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RESEARCH ARTICLE

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Improving governance outcomes for water quality: Insights from participatory social network analysis for chalk stream catchments in England

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Abstract

1. Globally important chalk streams in England are in poor ecological health, in part due to inadequate water quality. Addressing this issue requires an understanding of the governance systems that surround water quality. The complexity and uncertainty inherent in hydrological systems has led to the emergence of integrated and adaptive forms of governance. In these multi-actor governance systems, the structure of the relationships between actors (the social network) has been shown to affect governance processes and outcomes.
2. Using participatory social network analysis, we mapped and analysed the social networks for the River Test and River Itchen in Hampshire, United Kingdom, to identify actors and their roles, determine the network characteristics and identify interventions to improve governance.
3. Although the results suggest a well-connected network of actors from the state, private sector and civil society, we find that decision-making is not decentralised. Bureaucratic governance by central state actors dominates. However, trust in these central state actors and private actors in the networks is low, which undermines collaboration and co-ordination in the network.
4. Devolving authority to local actors, building trust in the networks and improving connections to important actors could help to improve governance outcomes for water quality.

KEYWORDS
adaptive co-management, chalk stream, co-production, Net-Map, SNA, social learning, water quality

1 | INTRODUCTION

Freshwater habitats are some of the most threatened in the world due to pressures such as over abstraction, impoundment, the impacts of climate change, pollution and invasive species (Dudgeon et al., 2006; Naiman & Dudgeon, 2011; Vörösmarty et al., 2010). Globally, freshwater species have seen a decline in monitored populations of 85% since 1970, a rate that far exceeds measured decline in terrestrial or marine populations (WWF, 2020). Society obtains many important ecosystem services from freshwater habitats including drinking water, food provision, recreational opportunities and energy production (Dodds et al., 2013; Hanna et al., 2018). Impairing the quantity and quality of freshwater ecosystems therefore threatens our well-being (Vörösmarty et al., 2010).

Poor water quality is a significant reason for the impaired health of many rivers in England. Despite efforts to improve ecological health and water quality, driven by the implementation of the EU Water Framework Directive 2000/60/EC (WFD) legislation, in the latest assessment in 2019, no rivers in England were classified as being of good chemical status and only 14% of good ecological status (Defra, 2020). This has implications as around 80% of the global distribution of rare chalk streams are found in England. Elevated levels of sediment, nutrients and chemicals arising from a range of domestic, industrial and agricultural sources have been identified as key barriers to improving the ecological health of these globally important ecosystems (Rangeley-Wilson, 2021). In order to improve water quality, a better understanding of the human and social dimensions of the challenge is important (Bennett et al., 2017), in particular the design of the governance system for ensuring adequate water quality (Gupta et al., 2013; Lemos & Agrawal, 2006).

1.1 | Governance and social network analysis

Governance of water is inherently complex. Water is in constant flow, moving around the system, being continually used and discharged, with different water users and actors who influence water resources at different spatial scales (Pahl-Wostl et al., 2011). Further complexity arises from the connectivity of water with other sectors, as decisions made in other spheres such as land management, agriculture and energy generation, can impact water (Pahl-Wostl et al., 2020). Uncertainty from future changes to the biophysical and social components of the system, for example, the impacts from climate change or from emerging contaminants (Reid et al., 2018), adds additional complexity.

Alternative approaches to the governance of water have emerged in recognition of this multi-actor complexity and inherent uncertainty, shifting away from state-centred, hierarchical control. Two of the more widely known alternative approaches to water governance are integrated water resource management (IWRM) and adaptive governance (Pahl-Wostl, 2015; White, 1998). IWRM emphasises the need for joined-up planning between the sectors responsible for economic and social development, and natural resources, to achieve sustainable water governance (Gupta et al., 2013; White, 1998). IWRM favours a participatory approach to governance that combines knowledge from a range of actors (Pahl-Wostl et al., 2011) and a focus on river basins and catchments as management units, rather than management being determined by administrative or political boundaries.

Adaptive governance is a form of environmental governance with an additional focus on adaptive capacities to reorganise in response to changing social and biophysical circumstances. Adaptive co-management (ACM) is a way of operationalising adaptive governance (Folke et al., 2005). Collaborative arrangements of actors are more likely than other arrangements to establish adaptive processes (Baland & Platteau, 2000; Ostrom, 2015; Sabatier et al., 2005). These collaborative arrangements are often referred to as polycentric networks or co-management structures, where power, rights and responsibilities are shared between different state, private and civil society actors (Carlsson & Berkes, 2005; Huitema et al., 2009), often through less formalised decision-making structures. This flexible system of actors facilitates an iterative process where social and ecological knowledge is tested through experimentation and the management of social–ecological systems is revised accordingly.

The success of the collaborative arrangements that underpin IWRM and ACM is posited to be influenced by several factors that shape the collaborative process and the resulting outcomes (Ansell & Gash, 2008; Emerson et al., 2012). These factors include repeated quality interactions—fair and open communication between a balanced representation of actors—which in turn can foster trust, commitment and understanding between actors, often referred to as social capital. Additionally, for collaboration to generate an agreed outcome, the capacity for action must be developed, facilitated by leadership, knowledge, resources and institutional arrangements. The starting conditions at the beginning of collaboration, for example, power imbalances and levels of trust, also determine the success of the process. Many of these factors are relational in nature and emphasise the importance of examining the connections and relationships between actors when evaluating governance.

There has been increasing use of social network analysis (SNA) to empirically study the formal and informal relationships between actors in natural resource governance, and how they are associated with governance processes and outcomes (Crona & Bodin, 2010; Sandström & Rova, 2010; Ward et al., 2020). SNA has been used to examine the aspects of water governance in a range of contexts, including understanding the networks of resilience communication for the UK water sector (Ward et al., 2020); institutional transitions in the Klamath river basin, United States (Chaffin et al., 2016); governance arrangements in the Mkindo catchment, Tanzania (Stein et al., 2011); formal and informal networks in urban water management in Indonesia (Larson et al., 2013); collaborative governance for floodplain management in The Netherlands (Fliervoet et al., 2015); and stakeholder networks underpinning collaborative water governance in Chile (Rojas et al., 2020). SNA has been successfully used in these studies to evaluate transitions to sustainable modes of governance (Chaffin et al., 2016), identify problems with water governance arrangements, for example, inadequate adaptive capacity (Rojas et al., 2020) and pinpoint interventions to improve water governance (Stein et al., 2011). These studies demonstrate that SNA provides a means to evaluate governance arrangements for water quality and highlight interventions to improve outcomes.

We consider a network analysis approach useful when evaluating integrated and adaptive governance for two reasons. Firstly, a polycentric network is often perceived as a social network of actors and acknowledges that actors, other than those with formal authority, may play a role in decision-making and management (Carlsson, 1996). Secondly, the pattern of interactions between actors, (the network structure), as well as the characteristics of these actors, affects the processes and outcomes of governance (Bodin & Crona, 2009; Friedkin, 1981). Therefore, certain network characteristics can enhance or diminish processes and properties that underpin integrated and adaptive governance (see Table 1) (Bodin et al., 2006). For example, densely connected networks can facilitate the development of social capital (trust, reciprocity and connectedness) making it easier for people to collaborate, and aid social learning by enabling actors to share and combine different types of knowledge (Folke et al., 2005; Pretty & Ward, 2001).

