

Research article

Mangrove management in Sri Lanka and stakeholder collaboration: A social network perspective

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ABSTRACT

Understanding the extent of collaboration among stakeholders is key to supporting mangrove management. Despite the existence of robust policies, collaboration among stakeholders of mangrove co-management remains largely unexplored in Sri Lanka. This was partly due to the civil war, natural disasters, and other socio-economic changes over the past 30 years. Our study aimed to identify the collaboration between stakeholders of mangrove management and their perceptions regarding mangrove co-management in Sri Lanka using social network analysis and content analysis. Surveys were conducted in all five coastal provinces of Sri Lanka. Stakeholders included in the study were from government departments, non-governmental organizations, and private institutes. Our results showed that there were differences between coastal provinces in the mangrove management networks, specifically in the number of stakeholders involved and their degree of collaboration. Some important stakeholders (for example the Land Use and Policy Planning Department) were excluded from the social networks in certain provinces (Eastern and Western provinces). There were various issues hampering effective mangrove management such as inefficient communication, inconsistencies between policies, and insufficient financial capacity of government stakeholders responsible for policy implementation. According to the stakeholders in our study, providing mangrove management initiatives with long-term collaboration, post-care, continuous monitoring, and funding may help to overcome these challenges. Additionally, we suggest the establishment of a common platform to coordinate stakeholders. We further encourage increasing the participation of academics, researchers, and students from national universities in the mangrove co-management of Sri Lanka. Insights from this island-wide survey can be adapted to mangrove and other natural resource management trajectories in other countries as well.

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1. Introduction

Mangrove ecosystems are found in the coastal intertidal zones of over 120 tropical and subtropical countries in the world. Some key functions of mangroves are: sequestering blue carbon,² attenuating waves, and providing habitats and breeding grounds for numerous aquatic species (Cannicci et al., 2008; Donato et al., 2011; Rovai et al., 2018; Miteva et al., 2015). Coastal communities around the world rely on these ecosystems for subsistence and benefit from mangrove-derived food, fuelwood, timber, honey, wax, and tannins (Dahdouh-Guebas et al., 2021). The management of mangroves is typically a multi-stakeholder endeavor (Ishtiaque and Chhetri, 2016). However, potentially contradictory decisions are often made in mangrove management, mainly because of the location of mangroves at the sea-land interface (and the subsequent overlap and/or mismatch of responsibilities), and the diversity of stakeholders involved (Dahdouh-Guebas et al., 2021; Friess et al., 2016). Mangrove management policies differ among countries. However, most policies are steered by the objectives and goals of the respective governments. Sri Lanka is one of the countries with specific policies for mangrove management and is identified as the first nation in the world to formally protect all of its mangroves by jurisdiction, regardless of land tenure (Wickramasinghe et al., 2022).

In Sri Lanka, an intricate network of land- and marine-related stakeholders are involved in mangrove management. Despite government-led conservation efforts (Appendix 1) and non-governmental interventions, Sri Lankan mangroves are continuously degrading due to natural and anthropogenic drivers (Dahdouh-Guebas et al., 2021). Even though mangroves are fully protected by law, mangrove co-management initiatives are still lacking in the country (Kodikara et al., 2017). Co-management refers to the distribution of authority and decision-making between multiple stakeholders such as local communities, government organizations, and non-governmental organizations (NGOs) (Berkes, 2010). Ideally, the involvement of a wide range of stakeholders in the co-management of an ecosystem would eventually increase shared motivation, trust, effectiveness, coordinated collective action, and collaboration (Dandy et al., 2014). Collaboration can be defined as “professional contacts aiming at some result, for example, exchange of information, coordination of activities, common planning, and discussion of common tasks” (Nohrstedt and Bodin, 2020). Collaboration between stakeholders is considered as an essential component of co-managing institutions and networks in environmental governance while a lack of collaboration hinders the effectiveness of co-management (Bennett and Satterfield, 2018; Cudney-Bueno and Basurto, 2009). The effectiveness of stakeholder collaboration largely depends on the stakeholders’ background, relevance, whom they trust, and their choice to select the most suitable stakeholder with whom to collaborate (Ghorbani and Azadi, 2021; Nohrstedt and Bodin, 2020).

1.1. Mangrove management in Sri Lanka

The departments involved in mangrove management in Sri Lanka are directly managed by respective ministries from the central government (Fig. 1).

Most of the natural forests in Sri Lanka, including the mangroves, are owned, managed, and protected by the Forest Department and the Department of Wildlife Conservation (UNR, 2016). The other government departments involved in mangrove management are the Department of Coast Conservation and Coastal Resource Management, the Marine Environment Protection Authority, the Central Environmental Authority, and the Department of Fisheries and Aquaculture (Fig. 2).

² Blue carbon– “atmospheric carbon (dioxide) captured and sequestered by marine and coastal vegetation and stored in their biomass or as recalcitrant organic matter in the water body or sediments” (Zimmer et al., 2022).

Since mangroves are found at the sea-land interface, which is managed by several stakeholders, there is often confusion regarding regulatory responsibilities and formal rules of collaboration (Rog and Cook, 2017); this is also the case in Sri Lanka. There are specific provisions for mangrove management for many of these departments (Table 1).

More than two decades of civil war in Sri Lanka (lasting until 2009), mainly in the Northern and Eastern provinces, has limited researchers’ access to mangrove forests. Fieldwork and surveys in conflict settings were challenging during that time. The situation was exacerbated by the 2004 Indian Ocean tsunami which partly destroyed Sri Lankan mangrove forests (Dahdouh-Guebas et al., 2005). This was then followed by rapid mangrove restoration initiatives in all coastal provinces, most of which ended up in failure (Kodikara et al., 2017).

In parallel to the ongoing (2019–2022) economic crisis in Sri Lanka, with an acute shortage of food, cooking gas, and fuel, mangrove management stakeholders are finding it difficult to reorient themselves according to the government’s priorities, funds, and agendas. Priorities have shifted to urgent matters regarding the health sector and essential services, whereas management of natural resources is currently not considered a priority. For example, the mangrove forest patrolling is nearly impossible without sufficient fuel. Therefore, it is imperative to understand the present status of collaboration between all mangrove management stakeholders and their interconnections so that better mangrove management practices can be recommended. We further hypothesized that all relevant stakeholders are (equally) connected to the mangrove management network of their respective province.

The specific objectives of this study are to:

1. identify the stakeholders involved in mangrove management in five coastal provinces in Sri Lanka;
2. understand and map the collaboration among mangrove management stakeholders;
3. delineate stakeholders’ views on mangrove management

Even though mangrove management is always viewed as complicated, a study of mangrove management stakeholder collaborations covering a whole country has never been carried out using social network analysis (SNA). Usage of SNA in environmental science and policy research is not prevalent in Asia (Zhang et al., 2021). The insights from this study can be used as a baseline to understand the current collaborative networks of mangrove management in Sri Lanka, to help to fill knowledge gaps, and to better plan mangrove (and other natural resource) management in the country and beyond.

2. Methods

2.1. Site description

Sri Lanka is a tropical island located in the Indian Ocean between 05°55′ and 09°51′ North latitudes, and 079°41′ and 081°53′ East longitudes with a land area of 65,610 km² and a coastline of 1620 km. There are five coastal provinces, all of which include mangroves (197.16 km², 18.21% of the coastline) (Fig. 3). Presently about 25% of the overall Sri Lankan population lives within the coastal region of these five coastal provinces. Furthermore, 70% of hotels and 62% of industrial units are located the coastal region (Abeykoon et al., 2021).

