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Bridging Actors and Their Role in Co-Managing Lakes: Cases from Greater Bengaluru Metropolitan Region (GBMR)

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Abstract: Co-management is seen as a means to effectively manage common-pool resources, especially collaborations based on sharing of roles and responsibilities between state and non-state actors. Collaborations depend on certain key intermediary bridging actors who facilitate and coordinate links between these actors. In this paper, we aim to understand the role of these bridging actors in shaping networks of co-management by developing a framework based on certain characteristics such as initiation, position, and facilitation of interactions whose application we illustrate for three lakes situated across a rural–urban gradient in Greater Bengaluru Metropolitan Region (GBMR). Drawing on concepts from co-management and social network analysis, we analyse data collected from documents, key informant interviews, and FGDs to identify that bridging actors play a critical role in resource gathering, enhancing mutual trust, and promoting innovation through information exchange irrespective of the social-ecological context. Beyond mere description, we highlight that state sponsorship plays an important role in establishment of bridging actors in urban and peri-urban areas due to heterogeneity in perceptions, actors, lack of trust and credibility in comparison to rural lakes where state sponsorship is less important and community engagement is stronger. We conclude that irrespective of the context, position of bridging actors plays an important role in facilitation of interactions within networks.

Keywords: bridging actors; co-management; social networks; natural resource governance; lakes; rural–urban gradient; Bengaluru

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1. Introduction

There is a consensus among researchers that urbanisation is one of the key drivers of environmental change not just at the local level but also globally [1]. This urban transformation of society is led by changes in land-use and associated administrative boundaries in accordance with societal dynamics rather than local ecology [1]. There is an increasing acceptance of the concept of *social-ecological systems* within urban ecology literature, whereby most studies focus on land-use patterns and their effects on ecosystem services and very few focus on management of common property resources engulfed by urban expansion [2,3]. There is a limited number of studies that consider interactions between human societies and local urban ecosystems, focusing mainly on "how diverse stakeholders contribute to collaborative management processes especially with regard to small-scale resource management" [4]. In this paper, we set out to understand how various actors collaborate to address issues of lake management across a rural–urban gradient within the Greater Bengaluru Metropolitan Region (GBMR) in India. In this paper, we focus on the role of bridging actors engaged in the formation and strengthening of collaboration networks, thereby contributing to the growing literature on how networks shape and are shaped by ecological contexts especially in view of urban transformations by identifying cases along a rural–urban gradient. Further, we augment the limited but growing literature on bridging actors by describing their roles as agents who promote and develop networks to manage small-scale natural resources in countries of the Global South.

In the Indian context, commons, particularly water, play a crucial role in ensuring local ecosystems and livelihoods of users [5] in both urban and rural areas [6,7]. Most of the commons are governed by the state, under public trust doctrine, and are formally vested within the revenue department [5]. The authority to manage commons is shared among various government departments, with local administration (city administration in urban and Gram panchayats (Gram Panchayats are the local self-government organisation at the village level in India) responsible for managing them [5,6] (personal interview, Aphn, 2019; personal interview, Bal, 2019). In addition, several policies and agencies provide resources—both human and financial—and are responsible for the management of public commons, specifically lakes. For example, the minor irrigation department funds activities, such as ensuring inflow and outflow of water, while the fisheries department is responsible for fishing rights within lakes. Further, there are local communities and residents, direct and indirect users, non-governmental and community-based organisations, and private companies who play active roles in the management of commons, such as lakes, in their neighbourhoods. This mosaic of actors and institutions, coupled with issues in differences in administrative and ecological boundaries [8], has created diverse values, perceptions, and knowledge among actor groups [9]. This diversity is mainly attributed to differences in "practices, interests, values and management structures" [10]. To overcome this diversity of information sources, government and non-government actors have invested in building networks, which link diverse knowledge systems necessitating the role of coordinators and facilitators to ensure collaboration between actors involved in managing the commons [10].

In this paper, we illustrate a framework describing the role of these coordinators and facilitators, or bridging actors, within networks in three cases along a rural–urban gradient and describing how these actors shape networks involved in co-management of lakes in GBMR. Ultimately, this allows us to make indications as regards how social-ecological contexts and particularly socio-economic heterogeneity affect the role of the state and communities for the emergence of bridging actors. The paper is structured as follows: in Section 2 we develop a framework for characterising bridging actors based on various typologies developed within the conceptual framework. Subsequently, in Section 3 we illustrate the application of the framework describing the case study area and the methodology used to analyse the results. Section 4 summarises the analysis of individual cases and results. Section 5 details the discussion and comparison across a rural–urban gradient leading to indications of how social-ecological context affects the emergence and role of bridging actors vis-à-vis the state. It is followed by the conclusion.

2. Co-Management and Bridging Actors

Co-management is recognised as an alternative to conventional management of resources [4]. The understanding of co-management as a collaboration between the state and resource users as considered in the literature does not hold true in real-life situations [11]. The state cannot be considered as a single coherent actor, as its authority varies vertically and horizontally, with individual state organisations possessing diverse aims and interests. The same applies to the users, who have different positions driven by self-interests [11]. Thus, co-management requires development of coherent networks between multiple actors from different areas of society [12,13] based on sharing of power [4,14], resource dependence based on formal jurisdictions, as well as rules and norms that govern the actual condition of exchange [11,14]. In the face of uncertainty and transformation, the capacity to create and prioritise whom you collaborate with and how you collaborate has an impact on the outcome [15]. These collaborations depend on development and sustenance of social relations in networks, mainly between actors across levels who often possess specific information and resources [3,16]. The structural patterns of the collaborative relationship shaping the outcomes differ based on the "role of central actors and bridging ties that enable collective action among previously unconnected actors" (Bodin and Crona [17] as quoted in Lee and Krasny [4]). This act of bridging ties by actors is a critical element necessary for the success of co-management [18]. Several scholars have indicated the need

for intermediary bridging actors, both individuals and organisations, who act as facilitators and coordinators, linking diverse actors [16,19] through a process of bridging [9]. Brown [20] describes bridging actors as organisations linking actors across sectors to tackle problems that individual actors are unable to solve by themselves, thus defining bridging actors as "*a conduit of ideas and innovations, a source of information, a broker of resources, a negotiator of deals, a conceptualiser of strategies [and] a mediator of conflicts*" (Brown as quoted in Crona and Parker [21]). In our paper, we use this definition of bridging actors to identify actors (both organisations and individuals) who facilitate collaboration between diverse actors across levels, thereby enhancing their capacity by increasing social capital through trust building among the networking actors [22,23].