1.2 | Co-producing network knowledge

Co-production of knowledge has emerged as a key approach to tackling complex social–ecological problems, acknowledging that science and society shape each other, and that solutions to complex problems are more effective when produced via pluralistic processes (Norström et al., 2020). Participatory social network analysis is increasingly used to coproduce network knowledge (Hauck et al., 2015). For example, Rojas et al. (2020) combined SNA with a broader participatory process to understand collaborative water governance in Chile, but the participatory process was not specifically linked to the SNA, which limits the conclusions of the SNA. Likewise, Ward et al. (2020) used a participatory approach to explore resilience communication in the UK water sector; they provided advanced quantitative analysis but did not present or analyse any qualitative data from their participatory workshop. We aim to build on the approaches of these studies and include qualitative data collection to provide additional understanding in our analysis.

1.3 | Aim and research questions

In this paper, we use participatory SNA to describe and analyse the water quality governance networks, with reference to integrated and adaptive governance, for the River Test and River Itchen catchments, two chalk streams of international importance, to make recommendations to improve governance and outcomes for water quality. To do so, we address the following research questions:

1. What are the main structural characteristics of the water quality governance networks, as determined by flows of finance, information and pressure?
2. Who are the key actors in water quality governance, what role do they play and how do they influence water quality governance?
3. What interventions could be undertaken to improve the governance of water quality?

2 | METHODS

2.1 | Study location

We selected the River Test and River Itchen catchments in Hampshire, United Kingdom (Figure 1), for our study as they are two of the best examples of chalk streams in the world (Environment Agency, 2016; Mainstone, 1999). The River Test and River Itchen have conservation designations that offer them an increased level of protection. Both rivers are designated Sites of Special Scientific Interest and the River Itchen also has a Special Area of Conservation designation, a strictly protected site under the EU Habitats Directive, due to the quality of its *Ranunculus* habitat and its populations of threatened species (Hampshire County Council, 2003). The two catchment areas are frequently treated as a single unit for management purposes (Environment Agency, 2016) and their combined area covers approximately 1760 km^2 (hereafter, the catchment). Land cover in the upper and middle reaches of the catchment is dominated by pasture and arable land, with several urban centres. While in the lower reaches both rivers flow through predominantly urban areas before flowing into Southampton Water estuary (Environment Agency, 2016; Test & Itchen Catchment Partnership, 2021).

Alongside their ecological value, chalk streams are economically and culturally important. Humans have modified and made use of the River Test and River Itchen water courses and floodplains for thousands of years, for example, by impounding the river to create fish ponds, installing water mills and establishing irrigation systems (Glasspool, 2007). Currently, the rivers and their aquifers are a main source of water for drinking and agricultural use, they support the industries of watercress cultivation and fish farming and offer a space for recreation and aesthetic enjoyment. The River Test and River Itchen are some of the most famous fly-fishing rivers in the world and they are home to many recreational fisheries (Test & Itchen Catchment Partnership, 2021). As a result of the diverse ways in which the rivers are used, there are a number of individuals and groups with a stake or interest in the rivers.

2.2 | Overall approach

We used Net-Map (Hauck et al., 2015; Schiffer & Hauck, 2010), a participatory SNA method that uses a semi-structured process to draw a network visualisation with interviewees based on their perceptions—the way they understand and observe the network.

TABLE 1 The links between the research questions and our analysis, including how the social network analysis (SNA) metrics calculated can help to characterise governance networks

Research question	Analytical approach	Theory-driven features of interest	Metrics and how they link to features of interest
1. What are the main structural characteristics of the water quality governance networks, as determined by flows of finance, information and pressure?	Network level metrics and qualitative analysis of the interviews and workshop	Features considered to be important for governance (adapted from Bodin et al., 2006): Trust Communication Adaptive capacity Learning and knowledge production Heterogeneity	Density—the total number of ties in a network divided by the total number of possible ties (Granovetter, 1973). Used as an indicator of: • Trust—dense networks can foster trust (Coleman, 1990), • Communication—is enhanced in densely connected networks and can facilitate collective action (Bodin & Crona, 2009), • Heterogeneity—high density can produce homogeneity of experience and reduce innovation (Oh et al., 2004). Network centralisation—variation in the centrality scores (Freeman, 1978). Used as an indicator of: • Adaptive capacity—a centralised network may be more easily coordinated for collective action, an indicator of adaptive capacity (Sandström & Carlsson, 2008b), • Learning—more centralised management can reduce experimentation and learning (Shaw, 1981). Diversity of actors—the number of actor categories. Used as an indicator of heterogeneity—polycentric governance requires a diverse range of actors (Sandström & Carlsson, 2008a; Tuda et al., 2021).
2. Who are the key actors in water quality governance, what role do they play and how do they influence water quality governance?	Node level metrics and qualitative analysis of the interviews and workshop	How are actors able to use their position in the network to exert influence. Central positions may give influence, e.g. facilitating better access to information (Burt, 1992) What other roles are actors adopting e.g. brokers, knowledge generators, stewards, leaders (Olsson et al., 2004)	Node level metrics • Perceived influence rating—assigned by interviewees to each actor they identified to allow fuller analysis of actor influence in relation to network position. • Degree centrality—the number of direct connections coming in or out of a node. Having many ties has been shown to positively impact influence (Degenne & Forse, 1999). • Betweenness centrality—the number of times a node acts a bridge for the shortest path between two other nodes (Freeman, 1978). An actor who sits between other actors can influence the flow of resources (Bodin & Crona, 2009). Brokers may learn about a range of actors in the network, and be able to facilitate new connections, or limit connection, in response to change (Burt, 2004; Granovetter, 1973)
3. What interventions could be undertaken to improve the governance of water quality?	Collective analysis via the workshop and qualitative analysis of the individual interviews	Features considered to be important for co-producing outcomes (Norström et al., 2020): context-based, diversity of knowledge, goal-oriented	No quantitative metrics analysed

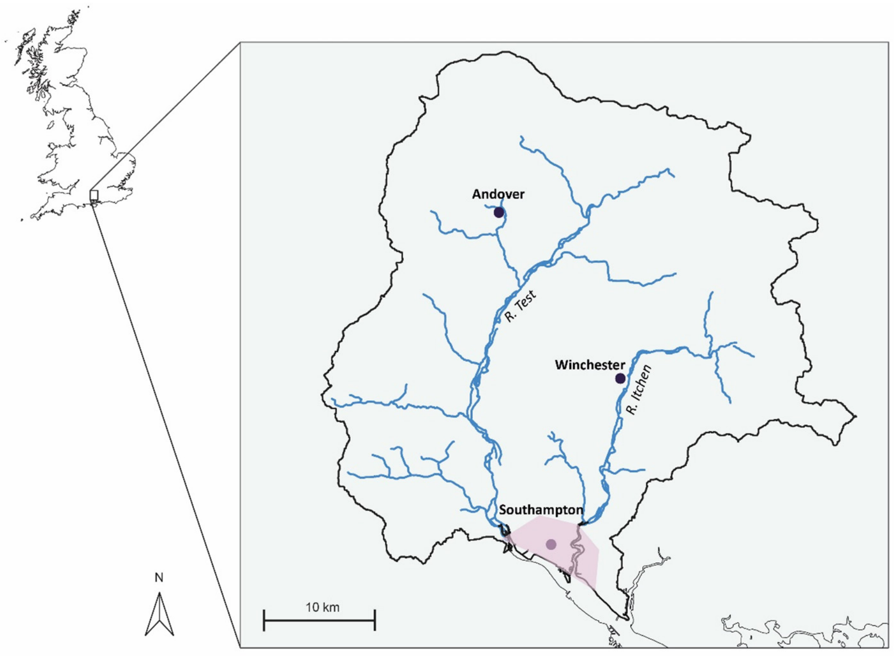

FIGURE 1 Catchment map of the River Test and River Itchen, Hampshire, United Kingdom.

