

A social network analysis of mangrove management stakeholders in Sri Lanka's Northern Province

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ABSTRACT

The sustainable management of complex social-ecological systems (SES) typically requires coordination and collaboration between various groups of stakeholders. Yet, research on collaborative stakeholder networks and their linkages with sustainable mangrove management strategies is lacking in Sri Lanka. This study presents a social network analysis (SNA) of mangrove management stakeholders and their perceptions of both existing and preferred collaborative relationships (or ties) between stakeholder groups, in the Northern Province of Sri Lanka. It further illustrates how SNA can be used to identify stakeholder collaboration and their potential role(s) in mangrove management. The perspectives of all key stakeholders have an impact on how mangroves need to be managed. Therefore, it is crucial to identify and meet with all key stakeholders in the early stages of management processes to understand their needs and constraints. Our findings indicate that the government departments mandated to conserve mangroves are not only formally appointed key stakeholders but are also perceived as central by others. Communication barriers, lack of awareness regarding the importance of mangroves, and shortages in staff and resources for conservation were major constraints to the existing mangrove management network. We highlight the potential of other stakeholders (i.e., non-mandated government stakeholders, non-governmental organizations (NGOs), and private organizations) in improving and influencing the social network in order to increase the diffusion of information. Despite existing resource extraction activities, private organizations were less represented in the mangrove management network of our study. After considering stakeholders' expectations and requirements, we suggest the inclusion of a bridging organization such as an "Environment Network Unit" or the establishment of bridging entities in the universities and research institutes. We also recommend certain government organizations (i.e., Central Environmental Authority) to take up the role of bridging. This may help to facilitate the incorporation of relatively marginalized stakeholders in an effort to foster sustainable mangrove management in the Northern Province of Sri Lanka and beyond.

1. Introduction

Collaboration in environmental governance can be explained as an

approach to management and governance involving a wide range of stakeholders. It comprises various strategies for empowering and integrating knowledge, activities, and perspectives of stakeholders to

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improve decision-making processes (Margerum and Robinson, 2016). Environmental governance processes include the “*articulation of institutional mandates, negotiation of values, conflict resolution, law making, policy formation, diffusion of information, and application of policy*” and this can be achieved through formal or informal co-management strategies (Bennett and Satterfield, 2018). Co-management refers to the distribution of authority and decision-making among stakeholders of different layers such as the local communities, government organizations, and non-governmental organizations (Berkes, 2010). There are various challenges to environmental governance such as insufficient power distribution, lack of accountability, and decision-making based on specific stakeholders (Lockwood et al., 2009). Ideally, the participation of diverse stakeholders in the co-management of a particular system results in shared motivation, increased mutual trust, and effective, coordinated collective action (Dandy et al., 2014). When co-managing institutions and networks in environmental governance consideration is given to knowledge production and collaboration (Bennett and Satterfield, 2018; Cudney-Bueno and Basurto, 2009). Government organizations are formally involved in decision-making and are largely responsible for the collaborative processes in environmental management (Koontz et al., 2010). The collaboration of government and non-governmental agencies in shared decision-making may help to build adaptive capacity in environmental governance, hence fostering much-needed social learning in the face of rapid environmental change (Collins and Ison, 2009; Kerret and Menahem, 2016). However, in certain instances actors occasionally engage in collaboration to advance their own interests, lacking a willingness to collectively address environmental issues (Bodin, 2017). Most studies on stakeholder collaboration focus on the presumed effectiveness of the collaboration process, rather than on the network of actors which underpins that effectiveness (Turrini et al., 2010).

Mapping how stakeholders are influencing environmental governance interventions is the first step to understanding collaborative processes (Koontz et al., 2020). Social networks highlight the relations between actors in a network (Scott, 1988). The behavior of actors can be analyzed by observing how different actors exert power, access information, and form links (Pisani et al., 2020). The relevance of network analysis in environmental governance has been highlighted in many studies related to the management of water resources, protected areas, and forests (Bodin and Tengö, 2012; Kleinschmit et al., 2018; Manolache et al., 2018; Narayan et al., 2020).

Social Network Analysis helps to understand the roles of actors in multi-stakeholder governance by exploring the connections between them. It helps to delineate the important connections among stakeholders such as the government departments, private organizations, and NGOs involved in a particular governance process (Manolache et al., 2018; Vance-Borland and Holley, 2011). It further supports to outline the influence of each stakeholder within the network, which is essential to resolve disputes and enhance the information and resource flow (Alexander et al., 2016). Forming more links between multiple stakeholders may not always be the answer to overcoming problems. Instead, collaborative networks need to be customized to solve specific problems by giving more emphasis on questions related to the purpose, and aims – in short, paying attention to how, why, and when collaboration is needed (Bodin, 2017; Raab et al., 2015).

Identifying and optimally positioning the most suitable stakeholders increases the effectiveness of the environment management networks (Armitage, 2008; Mbaru and Barnes, 2017; Ostrom et al., 2007). The efficient arrangement of the key stakeholders becomes more complex with the increasing diversity of both the stakeholders and the ecosystem of interest (Arias, 2015; Bottrill et al., 2008; Cohen et al., 2012). Therefore, the positioning of stakeholders in a social network plays an important role in the practicality of efficiently diffusing and spreading ideas (Mbaru and Barnes, 2017). However, few studies have applied the SNA approach to study stakeholder engagements in mangrove ecosystems (Orchard et al., 2015b; Purnomo et al., 2021; Thongphubate and

Piekkootod, 2016).

1.1. The role of bridging organizations

Bridging helps to reduce the knowledge action gaps and connect multiple actors ranging from government, industry, farmers, and practitioners in environmental conservation (Kadykalo et al., 2021). Thus, environmental management outcomes can be improved with the establishment or involvement of bridging organizations. They connect and align stakeholders at different management levels and in different sectors in such a way as to enhance group decision-making (Crona and Parker, 2012). These bridging organizations also play a crucial role in local knowledge transfer in co-management systems. In addition to that, they support building social capital, networking (Berkes, 2009), and foster bilateral relationships through distributing information (Hamilton et al., 2021). Bridging organizations in governance systems can act as facilitators between disconnected entities and “*provide an arena for knowledge co-production, trust-building, learning, vertical and horizontal collaboration, and conflict resolution*” (Folke et al., 2005). A formal organization or a platform in the governance system can take up the role of bridging in the environmental management networks when given the opportunity by playing a central role and solving and providing expert advice regarding social-ecological challenges. Transaction costs of collaboration can also be reduced with the involvement of bridging organizations (Kowalski and Jenkins, 2015). Ecosystems that are managed for various objectives by diverse stakeholders have a stake in their management because of overlapping jurisdiction and may require bridging organizations to promote complementary management strategies (Hamilton et al., 2021). Thus, the identification of stakeholders with the potential to take up the role of bridging is crucial for managing such ecosystems.

1.2. Mangrove social-ecological systems and multistakeholder collaboration

Mangrove forests have been globally declining due to population growth, urbanization, exploitation for timber production and raw materials (Goldberg et al., 2020) along with issues related to climate change, natural disasters such as tsunamis, political and institutional disruption, and soaring public demands for participation in mangrove management and usage of its goods and services (Dahdouh-Guebas et al., 2021). The status of mangrove ecosystems varies by country and region, and particularly shows a continued degradation in the global south (Romañach et al., 2018). Even though mangrove conservation efforts have produced mixed regional results, positive changes have been observed throughout the world in reducing mangrove degradation as well as providing opportunities for stakeholders and the public to engage with conservation efforts that contribute to sustainable mangrove management (Friess et al., 2020).

Considering mangrove forests as a social-ecological system helps to conceptualize the interaction between multiple stakeholders and the natural ecosystems (Dahdouh-Guebas et al., 2021; Orchard et al., 2015a). Social-ecological systems are typically comprised of disjointed social structures due to their diversity and complexity. Therefore, it is important to identify key stakeholders who can bridge conservation ideas and practices among disconnected entities, as well as stakeholders with a legitimate authority to steer and influence the network (Barnes et al., 2016; Morrison et al., 2019). The management of mangroves is often complicated due to the overlap of land and marine resources, tenures, and associated responsibilities. Thus, the social-ecological system management network must facilitate the core values and perspectives of all stakeholders (Tengö et al., 2014).

Mangroves in the Northern Province of Sri Lanka are included into two climatic zones (Mannar- Arid Zone; Jaffna, Kilinochchi, Mullaitivu-Dry zone) of the country. About 2450 ha of mangrove cover has already been lost in the dry and arid zones from 1983 to 2000 (Kodikara et al.,

2017). In 2015 the Sri Lankan government banned mangrove deforestation and started restoration initiatives in all coastal districts, along with the establishment of community benefit organizations in mangrove-fringing villages to improve community-based conservation (Dahdouh-Guebas et al., 2021; Friess et al., 2020; UNFCCC, 2018). Furthermore, the government pledged to restore mangroves through three major strategies. Those are protecting the existing mangrove ecosystems, converting abandoned shrimp farms and salterns back to mangroves, and finally restoring degraded mangrove forests island wide. Sri Lankan mangrove forests are yet declining despite government policy-led attention being focused on conservation (Dahdouh-Guebas et al., 2021).