Scholars such as Schultz [24], Olsson et al. [16], Hahn et al. [25], and Newman and Dale [26] highlight the importance of bridging actors, where they strengthen the capacity of all actors involved in the network to adapt to change. Scholars have highlighted that bridging actors play a crucial role within a network, as they can facilitate or block the flow of information and resources [4,27,28]. Crona and Hubacek [27] and Prell et al. [28]—looking at social networks—highlight that bridging actors influence flow of information and resources, enabling interactions and building social capital and trust among actors. Bridging actors can be seen as agents who build trust and enhance learning leading to vertical and horizontal collaborations [25]. The literature on urban regimes indicates that for a "governing coalition", i.e., collaborative networks, to be effective, there is a need to bring together adequate resources by identifying and working with actors who possess the right resources [29]. Literature on resource exchange highlights that organisations collaborate with others to access resources that are insufficiently available to them, prompting them to identify and collaborate with other actors to achieve their goals [30]. Thus, actors create connections and networks augmenting their access to financial, legal, and political resources. Berardo [30] highlights that a network performs successfully when a bridge is created between resource rich actors with those in need of resources. This can be achieved by building connections between disconnected actors through brokers (bridging actors) who are positioned to impact the flow of resources within a network [30,31]. Several scholars studying networks of natural resource governance have highlighted various roles of bridging actors including cross-scale bridging [3,10], within and across-type bridging [32,33], and bridging positions to reduce fragmentation [34]. Based on these various specific and general divisions of bridging activities we identify initiation, position, and facilitation of interactions as three main characteristics of bridging actors, which we consider to have an influence on their roles within networks managing natural resources (summarised in Table 1).

Characteristics of Bridging Actors

Initiation of a bridging actor is an important characteristic, and the literature indicates numerous reasons for the establishment of collaborative networks [35,36]. Agranoff and McGuire [29] and Imperial et al. [36] highlight that state actors facilitate the conditions and emergence of collaborative networks where state actors help in development, share the financial burden, and increase the likelihood of delivering goods and services. Imperial et al. [36] stress that networks can be initiated based on a shared understanding between actors to identify solutions to a common problem and provide a service. Rathwell and Peterson [10] underline that both governments and non-government actors have invested in building networks with an aim to improve coordination leading to the establishment of bridging actors who create, support, and maintain networks [37]. Sayles and Baggio [15] indicate that collaborations between actors based on shared interests are more productive than when they are mandated.

The position of bridging actors plays a crucial role in enabling collective action among actors within and across networks. It is an important factor as information exchange is a key characteristic of bridging actors. They are seen as key actors capable of extending information across scales and promoting mutual preferences and shared understanding among

diverse actor groups. Therefore, they are also referred to as 'knowledge brokers' [38]. The position of bridging actors not only helps in information exchange and building alliances within the network [11,38] but it also leads to development of common perceptions based on a common understanding of the problem [38]. Berkes [39] highlights that bridging organisations enable connections between disconnected actors with differing interests, lack of resources or mandate to work with each other by facilitating coordination for consistent management. Angst et al. [34] define two main positions based on bridging activities—periphery connectors, who connect disconnected actors to the core of the network and central coordinators, who facilitate action as they "connect a great number of actors" within a network. Central coordinators create the shortest path between actors enabling quick and easy dissemination of information between actors [34]. Periphery connectors help access new knowledge leading to information heterogeneity, enhanced effectiveness, and adaptability in natural resource management [11,34].

Facilitation of interactions between actors is one of the key characteristics of bridging actors as they connect actors across levels who might otherwise be disconnected [21,40]. McAllister et al. [41] opine that there are individual payoffs to actors which steer actor interactions. Network theorists differentiate between bonding and bridging capital, which can impede or encourage interactions between actors within networks to identify solutions [42]. Bonding capital promotes development of shared understanding between actors based on trust, thereby overcoming scepticism leading to the development of "close-knit" groups [41]. This limits actors' access to new information, resulting in homophily as all the stakeholders have a shared understanding and shared expectations [41]. Bridging capital involves development of interactions between actors who are disconnected leading to the acquisition of new information from varied actors ensuring heterophily [43], as there is no overlap of information in these network structures [42].

Applying the above understanding of bridging actors and their characteristics summarised in Table 1, we identify bridging actors (organisations and individuals) to understand how these actors shape networks involved in co-management of lakes. Further, we aim to understand how the local socio-ecological contexts shape the roles of bridging actors along three lakes situated across a rural–urban gradient in GBMR.

Table 1. Characteristics of bridging actors as described in this paper.

Characteristics of Bridging Actors	Categories	Description
Initiation	State sponsored (top-down)	Initiated to reduce financial burden and increase the likelihood of delivery of services
	Self-organised (bottom-up)	Initiated to gather information, build trust, credibility, and act towards common goals
Position	Central coordinator	Central coordinators create the shortest path between actors enabling information dissemination
	Periphery connector	Periphery connectors connect otherwise disconnected actors providing access to new knowledge
Facilitation of interactions	Bonding capital	Bonding capital refers to development of shared understanding between actors by building trust and overcoming scepticism
	Bridging capital	Bridging capital refers to access to new information based on interactions created with actors who are not connected leading to innovation

3. Materials and Methods

Our study was conducted in three lakes along a rural–urban gradient within a single watershed boundary in the Greater Bengaluru Metropolitan Region (GBMR). Bengaluru, with a population of 12.7 million [44], is undergoing rapid development and associated transformations, negatively impacting its local natural resources and ecosystems [1,45]. The region relies on water from reservoirs created by damming small streams, which are managed by designated communities and individuals from local villages, who are responsible

for maintaining bunds, clearing silt, and regulating flow from lakes to store rainwater and provide for water needs throughout the year [1,6]. In this paper we use a contrasting case study design [46], selecting three cases embedded within a single watershed (Vrishabavathi river) (refer Figure 1, the cases selected fall in region highlighted in orange). The lakes are nourished by continuous wastewater flows originating in the city and flowing outwards carrying nearly 50% of urban wastewater, leading to continued practice of agriculture in peri-urban and rural areas, creating a rural–urban gradient in Southwestern Bengaluru. Though present within a single watershed, the selected lakes were identified to cover diverse urban, peri-urban, and rural land use patterns with differing dominant livelihoods, societal and state actors, administrative boundaries, ecosystem services. This allows us to identify how actors in different socio-ecological contexts create collaborative networks to address issues of lake management within a single watershed. This case design provides us with an opportunity to compare cases across a gradient, analysing how core dimensions of urbanisation such as urban land use, encroachment, dumping of industrial and domestic wastes, and changes in institutions affect lake management at the local level in GBMR. Further, there are limited studies focusing mainly on urban lake management, providing us with an opportunity to assess and compare the role of bridging actors in the formation of networks involved in lake management in urban and non-urban areas within GBMR.

3.1. Methodological Framework

In this paper we use social network analysis, drawing insights from qualitative network analysis as posited by Ahrens [47]. Below we provide a brief overview of why we employ social network analysis against alternative approaches, the steps taken in identifying respondents, interview questions, and how we operationalise this data based on network parameters.