2.2. Stakeholder identification

A questionnaire survey was developed to identify the mangrove management stakeholders in Sri Lanka (Appendix 2). Initially, six government departments along with non-governmental organizations (NGO’s) and academics/researchers (Kodikara et al., 2017) working on mangrove management were selected (refer to Appendix 2 for respondent selection). The governmental departments were selected according to jurisdiction/legislation related to their involvement in mangrove

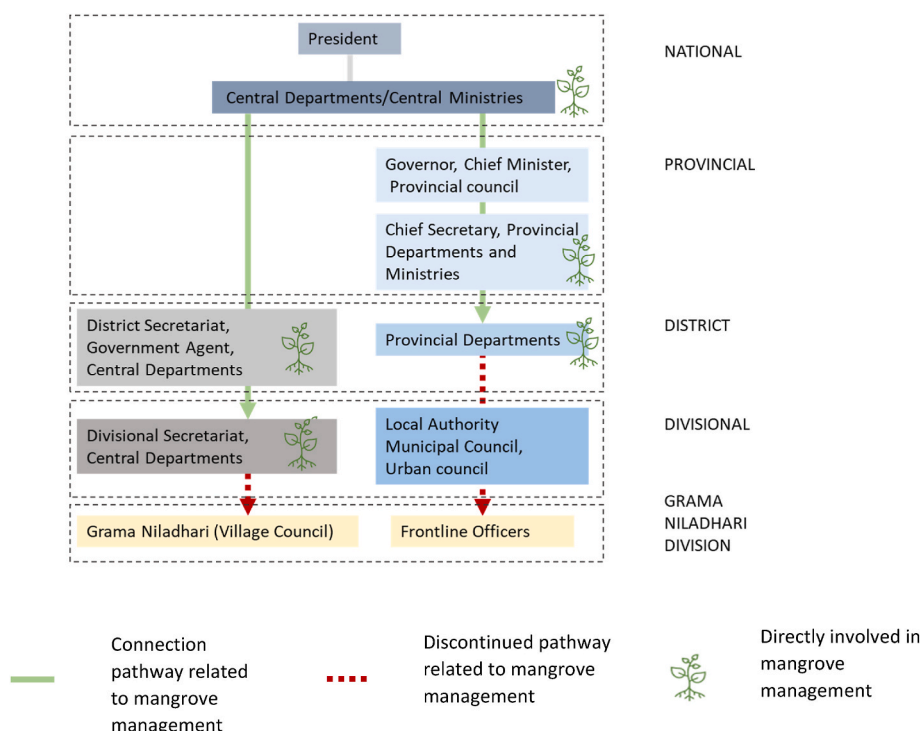


Fig. 1. Government structure of Sri Lanka showing possible pathways of mangrove management from different levels of authorities (connected with the government) until the village council and frontline officers who have direct contact with local communities. Red colour discontinued arrows show the entities that are not directly involved in mangrove management. Green colour arrows show direct pathways related to mangrove management. It is visible that at lower levels there are no clear pathways to translate mangrove management issues to local communities. Village council members and frontline officers are often involved in bureaucratic activities and do not have sufficient funding and staff to get involved in mangrove management.

conservation, and included: the Marine Environment Protection Agency, the Forest Department, the Central Environmental Authority, the Department of Coast Conservation and Coastal Resource Management, the Department of Fisheries and Aquatic Resources, and the Department of Wildlife Conservation (Table 1). The survey was carried out from January to February 2020 with respondents³ (n = 22; NGO: 3, Government departments: 15, Academics/researchers: 5) representing the above-mentioned stakeholders in various districts in Sri Lanka and 25 stakeholders⁴ consisting of 16 governmental organizations, 2 NGOs, 2 private organizations, and 5 universities (Table 2) were identified for SNA.

2.3. Social network analysis (SNA)

Social network analysis is a widely used method to study natural resources governance and management (Bodin and Prell, 2011). In SNA, the studied system is represented as a network composed of nodes and ties. Nodes can be individuals, institutions, or things, whereas ties are the relationships between the nodes. Ties can be either directed or undirected. In directed ties, the information transfer has a direction (sender to receiver) and no direction in the undirected tie. The formulation and representation of the networks in SNA can be analyzed through a variety of mathematical tools (Wasserman and Faust, 1994). Through the network plots, structural patterns, and network measures (Table 3) used in SNA, we can infer how actors manage complex environmental challenges (Bodin and Prell, 2011).

Stakeholders from each province (Table 2) were contacted to complete the SNA survey (Appendix 3). The SNA data from the mangrove management stakeholders were gathered from March 2020 to March 2022 using face-to-face and online interviews, in light of COVID-19 social distancing regulations. This survey (of 92 respondents from 25

stakeholders) was used to collect stakeholder collaboration data regarding mangrove management to construct social networks. The response rate was 85%. All respondents were selected according to their involvement with mangrove-related projects, as recommended by the relevant stakeholders (Table 4).

In order to create collaboration networks, total network approaches⁵ were used where all individual stakeholders and their direct relationships maintained with other stakeholders regarding mangrove management were considered. Each stakeholder's relationship with all others was then integrated into the adjacency matrix⁶ and later into a whole network. The transitivity, density, and centralization of the networks were calculated. After consolidating the information from the SNA on collaboration, graph visualization and network statistics were carried out using R (R Core Team, 2020) version 4.0.2, using the R-package "igraph" (Csardi and Nepusz, 2006) and "sna" (Butts and Butts, 2016).

For each tie, the respondents' communication with other stakeholders relating to resource transfers, joint activities (during the last year), as well as the frequency, mode, and type of information exchanged, were discussed one by one (Appendix 3, Question 7). The direction of communication and the details of shared information were also included to obtain a directed⁷ type of network. The SNA questionnaire further explored the position of each respondent in their own organization, their individual role, conflicts with other stakeholders regarding mangrove management, collaborative projects, communication patterns and ended with open-ended questions. Communication patterns were examined for how information is passed around the stakeholders, with specific emphasis on how frequently they communicate, mode of communication, and details shared during collaboration. The open-ended questions further focused on challenges in

³ Respondent: The participant from the mangrove management organization or department (stakeholder) who took part in the interviews and answered the questions as a representative of the stakeholder. They work directly with mangrove management-related processes.

⁴ Stakeholders: Organization related to mangrove management.

⁵ Total network approach: Information about each actor's ties with all other actors is collected.

⁶ Adjacency matrix: a simple square matrix (with 0 and 1 in the positions of V_i and V_j) that shows whether the pairs of nodes are adjacent to each other or not.

⁷ Directed: the communication between the actors is directional.

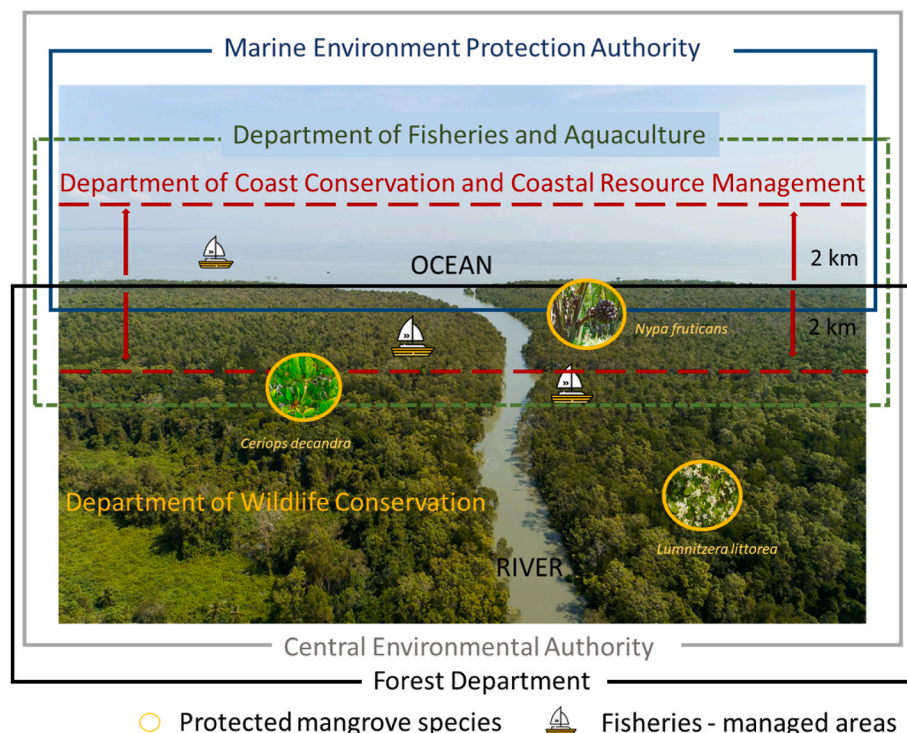


Fig. 2. Responsibilities of different departments over mangrove forests in Sri Lanka. Large boxes represent the land area covered by the departments according to jurisdiction. Boxes extending beyond the image of the ecosystem show further extension of the jurisdiction by respective departments. Department of Wildlife Conservation is responsible for the habitats around the protected mangrove species and the Department of Fisheries and Aquaculture is responsible for the fisheries-managed areas which constitute mangroves (Individual images <http://www.freepik.com>, and <http://www.flaticon.com>).

mangrove conservation, reasons for the slow or fast rate of information flow, suggestions to enhance the information flow, respondents' satisfaction levels 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 experiences regarding mangrove management, which were then used for the content analysis. The native languages Sinhala and Tamil were used to conduct interviews and then translated/transcribed into English.

2.3.1. Content analysis

The stakeholders considered for the SNA survey had many more details to share with the research team regarding their experiences in mangrove management beyond what was asked in the SNA survey. Specific details the stakeholders had to share were often unique to certain provinces. In order to capture this information, the stakeholders were asked about their overall experience and opinions of collaboration and mangrove management with the open-ended question, "Tell us about your overall experience regarding mangrove management and stakeholder collaboration in Sri Lanka/your respective province?". This additional information was investigated along with the different situations that arose through content analysis with NVIVO software (Elo and Kyngäs, 2008; Vaismoradi et al., 2013). Three phases were adopted in the content analysis (Fig. 4).