1.3. Governmental departments involved in mangrove management in Sri Lanka

Most of the natural forests in Sri Lanka are owned, managed, and protected by the Forest Department and the Department of Wildlife Conservation. This accounts for approximately 1,767,000 ha which is 26.5% of the total land area of Sri Lanka (UNEP, 2016). The main government organizations related to the management of coastal areas in Sri Lanka are the Department of Coast Conservation and Coastal Resource Management (Coast conservation Act), the Forest Department, and the Department of Wildlife Conservation (Fauna and Flora Protection Ordinance (FFPO)). The general overview and jurisdiction of these departments are summarized in Table 1.

Moreover, Sri Lanka has become the first country in the world to protect all of its mangroves by law (Seacology, 2016). Fig. 1 represents the departments in charge of mangrove management in Sri Lanka.

The objectives of this paper are to delineate the key mangrove management stakeholders in Sri Lanka's Northern Province to understand their collaborative ties in mangrove management, to recognize their needs and wants through a 'network of preferred ties' and finally to give suggestions to improve the prevailing mangrove management network which was not accessible for scientific research until 2009 due to civil war. This paper aims to address these objectives through a Social Network Analysis approach to identify and map the collaborative relationships, and consult key stakeholders involved in the mangrove management to understand the social dimension of the social-ecological network. The insights from this study can further be used to help building capacity, fill knowledge gaps, and better plan mangroves and other natural resource conservation projects in other parts of Sri Lanka and beyond.

2. Methods

2.1. Site description

The total extent of mangrove forests in Sri Lanka is about 197.16 km² covering approximately 18% of the country's coastline (Global-mangrovetwatch, 2016) with 20 true mangrove species out of 87 species in the world (Jayatissa et al., 2002). During the past 20 (2001–2021) years Sri Lanka has lost 106 km² (5.2%) of its primary forests (Global-forestwatch, 2022). In between 1996 and 2016, about 23.68 km² Mangrove Forest cover has been lost in the country (Globalmangrovetwatch, 2022). The distribution of mangroves is confined to narrow intertidal belts due to low tidal amplitude (Wijeratne and Rydberg, 2007). Sri Lankan mangroves are under pressure, mainly due to the development activities in coastal regions, such as land-use change, water pollution, erosion due to urbanization, and industrial shrimp farming (Ranawana, 2017).

The Northern Province of Sri Lanka was affected by the civil war for two decades and was not fully accessible for scientific research until 2009. War-induced migration of more than 700,000 people, both permanently and temporarily had changed the land use and forest cover drastically (Samarathunga et al., 2020; Suthakar and Bui, 2008). The

Table 1

General overview and Jurisdiction of mangrove management departments in Sri Lanka.

Department	General overview of the department	Jurisdiction in mangrove management
Forest Department (DF)	<ul style="list-style-type: none"> - Focuses on conserving and develop forest resources and maintain an optimal forest cover to ensure sustained flow of social and environmental benefits - Strengthening the forest protection in line with prevailing policy and legislation. - About 55% of the forest lands of the country fall under the purview of DF and manages ninety thousand ha of forest plantations. It is responsible for all forests in the country. 	<ul style="list-style-type: none"> - When mangroves are included in conservation/reserved forests, then whoever "removes the bark or leaves from any tree or strips of the bark from any tree or cuts its branches or taps or burns any tree or otherwise damages it" can be punished (Forest (Amendment) Act, No. 65 of 2009 page 6). - Under the Forest Conservation Ordinance (2000–2002) 1039.5 ha of mangrove areas were gazetted as conservation forests along estuaries and lagoons (Puttalam, Mundal Lake, and Mi Oya River Delta).
Department of Coast Conservation and Coastal Resource Management (CC)	<ul style="list-style-type: none"> - Focuses on the sustainable development of coastal resources and the management of coastal processes to optimize social, economic, and environmental status of the country. - Initiating "development activities" within the coastal zone requires the permission of CC. 	<ul style="list-style-type: none"> - According to the Coast Conservation Act "Coastal Zone" is defined as "... water line and a limit of 2 km seawards ... and of 2 km measured until of rivers, streams, and lagoons or any other body of water so connected to the sea" (Coast Conservation Act, No. 57 of 1981, Page 20) which includes the fringing mangrove forests along with other coastal ecosystems. - CC has no jurisdiction over mangrove forests extending inland along the riverbanks in excess of 2 km.
Department of Wildlife Conservation (DW)	<ul style="list-style-type: none"> - Focuses on wildlife and nature conservation through sustainable utilization, participatory management, research, education, and legitimacy. 	<ul style="list-style-type: none"> - According to the Fauna and Flora Protection Ordinance (FFPO) (Amendment) Act, No. 22 of 2009 three mangrove plant species are included in section 42 which summarizes the "list of plants that are protected" <ol style="list-style-type: none"> 1) <i>Nypa fruticans</i> 2) <i>Lumnitzera littorea</i> 3) <i>Ceriops decandra</i> - The habitats of these plants are also protected by this department. Furthermore, FFPO can grant the 'protected area' status to forests. - Additionally, the Marine Protected Areas (MPA) may include the nearby wetlands with mangroves and sanctuaries (i.e., Bird's Sanctuary in Kalmetiya).

(continued on next page)

Table 1 (continued)

Department	General overview of the department	Jurisdiction in mangrove management
The Department of Fisheries and Aquatic Resources (FA)	<ul style="list-style-type: none"> - Focuses on the sustainable development of fisheries and aquatic resources by adopting new technologies in line with national and international laws. 	<ul style="list-style-type: none"> - Under the Fisheries and Aquatic Resources Act of 1996, fishery-managed areas can be declared with limited access to licensed operators which may include mangrove forests. - An important regulation of the above act regarding mangroves is that “No person shall engage in removing, cutting or altering mangrove ecosystems grown in the coastal belt or in any area adjacent to Sri Lanka Waters”.
Marine Environment Protection Authority (MP)	<ul style="list-style-type: none"> - Focuses on the management of coastal and ocean environment by means of creating awareness, research, and public participation. MP encourages national, regional and international coordination related to marine protection. - The Marine Pollution Prevention Act, No. 35 of 2008 which applied to the maritime Zone is “for the prevention, control, and reduction of pollution in the Territorial Waters of Sri Lanka or any other Maritime Zone, its foreshore and the Coastal Zone of Sri Lanka and for matters connected therewith or incidental thereto”. - According to Part VIII 26 of the above-mentioned Act, this Department can punish a person with a fine of 4 Million-15Million Sri Lankan Rupees upon being found guilty of discharging pollutants to the areas under the purview of this Act. 	<ul style="list-style-type: none"> - The foreshore of the Maritime Zone under the purview of MP includes mangrove forests.
Central Environmental Authority (CE)	<ul style="list-style-type: none"> - Focuses on the protection and management of the overall environment in the country through new technology, coordination, participation, education, awareness and legitimacy. CE also regulate, maintain and control the quality of the environment, and to prevent, abate, and control pollution. - Through the National Environmental Act of 1980 (No. 47 of 1980) Part II 10 b, the Central Environmental Authority has the power “to 	<ul style="list-style-type: none"> - The mangrove forests come under the overall conservation of ecosystems

Table 1 (continued)

Department	General overview of the department	Jurisdiction in mangrove management
	<p>recommend to the Minister, national environmental policy and criteria for the protection of any portion of the environment with respect to the uses and values, whether tangible or intangible, to be protected, the quality to be maintained. The extent to which the discharge of wastes may be permitted without detriment to the quality of the environment and long-range development uses and planning and any other factors relating to the protection and management of the environment”.</p>	

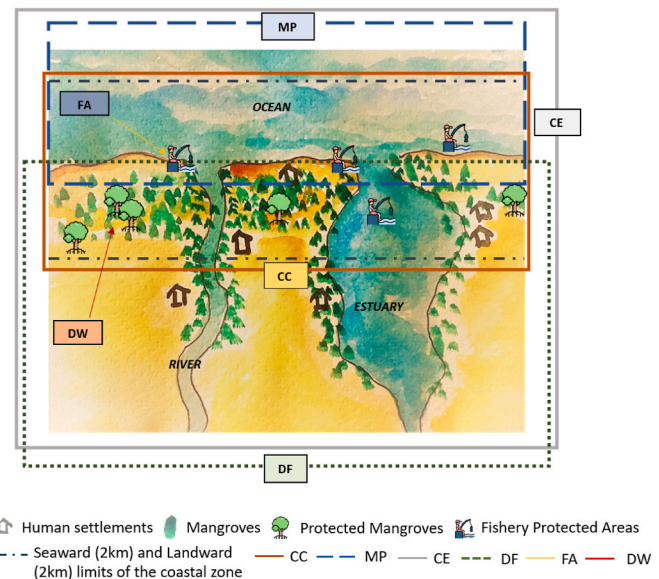


Fig. 1. Jurisdiction of different departments over mangrove forests in Sri Lanka is shown along a river, estuary, and seashore lined with mangroves. The relevant department related to the jurisdiction is shown in small colored boxes denoting the department names (refer Table 1 for abbreviations). Large boxes represent the land area covered by the departments according to legislation. Boxes extending beyond the image of the ecosystem show further extension of the jurisdiction by respective departments. DW is responsible for the habitats around the protected mangrove species and the FA is responsible for the fisheries-managed areas which constitute mangroves.

approximate mangrove forest cover in four coastal districts of the Northern Province is as follows: Jaffna – 2505 ha, Kilinochchi – 1885 ha, Mullaitivu- 1041 ha, and Mannar 1351 ha. (Fig. 2) (Edirisinghe et al., 2012; Ranawana, 2017). Mangrove ecosystems in this area are mainly used as medicinal, fuel, and timber resources. Anthropogenic pressure and coastal pollution were observed in mangrove ecosystems in the Northern Province (Arulnayagam, 2020). Harvesting of mangrove saplings and destructive, illegal construction of boat ramps are some other reasons for the failure of mangrove restoration projects in the study area (Vinoth et al., 2016).