Through the construction of the visualised network, the interviewee is encouraged to describe the network structure, discuss the relationships between actors and reflect on the network structure as a whole. In designing our approach, we recognised that effective co-production processes should be context-based, bring together different types of knowledge, expertise and actors, and be goal-oriented (Miller & Wyborn, 2020; Norström et al., 2020). Therefore, results of this analysis were then presented and discussed in a participatory workshop with the interviewees, to reflect on the network visualisation, co-analyse findings, and to produce interventions to improve governance. Collecting quantitative network data and qualitative narratives, as well as data from the workshop, allowed triangulation between these different datasets. We view these datasets as complementary, in that we are not solely focused on using one set of data to validate another, but rather that the quantitative and qualitative data enrich one another, helping to provide a more detailed understanding of the governance network (Nightingale, 2009). See the 'Data analysis' section for further details.

Ethics approval for this study was granted by the University of Southampton (Ref no. 52980) and informed consent was obtained from all participants in writing.

2.3 | Data collection

We conducted individual interviews with 15 stakeholders, each of which lasted for between 1 h 20 min and 3 h, between October 2019 and November 2020. We identified interviewees through a combination of purposive and snowball sampling: We began by interviewing stakeholders we knew to be involved in the network, and then used the network visualisations produced in these interviews to identify other stakeholders. We recruited stakeholders who represented a range of spatial viewpoints (i.e. national to local) and sectors (i.e. state, private and civil society). For a list and description of the interviewees, see Appendix S1. Only one person we approached declined to be interviewed. We stopped recruiting interviewees when further interviews did not elicit a significant amount of additional information. The number of interviews in this study is commensurate with that of similar research using Net-Map (e.g. Hauck et al., 2015; Winkler & Hauck, 2019). Eleven of the interviews took place in person, at a location of the interviewee's choice, and four interviews were conducted virtually due to COVID-19 restrictions implemented by the UK Government. All of the interviews were recorded with the interviewee's permission.

We conducted three pretest interviews with other academics to help refine our interview protocol and to ensure that interviewees were able to use the term 'water quality' as a boundary for the network. The interviews followed the three main steps of the Net-Map process (Figure 2):

1. Interviewees identified actors who are involved in water quality governance for the River Test or River Itchen catchments. The actor names were written down on actor cards, post-it notes in our case, and attached to a large sheet of paper.
2. Links between actors were then recorded by drawing arrows between the actor cards. Interviewees were invited to map three types of relational ties: information, financial and pressure. Interviewees were asked to give examples of the links they described. Information ties were defined as any means of providing details relating to water quality to another actor. Financial ties were defined as any financial link between actors that related to water quality including, but not limited to, grants, subsidies, fines and payments for goods or services. We defined pressure as attempts to persuade or coerce another actor into action that relates to water quality, this could be via formal (e.g. statutory powers) or informal means (e.g. public protest).

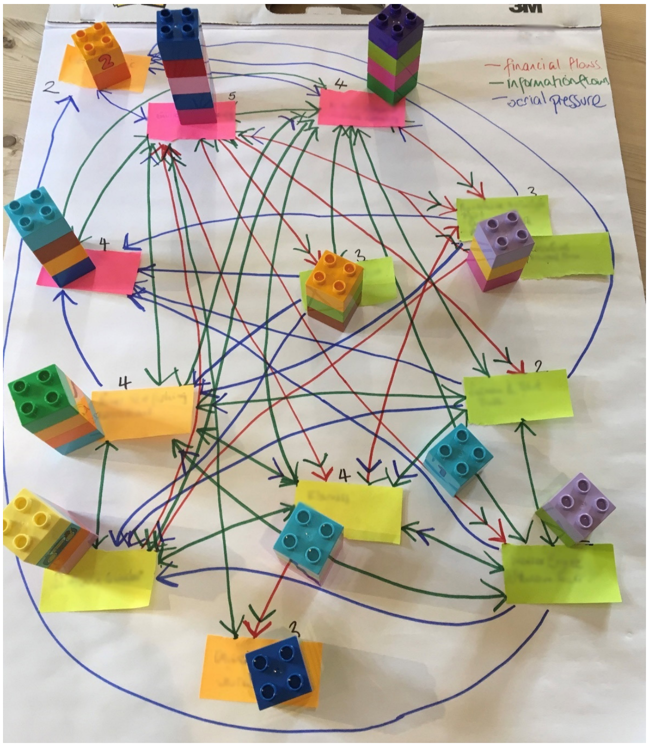

FIGURE 2 A Net-Map network visualisation. The image has been altered to anonymise the actors identified in the interview. Arrows indicate the direction of flow of a particular tie. Arrows in both directions indicate a reciprocal flow.

3. Each actor identified in the network was assigned a perceived influence rating. Interviewees were given 40 playing blocks to distribute across the actors they identified. The more playing blocks allocated to an actor, the more influence they were perceived to have. The number of playing blocks assigned to each actor was recorded as their influence value.

In addition, we also invited interviewees to reflect on the network visualisation they produced. For the full interview protocol, and details of adjustments to the protocol for the virtual interviews, see Appendix S2.

We then invited all the interviewees to attend a half day workshop on 10 May 2021. We digitised and amalgamated the visual networks produced in the individual interviews (for details, see the data analysis section) and used these to allow the group to reflect on the network structure, to facilitate collective analysis of the network, and to discuss interventions to improve governance (for the workshop protocol, see Appendix S3). We piloted the workshop with a group of eight academics, who were unconnected to the project, and used their feedback to refine the protocol, network visualisations and workshop facilitation.

Seven of the 15 original interviewees participated in the final workshop, which was recorded with their permission. The questions for the workshop were guided by the initial interpretations from the qualitative structural analysis (see the data analysis section), for example, an initial interpretation of relatively high density in the network underpinned a workshop question regarding whether there was trust in the network. The workshop participants also completed a short survey to allow us to evaluate the success of the method for generating actions and for facilitating social learning (for the survey, see Appendix S4). The workshop took place virtually due to restrictions implemented by the UK Government throughout the COVID-19 pandemic.

2.4 | Data analysis

The visual networks were digitised by creating adjacency matrices, listing every actor horizontally and vertically and noting the presence or absence of a link between pairs of actors. We used Visone (Brandes & Wagner, 2004) to visualise and analyse these matrices. Amalgamated networks were created, one for each type of connection, and one overall network, by counting how many times a particular actor, or type of connection between two actors, was mentioned across all of the interviews. The average assigned influence value for each actor was calculated by normalising and averaging the perceived influence ratings given by participants in each interview, we then normalised these average values. Table 1 provides an overview of our analytic approach for each research question, lists the network and node level quantitative metrics we have calculated, and details how these metrics are connected to features of governance. For details of the specific calculations, see Appendix S5. We calculated correlation values using Kendall's tau, as the data were not normally distributed, using R Statistical Software (R Core Team, 2016).