Due to the similar structure of the interviews carried out in the different provinces, 14 initial common codes were decided. Additional codes were implemented according to the thread of the conversation engaged by the stakeholders. In all three phases (Fig. 4), through the abstraction process, the initial codes were reduced to three main categories of topics:

1. Challenges related to mangrove conservation
2. Improvements to be made for better conservation
3. Mangrove related information and priorities

The three categories were then used for a final abstraction process to produce a comparative table that gathers the extracted results.

3. Results

3.1. Social network data and network matrices

3.1.1. Stakeholder collaboration

Networks show the differences in stakeholder collaboration in different provinces in Sri Lanka (Fig. 5). The relationships in the network are based on stakeholder collaboration related to mangrove management. Each node in the network represents a stakeholder and the directed arrows (ties) between the nodes represent the collaborative relationship. Government-related stakeholders (i.e., DF, CE, DW, MP) and NG seem to be dominant and centrally positioned within the networks in the mangrove management networks (Fig. 5).

3.1.2. Network measures

Mangrove management network density and centralization are higher for the Northern Province and lowest for the Eastern and Southern Provinces. Transitivity is higher for the North-western Province and lower for the Eastern Province (Table 5).

3.2. Communication patterns of the stakeholders

Communication patterns of the stakeholders in the collaboration networks were delineated through direct questions for each tie (Fig. 6 a, b, c).

The frequency of communication was comparatively low for weekly communication (6a). The respondents rely on sending letters as they perceive this to be a trusted source of information (6b), but it takes longer than expected for letters to arrive. Sri Lanka is currently facing its worst economic crisis and there is a shortage of printing paper, and the stakeholders are now encouraged to use email. There is comparatively low information transfer regarding funding (6c). A respondent from the Northern Province stated 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 a necessity that needed immediate attention.

Table 1

Mangrove management departments and corresponding jurisdictions in Sri Lanka.

Department	Jurisdiction for mangrove conservation
Forest Department (DF)	Forest (Amendment) Act, No. 65 of 2009: When mangroves are included in conservation/reserved forests, then whoever “removes the bark or leaves from any tree or strips the bark from any tree or cuts its branches or taps or burns any tree or otherwise damages it” can be punished.
Department of Coast Conservation and Coastal Resource Management (CC)	Coast Conservation Act, No. 57 of 1981: “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”. This includes mangroves within the coastal zone.
Department of Wildlife Conservation (DW)	Fauna and Flora Protection Ordinance (FFPO) (Amendment) Act, No. 22 of 2009: According to the three mangrove plant species are included in section 42 which summarizes the “list of plants that are protected” 1) <i>Nypa fruticans</i> 2) <i>Lumnitzera littorea</i> 3) <i>Ceriops decandra</i>
The Department of Fisheries and Aquatic Resources (FA)	Fisheries and Aquatic Resources Act of 1996: Fishery-managed areas can be declared with limited access to licensed operators which may include mangrove forests. “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)	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 fore-shore and the Coastal Zone of Sri Lanka and for matters connected therewith or incidental thereto”. The foreshore includes mangrove forests.
Central Environmental Authority (CE)	National Environmental Act of 1980 (No. 47 of 1980) Part II 10b: The Central Environmental Authority has the power “to 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”.

3.3. Content analysis of stakeholder perceptions on mangrove management

Content analysis carried out from interviews with governmental stakeholders led to the emergence of stakeholders' perceptions about roles and collaboration related to mangrove management, and to the identification of the main challenges. Major challenges related to mangrove management were a lack of collaboration between stakeholders, insufficient funding, and pollution. One of the major suggestions for improvement was to establish a common entity to manage mangroves. Stakeholders emphasized that mangroves are under threat in all provinces despite prevailing mangrove management policies (Refer to Table 6 in Appendix 4 for detailed perspectives).

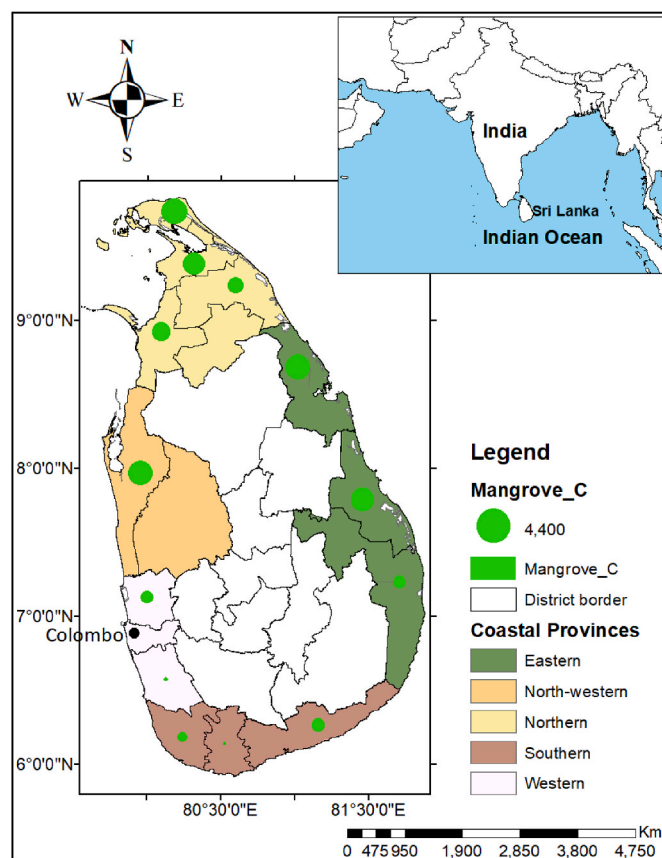


Fig. 3. Map of Sri Lanka indicating five coastal Provinces in colours. Green colour dots indicate the extent of mangrove forests in each district. Mangrove_C represents the mangrove cover and the dot in the legend represents 4400 ha of mangrove and the dot sizes in each district are proportional to the mangrove cover of the respective district.

Table 2

Stakeholders in mangrove management in Sri Lanka.

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), Bureau of the commissioner-general of rehabilitation (RA), National Aquatic Resource and Development Agency (NR), National Aquaculture Development Authority of Sri Lanka (NQ), Police Department (PD), Army, Navy, Special Task Force (AN), Developmental Agency/Organization (DA)
NGO	Sudeesa, World Vision (NG)
Private enterprises	Companies that work with mangrove stakeholders such as sanitary products and hoteliers (PE)
Universities	University of Jaffna, University of Peradeniya, University of Ruhuna, South Eastern University of Sri Lanka, Eastern University of Sri Lanka (UN)

4. Discussion

4.1. Mangrove management networks in different provinces of Sri Lanka

The mangrove management network density and centralization were higher in the Northern Province. Stable cohesive communities with fewer external connections tend to have dense networks (Oliveira and

Table 3
Network measures with descriptions used in SNA.

Network measure	Network measure description
Transitivity	Where two nodes are connected to a third node which increases the likelihood that those two nodes be connected to themselves, which can be explained as “the tendency for friends of friends to be friends and enemies of enemies to be enemies” (Carpenter et al., 2004; Hoff et al., 2002; Wasserman and Faust, 1994).
Density	It can be calculated by dividing the number of present ties to maximum number of possible ties and is used to evaluate the general level of cohesion in a network (Borgatti et al., 2018).
Centralization	Is the sum of the differences in centrality of the most central actor to all the others. It is used to indicate the solidarity of a particular actor in the center (Everett and Borgatti, 2005; Freeman, 1978).

Table 4
Degree of collaboration, score, and corresponding definitions.

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

Gama, 2012). According to the Small Fisher Federation of Sri Lanka, Seacology, and IUCN, the Northern Province is now recovering from the effects of civil war and mangrove management and conservation seem to be a key elements of post-conflict recovery (Peterson, 2020; Weerakoon et al., 2020). During the war period, landmines were laid in shallow lagoons (Dailedda, 2020), and part of the coastal forests was cleared and occupied by the Sri Lankan government security purposes (TOI, 2015). As part of post war rehabilitation, landmines are now being deployed. Most of the newly appointed officers are enthusiastic about conservation. A governmental stakeholder from the Northern Province stated, “Mangroves are the only type of forests we have; we need to conserve it for our future generation ...”. Moreover, the Northern Province was the only province in our survey where 95% of stakeholders communicated with each other in Tamil and had difficulties connecting with other higher authorities. They tried to resolve disputes within themselves rather than discussing with officers from Colombo, who generally spoke Sinhala. Addressing language gaps between and among the stakeholders is crucial for effective communication in environmental management (Djenontin and Meadow, 2018). This might also be a reason why the

Northern Province’s network is denser.