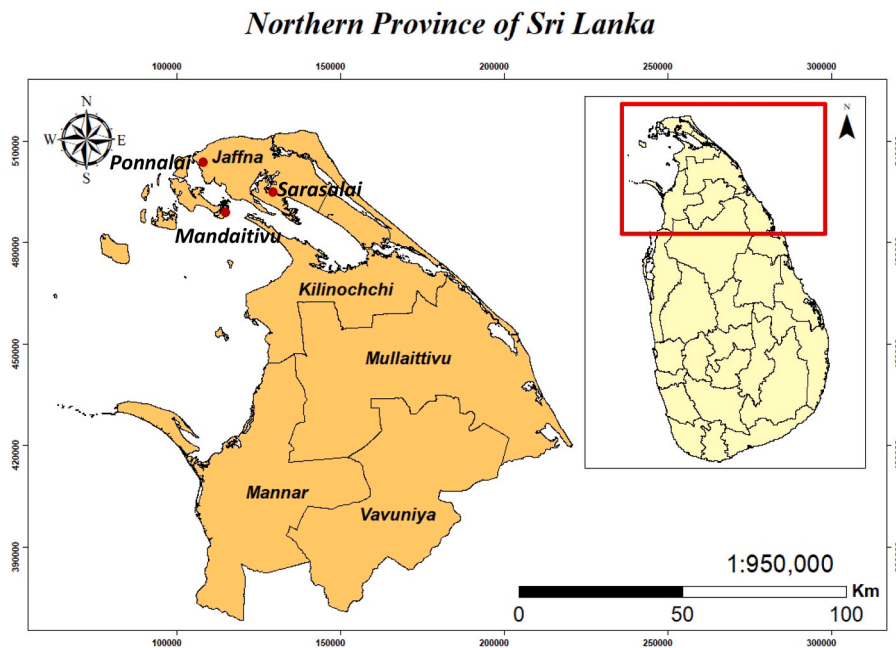


Fig. 2. Northern Province of Sri Lanka including five management districts. Red colour dots depict the areas of the ethnobiological survey (adapted from Malla-watantri et al. (2014)).

2.2. Preliminary survey and social network analysis to identify stakeholders

Social network data can be collected by questionnaires, interviews, and secondary sources (Marsden, 2005). In this study, all the above methods were included in different stages of data collection to identify stakeholders. Preliminary questionnaires were developed in four stages to identify the stakeholders involved in mangrove management. Following that an SNA questionnaire was developed concerning the collaboration among the stakeholders. Apart from the SNA survey (part 1 and part 2), ethnobiological surveys from the coastal communities in the Northern Province regarding mangrove stakeholder collaboration, were also considered for the networks of preferred ties. The steps of the surveys are shown in Fig. 3. Two networks were developed based on

stakeholder collaboration and preferred ties as in Table 2.

Table 2 Description of two stakeholder networks considered for Mangrove management in Northern Province of Sri Lanka.

Network	Description
Network based on stakeholder collaboration	Collaborations such as working together to implement a shared project or program, coordinate activities or services, share resources etc. among stakeholders regarding mangrove management in a more detailed manner with supporting evidence.
Network of preferred ties	Based on stakeholder preferences and ideas to be incorporated in the network towards better mangrove management.

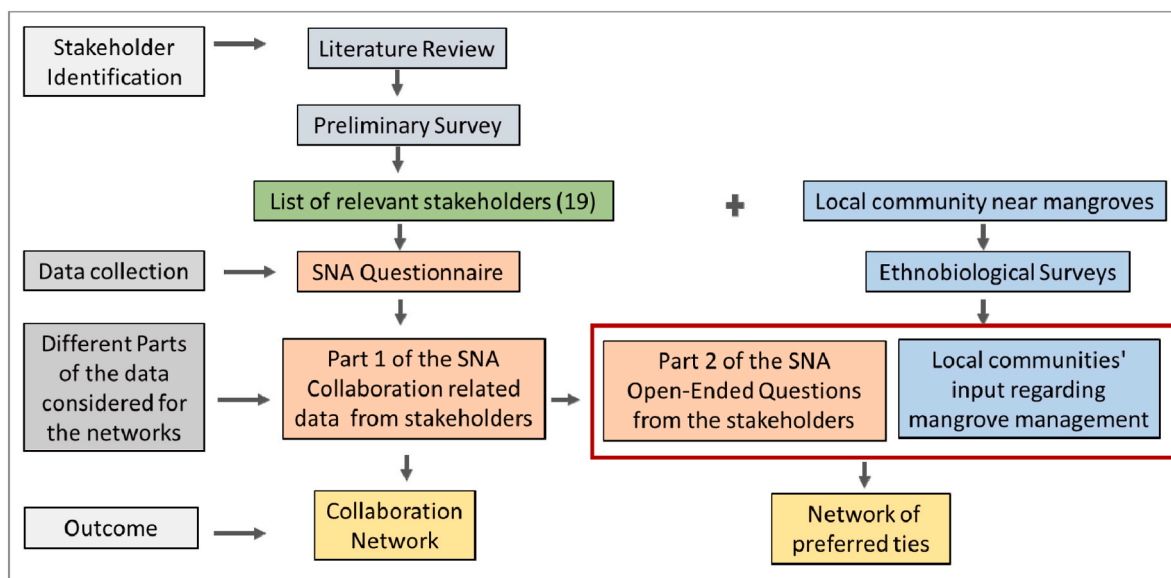


Fig. 3. Steps involved in the investigation of stakeholder networks on, collaboration, and stakeholder desires in the Northern Province of Sri Lanka. The red rectangle indicates the combination of the SNA questionnaire and the ethnobiological surveys for the development of the network of preferred ties.

After the Literature review (refer to section 1.3, Table 1 and Fig. 1), we identified six government departments (DF, CC, DW, FA, MP, CE) that were/might involve in mangrove management according to jurisdiction/legislation along with NGOs and academics/researchers working on mangrove management. The preliminary survey was carried out with respondents¹ (n = 22) representing the above-mentioned organizations in various districts in Sri Lanka from January to February 2020. Generally, twelve respondents are considered to be sufficient to enable consensus to be achieved (Vogel et al., 2019). The preliminary survey was developed to identify as many stakeholders² as possible to be included in the SNA (Appendix 1), and nineteen stakeholders related to mangrove management in Sri Lanka were identified (Table 3).

Additionally, 50 ethnobiological surveys were carried out with mangrove fringing communities in Sarasalai, Ponnalai, and Mandaitivu (Fig. 2) from July to September 2020 to explore the usage of mangroves by the local communities in the study area and their perceptions regarding stakeholder collaborations (Appendix 3). Only the last part of the ethnobiological survey exploring the role of stakeholders and expectations of the community was considered in this study (Appendix: 3 Q 67–72).

2.3. SNA survey and networks on stakeholder collaboration

The SNA data from the mangrove management stakeholders of the Northern Province were gathered from March 2020 to January 2021 using face-to-face and online interviews, in respect of COVID-19 social distancing regulation. A stakeholder survey (of 28 respondents from 17 organizations) was used to collect actor and social tie data, allowing us to construct social networks of local mangrove management regarding stakeholder collaboration. The response rate was 95 percent. All respondents were selected according to their involvement with mangrove-related projects as recommended by the relevant departments.

Each respondent was first asked to freely recall relevant mangrove

Table 3
Mangrove Management stakeholders in the Northern Province of Sri Lanka identified for the SNA.

