective monitoring of its implementation remains crucial to ensure impactful enactment comparable to the ICM Act.

Secondly, in the context of coastal governance, improved knowledge flow between different scales also includes a **stronger integration of climate information into ABM approaches**. Other studies have shown that existing coastal governance networks, such as those established through coastal committees and ABM approaches and frameworks

(e.g. Integrated Coastal Management (ICM), Marine Spatial Planning (MSP), and Marine Protected Area (MPA) mechanisms), can effectively support the exchange of climate information and knowledge and enhance collaborative governance across diverse stakeholders and their interests (Tobey et al. 2010; Frazão Santos et al. 2020). By incorporating climate information into these existing frameworks, decision-makers can make more informed choices.

Thirdly, there is a need to **support the role of bringing organisations and information providers** in collaboration and knowledge networks. Results show that bridging organisations plays a critical role in advocating for environmental protection and connecting stakeholders from both policy and practice domains. Organisations from the archetype *vocal-and-insistent* that exhibit characteristics such as local presence, high moral suasion, and vocal advocacy can effectively bridge the gap between stakeholders, fostering knowledge dissemination, and adaptive governance within the coastal governance context. For example, WESSA — one of the important bridging organisations in the collaboration network with potential future influence — disseminates knowledge between scientific actors and the public and stated that they plan on increasing their climate-related activities in Algoa Bay. It is also likely that there are organisations, which are currently not included in the analysis but may be of future relevance in providing relevant climate information and knowledge. These can include boundary organisations, such as climate service providers that can tailor climate information and knowledge to the local context, e.g. in the form of customised products for coastal municipalities (Swart et al. 2021). By improving the overall availability and accessibility of climate information, coastal governance can make informed decisions and foster collaboration across all levels of governance.

The importance of bridging organisations, to connect different stakeholder groups and leverage change, has been highlighted as an important feature for knowledge dissemination and adaptive governance in SES (Folke et al. 2005; Berkes 2009). Comparable results to our study were found in the context of the Swiss adaptation strategy, investigating the role of stakeholders in bridging between multi-level climate change adaptation governance (Braunschweiger 2022). The study finds that both cross-level and cross-sectoral collaboration for climate change adaptation was fragmented. While in our study NGOs were most important in terms of bridging between different stakeholders, results from Braunschweiger (2022) suggest that federal governmental actors exhibit a significant bridging role for cross-sectoral collaboration. Yet, they conclude that cross-level collaboration, e.g. between national and municipal levels, needs action from higher-level actors and by adaptation funding programmes (Braunschweiger 2022), which may be transferable to other case studies.

Another study, investigating the integration of climate change adaptation in coastal governance of the Barcelona metropolitan area, finds that the metropolitan administration acts as an important bridging organisation (Sauer et al. 2021). The metropolitan administration promotes climate change adaptation to different interest groups and passes knowledge between actors. In the Algoa Bay case study, the NMBM does not play a significant role as a bridging organisation (except the directorate for 'Economic Development, Tourism and Agriculture'), even though the municipality exerts comparably high agency to act in coastal governance processes. Improving the role of bridging organisations, thus, might include more substantial organisational changes, such as major shifts in the mission, strategy, or structure of organisations (e.g. Jozaei et al. 2020). In the case of the NMBM, this could be addressed through a directorate within the municipality that is specifically mandated to address climate change issues. However, such changes are often hard to operationalise given the lack of financial or human capacities.

Finally, results suggest that **less capacitated stakeholders are poorly connected to the networks**. However, the inclusion and support of marginalised stakeholders is an important feature of transforming to a more sustainable and socially desirable SES (Tengö et al. 2017). Incorporating relatively marginalised stakeholders, as emphasised by Nijamdeen et al. (2022), ensures that their perspectives and interests are considered in decision-making processes. By involving these stakeholders, coastal governance can foster a more equitable and effective approach to climate resilience. Such marginalised stakeholders may also be private sector organisations that do not have the capacities or knowledge to act on climate-related issues. Offering guidance to private sector organisations about how to engage in broader planning debates on societal levels has been highlighted as a transformative lever to address sustainability challenges, such as climate change (Linnenluecke et al. 2017). Thus, increasing the potential of bridging organisations to enhance cross-level and cross-sectoral collaboration and knowledge exchange, as well as the inclusion of marginalised stakeholders, can lead to more transformative changes in organisations and institutional structures.