On the other hand, centralization is higher in a network when the ties of a given network are concentrated on a single actor or group of actors (Brass, 2003). In our study, centralization was also higher in the Northern Province. However, having a high centralization does not necessarily mean that the network is stable because “highly centralized networks may not be appropriate for governing social-ecological systems over time” (Bodin and Crona, 2009). Transitivity shows the probability to have adjacent nodes interconnected, and is higher in the North-western Province. This province has been identified as having successful mangrove restoration projects, as well as extensive aquaculture facilities (Kodikara et al., 2017). Mangroves have always been a topic of discussion among the North-western stakeholders. Thus, experience and input from the stakeholders of this province such as collaborating with international NGOs, providing incentives for the villagers for mangrove conservation, and consulting relevant departments before starting restoration projects (Kodikara et al., 2017) can be adopted and integrated into the mangrove management networks of other provinces.

4.2. Stakeholder diversity

Some stakeholders were not connected to the networks and were completely isolated; the Bureau of the Commissioner-General of Rehabilitation in the Northern and North-western Provinces, universities, Mahaweli Authority, the Irrigation Department, the National Aquaculture Development Authority of Sri Lanka, the National Aquatic Resource and Development Agency, the Police Department, the Land Use and Policy Planning Department, and the Bureau of the Commissioner-General of Rehabilitation in the Eastern Province, Mahaweli Authority in Southern and Western Provinces, and finally the Land Use and Policy Planning Department in the Western Province. As seen in our networks, the Bureau of the Commissioner General of Rehabilitation is only integrated into the Southern Province and not elsewhere. The mission of Bureau of the commissioner-General of Rehabilitation is the “Rehabilitation of misguided men, women, children adopting varying therapies in order to ensure effective Reintegration and Reconciliation, through developing Socio - Economic standards having identified their Rights and Cultural values” (BCGR, 2022). This department is not directly involved with mangrove management, but the manpower of rehabilitated persons was highly appreciated in the Southern Province for the mangrove replantation projects. This department may be included into mangrove management networks of other provinces that claim they do not have enough capacity specifically of volunteers to carry out mangrove replantation or restoration initiatives. This type of program might further help rehabilitated people integrate into society.

Mahaweli Authority of Sri Lanka is responsible for 900,000 acres of land in river catchments as it provides irrigation facilities in Sri Lanka (MAS, 2022). Even though there are no Mahaweli Authority-owned lands with mangroves in the coastal districts of the Northern Province, it was still included in mangrove networks of Northern Province. The inclusion of Mahaweli Authority in the Northern Province network may be because the mangrove management stakeholders in the Northern

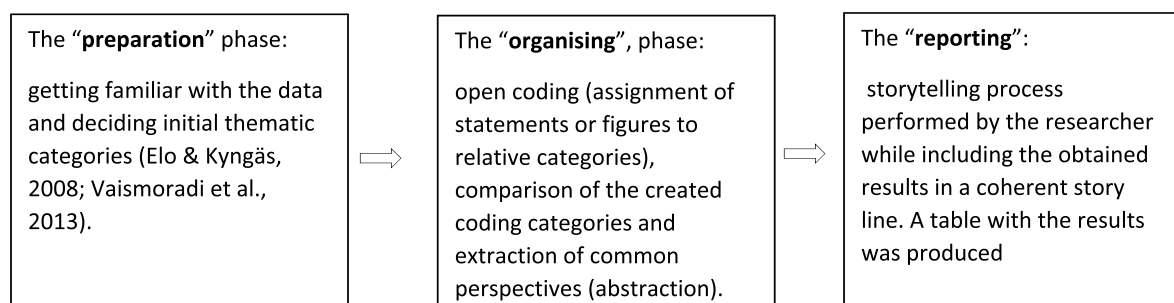
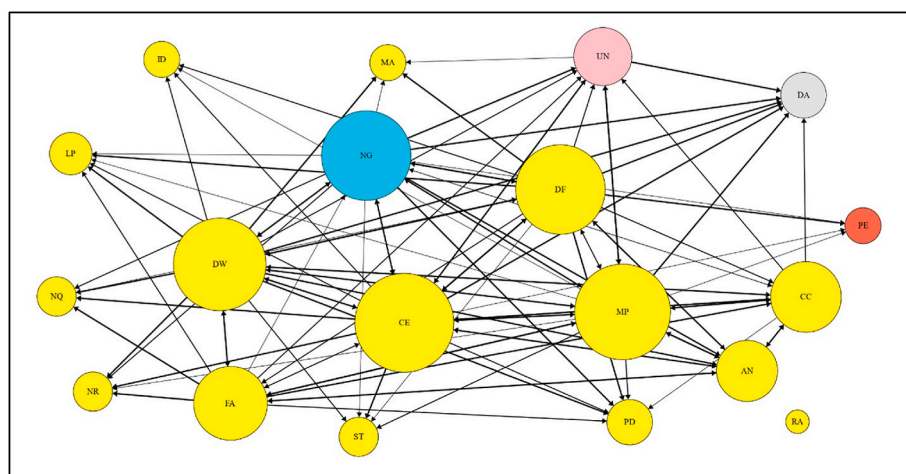
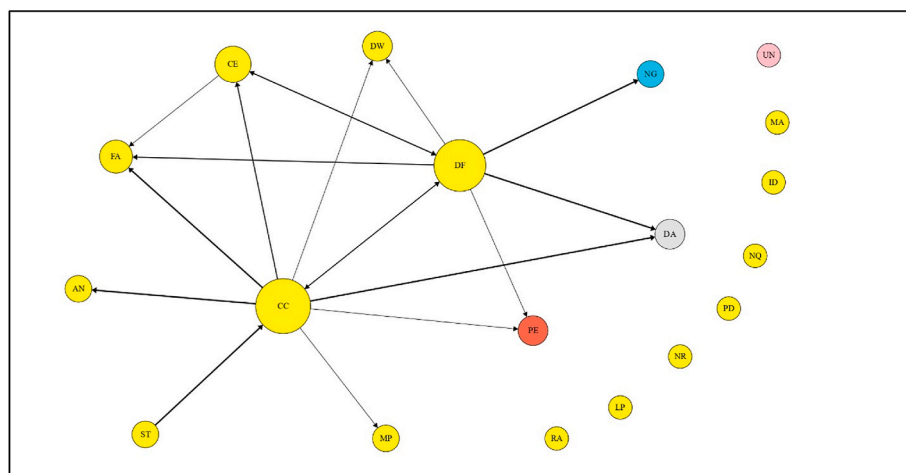


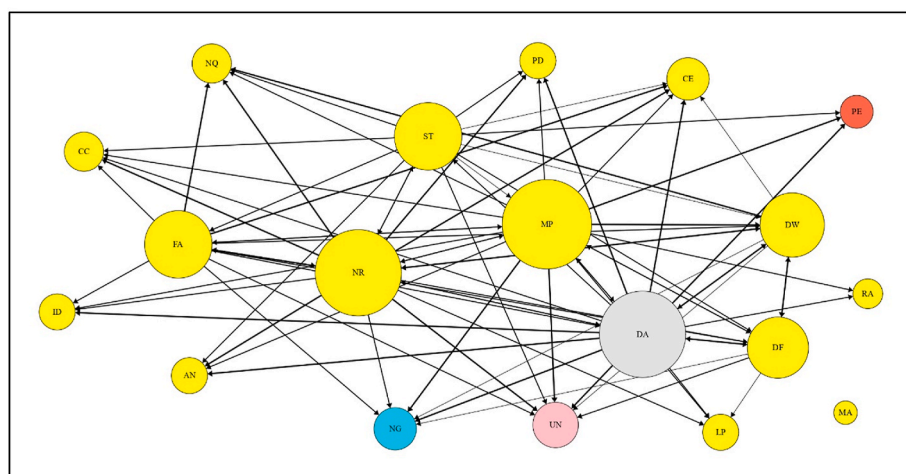
Fig. 4. Steps in content analysis.



a. Mangrove management stakeholder collaboration network of Northern Province of Sri Lanka