We use social network analysis to study the role of bridging actors within networks of actors involved in lake management. We use social networks as they are better suited to study the behaviour of an individual actor at the micro-level in addition to the structure of connections between actors in the form of network structure at the macro-level [48]. In contrast to the conventional approaches which focus on actors and their attributes, social networks emphasise on actors described by their relation to others [49]. Social network analysis has been used to study the characteristics of social networks in enabling collective action leading to successful management of natural resources [4,28,50,51]. In this paper, we focus on understanding the role of bridging actors in enabling co-management, which, as described in the conceptual framework, requires development of coherent networks highlighting the importance of relations between actors. Hence, we choose to use social network analysis instead of other conventional methods to identify the role, influence, and position of bridging actors in the facilitation of interactions within networks to enable co-management.

Qualitative data for the analysis was collected based on key informant interviews and focus group discussions conducted in 2018–2019. This data has not been corroborated with quantitative network data, as quantitative data could not be collected due to pandemic restrictions. Purposive sampling was undertaken to identify respondents, who were classified into state and non-state actors. Participants were considered as representatives of their organisations. State actors responsible for lake management were identified through document analysis, based on assigned responsibilities for lake management. Non-state actors were identified using a two-pronged approach of screening media articles (social and print media) on the selected case lakes, followed by visits to the lake and identifying users and key informants working towards lake management. The identified actors were further classified based on Stein et al. [52]: first on their influence, where we distinguish between direct and indirect influence. Direct influence indicates that "an actor directly uses water or modifies its flow through modification and control measures", while indirect influence indicates that "an actor through their activities influences other actors to modify land, water, or vegetation" [52] (p. 1088). Second is a relational criterion focusing on regular interactions

between actors. This classification reduced the number of actors to a small set who regularly and actively interact with each other. Though there are numerous state organisations that are responsible for lake management, respondents (direct influencers—users and state custodians) indicated that they rarely interact with other state actors, thus narrowing down the actors to three main groups: users (community residing around the lake), state custodians (directly responsible state agencies), and third sector organisations.

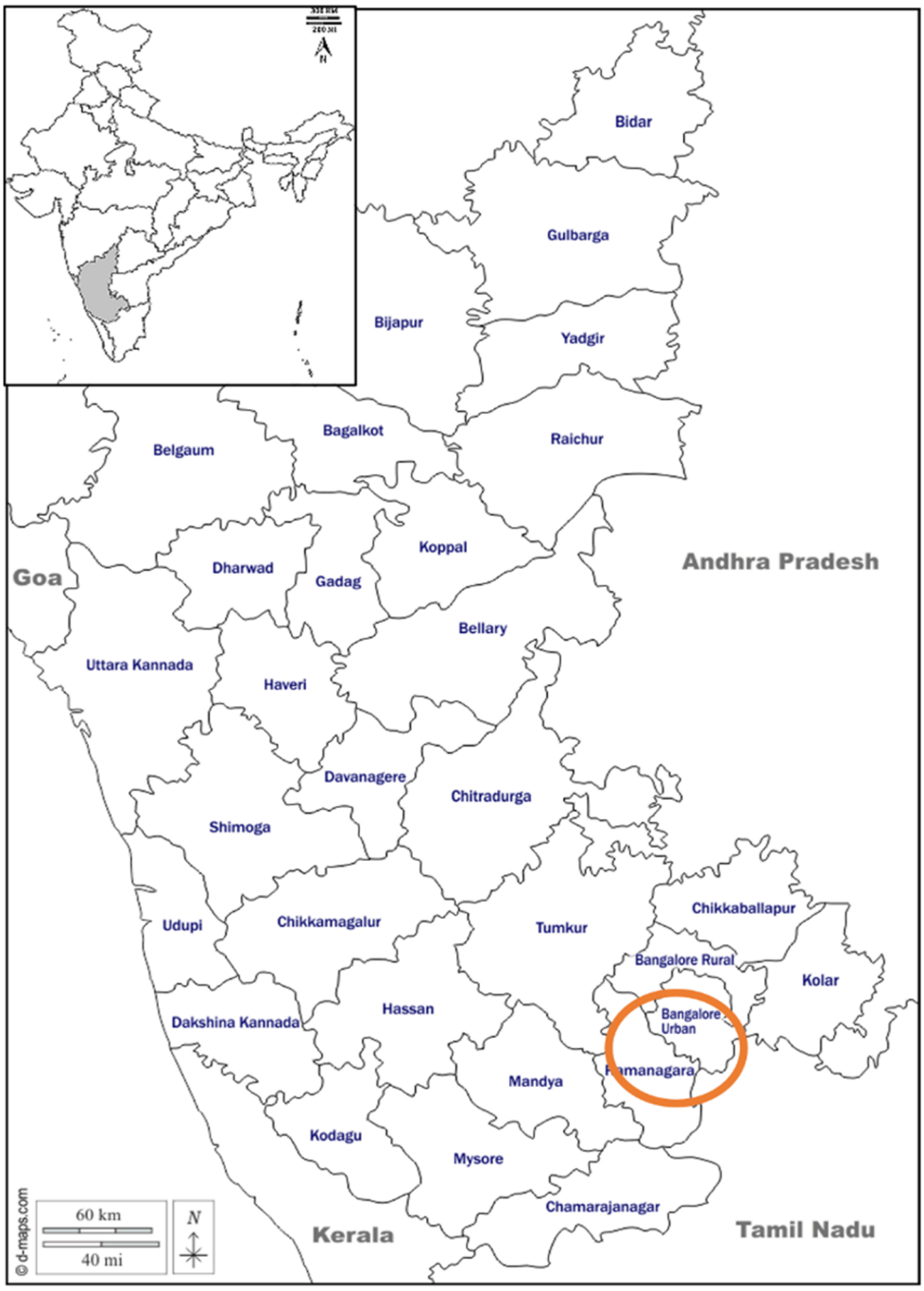

Figure 1. Figure highlighting the location of case lakes (within the orange box). Map sourced from d-maps (https://d-maps.com/carte.php?num_car=8763&lang=es (accessed on 13 March 2022)).

During the interviews, the respondents were asked who they collaborate with for lake management and their reasons for collaboration. Collaboration was defined to include repeated exchange of information, knowledge gathering, and provision of resources, both financial and human. We also inquired if the collaboration was based on official mandates

requiring actors to interact with each other leading to joint planning and management. Network data was derived from interviews, mainly based on the presence or absence of information and knowledge exchange (present = 1; not present = 0); resource support (support provided = 1; not provided = 0) and whether the collaboration was mandated or not mandated (mandated = 1; not mandated = 0) between actors. These binary codes were organised into adjacency matrices and analysed using the software UCINET [53].