Categories	Stakeholders
Government Departments	Department of Forest (DF), Irrigation Department (ID), Central Environmental Authority (CE), Department of Wildlife Conservation (DW), Department of Fisheries and Aquatic Resources (FA), Marine Environment Protection Authority (MP), Coast Conservation and coastal resource management Department (CC), Land use and Policy Planning Department (LP), Mahaweli Authority of Sri Lanka (MA), Sri Lanka Tourism Development Authority (ST), Rehabilitation Development Authority (RD), National Aquatic Resource and Development Agency (NR/NARA), National Aquaculture Development Authority of Sri Lanka (NQ/NAQDA), Police Department (PD), Army, Navy, Special Task Force (AN), Development Agency (DA)
NGO	Sudeesa, World Vision
Private enterprises	Companies that work with mangrove stakeholder such as sanitary products and hoteliers
Universities	The University of Jaffna, University of Peradeniya, The University of Ruhuna

¹ Respondent: The participant from the mangrove management organization or department who took part in the interviews and answered the questions as a representative of the stakeholder. They work directly with mangrove management-related processes.

² Stakeholder: The mangrove management organizations or departments (which are denoted as nodes in the network) rather than individual respondents, or households. The terms Stakeholder and Actor are synonymously used.

management stakeholders according to their experiences, and then afterwards was provided with the pre-compiled list (Table 3) of relevant stakeholders. Once they fully identified the mangrove management stakeholders, they were asked to rate their relationship based on stakeholder collaboration. Collaboration was defined as working together to implement a shared project or programming, coordinating activities or services, sharing resources etc. regarding mangrove conservation majorly based on evidence. The extent of relationships was scored based on the degree of collaboration (Table 4). In order to investigate the network on collaboration the complete network approach was utilized. We focused on the individual stakeholders and the direct relationships maintained with other stakeholders regarding mangrove management. Each stakeholder’s relationship with all others was considered and were integrated into the adjacency matrix and into a whole network. Here the ties/connections were “real” and each stakeholder was an “node/ego”.

For each tie, their communication with other stakeholders related to resource transfers, joint activities (during last year), the frequency, mode, and type of information exchanged, was discussed one by one (Appendix 2, Question 7) for the collaboration network. The direction of communication and the details of shared information was also included to obtain a directed type of network. Directed networks have connections between pairs of actors with a sender and a receiver and are usually illustrated through a directed arrow from the sender to receiver (Riyanto and Jonathan, 2018).

The SNA questionnaire further explored the job position of each respondent in their own organization, their individual role, conflicts with other stakeholders regarding mangrove management, collaborative projects, and finally the open-ended questions. Open-ended questions were further focused on challenges in mangrove conservation, reasons for the speed/slow nature of information flow, suggestions to enhance the information flow, the respondents’ satisfaction level with the current information flow, the distribution of authoritative power, and perspectives on overall mangrove management with inputs for improvement. In the open-ended questions, the stakeholders were also allowed to narrate their side of the story³ regarding mangrove management and their preferences regarding the formation of ties with other stakeholders.

After consolidating the information from the SNA on collaboration, graph visualization and network statistics were carried out using R (R Core Team, 2020) software version 4.0.2, using the R-package “igraph” (Csardi and Nepusz, 2006) and “sna” (Butts and Butts, 2016). Node level and network-level measurements and indices were calculated to quantify the relational and positional importance of stakeholders (Sapountzi

Table 4
Scores and definitions used in this study for stakeholder collaboration.

Degree of Collaboration	Score	Definition
Yes, currently	3	We are currently collaborating with this organization/department regarding mangrove conservation
Yes, in the past and would do so again	2	We have collaborated with this organization/department regarding mangrove conservation, and we would collaborate with them again if given the opportunity
Yes, in the past but not likely again	1	We have collaborated with this organization/department regarding mangrove conservation in the past, but we are unlikely to collaborate with them again in the foreseeable future.
Not at all	0	We have not collaborated with this organization/department regarding mangrove conservation

³ Story: Overall idea and their experiences about mangrove management and stakeholder involvement in the Northern Province of Sri Lanka.

and Psannis, 2018).

2.4. Network of preferred ties

The “Network of preferred ties” is a network based on what the stakeholders’ including the local community prefer to see in the mangrove management network along with suggestions for improvement. In the development of the network of preferred ties, the perceived connections were considered in two different ways. It was either, when a stakeholder wishes to have a connection with others (the links that do not exist) or when the stakeholders want to see a perceived connection across the entire network (i.e., between two organizations that they don’t belong to).

When considering mangrove management stakeholders, the local and indigenous communities are important stakeholder groups who are marginalized. To include the local communities in the study, perception-related data from ethnobiological surveys of the mangrove fringing communities were incorporated. In order to map the network on preferred ties, insights from the 50 ethnobiological surveys from three mangrove fringing communities from Sarasalai, Ponnalai, and Mandaitivu (Appendix 3) were incorporated with the second part of the SNA questionnaire that contained the open-ended questions and stories along with the data from literature review (1.3). We also looked into the department websites and reports (grey literature) for additional inputs.

These data were analyzed using content analysis through considering word-groups, themes, or concepts reflecting the perspectives on better mangrove management based on social learning. We used the concepts of social learning to create three themes because one of the key element of environmental governance is understanding the ecosystem dynamics through continual social learning (Bodin, 2017; Folke et al., 2005). Social learning can be further described as “... the collective action and reflection that occurs among different individuals and groups as they work to improve the management of human and environmental interrelations” (Keen et al., 2012). Social learning enhances the collaboration among multiple stakeholders by enabling shared solutions. It also helps to predict how diverse backgrounds and motivations could help to overcome the initial barriers of co-management. This can lead to convergence of actors’ perspectives on the problem addressed and improve positive relationships. In collaborative networks, social learning helps in combining knowledge from various experiences, defining problems, and jointly looking for solutions (Murti et al., 2020). Hence, this can result in the change of perception and attitudes among diverse stakeholders to solve common problems (Rist et al., 2006). Thus, the change in perception through social learning is often achieved by enhancing the generation of new knowledge and ideas (Christensen et al., 1996; Reed et al., 2010), disseminating knowledge and best practices (Matouš et al., 2013), and incorporation of relevant insights from diverse knowledge systems and experiences (Tengö et al., 2014).

The first theme is enhancing the production of new knowledge (keyword groups: “sharing ideas”, “disseminate new ideas”, “suggestions for improvement”, “new knowledge”) (Reed et al., 2010). The second theme is incorporating relevant insights from diverse knowledge systems (keyword groups: “technical support”, “consultation”, “guidance”) (Schoenefeld and Jordan, 2017), and the third theme is disseminating knowledge and best practices among a diverse group of stakeholders (keyword groups: “responsive”, “clear explanation”, “advice”, “actively involved”, “sustainability”) (Matouš et al., 2013). It was noted which stakeholder uses which word to describe the desired relationship with another stakeholder. The stakeholders or the community members described why they want to form or foresee a tie between two stakeholders using the above word groups.

2.4.1. Investigation of ties in the network of preferred ties

During the SNA interviews and ethnobiological surveys, the stakeholders/community members explained numerous situations where they preferred certain stakeholders to be connected. These included the

specifications like.

1. With whom they would like to connect
2. Which stakeholders need to be connected to each other

Regarding the content analysis, we focused on the word groups they used to delineate the links between two stakeholders. When they described a relationship/a possible relationship using these words then we considered it as a “tie”. For example, “*The universities should be “sharing” their “ideas” regarding mangrove conservation with us, it will be very useful. We like the universities to connect with us ...*” (CC) In the above situation, we formed a tie from the university to the CC.

The ethnobiological surveys (Appendix 3) also focused on the ideas of the communities regarding which stakeholders they desire to be connected with. For example, “*we like to get connected and to see the “active involvement” of the FD, WC, and NG’s in mangrove management. Those departments need to share ideas with each other first before advising us. It’s difficult to get different (contradictory) ideas from different departments regarding mangrove conservation. All scold us at the end*” (Community member, Sarasalai). At this point, we formed connections among FD, WC, and NG.

A possible tie was formed according to the policy search/archival studies/grey literature when we found that certain departments need to be connected to carry out mangrove management or they were connected in the past. For example, “*The District secretariat need to consult the Environmental division of the police department to resolve disputes among communities in the mangrove forests*” in such a case we established a tie between the District Secretariat and the Police Department (Fig. 4).

According to the above-mentioned steps, a combination of data from the SNA questionnaires (Part 2: Open-ended questions), the ethnobiological surveys (Q 67–72), and the review of legislation, policy documents, and institutional websites, reports was thus used to investigate the network of preferred ties (Fig. 4). The network-level and node level social network measurements considered in this study are listed in Table 5 and Table 6.

3. Results

3.1. Identification of stakeholders

The mangrove management network of the Northern Province includes a total of 25 stakeholders. Six new stakeholders were added to the predefined list (the District Secretariat (DS), Divisional Secretariat (DV), Village Councils (VC), Media (MD), Lobbyists (LB), and the Road Development Authority) through the SNA survey.

3.2. SNA survey and stakeholder collaboration

Government agencies dominate the mangrove management network (88% of organizations). Four government organizations, Department of Forest, Central Environmental Authority, Department of Wildlife Conservation and Management, Marine Environmental Protection Authority, and a Non-governmental organization were particularly centrally situated within the network (Fig. 5 a). These stakeholders may have the potential to act as bridging organizations for knowledge and information transfer, with each organization in a complementary position in the network.