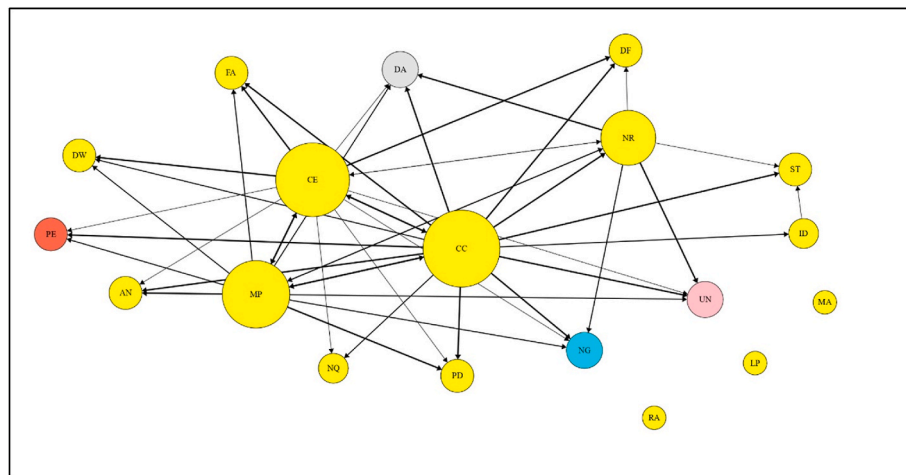


b. Mangrove management stakeholder collaboration network of Eastern Province of Sri Lanka

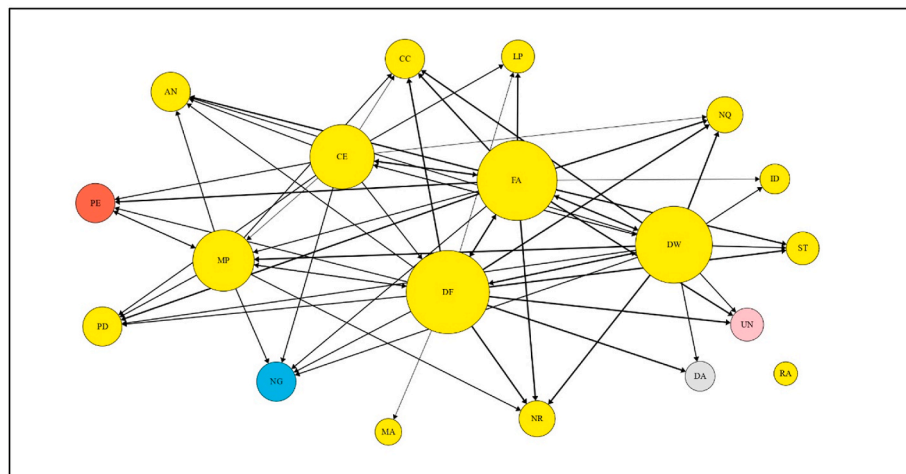


c. Mangrove management stakeholder collaboration network of Southern Province of Sri Lanka

Fig. 5. Networks showing relationships based on stakeholder collaboration in five coastal provinces of Sri Lanka (for stakeholder abbreviations refer to Table 2). The node size reflects “degree centrality”. The bigger the circle, the higher the degree centrality.⁸¹ The higher the degree centrality, the more central the node is.



d. Mangrove management stakeholder collaboration network of Western Province of Sri Lanka



e. Mangrove management stakeholder collaboration network of North-western Province of Sri Lanka

● Government Organization
 ● Non-Governmental Organization
 ● Developmental Organization
 ● Private Organization
 ● University

Fig. 5. (continued).

Table 5

Network-level measures in the collaboration network in the coastal provinces of Sri Lanka focusing on mangrove management.

Province	Density	Transitivity	Centralization
Northern	0.298	0.722	0.154
North-western	0.178	0.750	0.104
Eastern	0.064	0.425	0.108
Southern	0.065	0.426	0.109
Western	0.137	0.746	0.089

Province welcome the suggestions of the Mahaweli Authority. A stakeholder from the Northern Province recalled, “Mahaweli Authority is a very supportive organization, and they have sufficient maps and scientific data to share with mangrove managers”. In contrast, Mahaweli Authority is excluded from networks in the Southern and Eastern Provinces where there are Mahaweli Authority-owned land uses. The mission of the Mahaweli Authority is to “... use land and water for the innovative agriculture productivity based on the latest technology the supplementing the

generation of renewable energy, best environment and tourism for the enrichment of the Sri Lankan community and their living standards” (MAS, 2022). When mangrove forests in the river catchments extend beyond the jurisdiction of the Department of Coast Conservation and Coastal Management, they can be conserved by the Mahaweli Authority. Moreover, according to the objectives of Mahaweli Authority, the authority works closely with the Department of Census and Statistics, Department of Agriculture, Department of Irrigation, Central Environment Authority, and the Survey Department of Sri Lanka. Therefore, it would be useful if this department is included in the mangrove management networks of all provinces. Clarification of the land ownership of mangrove forests can be considered an important step to initiating conservation.

Mangrove forests in our study are found in the sea-land interface and along river margins and lagoons in both public and private lands. They need to be demarcated as private or public to continue conservation. Studies show that it is challenging to impose environment regulations on privately owned lands due to conflicts among landowners and the government (Brook et al., 2003). In Sri Lanka, certain mangrove patches are owned by local communities who have valid legal documents (which is called as “Oppuwa” in Sinhala) proving their ownership. Government

⁸ Degree centrality: the number of ties that a node has.

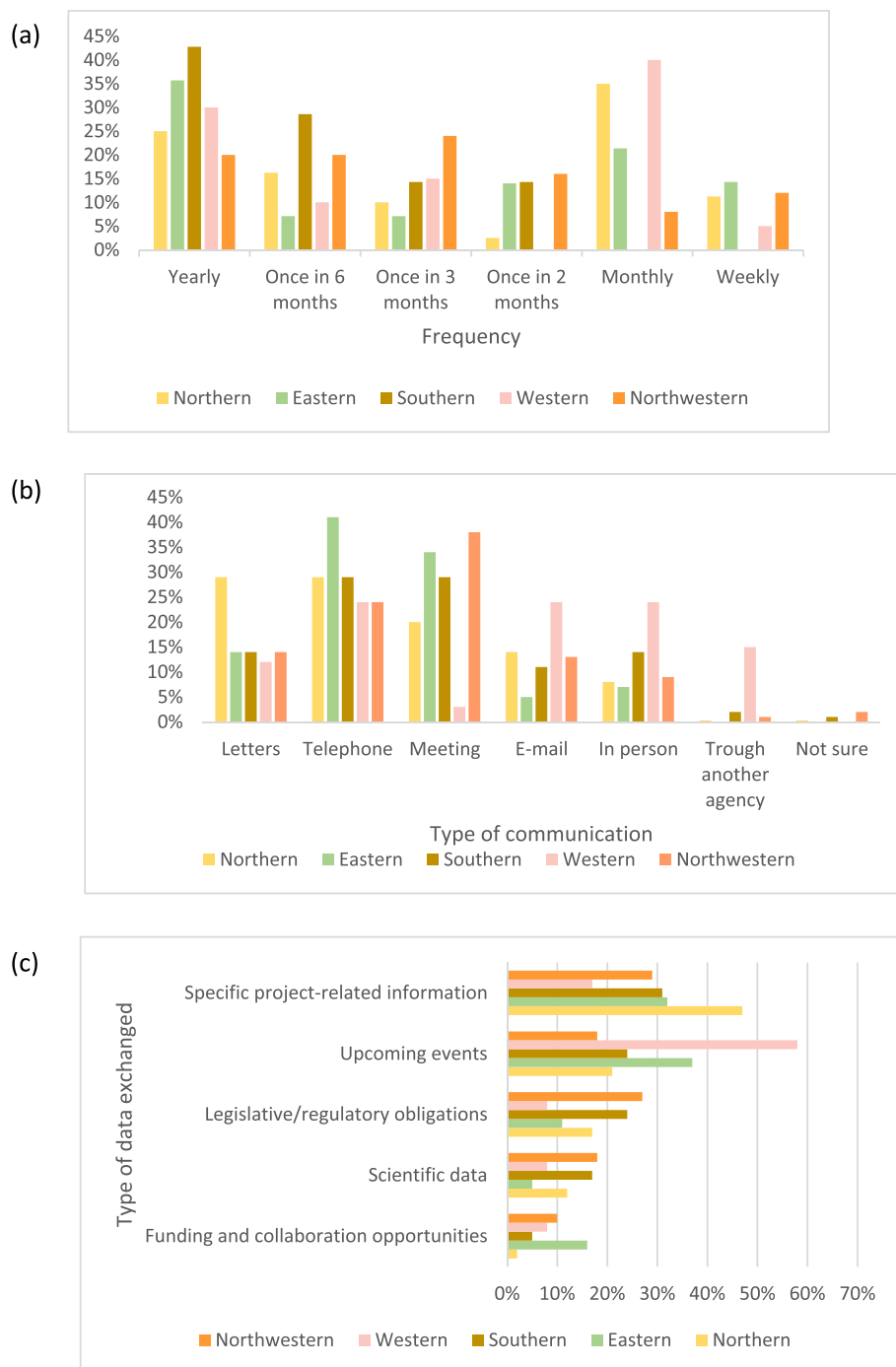


Fig. 6. Communication patterns of mangrove management stakeholders in the coastal provinces of Sri Lanka, (a) Communication frequency and the percentages regarding mangrove management between stakeholders, (b) Mode and percentage of communication between stakeholders regarding mangrove conservation, (c) Type of information exchanged between stakeholders and their percentage out of all shared information regarding mangrove conservation.

officers are often not allowed to enter these lands without prior permission. The mission of Land Use and Policy Planning Department is “*Formulation of policies, preparation of plans and facilitating their implementation to achieve the optimum utilization of land resources while maintaining sustainability and environmental balance*” (LUPPD, 2022). In the North-western and Western Provinces, Land Use and Policy Planning Department is not included in the networks. The Land Use and Policy Planning Department is currently carrying out land tenure and ownership surveys at divisional and district levels. Therefore, this department can be considered as an important addition to mangrove networks in all provinces.