3.2. Operationalisation of Network Data

Qualitative data obtained by interviews was operationalised based on the network measures of density, centrality, and core-periphery analysis to identify bridging actors (summarised in Table 2). The data was further used to identify how bridging actors were initiated. To analyse the position of the bridging actors, we undertake the core-periphery analysis to identify the core and peripheral actors, within each network. As the networks are small, this analysis leads to identify the key central and peripheral actors as well as the bridging actors who connect these otherwise disconnected actor groups. Further, we use a centrality measure of betweenness centrality to identify central coordinators as suggested by Angst et al. [34]. The betweenness centrality refers to the number of times an actor rests between two others who are themselves disconnected [54–56]. Angst et al. [34] indicate that betweenness centrality measures the shortest path between any two actors, defining it as the "minimal number of connections that an actor needs to reach another actor". High betweenness centrality performs the role of broker, or acts as a bridge, bringing together "disconnected segments of the network" [54] (p. 504). They might have to take sides during a conflict, which can be disadvantageous. Following the method outlined in Angst et al. [34], betweenness scores were analysed based on an actor's position taking into account cross-connections between all actors that an actor is connected to.

We then use the measures of density and centrality to identify bonding and bridging capital. The strength of a collaboration is reflected in the density or strength of a tie between the collaborating actors. The stronger the tie, the greater the influence among actors, which can lead to sharing of information, higher trust, mutual learning and support [50,54], but also to information redundancy when compared to weak ties, which are characterised by less frequent communication. Prell et al. [54] distinguish two kinds of centrality when considering resources management: betweenness and degree centrality. The former is used as a measure of bridging capital and refers to the "number of times an actor rests between two others who are themselves disconnected" [54–56]. Whereas the latter is used to measure bonding capital of bridging actors, indicating the number of actors directly connected to other actors. Actors with high degree centrality are considered important players, who can bring actors together. These actors possess weak ties, as they must maintain ties with numerous actors within the network compared to others. Actors with high degree centrality can use their links to share information, but this does not guarantee that they can also influence other actors.

Table 2. Network measures used for the analysis of the role of bridging actors in lake management (derived from Prell et al. [52], Enqvist et al. [1], Bodin et al. [51], Ernstson et al. [3], Fliervoet et al. [57].

Network Characteristics	Description	Measures
Density	The number of realised ties in the network as a measure of the extent to which all actors in the networks are tied to each other (Wasserman and Faust, 1994)	• High density increases trust between actors, thus increasing possibility for social cohesion and reduces the cost of collaboration which is essential for collective action • It can also lead to increased dissemination of information and exchange of resources • Can lead to homogenisation of knowledge

Table 2. *Cont.*

Network Characteristics	Description	Measures
Reachability	Indicates the number of steps needed to reach from one node to another	• High reachability indicates the presence of higher channels for information sharing between actors leading to enhanced social cohesion and development of shared understanding
Degree centrality	Indicates the number of links for every node, central actors have a higher number of ties to other actors within the network (Wasserman and Faust, 1994/2009)	• Higher degree centrality facilitates information sharing between actors leading to shared understanding • Actors with contacts to many others can be targeted for motivating the network and diffusing information fast through the network, i.e., these are the focal actors in a centralised network • High degree centrality can lead to centralising decision-making to a few central actors and reduce the access to diverse sources of information for individual actors
Betweenness centrality	Indicates the role of 'actors in the middle' (actors that lie in between other actors), who have some control over reachability in the network (Wasserman and Faust, 2009, p. 188)	• Large betweenness centrality indicates that an actor must be between many actors within the network highlighting its central role in ensuring exchange of resources and information sharing • These actors can help link otherwise isolated actors/groups • Can lead to assimilation of distinct knowledge systems located among various actors

4. Results

The resulting social network map of the case lakes located along the rural–urban gradient highlights the presence of two distinct unconnected network clusters. This can be attributed and delineated based on the administrative boundaries of urban Bengaluru. The networks are termed urban and non-urban clusters (Figure 2). The non-urban cluster can be further divided into peri-urban and rural clusters, with rural cluster being relatively well-connected compared to the peri-urban cluster. Below we describe the two network clusters separately, as we see a distinct separation between the two networks. We consider the role of bridging actors when present in enabling collaborations between actors involved in lake management in GBMR.

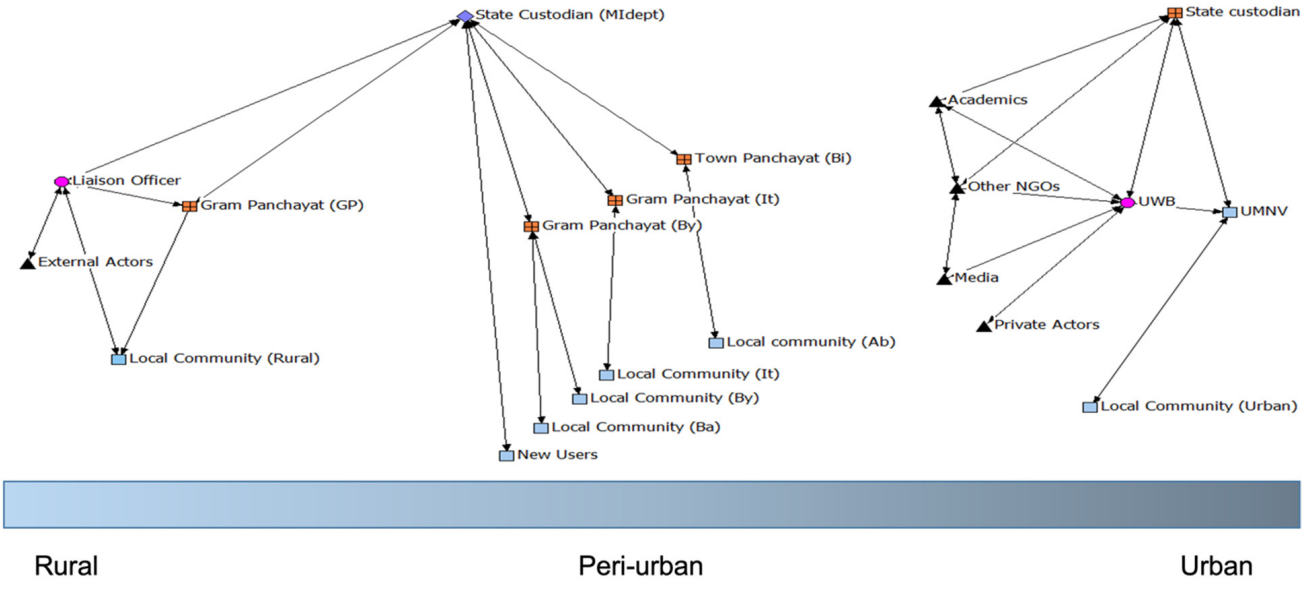

Figure 2. Network map indicating the social network among actors across lakes along the rural–urban gradient in GBMR.