Having calculated the network and actor metrics, we then used a qualitative structural analysis approach as suggested by Herz et al. (2015) to guide our analysis of the network visualisation and qualitative data. A list of questions about the network structure and actor positions and roles was generated, underpinned by SNA theory (see Table 1) and guided by the network and actor metrics we calculated. For example, 'Which actors connect otherwise unconnected actors?', 'Are there areas of the network which have more ties than others?', 'Which actors are central in the network?'. This process helped us to develop a series of initial interpretations about the network and further questions to pose to the qualitative data. For example, 'The network has a high density of connections. Does this high density foster trust?', 'Actor X occupies a central position in the network but does not have high influence, why?, 'Several individual citizens are relatively central in the network, why do they occupy these positions?'. This process helped to embed a structural approach in the qualitative analysis by sensitising the qualitative analysis to points of interest underpinned by SNA theory. The qualitative data were deductively coded using Nvivo.

A summary of interventions to improve governance that arose from the workshop was generated by reviewing the discussion from the workshop. The summary of interventions was circulated to participants by email, which they reviewed and approved. These actions were triangulated to findings from the analysis of the interview data to strengthen our understanding of the issues and actions. We also used the initial interpretations and questions generated by the qualitative structural analysis of the interview data to analyse the qualitative data from the workshop in order to refine our findings.

We have anonymised all actor names, with the exception of state actors, in order to maintain confidentiality. We took this approach as state actors are easily identified from descriptions of their roles and information about their work is publicly available.

3 | RESULTS

3.1 | Network characteristics and patterns of flows

Interviewees identified 74 different actors (organisations or individuals) involved in the governance of water quality that operate at local, regional, national and international scales. The majority of the interviewees were identified as actors in the network by themselves or others. Actors were assigned to one of 20 categories based on their primary role within the catchment, as determined from the qualitative data from the workshop and individual interviews, see Table 2 for descriptions of the actor categories. The actor categories were developed using qualitative data from the interviews. We considered the interests and motivations of the actors, and the types of organisation (e.g. differences in their ownership) when defining the categories. In instances where an actor had multiple roles, we used evidence from the qualitative data and our judgement to determine which category to assign them to. Aggregating the actors into categories helped to ensure actor anonymity as actors may have been identifiable in a disaggregated network visualisation.

Interviewees identified 1173 ties across the three types of flow; information, finance and pressure, between the 74 actors. The overall network (Figure 3) had a centralisation of 61% and a density of 0.16. The network formed one structure, with the exception of the rail network, who was unconnected to other actors. The majority of ties identified by interviewees were flows of information (66%) and the ties of information had a relatively high density of 0.14, when compared to the ties of finance and pressure, which had densities of 0.03 and 0.04 respectively (Figure 4).

Ties of information were all reciprocal, that is, information flowed in both directions. However, the qualitative data indicated that the extent of the information flows varied, with some being weaker ties of basic information exchanges, for example, emails from individual citizens to the Environment Agency (EA) reporting an issue, and others stronger ties of more extensive communication, for example, running and chairing local stakeholder forums. In addition, we noted several themes in information flows. Information flows indicated that the relationship between some actors went beyond information sharing to collaborating and partnering to facilitate action or solutions. For example, ENGO, state and private actors partnered to develop, fund and deliver a project to protect and restore local chalk streams. Additionally, civil society actors co-ordinated responses to government consultations. Collaborating to generate research and data was also a strong theme. Local universities, ENGOs and local citizens collaborated to identify knowledge or evidence gaps and facilitate research and data collection, for example, to understand the impacts of particular pollutants on biotic communities, or to collect detailed water quality data. Flows of information related to regulation were prominent. Interviewees noted communication between regulated industries, such as the water industry, and the EA to share technical regulatory details, advice and progress updates and also communication on progress updates and regulatory initiatives were provided by the EA to civil society actors. In return, civil society actors reported issues to the EA, for example, incidents of pollution, and shared data. Sharing advice was also a noticeable theme. Often this was from state actors or private consultants to private business, farmers and landowners, focused on ways to reduce pollution. For example, Natural England (NE) provided technical advice to farmers about how to reduce diffuse pollution through land management options such as buffer strips and hedgerows.

Financial flows were typically unidirectional, for example, a flow of grant money from a donor to a recipient. At a national level, funds flow from central government to key state actors such as EA, NE, Ofwat and Rural Payments Agency. These funds were either used directly by these actors or distributed to local actors in the network. Examples of the fund flows include: the Rural Payments Agency managed agri-environment grants and checked compliance with land management standards in exchange for funds; the EA co-funded river restoration schemes with landowners; and the EA and NE co-administered funding to organisations and land owners that then delivered projects to improve the condition of waterbodies or halt their decline. As the main environmental regulator, the EA also received licence and permit funds and collected fines. At a local level, there were further sources of funds. Through membership donations, the general public supported ENGOs, funds which were then used to run projects to protect chalk streams. Individual landowners provided one-off donations to particular ENGOs, for instance, to fund a particular legal challenge against the state. Collectively, riparian owners funded membership organisations who advocated on their behalf on water quality issues. Local ENGO, state actors and private actors co-funded research projects on catchment water quality, for example, to understand phosphorous inputs into chalk streams. Private actors provided funds to farmers to change land management practices to reduce pollution, which was viewed as a more financially efficient way to achieve favourable changes in water quality.

A range of both formal and informal ways to pressure other actors (persuade or coerce them into action related to water quality) were identified. Flows of pressure were centred around the EA. Pressure was exerted from the EA to the industries they regulate, including the water industry, aquaculture and agriculture, via formal legal mechanisms and more informal conversations. These regulated industries pushed back on the EA with regard to the standards and targets they were expected to adhere to. The flows between regulated industries and the EA were therefore reciprocal flows, in contrast to many of the other flows of pressure, which were unidirectional. Civil

TABLE 2 Descriptions of the main actor categories (those mentioned by more than five interviewees) and their role in governance, as determined by the network and qualitative analysis. We have singled out actors within these categories for discussion where their role differs to others, or where they have a relatively high level of influence