Compared to all other provinces, the Eastern Province network did not include many departments. Mangroves in the Eastern Province have been comparatively neglected, despite making up 28% of the total mangrove area of Sri Lanka (Prasanna et al., 2019). University students in the Eastern Province can take up research questions from the stakeholders to work on their undergraduate or master's theses, which would enhance collaboration and reduce the issues related to funding as most university students are funded by the university, government grants, or self-funded.

It is still unclear why the National Aquatic Resource and Development Agency, the National Aquaculture Development Authority of Sri Lanka, and the Police Department are not included in the network of Eastern Province. The National Aquatic Resource and Development Agency is known as 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*” (NAQDA, 2022). The lack of infrastructure, staff, regional centers, and the need to cover a wide range of aquatic resources under its purview might be reasons the National Aquatic Resource and Development Agency is limiting its participation with mangrove management stakeholders in the Eastern Province. On the other hand, the National Aquaculture Development Authority of Sri Lanka is tasked with developing the aquaculture and inland fisheries sector in Sri Lanka. Aquaculture and fisheries are prominent in the Eastern Province, and the involvement of this department would provide guidance on how to maintain fisheries in mangroves without damaging the habitats.

4.3. Communication patterns between stakeholders

High reliance on mailing letters (through regular postal services) and telephone calls were observed in communication. 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 at our hands*”. This shows the need for swifter and reliable communication strategies. A majority of stakeholders contact each other regarding mangrove management yearly and do not share frequent connections, yet they attend stakeholder meetings in administrative offices.

According to the 1978 Constitution of Sri Lanka, provincial councils were established for each province, and additionally for each (coastal) district there are also district secretariat offices (“*kachcheri*” in Tamil and Sinhala) for administrative need. Even though there are regular stakeholder meetings at these offices, the continuous participation of the stakeholders was limited, and mangrove topics were mostly missing. We

suggest organizing provincial-level meetings in the coastal provinces at least every four months specifically to discuss mangrove-related matters so that all stakeholders can have a clear understanding of how other stakeholders perceive mangroves. Continuous engagement of stakeholders is an important factor to improve mangrove management (Huxham et al., 2015). Most of our respondents knew that mangrove management is mandated by jurisdiction. 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*”. Less than 15% of the information exchange was regarding funding and collaborative opportunities. Another government officer claimed that, “*Without sufficient funding, all project ideas vanish after a few meetings, and we are tired of such meetings ...*”. Insufficient financial assistance from the ministries related to environment management to carry out mangrove conservation is another important necessity requiring immediate attention.

4.4. Views of stakeholders regarding mangrove management

Almost all stakeholders emphasized that the replantation initiatives were mostly unsuccessful except for the North-western Province. In the North-western Province, an international NGO is mainly involved in mangrove restoration projects with the involvement of the local community and other government stakeholders. Such community involvement was not observed in other provinces. One prime reason for this is that the policies prevent the coastal communities to enter the mangroves, except for specific reasons such as fishing. Therefore, the coastal communities are no longer interested in working with the mangrove management stakeholders to conserve these forests unless high enough incentives are offered, and permanent job opportunities are provided. Although stakeholders' priorities on mangrove management vary, enhancement of ecotourism was consistently mentioned and could thus be better incorporated in all provinces in collaboration with Sri Lanka Tourism Development Authority.

4.5. Challenges related to mangrove conservation

Challenges related to mangrove management varied among provinces. Overall, lack of financial assistance, lack of awareness regarding the importance of mangroves among stakeholders and communities, poor collaboration and communication, encroachment, and issues related to land ownership were common major challenges hindering mangrove management in Sri Lanka. These challenges need to be considered when developing policies for mangrove conservation. Inconsistencies between mangrove management policies and the financial capacities of the government stakeholders responsible for the policy implementation were observed. This in turn created a dependence on private stakeholders or NGOs for funding mangrove management projects. Dependence on external funding further resulted in conflicts between governmental and private stakeholders regarding decision-making on project priorities such as site selection for mangrove plantation, species selection, and which communities need to be provided incentives for involvement. Moreover, mangrove ecosystems are an important source of blue carbon stocks. Damaged mangrove ecosystems have the potential to become sources of CO₂ and CH₄, both of which are green house gases (GHGs) (Vanderklift et al., 2019). When mangroves are conserved, protected, and restored in a sustainable way by certain

countries, in return those countries should be given benefits for their contribution to reducing GHGs. Such benefits may also be in the form of financial benefits through future international frameworks (Zimmer et al., 2022). Financial support to conserve mangroves would greatly benefit countries like Sri Lanka, which is currently in an economic crisis.

Mangrove restoration initiatives involving only government stakeholders mostly resulted in failure in most of the coastal provinces of Sri Lanka (Kodikara et al., 2017). Failure to fulfill the national mangrove policy objectives led stakeholders to show “fake restoration success” only focusing on the number of saplings planted and the area utilized without considering the sustainability of the projects. “Sometimes project managers showed pictures of old restoration sites as new/ongoing successful ones. We could find nothing but bare land when we actually visited the sites ...” a government stakeholder pointed out. An island-wide survey in Sri Lanka showed that there were numerous “ghost mangrove plantation sites” throughout the coastal provinces, and out of 1000–1200 ha of mangrove restoration land in Sri Lanka, only 200–220 ha were successfully completed mainly due to a lack of post-care and insufficient scientific input (Kodikara et al., 2017). Similar issues related to the mangrove conservation have been observed in countries like Thailand (Thompson, 2018), Vietnam (Orchard et al., 2015), the Philippines (Calicdan et al., 2016) and Bangladesh (Afroz et al., 2016). However, insufficient funding usually hinders the enactment of state policies (Blaikie and Muldavin, 2014). Additionally in the Northern Province specifically, the language barrier is a prevalent issue that is preventing stakeholders from freely connecting with head offices. Trained translators and interpreters can be either recruited or language courses can be promoted to solve this issue to foster collaboration.

4.6. The current Sri Lankan situation: fuel and energy crisis and mangrove management

According to the International Monetary Fund (IMF), in Sri Lanka “due to the pre-pandemic tax cuts, weak revenue performance in the wake of the pandemic, and expenditure measures to combat the pandemic, annual fiscal deficits exceeded 10 percent of GDP in 2020 and 2021. Public debt is projected to have risen from 94 percent of GDP in 2019 to 119 percent of GDP in 2021” (The Island, 2022). Sri Lanka is currently facing domestic political pressure due to the soaring economic and financial crisis. The Sri Lankan rupee fell sharply against the dollar and the Central Bank of Sri Lanka has announced a shortage of foreign currency. Further, there is a shortage of gas for cooking. The fuel shortages have resulted in a major energy crisis, with power cuts extending up to 12 h per day (Wolf, 2022). These changes in the economy might compel the community that once stopped using mangrove firewood to start encroaching on these forests again. “There are hundreds of people waiting in long queues for gas for days. The community has started to overexploit the coastal forests now. Most of the people are changing back to wood stoves and we have no control over secret encroachment now” (Government respondent, Eastern Province). In such situations we propose stakeholder meetings to be arranged to discuss establishing buffer zones where communities adjacent to mangroves can utilize mangrove goods and services at sustainable levels.