4.1. Urban Network Cluster

The lake was once a main source of irrigation for the village and has undergone changes in its governance since the lake was built in 1896. There have been numerous proposals on converting the lake into an open space with tree parks by various committees examining the feasibility of preserving the lake. There has been a change in the ecosystem services derived from the lake, namely from provisioning services to more social and cultural services with urban transformation. The lake area was protected from encroachment by the fencing of the boundary by the Karnataka Forest Department in 1994 (personal interview, mmuw, 2019). The custody of the lake has changed several times and is now under the city administration, i.e., the Bruhat Bengaluru Mahanagara Palike (BBMP), which restored it in 2010 and invited a third sector organisation to help in carrying out the day-to-day activities of lake management. The main actors involved in lake management are the city administration (BBMP—state actor), third sector organisation (United Way Bengaluru—UWB), and the resident community (users).

An analysis of the urban network highlights the prominence of UWB within the network (Figure 3a,b). The core-periphery analysis of the network identifies UWB, UMNV (local community association), and the state custodian (BBMP) as the core actors which also represent the close-knit group of actors with strong ties. The density of the urban network is 0.607, indicating that only half the network are directly connected to each other. The network is highly heterogeneous (0.922), highlighting the presence of diverse actors, who are connected through UWB, which has high betweenness and degree centrality values (Figure 3a,b, refer to Table 3 for centrality measures), indicating its role as bridging actor. Below we describe the three characteristics of how initiation, facilitation, and position of UWB (bridging actor) shape urban lake management.

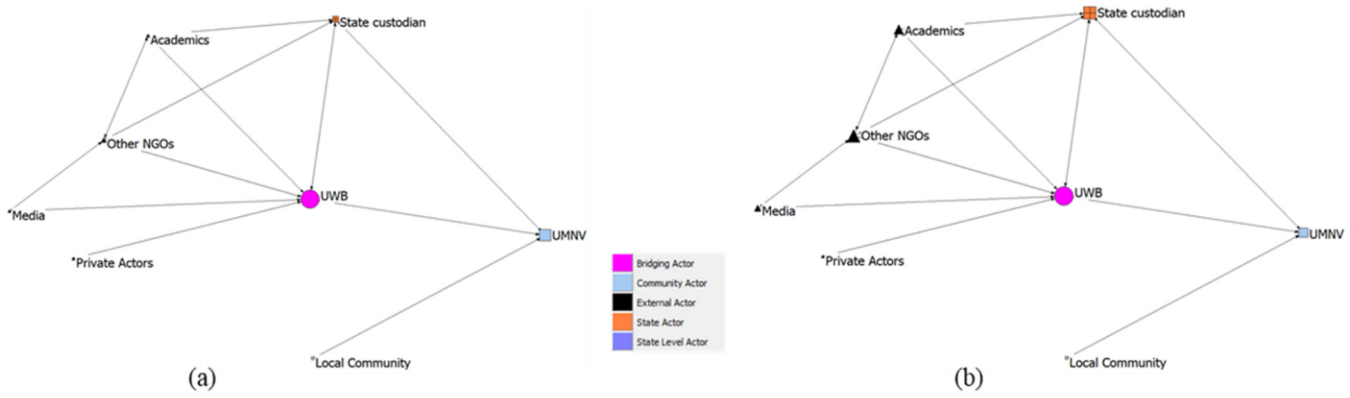

Figure 3. Figures highlighting the networks for lake management in urban case. (**a**) Depicts the betweenness centrality and (**b**) degree centrality for actors within the network. (Size of the node indicates a higher centrality value.)

Table 3. Centrality measures for the urban network (analysed using UCINET).

Actor Name	Actor Attribute	Degree Centrality	Betweenness Centrality
State custodian (BBMP)	State actor	0.333	2.880
Third sector organisation (UWB)	Bridging actor	0.476	16.640
Local community association (UMNV)	Community actor	0.286	8.320
Local community	Community actor	0.048	0
Media	External actor	0.095	0
Academics	External actor	0.143	0
Private actors	External actor	0.048	0

We identify a top-down initiation of the bridging actor, as the state custodian (BBMP) approached UWB to secure funding and undertake day-to-day lake management and

signed a memorandum of understanding outlining specific roles and responsibilities. UWB did not have any local presence in the area and had to work with a heterogeneous community belonging to different socio-cultural and economic backgrounds and having varied perspectives of the lake (personal interview, wng1, 2019). UWB undertook numerous outreach and community building activities with the help of certain interested community members and local elected representatives. This led to the creation of a local community association named Uttarahalli Moggekere Nadigedarara Vedike (UMNV), which was made signatory to a tri-partite agreement between state custodian and UWB. Thus, even the local community association was developed in a top-down manner and involved in lake management.

UWB helps facilitate interactions, building both bonding and bridging capital within the network. UWB facilitated the development of a group of close-knit actors working towards lake management based on a shared understanding of the issues that need to be resolved. This was possible with the organisation of a heterogeneous community and setting up of UMNV, as well as making them a signatory to the tri-partite agreement detailing individual roles and responsibilities. Thus, UWB was able to facilitate bonding capital between the state and community by building trust and overcoming scepticism that was existing between them. This close-knit group of actors are connected to external actors (academics, media houses, other NGOs, and community groups in addition to private actors) through UWB, to gather information and funding. Thus, UWB facilitates interactions between previously disconnected actors enhancing the bridging capital by providing access to new information and innovation in lake management.

UWB is positioned both as a periphery connector and a central coordinator as it helps to connect disconnected actors to ensure information and resource transfer as is mandated in the tri-partite agreement. It is a well-known face within the small and growing network specialising in lake management in Bengaluru. This was clearly highlighted during the interview: "UWB is an organisation reputed securing funds from private companies, under the corporate social responsibility policies, has prior experience in working with academics and other like-minded NGOs working on lake management in the city, which was also the reason for state authorities to collaborate" (personal interview, wng1, 2019). Thus, it was easier for UWB to connect with external actors working on lake management to gather information and knowledge, acting as periphery connectors linking the close-knit group with the wider network involved in managing the lake. Figure 2 shows the high values of centrality of UWB indicating that it lies between other actors, creating the shortest paths between two actors within the network, and thereby ensuring its role as a central coordinator. Hence, UWB enables information and resource exchange based on assimilation of diverse knowledge located among various actors, further bolstering their shared understanding regarding lake management.

The urban network is highly centralised around UWB, which holds most ties within the network. Literature indicates that even though such centralisation is helpful during the formation of networks, it is highly unfavourable in long-term planning as it can lead to dominance and control of the network by the centralised actors [50,54]. Though UWB has a high degree of centrality, the sharing of roles and responsibilities detailed in the tri-partite agreement ensures there is no centralisation of decision making by UWB.

4.2. Non-Urban Network Cluster (Peri-Urban and Rural Networks)

Looking at Figure 2, we can clearly distinguish two distinct networks connected by the state custodian, the Minor Irrigation Department (MIdept) at the state level within the non-urban network cluster. We identify a hierarchical tree network in the peri-urban lake and a well-connected network in the rural lake, with no interactions between community actors. MIdept as the responsible actor for the lakes is mainly located at the state level with limited interactions at the local level of the lake. The peri-urban and rural lakes are managed by the MIdept separately, with limited interactions (personal interview, OfG3,

2019). In the following, we look at the peri-urban and the rural networks as separate networks and first describe the peri-urban lake network followed by the rural lake network.