3.3. Network of preferred ties

Mangrove management stakeholders and local communities highly anticipated that connections between certain departments were urgently needed for better management of these ecosystems. About 70% of the stakeholders were suggesting the inclusion of a “common platform” to discuss mangrove management issues and to share knowledge and ideas. “*It would be nice if an organization or department take over the role of*

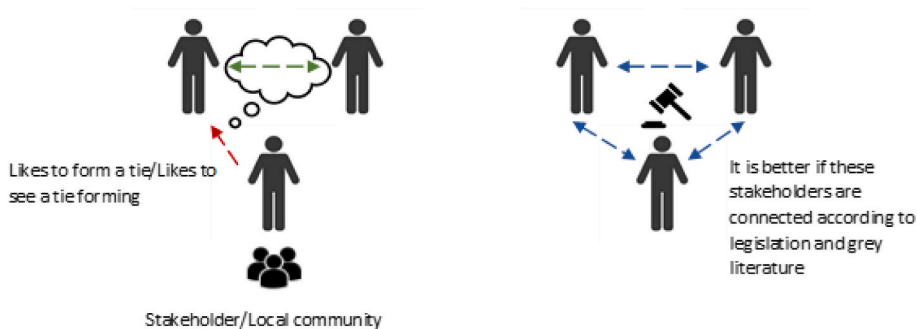


Fig. 4. Different types of formation of ties in the “Network of preferred ties”.

Table 5

Network level measures considered for the development of the collaboration network and the network of preferred ties.

Network Level Measure	Description
Transitivity (Carpenter et al., 2004; Hoff et al., 2002; Wasserman and Faust, 1994)	Transitivity is where two nodes being connected to a third node increases the likelihood that they will be connected to themselves. It is the tendency for friends of friends to be friends and enemies of enemies to be enemies. Transitivity is a triadic, algebraic structural constraint.
Centralization (Everett and Borgatti, 2005; Freeman, 1978)	Centralization is a measurement of the extent to which the ties of a given network are concentrated around a single node or group of nodes, it is the sum of the differences in centrality of the most central actor to all the others Centralization refers to the extent a network is dominated by a single node.
Density (Borgatti et al., 2018; Harary, 1969)	The proportion of group members who are tied (with a “positive” relation, such as friendship, respect, acquaintance, past collaboration, etc.). The proportion of observed connections among stakeholders to the maximum number of possible connections. This also reflects the degree of interconnectivity between different organizations.

Table 6

Node level centrality measures considered for the development of the collaboration network and the network of preferred ties considered to investigate the collaboration and desired networks.

Node level centrality measure	Definition	Description
Betweenness Centrality (Borgatti et al., 1998; Freeman, 1978)	The number of times that ego falls along the shortest path between two other actors.	Actors with high betweenness link together actors who are otherwise unconnected, creating opportunities for exploitation of information & control benefits, increases facilitation and the possibility for brokerage.
Eigenvector Centrality (Bonacich, 1972; Borgatti et al., 1998)	The extent to which ego is connected to nodes who are themselves high in eigenvector centrality.	An actor has high eigenvector scores when they are connected to well-connected others.

connecting different mangrove management projects and stakeholders. It is scattered everywhere. For example, when an officer who works on mangroves gets a transfer or retires, the whole systems collapses. We need a common platform which is maintained properly” (Government officer, Northern Province). Since bridging was rarely observed in the mangrove

management networks in the Northern Province, an entirely fictional entity was included by us called the Environmental Network Unit (EN) for bridging purposes in this network. Further, according to some stakeholders (i.e., CE) Universities are perceived to have the potential to be a bridging organization (Fig. 5b).

3.4. Node level network measurements

Node level measurements of the collaboration network are presented in Table 7.

Betweenness is high in the Central Environmental Authority (14.55) followed by the Marine Environment Protection Authority (12.68). Therefore, we can assume that these two departments have a high potential to occupy bridging positions in the network. In spite of the need for scientific input in mangrove management, the National Aquatic Resource and Development Agency and the National Aquaculture Development Authority of Sri Lanka have low betweenness. Actors tend to have high eigenvector scores in a network when they are connected to well-connected others. The Central Environmental Authority and the Marine Environment Protection Authority have the highest eigenvector centrality scores (0.3988833) followed by the Department of Forest, Department of Wildlife Conservation, and the Department of Fisheries and Aquaculture (0.3508885). Out of many departments which have a low eigenvector, departments such as the National Aquatic Resource and Development Agency, the National Aquaculture Development Authority of Sri Lanka and Land use and policy planning Department have low eigenvector scores implying that they are not connected to well-connected others.

3.5. Network-level measures

Transitivity, Centralization, and Density are higher in the Network of preferred ties compared to the collaboration network (Table 8).

3.6. Communication patterns of the stakeholders

Communication patterns of the stakeholders in the collaboration network were further delineated through direct questions (Q 6 and 7 Part 1, Appendix 1 and open-ended questions), (Fig. 6).

3.7. Challenges faced by the stakeholders regarding mangrove conservation

High reliance on letters (through regular postal services) and telephone calls (29% each), were observed (Fig. 6 a). According to a respondent “We consider letters as a trusted source of information, because we will have evidence in our hands as a hard copy with all approved signatures, but the real problems that need to be addressed through that letter would fade away by the time they get approved and arrive into our hands”. This shows the need to have more swift and reliable communication strategies.

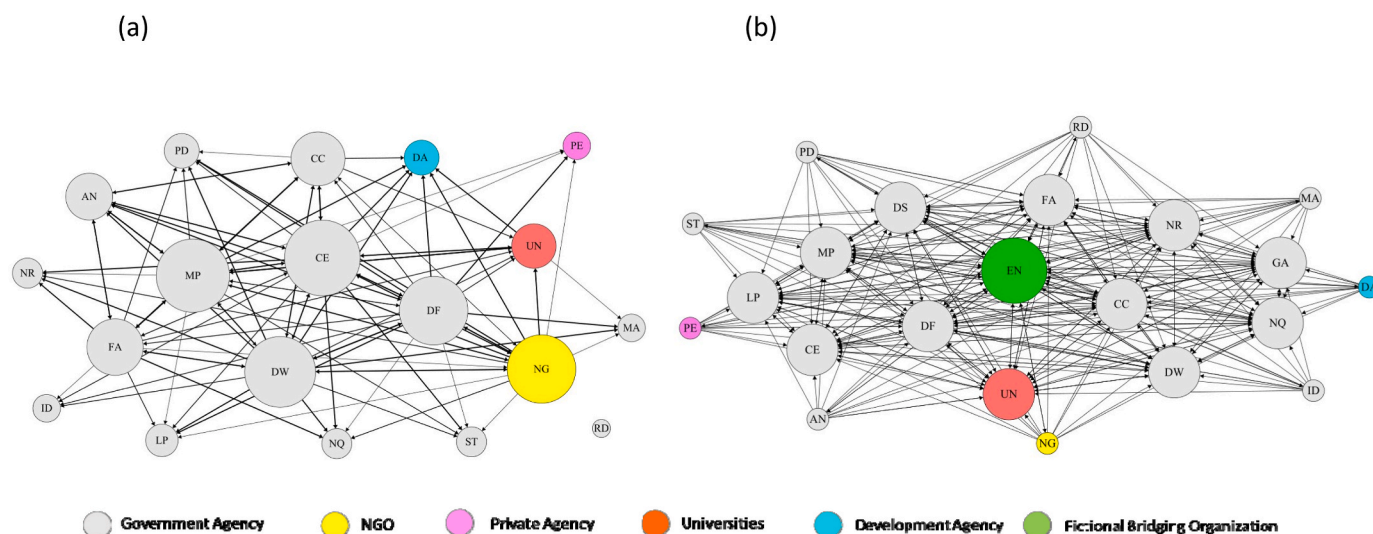


Fig. 5. Networks showing relationships based on stakeholder collaboration (a) and preferred ties (b) related to mangrove management in the Northern Province of Sri Lanka (for stakeholder abbreviations refer to Table 3). The collaboration network is fully embedded in the network of preferred ties. The node size reflects “degree centrality” (the bigger the circle, the higher the degree centrality). The higher the degree centrality, the more central the node is.

Table 7
Node level measurements for the network based on collaboration.

Node	Betweenness	Eigenvector centrality
Department of Forest	5.03	0.3508885
Irrigation Department	0	0
Central Environmental Authority	14.55	0.3988833
Department of Wildlife Conservation	4.83	0.3508885
Department of Fisheries and Aquatic Resources	2.12	0.3508885
Marine Environment Protection Authority	12.68	0.3988833
Coast Conservation and Coastal Resource Management	1.22	0.3028938
Land use and Policy Planning	0	0
Mahaweli authority	0	0
Sri Lanka Tourism Development Authority	0	0
Rehabilitation Development Authority	0	0
National Aquatic Resource and Development Agency	0	0
National Aquaculture Development Authority of Sri Lanka	0	0
Police Department	0	0
Non Governmental Organization	4.38	0.3508885
Army/Navy	0.85	0.2856034
Development Agency	0	0
University	1.33	0.1264093
Private Enterprise	0	0

Table 8
Network-level measures in the collaboration network and the network of ties investigated in the Northern Province of Sri Lanka focusing on mangrove management.