4.7. Policy implications

Mangrove management around the world has always been challenging due to the involvement of multiple stakeholders (Golebie et al., 2022). Even though there are case studies using SNA in mangrove

research around the world, this type of study at the scale of an entire country is rare. Such nationwide studies would give a clear understanding of how the different stakeholders in various parts of the country perceive the same regulations or management of the central government. SNA in policy research is not widely used in Asia (Zhang et al., 2021). No studies including SNA in environmental policy research have been carried out in Sri Lanka to the best of our knowledge. In Sri Lanka, there is a wide disparity between provinces in terms of political climates after the end of the civil war in 2009. According to our results, 25 mangrove stakeholders are not equally connected to mangrove management networks in Sri Lanka in all coastal provinces. These differences in the number of stakeholders and extent of connection with mangrove management networks of their respective provinces can be approached in at least three ways. First, it can simply mean that there is no actual need for all stakeholders to become connected with a mangrove management network if mangroves are already being conserved by central stakeholders in a province. Second, stakeholders who do not have jurisdiction over mangroves are not contacted by other mangrove stakeholders to become involved in mangrove management. Finally, when stakeholders realise that mangroves are fully conserved by jurisdiction, then certain stakeholders limit their involvement or refrain from connecting with the mangrove management network.

In our study, the mangrove network in the Eastern Province seems to have excluded many stakeholders compared to other provinces. Soon after the tsunami in 2004, government stakeholders appear to have reoriented themselves toward the development of infrastructure rather than mangrove conservation (Dahdouh-Guebas et al., 2021). Studies further show that the eastern shoreline (Ampara District) is eroding at an alarming rate and needs immediate conservation (Nijamir et al., 2022). Mangroves have the ability to minimize coastal erosion. Nevertheless, mangrove replantation initiatives after the tsunami in 2004 failed on the eastern coast (Kodikara et al., 2017). Stakeholders such as the National Aquatic Resource and Development Agency and the National Aquaculture Development Authority seem to have insufficient funding and staffing to fully involve in the mangrove management network in the Eastern Province. However, when given the legal authority and funding to conserve mangroves, previously mentioned stakeholders can become advocates of policy proposals regarding mangrove management in the Eastern Province and beyond. The current statutes and mangrove management regulations in Sri Lanka may be imposing duplicative requirements on stakeholders. For example, the Department of Fisheries and Aquatic Resources and the National Aquaculture Development Authority are both involved in fishery-related activities in mangrove areas. Conservation of the same mangrove area by two stakeholders would be more efficient if these two stakeholders are connected with each other. Furthermore, mangrove management networks can be audited by central actors such as the Central Environmental Authority to assess the performance of networks. Baseline data from our study can be incorporated into policy planning, ultimately leading to the effective conservation of mangroves in Sri Lanka.

4.8. Improvements to be made for better mangrove conservation

Stakeholders of all provinces of our study recommend establishing one ministry or department that deals with mangrove conservation. This is not always possible because the legal provisions for each department regarding mangrove management are mostly inflexible. Another common opinion was to improve collaboration among stakeholders

regarding mangrove management. Instead of establishing a single department, online platforms (e.g., websites, databases) can be built where all stakeholders would have an opportunity to share their ideas and create awareness programs for the community. Furthermore, online discussion sites (e-forums) can be established, where stakeholders can hold conversations and exchange ideas. Such e-forums can be managed by an organization with a high degree centralization (e.g., Central Environmental Authority) and the capacity to act as a bridging entity for all stakeholders involved. In addition to the mangrove management stakeholders, the active participation of coastal communities is necessary to identify goals and objectives to implement sustainable mangrove management policies and projects. To shift the passive participation of communities to active participation, strong collaborations should be made with other mangrove management stakeholders. As an initial step, communities can negotiate mangrove management problems with the village councils/“*Grama Niladhari*” who are frontline government officers. Village council heads can then pass inputs from communities to a bridging organization, which can then be posted onto an e-forum where all mangrove management stakeholders can participate. Moreover, creating awareness regarding mangrove conservation has long been considered important to the stakeholders and the coastal community of Sri Lanka (Kodikara et al., 2017; Satyanarayana et al., 2013), and can be achieved with the involvement of state universities in the coastal provinces.

5. Conclusion

This study mapped existing stakeholder collaboration and allowed us to identify the diversity of mangrove co-management practices in Sri Lanka. Policy design and implementation needs to consider the diversity of stakeholders and should be flexible enough to include all relevant stakeholders. In our study, there are differences between provinces in the number and degree of mangrove stakeholder collaboration, and it is difficult to propose a common framework that would fit all provinces. The government should consider the establishment of common forums or online platforms to discuss mangrove-related issues and enhancement of communication pathways should be considered as a priority in mangrove management. Furthermore, when developing mangrove management projects, consideration should be given to the prevailing economic situation of the country and how this would affect stakeholders' capacities and collaboration. Such measures can help mangrove

management stakeholders overcome long-standing stakeholder and institutional challenges that have hampered the effectiveness of mangrove management policy and practice in the past. Inferences from this study can be used to develop better mangrove management initiatives in Sri Lanka and beyond.

Credit author statement

T.W.G.F. Mafaziya Nijamdeen: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review and editing, Funding acquisition. **Jean Hugé:** Conceptualization, Methodology, Writing-Review, and editing, Supervision. **Hajaniaina A. Ratsimbazafy:** Conceptualization, Methodology, Writing-Review, and editing, Formal analysis, Supervision. **Kodikara Arachchilage Sunanda Kodikara:** Conceptualization, Methodology, Writing-Review, and editing, Supervision. **T.W.G.F. Ashara, Nijamdeen:** Methodology, Writing-Review, and editing. **Thahira Thajudeen:** Methodology, Writing-Review, and editing. **Sofia Peruzzo:** Methodology, Writing-Review, and editing, Funding acquisition. **Farid Dahdouh-Guebas:** Conceptualization, Methodology, Writing-Review, and editing, Supervision.

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.

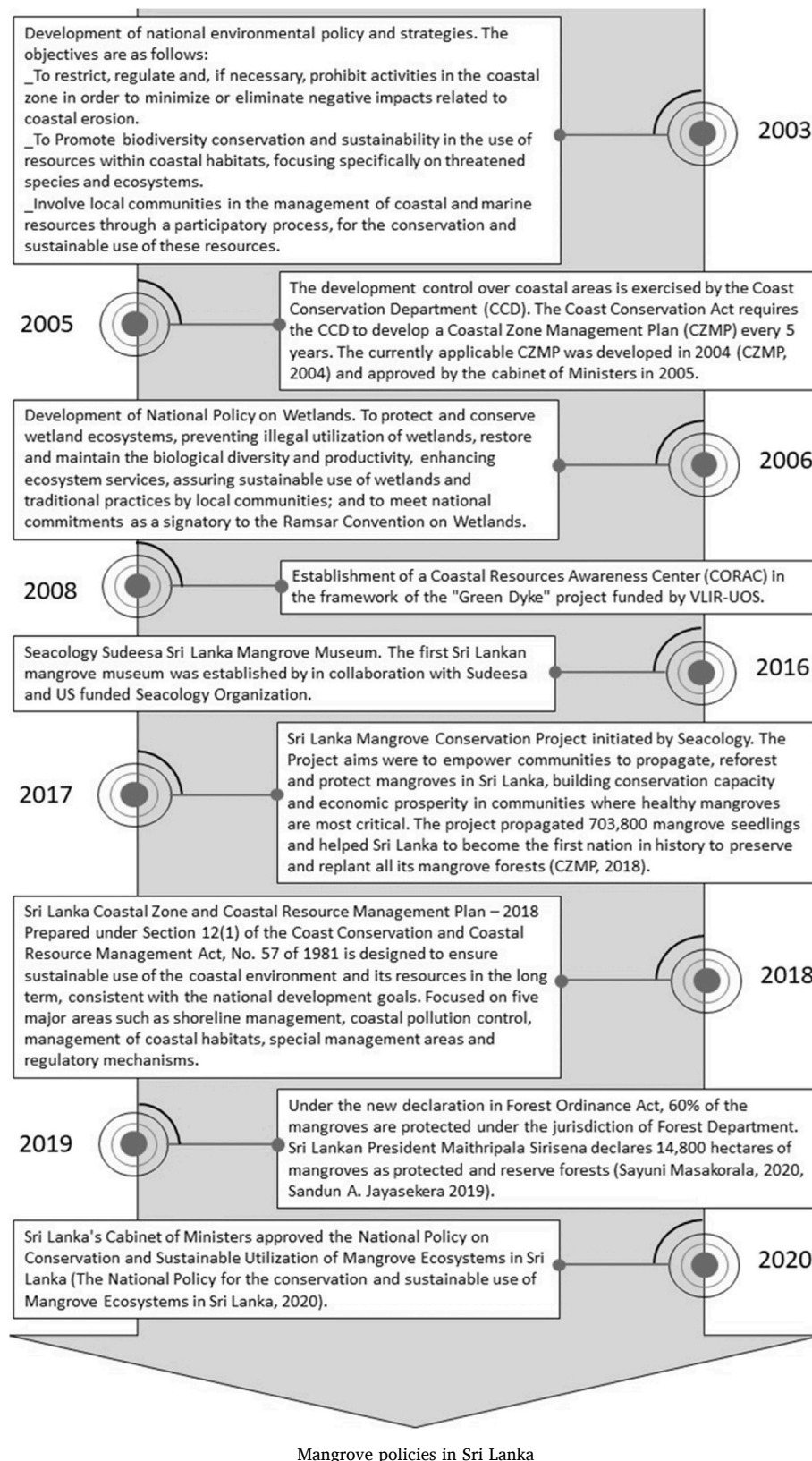
Data availability

Data will be made available on request.