4.2.1. Peri-Urban Lake Network

The peri-urban lake, located downstream to the urban lake, is the recipient of the urban wastewater which has converted the lake into a perennial source of water. The lake is bound by four villages located under different administrative boundaries, with one of the villages being incorporated into the nearest town administration leading to the presence of diverse disconnected actors in the network (Figure 4). The network consists of mainly mandated vertical collaborations between users and state agencies through local administration (Gram Panchayat at village level and Town Panchayat). Thus, the local administration acts as a bridging actor between MIdept and users. It also plays the role of a central coordinator, mainly enhancing bridging capital between the actors through organisation of village meetings. There is no shared understanding among the users as new users are happy to receive water and want authorities to continue the same practices, whereas older users want the water-flow to be regulated and the quantity of water in the lake to be reduced (personal interview, OfGl1, 2018), leading to fragmentation of the network. Further, there is no inter-GP coordination between the local administrations, as is reflected in the low density of the network (density value 0.113). There is also a lack of trust between actors as was pointed out by users during discussions: "the officials come, tell us they are working on the lake, and they go away". This is exacerbated by a lack of interaction between MIdept and the users (personal interview, OfGl1, 2018). Jurisdictional ambiguity and administrative overlap have reduced trust and reciprocity among users as indicated during FGD: "Byr is now a different panchayat, they will get some things approved and they will eat up the money themselves". The addition of new users, located up to 10 km from the lake, with expansion of irrigation channels by MIdept to manage the water flow without deliberations with local communities, has added to the complexities due to increasing actors in lake management. During discussions, users highlighted the hope that the state can do "something", as they perceive themselves unable to manage the lake due to administrative overlaps in addition to the perceptions that they are "poor people with no power". The need for a "bridging organisation which can connect across communities and state organisations to ensure information exchange and create a shared understanding" was also pointed out by both users and officials of local administration.

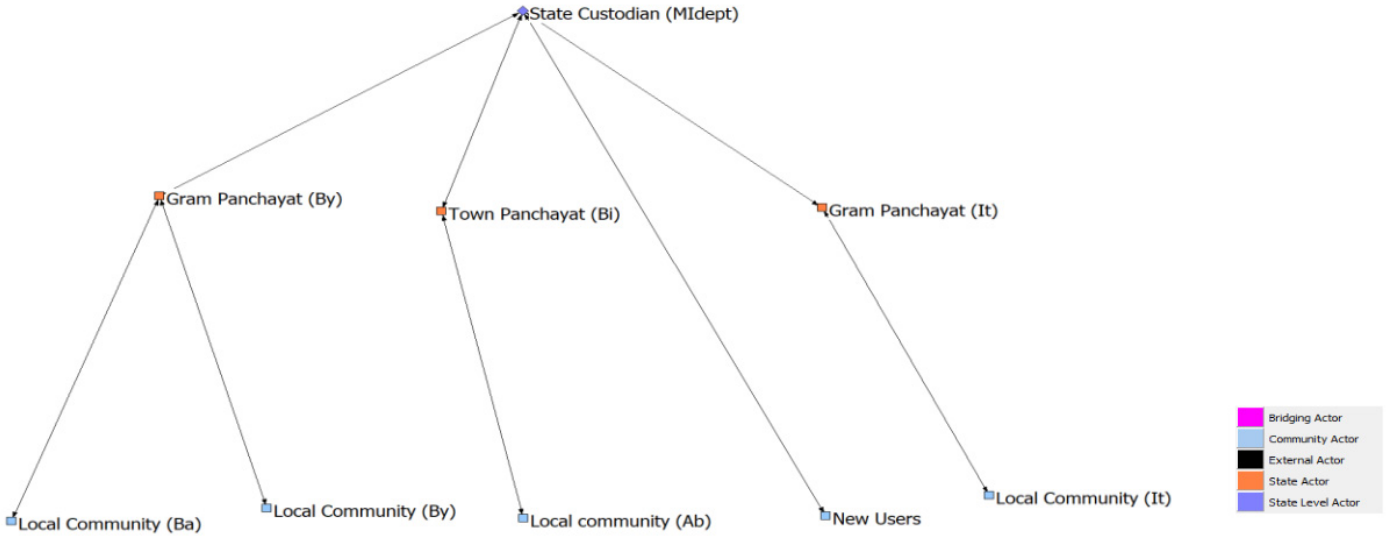

Figure 4. Network of actors involved in peri-urban lake.

4.2.2. Rural Lake Network

The rural lake, located downstream to the peri-urban lake, is also a recipient of urban treated wastewater. This has led to the continued practice of agriculture in the village and brought economic benefits to the community. Though the user community has economically benefitted from the lake, they have had to adapt their cropping patterns and shift from traditionally grown crops to cash crops. Furthermore, the use of wastewater has also impacted the health of the soil. This led the users to identify alternate ways of conserving the lake while still having access to uninterrupted supply of water for agriculture. Thus, the main actors involved in lake management are the state custodian (MIdept), village administration (Gram Panchayat), and the users.

The analysis of the rural network highlights that the network is mainly composed of state actors (custodian (MIdept) and village administration) and users, indicating a low heterogeneity in terms of actors. External actors consisting of politicians (state and national levels) support the community in terms of knowledge transfer and legal support. We see the presence of a close-knit group consisting of state custodian (MIdept), GP, users, and a liaison officer. The core-periphery analysis of the network highlights the prominence of the liaison officer and the Gram Panchayat (village administration) as crucial actors within the network (Figure 5a,b). The network is found to be highly dense with a value of 1, indicating very high group cohesion. The liaison officer has high centrality values (betweenness and degree) whereas the GP has high degree centrality (refer to Table 4 for centrality measures). There are strong ties between the state actors and between users and the GP, as they are mandated to collaborate to share information and resources required for lake management. Below we describe the three characteristics outlined in Table 1 to identify how initiation, facilitation, and position of bridging actors (GP and liaison officer) shape lake management.

The GP, a bridging actor, was established by the state government under the 73rd Constitutional Amendment followed by the Karnataka Panchayat Raj Act 1993 to promote local self-governance. The GP is mandated to facilitate interactions between users and state actors by providing a platform for regular village meetings highlighting a top-down initiation of this bridging actor. The users needed to gather more information to ensure deliberations at village meetings leading to the identification and nomination of a liaison officer from among them to connect with MIdept and other state authorities mainly for information gathering. Hence, the liaison officer, who is another bridging actor, was initiated by a self-organised bottom-up approach to solve the information deficit by the community.