Network	Transitivity	Centralization	Density
Collaboration Network	0.72	0.38	0.3
Network of preferred ties	0.95	0.41	0.61

Out of all the responses about 44% of the stakeholders contacted each other regarding mangrove management only when needed and did not share frequent connections. Within the rest of the responses (56%), monthly communications were the highest (35%). Stakeholders’ meetings at the District Secretariat office held every month were cited as a reason for this frequent communication, even though the participation of the stakeholders was limited (Fig. 6 b).

There was a lack of clear communication objectives regarding the need for mangrove management and conservation in the Northern Province. One respondent stated that “We know that the law is very strict, the rule-breakers will immediately be punished and we arrest a lot of people who encroach, its less about the status of these ecosystems and more on enforcing the law”. Only 2% of the information exchange was regarding funding and collaborative opportunities (Fig. 6c). Another government stakeholder claimed that “Without sufficient funding, all project ideas vanish after a few meetings, and we are tired of such meetings ...”. Sufficient allocation of money for mangrove management projects was considered an important necessity that needed immediate attention.

The major challenges for mangrove management were mentioned as the language barrier and the use of technical terms and translations in policy documents. Information transfer in both Tamil and Sinhala languages was hampering fluid communication to connect with other departments to exchange ideas across districts and provinces. The other main element affecting mangrove management was land ownership, as it is still not clear whether some mangrove areas are government or privately owned following the end of the civil war. Lack of knowledge about the position of the stakeholders, legal mandates of the departments, not connecting the relevant stakeholders before establishing projects, and changes in ministries were other notable constraints (Fig. 6d).

4. Discussion

4.1. Key stakeholders in collaboration network

Stakeholders responsible for managing mangroves in Sri Lanka, come under the umbrella of national authorities (i.e., ministries), ranging from government departments to village councils along with private agencies, universities, and non-governmental organizations. The Central Environmental Authority has high centrality scores in the study. It is a department with multiple roles to play. The National Environmental Act No.47 of 1980 is the key environmental law at the statutory level in Sri Lanka which is responsible for Environment Impact Assessments (EIA) procedures. “The Central Environmental Authority is always connected to all key stakeholders related to mangrove conservation; they give advice related to EIA for most of the time which include development activities in all mangrove ecosystems in the Northern Province” a respondent explained. Therefore, the Central Environmental Authority is well connected with other powerful stakeholders and at times the mangrove

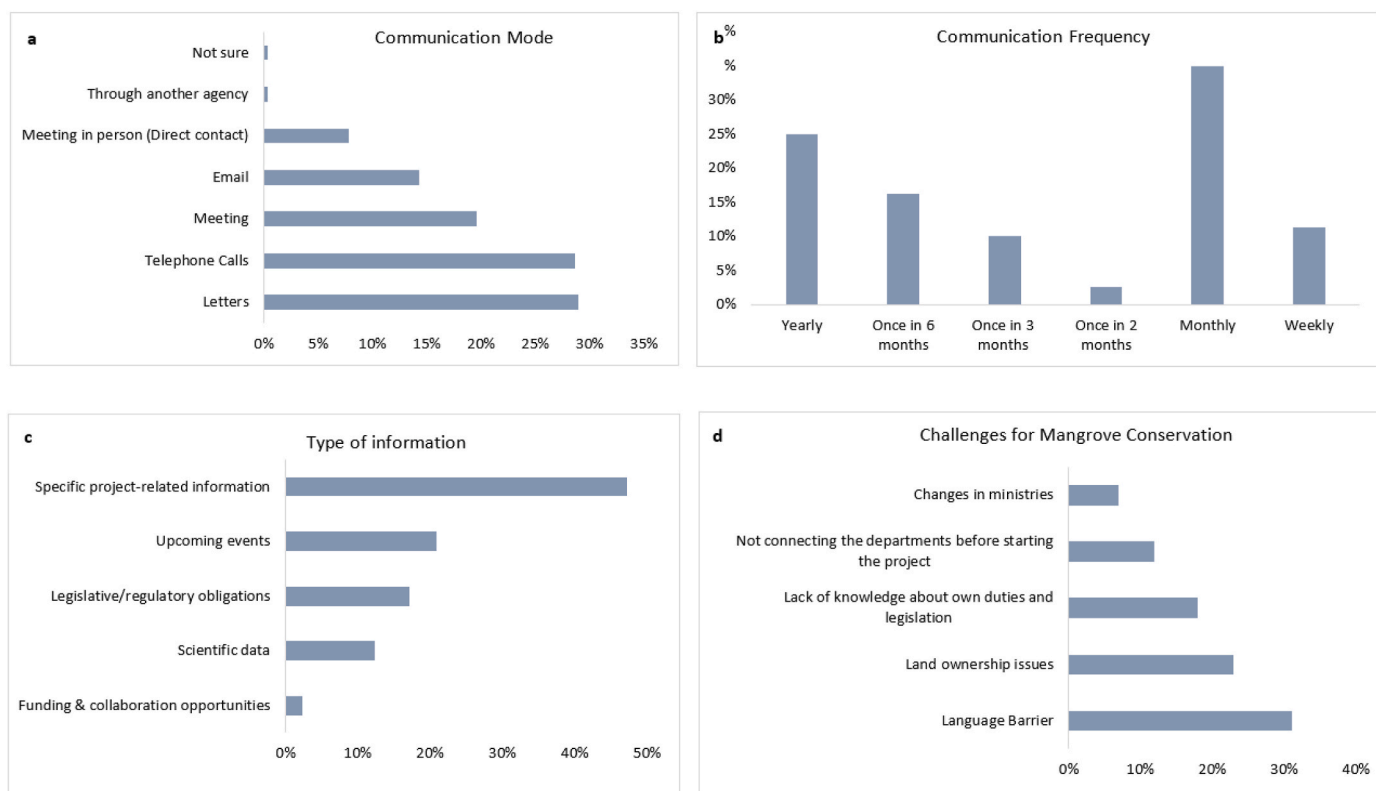


Fig. 6. Communication patterns of Mangrove management stakeholders in the Northern Province of Sri Lanka showing mode (a), frequency (b), and the type (c) of communication and information exchanged and the Challenges faced by mangrove management stakeholders (d).

management related laws are applied indirectly to tribute environmental monitoring issues such as the EIA. Furthermore, the Central Environmental Authority has the highest betweenness centrality in the collaboration network showing high possibilities to act as a bridging entity. In the Northern Province, this department is mostly involved in creating awareness programs (especially for school children). Since they have a wide range of environmental issues to tackle, less consideration is given to mangrove management. In addition to the Central Environmental Authority, Forest Department, Department of Wildlife Conservation, the Marine Environmental Protection Authority and the NGO's are found to be key stakeholders. Except for the NGO's, other stakeholders mentioned are mandated (directly or indirectly) to conserve mangrove ecosystems and are not only formally appointed as major stakeholders but were also perceived to be central by other stakeholders.

The Forest Department has an involvement in all mangroves co-management activities in the study area. Apart from controlling encroachment in mangrove forests, the Forest Department also takes part in mangrove restoration and pollution control. A respondent from the Forest Department stated that "People do not know much about mangroves, and illegal dumping of wastes is a major problem in mangrove areas. All stakeholders need to work together to mitigate this". In such situations, it would be necessary for these key stakeholders to discuss and devise feasible solutions as the mangrove ecosystems fall into the jurisdiction of several departments.

4.2. Stakeholder expectations according to the network of preferred ties

Visualizing the current social network is the first step to understanding collaborative processes (Koontz et al., 2020). Apart from that, it is useful to know what the stakeholders desire in order to improve the prevailing network. This would help to disentangle misconceptions among stakeholders before the arise of conflicting situations. Failed expectations and pressure from other (higher) entities are often

considered as major barriers for successful projects planning (Walker et al., 2008). In the networks, we observed some stakeholders like, the universities, Land use and Policy planning Department (LP), The National Aquatic Resources Research and Development Agency (NARA), and National Aquaculture Development Authority of Sri Lanka (NAQDA) were actually in the periphery of the collaboration network but central in the network of preferred ties. Similarly, highly connected central stakeholders such as the NGO was found in the periphery of the network of preferred ties. The "Environmental Network Unit" is not currently available. But the establishment of such a common platform was of prime importance for the stakeholders and it occupies a central position in the network of preferred ties. There were some actors who were central in the network of preferred ties but not found in the collaboration network such as District Sectarian and Divisional secretariats (DS), and Gramasevaka/Village council (GA). The village council members usually closely work with the communities and have better knowledge about the history of the forest, village etc. They are aware of and even sensitive to the mangrove usage and other informal practices. GA's have direct contact with the DS. These stakeholders play a key role in understanding on the ground level mangrove management practices of the communities, and we suggest to include them.