Actor category	Description & role
Agriculture	Farmers were viewed as the fourth most influential actor (influence value: 0.49) due to their role in managing large areas of land in the catchments and the potential impact of their decisions on water quality. Several interviewees perceived that despite this influential role, agriculture receives less pressure than other industries due to the more diffuse nature of agricultural pollution and the large number of individual farmers within this industry. Farmers were considered by many interviewees not to be as engaged with water quality issues as other polluting industries, for example, aquaculture, in part due to their lack of representation at catchment stakeholder forum meetings
Aquaculture	Watercress growers and fish farms were singled out as industries that impact water pollution, through their discharge of water directly into the rivers, although their influence on governance is considered lower than other polluting industries such as agriculture. One company within this group was singled out for their engagement with the issue of water pollution and their leadership role; establishing stakeholder forums and coming 'to the table' to talk to other stakeholders, and investing in conservation projects in collaboration with Environmental Non-Governmental Organisations (ENGOs). This was reflected in their higher influence value of 0.06, compared to the group average of 0.05. Although there is little collaboration and co-ordination between companies within this sector, these actions are perceived to have encouraged other companies within the sector to engage in discussions about water quality
Citizens and community	Several individuals were highlighted in the interviews and collectively they played key roles in the network: they brokered information flows between other actors, notably connecting MPs and other political figures into the network; provided 'on the ground' local knowledge about the state of the rivers; took on leadership roles; were a source of finance; held state actors to account; and facilitated scientific research projects. The most influential individuals (highest influence value: 0.16) were considered to have built considerable social connections and trust, or to have influence via their financial resources Some local community groups were mentioned due to their role in citizen science projects or in flagging up concerns about their local rivers, but in general were not well connected to the rest of the network and were perceived to have low influence (influence value 0.05). The general public were referenced for their role as water users and polluters, as funders of some ENGOs, and for their potential collective influence on issues such as water quality. The general public were perceived to have low influence (influence value: 0.13) but several interviewees noted a shift in public interest and engagement with the issue of water pollution, and the potential for their influence to be greater
Environmental Non-governmental Organisations (ENGOs)	Collectively, ENGOs in the network played several key roles: acting as a broker of information, notably between the general public and the rest of the network; as a broker of finance; pressurising and lobbying state actors and regulated industries; gathering evidence and undertaking independent monitoring; and bringing in new sources of finance. Some of these roles, for example, water quality monitoring, had been adopted in response to the perceived failure of the state regulator to carry them out effectively. The influence values for individual ENGOs varied considerably (influence values between 0 and 0.45), partly reflecting different approaches by ENGOs to influencing governance and partly the resources available to each ENGO. Some ENGOs used collaborative partnerships to deliver solutions and undertake research while others used direct pressure, for example, initiating legal challenges. The latter approach was generally perceived to be more influential
Land and riparian owners	Due to their ability to make direct decisions that impact water quality, land and riparian owners were mentioned by many interviewees, but the level of influence attributed this actor category varied. Some interviewees viewed the ability of land owners to make direct decisions about land management as influential, while others perceived the actions of individual landowners to be relatively insignificant
Member organisations	Several member organisations were involved in the network, bringing together individual actors with shared interests, for example, farming, riparian ownership and land ownership. These organisations often provided advice to members, acted as a conduit for the concerns of members and lobbied the state on behalf of their members. The perceived collective influence of these organisations was low (influence value: 0.08) and they were only moderately central in the network (degree centrality: 0.29). Their limited influence was attributed to the lack of financial resources of the smaller organisations, and due to water quality not being a priority of many of the larger membership organisations
National government	The Department for the Environment and Rural Affairs (Defra) played an important role in setting the direction of and allocating primary funding for two influential state actors Environment Agency (EA) and Natural England (NE). Despite this role they were not identified by the majority of interviewees. The EA were perceived to be the most influential actor (influence value: 1) and primarily responsible for water quality through their roles in managing permits for water abstraction and discharge, monitoring water quality and compliance with standards and undertaking river restoration projects. As well as being the most influential actor, the EA was also the most well connected, having ties to the majority of other actors (degree centrality score of 1.45) and acting as a bridge between otherwise unconnected actors, as shown by having the highest betweenness score (0.22). The EA played a role in distributing financial resources to civil society actors for projects, such as river restoration, and for academic research projects. The EA were a hub for pressure—receiving pressure from NGOs, the local community and the industries they regulate, and then applying pressure back to the regulated industries NE was perceived to have a role in regulation due to their responsibility for the monitoring and compliance of designated sites, and to have influence as advisors on standards for water quality and as advisors to farmers. Due to having a more significant role as advisors rather than regulators, NE was not viewed as being as influential (influence value: 0.79) as the EA. However, their significant links with farmers were seen to be particularly important as the agriculture sector was not perceived to be well connected to other actors

TABLE 2 (Continued)

Actor category	Description & role
Research and academia	Universities were the main source of new scientific knowledge in the network, for example, providing new information on the effects of water pollutants. One local university had a long history of undertaking scientific research projects associated with chalk streams. Funding for research came from environmental regulators, ENGOs and local individuals. Despite many interviewees emphasising the importance of underpinning decision-making with scientific knowledge, the influence of academic institutions was relatively low (influence value: 0.12). This was attributed to limited dissemination of the research findings and little implementation of any recommendations, for example, the findings did not influence policy making
Stakeholder forums and partnerships	Stakeholder forums & partnerships were recognised as having a key role in convening stakeholders and brokering information, as reflected in their centrality values: the second highest degree value, 0.55 and a moderately high betweenness value, 0.21 There were two established stakeholder forums for the rivers, where a range of actors—state, businesses and civil society—came together to discuss the conservation of the rivers, focusing on water quantity and water quality. The forums were perceived to have several roles: brokering information between different actors, many of whom are only connected via the forum; applying pressure to those seen as responsible for water pollution; expressing the collective viewpoint of the forum members in government consultations; and giving space to opposing views. One of these forums was perceived as relatively influential (influence value: 0.3) due to the broad range of stakeholders present at the meetings and the quality of the chairperson Additionally, the Test & Itchen Catchment Partnership (T&ICP), a Defra supported mechanism to deliver catchment-based, collaborative approach to land and water management, brought together civil society, state and private actors. The perceived influence of the T&ICP was low (influence value: 0.12), but interviewees varied in their assessment; some noting that the convening power, shared decision-making and co-ordination that the T&ICP provides makes a positive contribution to governance, but others believed that the T&ICP could be more effective
Water industry	The main water company covering the catchment supplied water and sewerage services to residential and industrial customers. They were perceived to be the third most influential actor (influence value: 0.51) because of their direct impact on water quality from discharging treated sewage into the rivers and indirectly by concentrating pollutants by abstracting water from the rivers and groundwater. The main water company was connected to many other actors in the network (degree centrality: 0.93), but some of these connections were unidirectional—incoming flows of pressure from other actors without a reciprocated flow. Trust in the water companies appeared low, resulting from historic behaviour regarding sewage discharges and their lack of attendance at stakeholder forums. Water companies were in a unique position of being regulated by both environmental and financial regulators (Ofwat). This regulatory divide was perceived to be one of the reasons preventing water companies from reducing their impact on water quality—the financial regulator prevents investment in necessary resources, for example, upgrading sewage systems

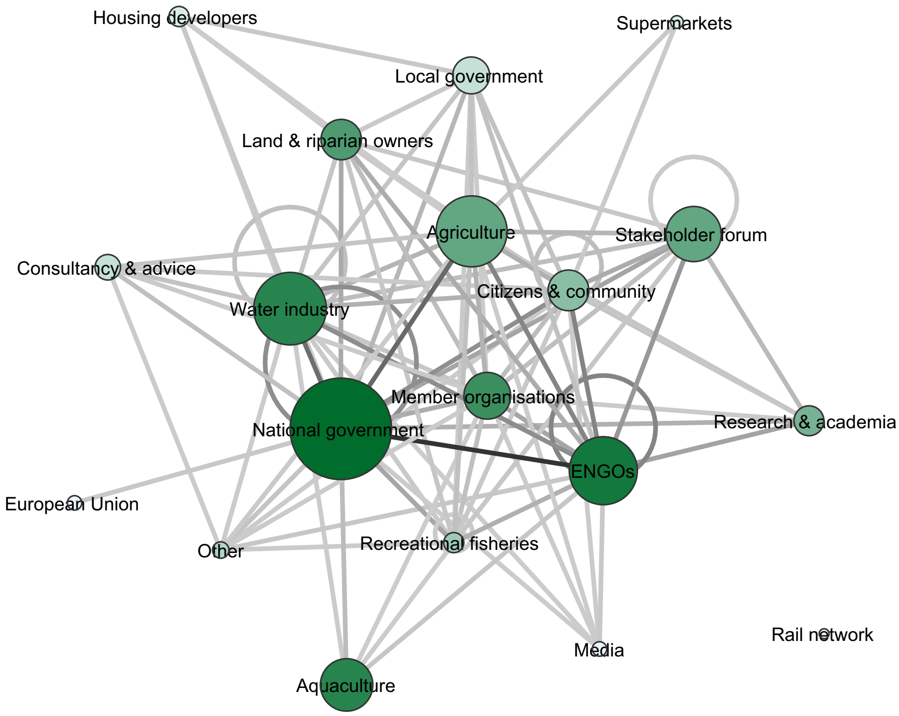

FIGURE 3 Aggregated governance network of information, financial and pressure flows as perceived by interviewees. Circle size indicates the maximum perceived influence of a particular actor category (calculated from the perceived influence ratings given by interviewees to each actor they identified), the larger the circle the higher the influence value. Circle colour indicates the number of times an actor group was mentioned, the darker the circle the more times a group was mentioned. Line colour indicates the number of times a link was mentioned, darker lines indicate more mentions.

society actors, such as ENGOs and individual citizens, pressured polluting industries directly through conversations or letters, but also indirectly by pressurising the EA, sometimes informally by personal conversation or through more formal channels threatening legal action. Additionally, civil society actors, particularly ENGOs, attracted media attention to water quality problems in chalk streams as a way of garnering public attention and pressure.