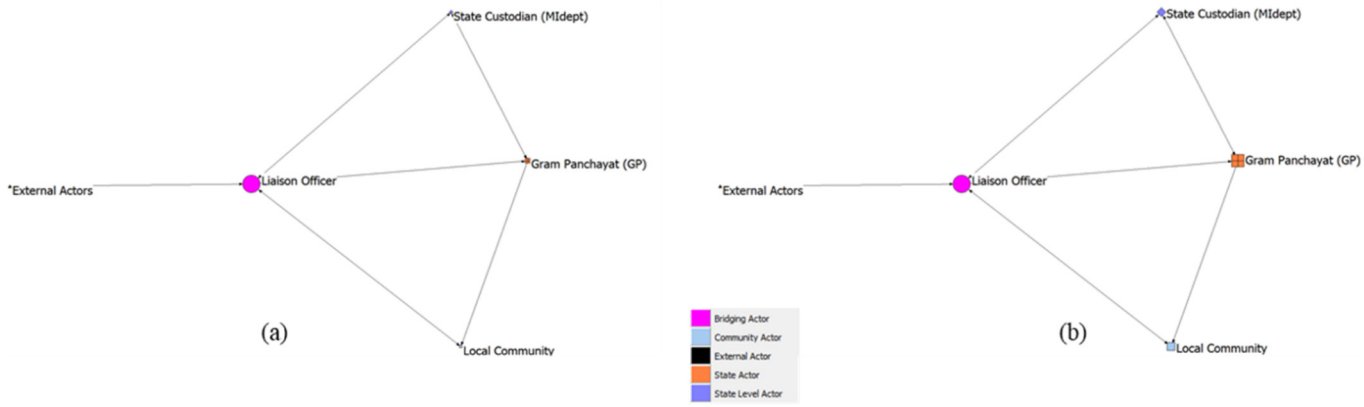

Figure 5. Figures highlighting the networks for lake management in rural case. (**a**) Depicts the betweenness centrality and (**b**) degree centrality for actors within the network. (Size of the node indicates a higher centrality value).

Table 4. Centrality measures for the rural network (analysed using UCINET).

Actor Name	Actor Attribute	Degree Centrality	Betweenness Centrality
State custodian (MIdept)	State level actor	0.250	0
Gram Panchayat (GP)	State actor	0.500	0.40
Liaison officer	Community actor	0.417	6.80
Local community	Community actor	0.417	0

The liaison officer as a bridging actor helps in facilitating both bonding and bridging capital within the network. This is based on information exchanged between actors, enabling a shared understanding of the lake as an important source of livelihood of the village. As pointed out during discussions, users indicated that repeated interactions by the liaison officer have led to improved trust and credibility of each other. The state officials now view the community as credible actors who are well-informed on state policies and regulations (personal interview, OfG3, 2018). In terms of facilitation, the liaison officer facilitates bonding capital between state and users through information exchange and building credibility. In search of information—legal and policy related—regarding lake management, the liaison officer has connected with external actors, linking the close-knit group of actors with new information sources, thus enhancing the bridging capital of the network. The GP, through the facilitation of the village meetings, provides a space for the development of shared understanding between state custodian (MIdept) and the users, facilitating bonding capital based on building trust and understanding.

The GP plays the role of a central coordinator within the network as it formally coordinates state–user interactions, mainly in the form of a deliberation platform, as is stipulated by law where users deliberate with state agencies. The liaison officer is also a central coordinator, creating the shortest path between actors by establishing connections with all actors within the network (Figure 5a,b), mainly to gather information based on the needs of the community. The liaison officer is also a periphery connector supporting information exchange between external actors and the close-knit group of users and state actors within the network (Figure 4). This has enabled mobilisation and diffusion of information among all actors, thereby providing a holistic view of lake management.

5. Discussions: Bridging Actors and Co-Management of Lakes across Rural–Urban Gradient

Based on our analysis of networks in three lakes along the rural–urban gradient, we identify and describe actors who are the main source of information, broker of resources, and negotiator of deals as bridging actors based on the definition adopted in this paper. These actors are crucial to the formation of networks shaping co-management of lakes along the rural–urban gradient. In accordance with Rathwell and Peterson [10], we indicate that bridging actors can be developed by both state (urban case) and non-state actors (rural case) based on contextual reasoning (summaries in Table 5). As is seen in our urban case, the state custodian approached a third sector organisation (UWB) to secure resources and organise a heterogeneous community with low willingness to collaborate. Whereas in our rural case, the community nominated a liaison officer who connects state and non-state actors mainly through information exchange as required by the community. We briefly indicate a possible explanation below. In both rural and urban cases, we see the presence of a third-party (bridging organisation) who provides the bridging activity as indicated by Westley and Vredenburg [58].

We highlight that the socio-ecological contexts across the gradient influences the characteristics of bridging actors (refer Table 5). This is clearly identified in the process of initiation, as the bridging actor (UWB) in our urban case was approached by the state actor to share certain responsibilities and reduce the financial burden, whereas in the non-urban network cluster, the bridging actors were state mandated (GP—village administration) based on law. The need for information of the rural community to deliberate in meetings

led them to self-organise and identify a liaison officer to aid them in collecting and disseminating information between the state and users. Thus, we can clearly indicate that resources (finance) and information gathering as well as exchange are the key reasons for the initiation of bridging actors in our urban and in rural cases, respectively.

Table 5. Summarising the results of the characteristics of bridging actors observed in urban and rural case.

Location of the Lake	Bridging Actor	Characteristics of Bridging Actors		
		Initiation	Facilitation of Interactions	Position
Urban lake	Third sector organisation (UWB)	Top-down (state sponsored)	Bonding and bridging capital	Central coordinator and periphery connector
Peri-urban lake	Gram Panchayats (GPs)	Top-down (state sponsored)	Bonding capital	Central coordinator
Rural lake	Gram Panchayat (GP)	Top-down (state sponsored)	Bonding capital	Central coordinator
	Liaison officer	Bottom-up (self-organised)	Bonding and bridging capital	Central coordinator and periphery connector

As indicated by Crona and Parker [21], we highlight that, even though the reasons for developing bridging actors differ for the urban and rural lakes, they have been successful in facilitating bonding capital within the networks by building credibility and trust, overcoming scepticisms, and enabling information access and exchange through facilitation of bridging capital among actors enabling co-management. In our urban case, UWB organised a heterogeneous community based on a shared understanding leading to the development of a close-knit network between the bridging actor (UWB), users, and the state, built based on shared understanding and mandated by the signing of the tri-partite agreement, has facilitated bonding capital among actors built on trust and reciprocity. Further, UWB provides this close-knit network access to new sources of information and resources by facilitating connections between various external actors which are characterised by weak ties (Figure 2). This bridging capital makes it feasible for actors to support each other by identifying opportunities to generate innovative ideas for lake management, as these actors are located in different knowledge circles, thus having access to diverse information sources as indicated by Granovetter [59] and Olsson et al. [16]. This has led to information exchange enhancing credibility among actors as indicated by Bodin et al. [54], reducing the cost of collaboration. The liaison officer in the rural lake acts mainly as a 'knowledge broker', who, as indicated by Cvitanovic et al. [60], helps to develop community credibility with both state and external actors based on informed discussions. Further, informed deliberation between actors has promoted development of mutual preferences between and within actor groups, leading to collaborations between state and non-state actors based on shared understanding as indicated by Ernstson et al. [3], Olsson et al. [16], and Imperial [36]. This is in line with Crona and Parker [21] who highlight that access to information enables non-state actors to effectively interact with state actors. The liaison officer is connected to other actors within the network with weak ties (Figure 4), which helps in information access and exchange across actors leading to generation of new knowledge and opportunities as indicated by Granovetter [59].