NARA is the "apex national institute which was given the responsibility of carrying out and coordinating research, development, and management activities for development and sustainable utilization of living and non-living aquatic resources" (NARA, 2021). But the eigenvector centrality and the closeness centrality of NARA were very low (zero) in the collaboration network in the Northern Province. Even though NARA is an important institute that coordinates research activities, lack of infrastructure, staff, regional centers, and the need to cover a wide range of aquatic resources under the purview might be reasons for why NARA is limiting its participation with mangrove management stakeholders. According to "The National Aquatic Resources Research and Development Agency Act, No. 54 of 1981, the main objective of the establishment of NARA

was to face the challenges offered by the 200 nautical miles Exclusive Economic Zone (EEZ). This includes a sea territory covering 460,000 Sq. km, which is around eight times the land territory of Sri Lanka" (NARA, 2021). Covering a very large sea and land area and not having direct jurisdiction to conserve mangroves along with lack of capacity can be inferred as reasons for being positioned in the periphery rather being central.

The importance of proper scientific input in mangrove restoration in Sri Lanka was highly emphasized by Kodikara et al. (2017) in a survey carried out island wide in Sri Lanka on the fate of mangrove restoration projects in all coastal Provinces. The results included a site in the Mannar District (Out of the four coastal districts) in the Northern Province with a 26–50% success rate of mangrove restoration initiatives. The major reason for the failure of mangrove restoration was due to unscientific approach and intervention, and not following the technical guidance. It is seen that there are departments with the objective to provide such guidance, for example, according to the NARA Act, No. 54 of 1981, one of the objectives of this organization is "the development, management, and conservation of aquatic resources in the inland waters, coastal wetlands, and offshore areas". Even though there were occasional interactions and technical guidance mentioned by the stakeholders, we recommend to increase the involvement and technical guidance of NARA in the mangrove management of the Northern Province.

4.3. Suggestions for improvement

The distribution of responsibilities on mangrove co-management needs to be clearly discussed among the key stakeholders so that they can work together to conserve mangroves. The key stakeholders in a network have the potential to change the prevailing system towards collaboration and information sharing, they also have the power to diffuse or restrict information and communication flows in the management networks (Forkam et al., 2020; Reed et al., 2009). The key stakeholders are important and influential in the network, and they have the ability to exert a negative or positive impact on conservation projects being implemented according to their priority. Such situations are challenging for state agencies in the creation and maintenance of successful and sustainable co-management regimes without sufficient inputs from other entities (Manolache et al., 2018).

The network level measurements (i.e., density) are higher for the network of preferred ties compared to the collaboration network (refer Tables 5 and 8). Apart from increasing the communication systems and capacity building, stakeholders in general prefer a denser network than the current collaboration network. New links with the departments which were not connected before are therefore encouraged. Extensive interconnections in collaborative networks encourage and facilitate the exchange of information and help establish common goals and standards which enhances the performance of the network in long term (Savage et al., 2010). But the establishment of new links and interconnections is not enough to really ensure collaboration and coordination processes. A system that ensures reliable, frequent knowledge exchange through the links is equally important. The insights from all stakeholders regarding the possible future connections that can be established need to be considered as much as possible to further improve the prevailing mangrove management in the Northern Province of Sri Lanka.

As we observed in our analysis, the government departments which have the same jurisdictional status try to act together and involve in mangrove co-management. In certain instances when two stakeholders have conflicting interests in mangrove management (i.e., the Coast Conservation and Coastal Resource Management Department's priority is coast conservation, and the Road Development Authority or the Tourism Board's interests are mainly related to development projects) it becomes more challenging to foresee common goals and work together. The conflicting departments tend to wait for future collaborative projects to arise to negotiate further or try as much as possible to minimize their intervention. Therefore, such departments can focus on mapping networks of preferred ties according to the project objectives and learn

about the possibilities of co-management before the initiation of development projects.

Key stakeholders with high influence and importance such as the Central Environmental Authority and Marine Environment Protection Authority could provide the coalition of support to sustainably continue the management of mangrove ecosystems. Conversely, it is necessary to understand whether there are stakeholders with high influence but with low importance to sustainably co-manage mangroves. For example, according to the stakeholders and the local community, the Land use and Policy planning department and the Mahaweli Authority are supposed to play a key role in mangrove management to clarify whether the land is publicly or privately owned, even though those two departments are not directly involved in mangrove management. It is nearly impossible to conserve any land without exactly knowing its extent, history, and ownership. Such stakeholders responsible for land ownership clarification need to be identified and hence be involved in formal mangrove management so they can be consulted or informed.

Clarification of land ownership issues in the Northern Province is considered fundamental by the stakeholders and the local communities. After the civil war for two decades and migration of people followed by urbanization and development resulted in a permanent change in land ownership in the study area. Multiple land ownership regimes were present during the past two decades and there were no well-defined property rights, hence there is confusion between all stakeholders regarding land tenures. Village councils have knowledge about land use changes in the villages over decades and have considerable understanding in this regard. But they are not formally included in the mangrove management processes. We recommend consulting and including village councils when developing mangrove management initiatives.

In the post-conflict Northern Province, infrastructure development (such as roads) needs to be improved and the mangrove management stakeholders are resistant to caution the Road Development Authority regarding development initiatives. It has been observed that Mangrove forests in certain areas in the Northern Province have been cleared for road/bridge construction (Weerakoon et al., 2020). Therefore, the involvement of the Road Development Authority is perceived as important before the implementation of such projects. The Mahaweli Authority is responsible for 900,000 acres of land in the river catchments by providing irrigation facilities in Sri Lanka (MA, 2021). Even though there are no Mahaweli Authority-owned lands with mangroves in the coastal districts of the Northern Province, it was considered an important stakeholder. It can be assumed that the involvement of Mahaweli Authority in other Provinces regarding mangrove management may have encouraged the stakeholders in our study to perceive this stakeholder as important. Furthermore, scientific input and technical guidance are necessary to successfully carry out mangrove restoration projects. Even though there were occasional interactions and technical guidance mentioned by the stakeholders, we recommend to increase the involvement and technical guidance of NARA in the mangrove management of the Northern Province.

Additional stakeholders such as District Secretariat, Divisional Secretariat, Village Councils, Media, and Lobbyists were suggested by the stakeholders and the local community to the network of preferred ties. The current collaboration network can be further improved by the participation of more stakeholders at the local, village, and community levels with power and willingness to participate.

4.3.1. Recommendation of bridging entities to improve the prevailing mangrove management network

The functionality of bridging organizations (which was referred to as "connecting through another agency") was very low among the mangrove management stakeholders. It can be assumed that the necessity of bridging is not fully understood by the stakeholders in our study. Most stakeholders only connected with each other regarding mangrove-related projects when needed in a reactive way to fulfill an

obligation or when a problem arose. The response “only when needed” for communication can be considered as a convenient response rather than a responsible response by the mangrove management stakeholders. It can be assumed as ineffective and insufficient because ninety percent of the stakeholders were not satisfied (Part 2 Question 4 [Appendix 1](#)) with the current information flow/exchange and communication methods. This happens with the emergence of an environmental issue instead of being precautionary from the beginning. The diversity of multiple stakeholders in mangrove co-management and the involvement of certain stakeholders in the middle of a program often led to frustration and abandonment of the projects altogether. There we found multiple abandoned mangrove conservation projects in the Northern Province without adequate funding and sound project management.

Lack of awareness about mangrove conservation among stakeholders and the communities was mentioned as a major cause for the destruction of these ecosystems in the Northern Province. Studies show that intermediary bridging organizations, such as environmental knowledge brokers and information providers, can be very effective in providing environmental awareness ([Melindi-Ghidi et al., 2020](#)). With overall poor communication, information exchange, and funding, it is difficult for the government departments to perform the critical role of bridging.

Even though the collaboration network has all key stakeholders connected in the Northern Province, they do not have the fundamental facilities of information transfer or the needed staff members or enough resources to focus on mangrove management. Specifically, the Forest Department which has provisions to conserve mangroves, does not seem to have enough staff or vehicles to efficiently carry out patrolling in mangrove areas in the Northern Province, according to our observations. The Central Environmental Authority plays a central role in connecting other stakeholders and seems to have high potential to act as a bridging organization (high betweenness centrality). Currently, there is no specific legislation or policy focusing only on mangroves, although the jurisdiction includes mangroves along with other ecosystems to be conserved it does not specifically mention mangrove conservation. Therefore, the staff of this department are not obliged to investigate mangrove management. The Central Environmental Authority can act as a bridging organization if specific policies are introduced focusing on mangroves along with the development of research, staff, and other capacities. The Marine Environment Protection Authority also has a high potential to be a bridging organization and has the jurisdiction to conserve the foreshore which may include mangroves, but the mangroves in other parts of the lagoons and rivers are left out under the jurisdiction of different departments. When recommending a potential department for bridging it should have specific policies that cover all mangroves along with enough capacity. The current mangrove related regulatory and law enforcement mandates are fragmented between different departments and makes it difficult to recommend a specific stakeholder to take up the role of bridging.