3.2 | Key actors and their role in governance

Interviewees were able to differentiate between the aspects of an actor's role that related to water quality governance and those focused on other components, such as water supply. For descriptions of the main actor categories (those mentioned by more than five interviewees) and their roles in governance, see Table 2. For the node level metrics for each actor category, see Table 3. For the node level metrics disaggregated by actor, see Appendix S6.

Interviewees noted different types of influence exerted by actors in the network, which we categorised as financial, legal, land use, political, expert and social capital. We define these types of influence as follows: Legal influence is achieved through statutory laws; political influence is influencing law making through lobbying or being directly involved in formulating laws; land use influence refers to the influence exerted by the decision-making of landowners; financial influence is influencing decision-making by directing financial resources; expert influence is the ability to direct decision-making due to a perceived level of knowledge not held by other actors; and finally, influence derived from having social capital - many, reliable and trustworthy relations.

We noted a positive correlation between the number of times an actor was mentioned and their perceived level of influence ($r_\tau = 0.67$, $p < 0.05$). However, there were some exceptions. Ofwat, a statutory financial regulator, was not frequently mentioned but considered relatively influential, in contrast to several membership organisations, who were frequently mentioned but have a lower influence values. Actors who are more salient are often more influential, but some actors appear to be perceived as involved in governance with limited influence over governance processes and outcomes. Similarly, actors with higher degree centrality were more influential ($r_\tau = 0.64$, $p < 0.01$). However, we noted similar exceptions, for example, Ofwat had low centrality but relatively high influence, in contrast to some ENGOs who had high degree centrality but limited influence. We attribute this in part to the type of influence these actors were perceived to have and the remit of their role. Ofwat has regulatory power and so has formal influence over other actors and a direct role in decision-making regarding investment in improving water quality. In contrast, many ENGOs were seen as relevant to the governance network, but their influence was informal and reliant on connecting with others to exert any influence. This suggests that while an actor's influence is impacted by their position in the network, the type of influence they exert is also an important factor (Bodin & Crona, 2009).

Influence and pressure appear to be related. Although we are not able to quantify this relationship, we note actors with high influence values are prominent in the pressure network. For example, the EA have the highest influence value and are able to both exert pressure on other actors due to their regulatory role, while at the same time being the recipient of substantial pressure. Similarly influential actors who are perceived to be the cause of problems with water quality, for example, the water industry and agriculture, are recipients of pressure.

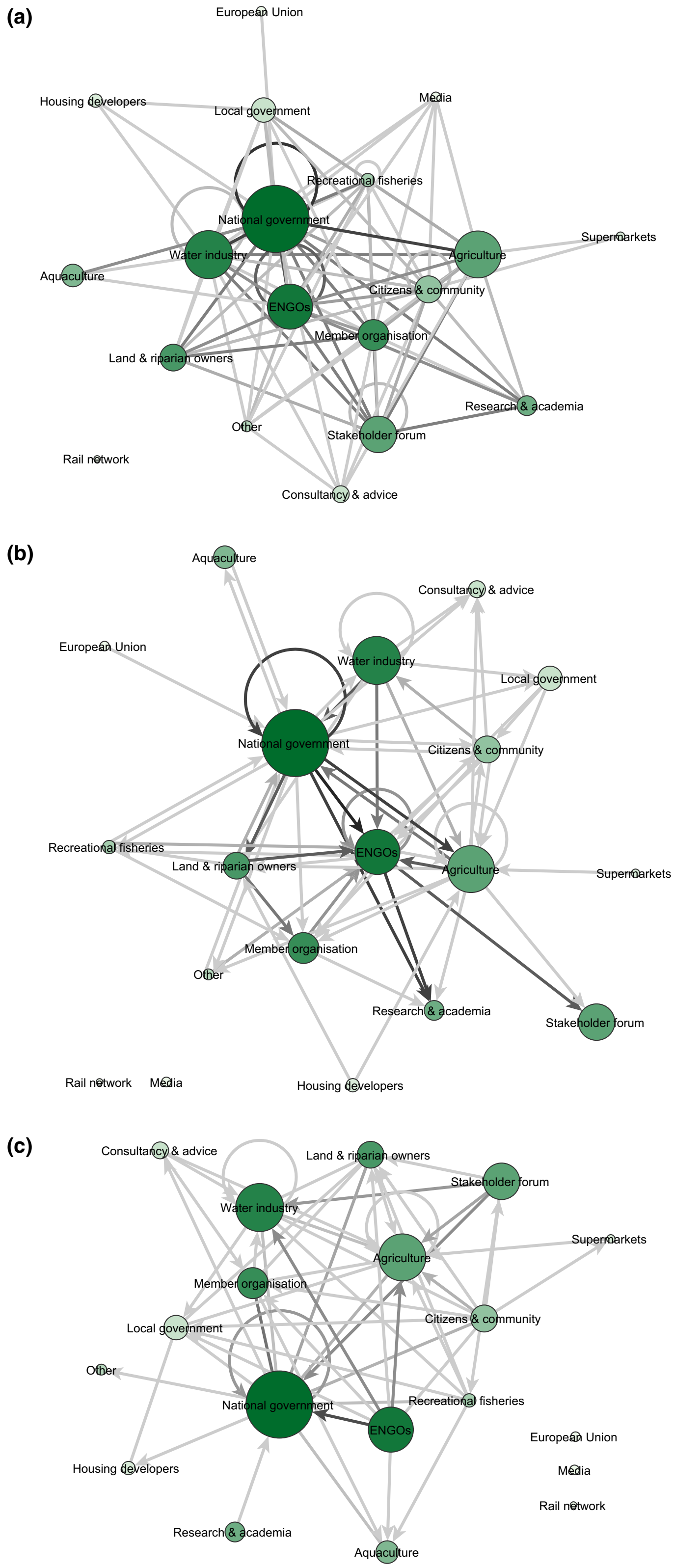

FIGURE 4 Network visualisations (a) information, (b) finance and (c) pressure. Circle size indicates the maximum perceived influence of a particular actor category (calculated from the perceived influence ratings given by interviewees to each actor they identified), the larger the circle the higher the influence value. Circle shade indicates the number of times an actor group was mentioned, the darker the circle the more times a group was mentioned. Line shade indicates the number of times a link was mentioned, darker lines indicate more mentions. A line without a directional arrow represents a reciprocal connection, for example, information flowing in both directions between actors. Unidirectional flows are depicted with an arrow, which indicate the actor category the flow is going to. Flows between actors within the same actor category are indicated by a circular line.