Advances and potential future applications of the combined approach

By using a combination of stakeholder analysis and social network analysis, this study advances the understanding of network structures considering organisational characteristics describing their agency to act in coastal governance processes. It provides information on how networks could be strengthened, e.g. by identifying betweenness and eigenvector centrality, as well as specific stakeholder characteristics.

The novel approach of combining an assessment of stakeholder agency with a social network analysis may have a broader application for mapping stakeholders and the relations between them in the field of climate change adaptation and other sustainability challenges. It enables a systems perspective on the connections between stakeholders with different degrees of agency and has the potential to identify who are the critical actors to achieve a desirable system state, especially in face of change (e.g. Otto et al. 2020a, b). This may be of particular importance, if research objectives deal with conflicts and strong power imbalances in governance systems, such as agriculture-biodiversity conflicts or fisheries management (e.g. Gorris 2019, Lécuyer et al. 2021, Strand et al. 2022).

In addition to the above recommendations, there is also a need for further qualitative network approaches to assess the nature of collaboration and the type and form of information and knowledge that organisations require. This will help build the capacities for climate change adaptation and identify key organisations that can play a crucial role in the knowledge network by bridging between information providers and information seekers at the local Bay level. Future applications of the stakeholder analysis and social network analysis may assess financial flows between organisations, which are of high relevance when actions for climate change adaptation need to be operationalised. Such an approach should consider supporting marginalised stakeholders to promote sustainability and socially desirable outcomes in the social-ecological system. Using agency and network assessment can help identify stakeholders with limited financial resources and connections to well-resourced governmental agencies.

Conclusion

The aim of this paper was to gain an improved understanding of collaboration and knowledge networks, and stakeholder agency to act in coastal governance processes facing climate change to ultimately enhance the resilience of coastal SES to climate change. The findings reveal crucial insights into the status of collaboration and knowledge exchange in Algoa Bay. While collaboration was established overall, the study highlights a significant lack of cross-level and cross-sectoral connections in both collaboration and knowledge networks. Organisational mandates and strategic planning appeared remote within the collaboration network, reflecting a disconnect between strategic planning and the operational realities of coastal managers. Similarly, the knowledge network relied predominantly on top-down processes and failed to reach the local level sufficiently.

Based on these findings, the paper proposes four key recommendations to enhance climate resilience within coastal governance:

1. Improve leadership and support for knowledge transfer and climate action through commitment from higher-level governments.
2. Strengthen knowledge flow by integrating climate information into existing coastal governance frameworks and decision-making processes.
3. Support bridging organisations to connect stakeholders and foster knowledge dissemination and adaptive governance.
4. Integrate and support marginalised stakeholders to ensure their perspectives and interests are considered in decision-making processes for climate change adaptation.

The combination of a stakeholder analysis of agency and social network analysis holds promise for a more comprehensive understanding of climate adaptation efforts and resource flows, supporting effective governance and decision-making in the context of climate change adaptation. For future research, the paper suggests the need for qualitative network approaches to assess the nature of collaboration and the type of information and knowledge required by organisations. Furthermore, exploring financial flows between organisations and supporting marginalised stakeholders can promote sustainability and socially desirable outcomes in coastal social-ecological systems. Thus, the combination of stakeholder analysis of stakeholder agency and social network analysis offers a robust framework for future research in climate change adaptation and other complex governance issues.

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Data availability The data supporting the findings of this study are available in the supplementary materials of this publication. The raw data and R script used for analysis can be provided upon request.

Declarations

Conflict of interest The authors declare no competing interests.

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