Research institutes are often viewed as unbiased and mentioned among the most trusted sources for information on environmental management compared to government and private stakeholders ([Bickerstaff et al., 2008](#); [Lorenc et al., 2014](#)). The government institutes and private organizations are perceived as either driven by political motivation or financial interests ([Nisbet and Markowitz, 2016](#)). Furthermore, bridging organizations can provide learning opportunities, co-create knowledge, build trust, resolve conflicts, and be equipped with expert knowledge, resources, and funding ([Crona and Parker, 2012](#); [Stewart and Tyler, 2019](#)). Due to trust and acceptance, it would be ideal to involve research organizations (e.g., universities) and NGOs to act as bridging entities to communicate environmental issues with all stakeholders and local communities if enough funds and resources were given ([MacKeracher et al., 2018](#)).

Most stakeholders interviewed stated their interest to collaborate with the universities. “*University academics usually clearly explain the potential environmental pollution with scientific evidence*” a respondent recalled. Therefore, the universities in Sri Lanka can be suggested as a

potential bridging entity due to the perceived neutrality, scientific expertise, and the resources like multi-language skilled scientists who have familiarity with the sites. Furthermore, state universities are situated in all coastal provinces of the country. We further suggest that the establishment of a “bridging unit” in each university or higher national institute is useful to support the stakeholders. This bridging unit could consist of undergraduate and graduate students. We assume that the students may get an opportunity to be directly involved with practical questions in the country and contribute to capacity building. These university bridging units could be ideally coupled with other universities and the EN.

In the Northern Province of Sri Lanka aftermath of the civil war, conservation initiatives have started to take place slowly. In this situation, stakeholders are learning to understand the perspectives of others, and many do not have a clear understanding of the legal limitations and expectations, as mangroves span various jurisdictional boundaries. Databases can be developed as by [Dahdouh-Guebas et al. \(2021\)](#), for the social and ecological components of the Sri Lankan mangroves which would include accurate details about the area, composition, and distribution of these ecosystems, stakeholder participation, policy documents, research questions to be addressed by each stakeholder, and other mandatory literature. This database/website could act as a potential platform for stakeholder involvement and communication.

One of the major limitations is that some questions cannot be asked directly, as they touch upon politically sensitive issues. Sudden direct questions on perspectives rather result in vague answers such as “*We like to work with everyone*”. To overcome this issue, combining the narratives of stakeholders with open-ended questions followed by a content analysis gives a better understanding of the situation without disrupting the interview flow. A Delphi, Q method or Nominal Group Technique workshop focused on mangrove co-management would be a promising future approach to incorporate stakeholder’s views. Our study consisted of <25 stakeholders. But for bigger complicated mangrove management networks these steps can be further developed. Secondary data on stakeholder interactions can be used when direct interviews are not feasible. More networks on cash flow, resource flow, etc. could be included according to the mangrove management project objectives in the future, to predict the progress of conservation initiatives.

4.3.2. Further recommendations to be adapted by the government

In our study, stakeholders preferred to incorporate the suggestions of other departments before initiating a project to prevent the barriers that might occur halfway through the process. Moreover, evaluation of stakeholder perspectives regarding mangrove management in the initiation phase of projects would help to understand the potential pressures that may weaken conservation measures. These issues need to be taken into consideration by the development project initiating authorities (i.e., ministries).

The language barrier hampers information exchange among mangrove management stakeholders in the Northern Province. The respondents find it challenging to convey ideas clearly with other stakeholders or co-workers/officers of higher authorities. In the Northern part of Sri Lanka Tamil is widely spoken as opposed to Sinhala which is used in most of the other parts of the country. The urgent need for the promotion of these two languages has been a subject of many current political, policy, and popular discourses in post-war Sri Lanka ([Liyanaage and Canagarajah, 2014](#)). Recruitment of sufficient translators (at least to the stakeholder meetings) and language courses (for field officers and others involved in co-management) can be suggested to improve communication.

In line with ([Schoenefeld and Jordan, 2017](#)) we assume that the government stakeholders might be under considerable political pressure and are being less critical about mangrove management. “*What can we do if the higher authorities and political parties want to involve in the decision-making about mangrove ecosystems? We would not have any voice over them. Especially new lower-ranking officers ...*” a respondent stated.

According to the open-ended questions, we assume that (except a few) most government departments of the Northern Province are interested in fulfilling their legal mandates concerning mangrove ecosystems. They seemed to know that mangroves are fully protected by law. While this “full protection” is mostly on paper and not in real practice. This raises the question of whether it is a successful initiative to impose laws to simply protect an ecosystem without actual follow-up measures, funding and awareness. Giving suggestions to improve the ecological conditions of mangrove ecosystems is as important as making the stakeholders understand the prevailing mangrove management network and the degradation status of these forests. Therefore, a better understanding of the mangrove co-management networks helps to find gaps in information flows and to suggest potential bridging entities.

The involvement of private organizations regarding mangrove management was not widely observed in the Northern Province. “They get a lot of benefits, there are hotels, and many tourists are coming. But their involvement in mangrove conservation is very low” a respondent recalled the participation of private organizations in mangrove management in the study area. Kajanini and De Zoysa (2018) explain that there is a positive attitude among 68.3% of the local community towards the development of ecotourism initiatives in the Mandaitivu island in Jaffna which is covered by mangrove forests. The lack of knowledge regarding ecotourism policies was apparent among ecotourism operators in Sri Lanka (Bandara, 2009). We recommend that the involvement of private organizations need to increase despite the exploitation of mangrove ecosystem goods and services. This involvement can be increased with proper collaboration with government organizations such as the Sri Lanka Tourism Development Authority, Sri Lanka Tourism Promotion Bureau, Sri Lanka Institute of Tourism and Hotel Management, and Sri Lanka Convention Bureau (Vipulan et al., 2019). Therefore, we suggest including these organizations in the mangrove management networks.

As a result of the civil war, approximately 8 Million people in Northern and the Eastern Provinces have been displaced (Siriwardhana and Wickramage, 2014). Post-war urban reconstructions and population resettlements are currently in progress. Some coastal areas have been permanently banned for locals due to security reasons. Relocations in the coastal areas in the Northern Province have modified the relations between local communities and their environment. “After the civil war people are still relocating. Some communities did not have the possibility to come back to the coastal areas due to security reasons and permanent emigration. We do not have the exact old inhabitants who co-existed with mangroves anymore” a respondent stated. Incorporating the insights of the local community regarding mangrove management stakeholders can help to understand the day-to-day realities of mangrove forest management at the local level.

5. Conclusion

Sustainable mangrove management ideally requires the involvement of multiple stakeholders in the management process. Mangrove social-ecological systems are complex adaptive systems consisting of diverse stakeholders with different responsibilities. Before bridging together all possible stakeholders, it is necessary to identify their specific roles in mangrove management along with the legitimate authority and interests. Understanding the prevailing management networks of stakeholders, and their collaboration helps in capacity building and foresee probable shortcomings in conservation planning. The SNA used in mangrove co-management provides insights into stakeholder interactions and delineates the roles of different departments in transmitting ideas and information. Although stakeholders acknowledge the need to collaborate more often, the way how this can be achieved needs to be discovered. In the Northern Province of Sri Lanka, identifying the stakeholders in mangrove management helps to find the most relevant stakeholders regardless of their jurisdiction and to engage them at the early stages of project planning and the selection of suitable integrated

mangrove management tools. Reducing communication barriers, increasing awareness about these ecosystems, providing resources such as trained staff members with enough facilities can further enhance mangrove management. Moreover, bridging organizations and databases/websites would increase stakeholder involvement and communication. Universities can actively involve in mangrove management through consultancy and research in collaboration with other stakeholders. Mangroves can be efficiently co-managed by knowing the existing and probable links between relevant stakeholders. This can be adapted to the management of any other ecosystem. The SNA based networks can be used by the government ministries before the execution of mangrove management projects, as well as evaluating ongoing and past projects. It can save considerable amounts of time, effort, money, and other resources used for development projects. The visually attractive SNA graphs can be easily understood by the stakeholders with a limited number of nodes (e.g., 25), but may become complicated with the increasing number of stakeholders. A considerable amount of time and effort is required to conduct a thorough SNA, especially as the network gets bigger and more complex. Creating several social networks for specific objectives of the same project or management schemes may help to minimize the complexity. These objective-specific separate networks (e.g., community participation, funds, and resources etc.) can reduce the number of the overall nodes and increase specificity. Mangrove ecosystems are fully protected by law in Sri Lanka, yet it needs to incorporate flexibility in administrative decision-making concerning health, sustainability, and the use of mangrove resources by local communities. The initial steps of understanding the stakeholder relationships through our study can provide baseline data for such management practices.

More research in the future related to SNA based environmental management could provide insights into how to structure management regimes focused on engaging multiple stakeholders including the local community. This would help to ensure and achieve desired social and environmental outcomes that can be sustained long-term in Sri Lanka and beyond.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ocecoaman.2022.106308>.

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