3.3 | Interventions to improve the governance of water quality

Participants responded to the visual network presented in the workshop with interest and curiosity. The discussion provoked by the network was open and participants expressed that the workshop offered a safe space to share their thoughts. No single participant dominated the conversation, but several of the participants knew each other well and so engaged in the discussion to a greater extent than others. The facilitator invited contributions from quieter members of the group to balance the conversation. Initial surprises on viewing the visual network were the amount of pressure links to the

TABLE 3 Attributes of aggregated actor categories ranked by the number of times the actor group was mentioned across the 15 interviews. ENGOs = Environmental Non-Governmental Organisation. Two measures for influence, degree centrality and betweenness centrality are provided: the average for the actor category and the highest value or any one actor within that category.

Actor category	# of times mentioned	# of actors in category	Average influence	Highest influence	Average degree centrality	Highest degree centrality	Average betweenness	Highest betweenness
National government	15	9	0.26	1.00	0.44	1.45	0.037	0.222
ENGOs	14	8	0.19	0.79	0.52	0.97	0.023	0.055
Aquaculture	13	2	0.05	0.06	0.52	0.82	0.026	0.051
Water industry	13	5	0.11	0.51	0.38	0.93	0.016	0.066
Member organisations	11	5	0.08	0.21	0.29	0.80	0.009	0.042
Land & riparian owners	10	1	0.01	0.01	0.58	0.58	0.017	0.017
Agriculture	9	1	0.49	0.49	0.70	0.70	0.053	0.053
Stakeholder forum & partnerships	9	3	0.05	0.10	0.55	0.62	0.021	0.025
Research & academia	8	4	0.12	0.30	0.19	0.42	0.001	0.004
Citizens & community groups	6	12	0.07	0.24	0.25	0.50	0.007	0.022
Recreational fisheries	5	5	0.03	0.13	0.21	0.42	0.001	0.006
Other	4	3	0.01	0.02	0.10	0.21	0.000	0.000
Consultancy & advice	3	5	0.05	0.08	0.10	0.13	0.000	0.000
Local government	3	5	0.10	0.10	0.15	0.25	0.002	0.007
Other industry	3	1	0.06	0.16	0.12	0.12	0.000	0.000
Housing developers	2	1	0.21	0.21	0.16	0.16	0.000	0.000
Supermarkets	2	1	0.06	0.06	0.05	0.05	0.000	0.000
European Union	1	1	0.09	0.09	0.07	0.07	0.000	0.000
Media	1	1	0.00	0.00	0.20	0.20	0.000	0.000
Rail network	1	1	0.03	0.03	0.00	0.00	0.000	0.000

EA compared to NE, and the lack of influence of some of the ENGOs. Participants were largely in agreement about the main issues, for example, the limited connections to the regulator Ofwat. There were differences of opinion, for example, regarding the extent of actions taken by farmers to tackle water pollution, but these were discussed respectfully.

The positions in the network of Ofwat and the general public were of particular interest to participants. Despite their important role approving capital investment by water companies to mitigate water pollution, Ofwat were perceived to be less central in the network than participants expected and had few ties to civil society actors. Participants recognised a need to improve communication with Ofwat and suggested that actors should be identified who could help to build relationships between Ofwat and key civil society actors. Additionally, the general public were perceived to be poorly connected to other actors in the network. Participants recognised the general public as a potentially important actor due to their ability to apply collective pressure to local and central government to act on water quality. Fostering an appreciation of the rivers by the general public was viewed as an important foundation for building engagement with the issue of water quality. Improving access to the rivers (e.g. by encouraging private landowners to provide temporary access and tours of the rivers) was suggested as a way for the general public to develop an appreciation of chalk streams, improve connections to other actors in the network and give the general public more influence in the governance network.

Improving the effectiveness of stakeholder forums was also identified as an action. Some key actor groups were not directly connected to some of the stakeholder forums, for example, agriculture, and the group discussion highlighted that other key actor groups do not consistently attend meetings, for example, water companies. Participants reflected that improving representation at the meetings and encouraging regular attendance could help to improve communication and facilitate more effective discussions.

A significant theme in the workshop was trust in the network. Participants observed that there was a lack of trust in certain actors, particularly state environmental regulators and advisors, and private companies, although often at an organisational rather than individual level. The lack of trust was attributed to perceived under resourcing of environmental regulators and advisors and a belief that these organisations could not carry out their roles effectively. In the case of private actors, the lack of trust was associated with historic behaviours and their perceived motives. Repairing trust was identified as an action but participants found it challenging to identify tangible ways to do so.

Participants highlighted the importance of scientific knowledge in underpinning decision-making, which contrasted with the low influence values and degree centrality of academic institutions in the network. There was acknowledgement that more could be done to improve how new knowledge was disseminated around the network and applied in management practices. Making better use of existing channels, such as established stakeholder forums and networks, and creating new ones, for example, connecting with actors via social media, were proposed.

The issues and actions identified by the group covered a range of scales, from local changes (e.g. improving the representation at stakeholder meetings) to national scale actions (e.g. increasing the financial resources of environmental regulators to improve regulatory enforcement). On occasion, the group found identifying tangible actions to mitigate the issues challenging, for example, how to build trust in the network.

4 | DISCUSSION

A key finding is that regulatory enforcement is the main mechanism for maintaining and improving water quality in the catchment. There are a mix of state, civil society and private actors in the network who appear well connected, suggesting polycentricity. However, our analysis indicates that decision-making is actually relatively centralised with the Environment Agency (EA) and Natural England (NE) holding significant decision-making influence as a result of their regulatory and advisory roles. Civil society actors in particular have relatively limited influence on water quality decision-making. Notably the formalised mechanism for collaborative management in the network, the Test & Itchen Catchment Partnership, is not perceived to have significant influence. These findings indicate that governance is predominantly bureaucratic (Pahl-Wostl, 2019), characterised as hierarchical, state-led and rule-driven, consistent with the findings of Watson et al. (2009). The lack of formal authority devolved to local actors in the network limits their ability to affect change.

Despite being central in the network, there is an evident lack of trust in the EA and NE due to a perceived inability of these actors to carry out their responsibilities adequately, a failure often attributed by interviewees to underfunding from central government. This finding contrasts with Coleman's (1990) assertion that many connections between actors foster trust, as the network is relatively densely connected for a network of its size (Fliervoet et al., 2015; Stein et al., 2011). Additionally, the motives and transparency of private actors were also questioned leading to degree of corporate distrust. Much of the distrust of state and private actors was 'rational'—based on perceptions of past actions (Coleman & Stern, 2017). Flows of pressure around the network were primarily directed at these state and private actors, often as efforts to hold these actors to account, for example, ENGOs threatening judicial reviews, or to mitigate a perceived lack of transparency, for example, citizens instigating freedom of information requests. As trust is an essential factor for successful collaboration and ACM, environmental regulators and private actors need to repair trust (Ansell & Gash, 2008; Olsson et al., 2004). Trust enables actors to better understand the needs and perspectives of others and contributes towards a 'shared motivation' between actors, which facilitates better collaborative processes and ultimately actions (Emerson et al., 2012). Identifying tangible actions to facilitate trust building was a challenge for participants. However, there are principles and actions that can underpin repair: honesty, making changes to address problems, regular quality communication, ensuring transparent and legitimate procedures and time (Coleman & Stern, 2017; Cvitanovic et al., 2021). Once established, trust can help to sustain engagement between actors to address an issue such as water quality (Emerson et al., 2012).