Bridging actors in both urban and rural cases are positioned as periphery connectors enabling information exchange by connecting various disconnected actors within the network. They also act as central coordinators as they create the shortest path between any two actors ensuring easy diffusion of information, and thus can be defined as central coordinators and, as indicated by Prell et al. [28], enhance adaptive capacity of lake management. In our urban lake, the bridging actor UWB is characterised as both a central coordinator and periphery connector as it creates the shortest path between actors in the network and connects the close-knit group of state and users with external actors. In

the rural case, the liaison officer is positioned as both a periphery connector and a central coordinator connecting the community with external actors and creating the shortest path between actors (Figure 4). In contrast, the GP is positioned as a central coordinator enhancing state-user interactions by creating the shortest path between them within the rural network. We see the presence of two bridging actors in the rural case as against the urban case. This can be attributed to the establishment and the effective functioning of the decentralisation of local administration through involvement of residents in India pushed by the 73rd constitutional amendment in rural areas compared to the lack of establishment and inefficient functioning of the decentralised local self-government in urban Bengaluru (personal interview, KC, 2018).

We also indicate from the above network analysis that there is a higher diversity of actors in the urban networks, who have access to academics, other NGOs, and media actors to gather information, while the rural networks are more homogenous and mainly limited to state and community actors. This observation takes the analysis of case studies beyond mere description. The state actors in both rural and urban cases, mainly local governments (GP in our rural case and state custodian in urban case), do not themselves act as periphery connectors but they work with bridging actors who act as periphery connectors [34]. The rural and urban case highlight the importance of state actors not just as a resource provider but also as the authority who needs to take an active responsibility of involving the users, especially in managing commons such as lakes as an area undergoes urban transformation. Thus, beyond pure description of the role of bridging actors, our cases corroborate Foster [61], highlighting that support of state actors is a prerequisite for managing commons such as lakes collectively. This can be seen in the lack of co-management of the peri-urban lake, attributed to the absence of a shared understanding among and within actors, amplified by urban development leading to heterogeneity, perceptions, lack of trust, and credibility among actors. Though the local administrations play the role of bridging actor between state (MIdept) and users, these interactions are mainly mandated by law, and have not enabled co-management of peri-urban lakes—confirming the statement by Sayles and Baggio [15] that mandated collaborations are not productive in enabling co-management.

In our study, we further find that that diversity in socio-ecological contexts and particularly socio-economic heterogeneity influence networks managing lakes and the mode in which bridging actors emerge. It seems to mainly depend on the community of users (homogeneity or heterogeneity) and the associated importance for the lake. Specifically, we see that the rural community is highly homogeneous and is dependent on the lake for its livelihood. Hence, the community, in a bid to conserve their source of livelihood, identified a liaison officer to gather information, leading to increased deliberation, building of credibility, and co-management. In contrast, we identify that a heterogeneous urban community with limited information and dependence on the lake for livelihoods were not very motivated to contribute towards lake management. Therefore, the state actor identified a third-party organisation not local to the area to secure funding and organise the local community for lake management. Hence, the state custodian invited UWB to act as a bridge between state and non-state actors leading to co-management of the lake.

6. Conclusions

In this paper, we characterise and describe the role of bridging actors in the establishment of networks for co-managing lakes along a rural–urban gradient in GBMR, India. As indicated by Lee and Krasny [4], our study contributes to the literature on the role of bridging organisation by describing the role of actors in enabling co-management. The paper adds to the limited literature which understands bridging actors as agents to promote beneficial networks aiming to manage small-scale interconnected natural resources in developing countries. We also contribute to the literature on how social networks shape and are shaped based on the ecological context (rural–urban).

In this paper, we developed a framework to categorise bridging actors based on various typologies available, illustrating the role of bridging actors enabling lake co-management along a rural–urban gradient. For this purpose, we develop social networks based on quantifying qualitative data gathered from key informant interviews and focus group discussions. Further, as indicated in Section 3, the watershed is unique as the lakes filled with wastewater are used to irrigate multiple crops a year leading to a high dependence on agriculture. To illustrate the framework the paper assessed the role of bridging actors in developing networks across the three lakes; however, they cannot be considered representative of over 1000 lakes in the region. These lakes have varying degrees of actor involvement depending on various factors such as dependence of the resident community on the lake and the government departments in charge of managing them. For example, to arrive at a generalisation of our findings concerning the role of socio-economic heterogeneity requiring state involvement for bridging actors, further research covering larger number of lakes across urban, peri-urban, and rural areas of GBMR would be necessary.

In this paper we focus on the role of bridging actors within networks enabling lake management by not only aiding networks through information exchange, but also connecting actors to diverse sources of resources that are essential in adaptive governance of natural resources. Along the rural–urban gradient, we see that both state and non-state actors can initiate and develop bridging actors for lake management, though the reasons for initiation are contextual. From the considered cases, we see that both in urban and peri-urban lakes state sponsorship plays an important role in the establishment of bridging actors, whereas the bridging actor in the rural area was more self-organised in addition to the presence of state-sponsored actors. We conclude, that irrespective of the social-ecological context, the position of bridging actors plays an important role in the facilitation of interactions within the networks. Further, specifically in the urban and peri-urban contexts of social-ecological (and socio-economic) heterogeneity, we found that state engagement in promoting bridging actors played an important role, whereas in the rural, more homogenous context, communities established bridging actors through self-organisation. Bridging actors who are state-sponsored are mainly positioned as central co-ordinators, as is seen in all the three cases (refer to Table 5). The bridging actor in the urban lake, which is a third sector organisation, though state-sponsored, is positioned both as a central co-ordinator and a peripheral connector as it draws on its connections based on previous work on lake conservation and management in the city. In the rural case, the need to conserve and protect their source of livelihood has required the bridging actor to position themselves to connect to external sources of information and thus, as a peripheral connector. On the whole, we found that presence of bridging actors helps overcome state scepticisms, builds credibility, and develops shared understanding among heterogeneous actor groups, promoting co-management of lakes across the rural–urban gradient.

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Institutional Review Board Statement: This study was approved by the central ethics committee of the University of Kassel under the transaction number zEK-31.

Informed Consent Statement: All interviewees participating in this study were fully informed about the study purpose and were assured that their information would be treated anonymously. Therefore, only persons giving explicit informed oral consent were interviewed.

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