Features important for adaptive co-management (knowledge generation, communication and collaboration) were identified in the governance network. Local actors were committed to underpinning decision-making with scientific knowledge and generating new knowledge and understanding about water quality and chalk streams. Direct observations of the rivers were often the catalyst for research projects and ENGOs, academic institutions and local citizens collaborated to carry out and fund the research. However, there is a disconnect as the outcomes of the studies do not often find their way into decision-making, particularly at a national scale. The low influence value attributed to research and academia reflects this disconnect. Completing the learning cycle so that new knowledge can easily be incorporated into decision-making is an important part of improving the adaptive capacity of the network. This requires better connections between the EA and NE, at a national level, who are primarily responsible for decision-making, and local actors such as universities. Local actors have also established spaces for communication and collaboration in the form of stakeholder forums. The forums provide opportunities for 'principled engagement', repeated high-quality interactions that help to foster trust, understanding and commitment between actors (Ansell & Gash, 2008; Emerson et al., 2012). Workshop participants recognised the importance of improving representation at these meetings, ensuring a full range of knowledge and perspectives, to facilitate considered decision-making. Additionally, the forums may provide a space for more targeted interventions to repair trust in the network and a structure on which to build further collaborative opportunities, particularly if local actors are given more authority to effect change.

Both the results of the interviews and workshop highlight the need to improve connections with Ofwat and the general public to facilitate communication and collaboration. Ofwat are primarily only connected to private water companies, which may limit and bias the information that they receive. Forging connections from civil society actors to Ofwat may help influence decision-making. Through activism and public will, the shared recognition of a problem, the general public has the potential to influence decision-making (Leiserowitz, 2019). Improving connections with the general public to improve understanding and engagement with the issue of water quality is therefore important.

Further attention should also be given to the integration of land and water governance. Land-use decision makers, in particular local government and developers, are not central in the water quality network and have little influence, suggesting weak integration of land-use decision-making with water quality governance. This limited integration may be exacerbated by a spatial mismatch between primarily national-scale decision-making for water (via central government) and local level land-use decision-making (Watson et al., 2009). As catchment land use is such a significant driver of water quality, better integration is needed to improve governance outcomes.

5 | LIMITATIONS, REFLECTIONS AND FURTHER WORK

Participants strongly engaged with the Net-Map process and our follow-up survey indicated that participants found the strengths to be that it offered a new perspective on the issue of water quality, and that the collective discussion provided an opportunity to understand more about the concerns of others, and to develop shared actions. The visual map served as an effective boundary object (Hauck et al., 2015), creating a space for social learning and co-production of knowledge. The atmosphere during the interviews and the workshop was very positive. Both the researchers and participants reflected that the follow-on workshop would have benefitted from being longer to allow time to consider how to implement the identified interventions. However, as the workshop was held online, we recognise that a longer session may have resulted in fatigue.

As the Net-Map process is based on the perceptions of participants, it is important that the selection process collects a broad range of perspectives. We did not experience any significant challenges in recruiting interviewees for the first stage of the process and we achieved broad representation. However, representation at the follow-on workshop was more limited; fewer private sector actors were present at the workshop and this may have created some bias in the results. While it would have been preferable to broaden the perspectives of the participants at the workshop, we also needed to be pragmatic and work with those who were able to take part at that stage.

Our research plans were impacted by the COVID-19 pandemic and the restrictions implemented by the UK government, resulting in four of the interviews and the workshop being conducted online, rather than in person. However, other than influencing the planned duration of the workshop, as we felt that an online workshop needed to be shorter, we do not believe that these changes will have substantially affected the results of our research and they may have made it easier for some participants to have been involved as it reduced the time and travel required.

The network data collected are a snapshot, a static view of a dynamic network. Further research to understand how anticipated policy changes might impact water quality governance, for example, the implications of the Environment Act and environmental land management schemes, would be useful to maximise the potential benefits of these changes. Additionally, further understanding of the longer term resilience of the network, particularly how it is impacted by the removal of key individuals, would be of interest. As an important action from our work is to develop trust in the network, more research to understand how to facilitate this in a complex governance network would be valuable. Longer term engagement with the stakeholders in this network is also desirable to make the most of the research partnership and maximise the impact of the findings.

6 | CONCLUSIONS

Chalk streams are priority habitats in England and important global ecosystems. Using participatory SNA in the River Test & River Itchen catchments, we have shown some of the complexity that underpins water quality governance. We do not claim to be able to determine an 'optimal' network structure, and recognise the limitations of SNA in assessing governance. However, our findings provide a visualisation of the current formal and informal governance arrangements and suggest areas where interventions might improve outcomes for water quality, based on the theory behind integrated and adaptive governance, and SNA. The impact on water quality from changing governance arrangements is not necessarily direct but can alter the processes that underpin decision-making. Improved decision-making in turn enhances the outcomes for water quality (Sandström & Carlsson, 2008b).

Governance for the River Test and River Itchen is relatively hierarchical with central government actors, in particular the Environment Agency and Natural England, holding most influence. Local actors carry out important roles but ultimately have a limited role in decision-making. While vehicles for collaboration at a catchment scale have been created by central government, they do not have significant decision-making authority. Devolving more formal authority to local actors and giving them opportunities to directly participate in decision-making are required to shift towards polycentric governance arrangements. Further attention could be given to the existing informal networks in the catchment and how they can be mobilised more effectively to help guide water quality decision-making. Alongside changes to the distribution of power in the network, trust needs to be repaired, particularly by state and private actors, such as the Environment Agency and water industry. This finding is particularly important as trust is a key factor shaping the effectiveness of the collaborative processes that underpin adaptive governance. Our decision to conduct this research in a way that facilitates social learning and relationship building makes a small contribution to improving trust in the network and demonstrates part of the value of transdisciplinary research.

Our findings have implications for UK policy surrounding water quality, particularly for chalk streams, and could be integrated into current strategies, such as the Chalk Streams Restoration Strategy (Rangeley-Wilson, 2021). Without addressing some of the governance issues found in our study, such as the lack of trust in environmental regulators, there is a risk that other interventions to improve water quality may fail. Additionally, our findings are locally relevant and have been used as a catalyst for self-reflection about roles, influence and effectiveness by some actors in the network.

While the recommendations we make are context specific, our study demonstrates how place-based, participatory SNA can be used as a tool to recognise structural problems in a governance network and identify opportunities to improve outcomes. In addition, our approach can be applied to other catchments and other important habitats. Combining quantitative network data and qualitative narrative data enabled deeper insights into the relationships and roles of actors. While creating opportunities for collective analysis by participants enabled social learning and further refined our understanding of the issues and potential remedies.

AUTHORS CONTRIBUTIONS

Jennifer Ball, Jennifer Hauck and Kelvin S.-H. Peh conceived the idea and designed the methodology; Jennifer Ball managed the project; Jennifer Ball and Amy Lovegrove collected the data; Jennifer Ball led the data analysis; Jennifer Ball, Amy Lovegrove, Robert A. Holland, Kelvin S.-H. Peh, Jake Snaddon and Jennifer Hauck contributed to the interpretation of the data; Jennifer Ball led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication. Kelvin S.-H. Peh, Robert A. Holland, Jake Snaddon and Gail Taylor provided supervision.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interests.

DATA AVAILABILITY STATEMENT

Data used in this study are deposited in the Dryad Digital Repository https://doi.org/10.5061/dryad.crjdfn36x (Ball et al., 2022).

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