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Appendix 1. : Mangrove Policies in Sri Lanka



Appendix 2

Preliminary Questionnaire

The preliminary questionnaire consisted of four steps to identify as many stakeholders as possible to be included in the list (which was then used for the Social Network Analysis. Initially the heads of departments (Table 1) were contacted in five coastal provinces and asked for suitable respondents who are working on and most experienced with mangrove management. Those respondents as recommended by the heads were selected for the preliminary questionnaire. In the first step, respondents recalled possible mangrove management stakeholders in Sri Lanka. Whereas in the second step, they listed other possible stakeholders with whom they are working/worked regarding mangrove management. In the third step, a list of prospective stakeholders involved in mangrove conservation was prepared by the research team, using the details given by the stakeholders in the previous two steps. In the final step, they were asked to include any other additional stakeholders that might not have been listed in the previous stages. Finally, nineteen stakeholders (Table 2) related to mangrove management in Sri Lanka were identified.

Step 01:

What are the different organizations/departments/agencies you think are related to the conservation of mangroves in Sri Lanka?

Step 02:

What are the different organizations/departments/agencies you think are related to the conservation of mangroves apart from the following? (e.g.: DF, DWC, CEA) With which organizations have you worked with/working together in mangrove conservation.

Step 03:

Stakeholders from the previous two rounds compiled.

Step 04:

Stakeholders were asked whether they can think of any other department/organization that might not have been listed in the first two rounds related to mangrove conservation and add to the list.

Appendix 03. SNA Questionnaire

Co-management of mangroves in Sri Lanka

In the first part of the SNA questionnaire, the list of 19 stakeholders from the stakeholder identification survey was shown and each respondent was asked to add additional stakeholders according to their experience. Once they fully identified the mangrove management stakeholders, they were asked to rate their relationship based on stakeholder collaboration.

Part 1. Collaboration

What are the different organizations/departments/agencies you think are related to the conservation of mangroves. Underline the organizations which you think are related to mangrove conservation.

1. Department of Forest (DF)
2. Irrigation Department (ID)
3. Central Environmental Authority (CEA)
4. Department of Wildlife Conservation (DWC)
5. Department of Fisheries and Aquatic Resources (DFAR)
6. Marine Environment Protection Authority (MEPA)
7. Coast Conservation and coastal resource management Department
8. Land use and Policy Planning Department
9. Mahaweli Authority of Sri Lanka
10. Sri Lanka Tourism Development Authority
11. Rehabilitation Development Authority
12. National Aquatic Resource and Development Agency (NARA)
13. National Aquaculture Development Authority of Sri Lanka (NAQDA)
14. Police Department *
15. Army, Navy, Special Task Force
16. Non-Governmental Organizations
17. Development agencies
18. University
19. Private enterprise

Please refer to the scoring guide and fill the table.

Scoring Guide

Collaboration						
Do you collaborate with this organization?						
By collaboration, we mean working together to implement a shared project or programming, coordinate activities or services, share resources, etc. regarding mangrove conservation						
3. Yes, currently						
We are currently collaborating with this organization/department regarding mangrove conservation						
2. Yes, in the past and would do so again						
We have collaborated with this organization/department regarding mangrove conservation, and we would collaborate with them again if given the opportunity						
1. Yes, in the past but not likely again						
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.						
0. Not at all We have not collaborated with this organization/department regarding mangrove conservation						
Name of the Agency			Collaboration			
1. Department of Forest						
2. Irrigation Department						
3. Central Environmental Authority						
4. Department of Wildlife Conservation (DWC)						
5. Department of Fisheries and Aquatic Resources (DFAR)						
6. Marine Environment Protection Authority (MEPA)						
7. Coast Conservation and coastal resource management Department						
8. Land use and Policy Planning Department						
9. Mahaweli Authority of Sri Lanka						
10. Sri Lanka Tourism Development Authority						
11. Rehabilitation Development Authority						
12. National Aquatic Resource and Development Agency (NARA)						
13. National Aquaculture Development Authority of Sri Lanka (NAQDA)						
14. Police Department *						
15. Army/Navy/STF						
16. Non-Governmental Organizations						
17. Development agencies						
18. University						
19. Private enterprise						
		Type of agency				
Scale	Development Agency		NGO	Government agency	University	Private enterprise
International						
National						
Provincial						
Local						

Specific details regarding the type of relationship.

Question No	Question	Method	Type of relation	Details
Q1	Information regarding the position: Duration, Previous employment,	–	–	
Q2	What is the role of your department regarding mangrove conservation in your district	Recognition	–	
Q3	With which department can you discuss important matters regarding coastal conservation?	Recall	Support	
Q4	If you noticed changes in the natural environment (the condition of the mangrove forest), with which department would you discuss?	Recall	Information or knowledge exchange	
Q5	Is there any Department you depend, or depends on yours, to carry out your (their) tasks related to mangrove conservation? (Y/N) If yes, name the departments	Recall	Dependency	
Q6	Do you ever send/receive money to other departments related to mangrove/coastal conservation? If yes, name the department/s	Recall	Financial exchange	
Q7	Have you ever encountered a dispute with any department related to Mangrove conservation? Specify why and with which department.	Recall	Conflict resolution	
Q8	If you see that someone is breaking the law (within the area of your control regarding mangroves) do you tell some other department? (Apart from the Police) If so, who?	Recall	Conflict resolution	

Information, communication, resource transfers, and joint activities (During last year).

1. Frequency
 - a. Yearly
 - b. Monthly
 - c. Weekly
 - d. Daily
 - e. Only when needed
2. Method
 - a. Emails

- b. Meetings
 - c. Joint activities
 - d. Collaborative projects
 - e. Negotiations as part of economic activities (trade.)
 - f. Telephone Calls
 - g. Meeting in person (Direct contact)
 - h. Letters
 - i. Not Sure
 - j. Through another Agency
3. Type of information exchanged
- a. Scientific data,
 - b. Legislation, legislative/regulatory obligations
 - c. Funding & collaboration opportunities
 - d. Specific project-related information
 - e. Upcoming events, etc.

Part 2. Open-ended question

1. What are the challenges for your organization regarding mangrove management?
2. What could slow down (the information flow of) some of the ties in the mangrove management network?
3. What could enhance (the information flow of) some of the ties in the mangrove management network?
4. Are you satisfied with the current flow of information through the mangrove management network as it is now?
5. How did the COVID 19 situation affect mangrove conservation?
6. How did the tsunami/war situation affected the mangrove conservation?
7. Who are the most authoritative actors and explain how power (power explanation) is distributed throughout the network.
8. What are your suggestions/perceptions to improve the prevailing mangrove management network
9. How do you expect the stakeholders to be connected in future mangrove management networks
10. What is a perfect mangrove management network according to you?

Appendix 04. Stakeholder perspectives on mangrove management

Table 6

Mangrove management stakeholders' perspectives regarding challenges, suggestions for improvement and mangrove related specific information for each coastal Province of Sri Lanka

	Category 1 Challenges related to mangrove conservation	Category 2 Improvements to be made for better conservation	Category 3 Mangroves-related information and priorities
Northern Province	<ul style="list-style-type: none"> - Problems in coordination among different departments, political influence - Language barriers between Sinhala and Tamil officers, lack of manpower - Officers missing during stakeholders' meetings - Failure of replantation projects because of wrong guidelines - Power unevenly distributed among departments and ranks - Low priority given to mangroves-related projects - Lack of environmental data - Low community environmental awareness - Lack of funding 	<ul style="list-style-type: none"> - Establishment of one ministry to incorporate all environmental-related departments, - Implement workshops and meetings with higher frequency for the stakeholders to enhance communication and collaboration - To increase departments and community awareness - To introduce environmental research projects - To improve technical communication means - To recruit district officers instead of officers coming from the capital (Colombo) 	<ul style="list-style-type: none"> - Mangroves were widely cleared during the civil war - Several replantation projects have been implemented but were only partially effective - Establishment of sanctuaries within mangroves has been suggested - Projects for building touristic hotels in the mangroves have also been proposed and temporarily paused due to a debate regarding the environmental concern
North-western Province	<ul style="list-style-type: none"> - Weak collaborations among departments, - Lack of funds - Lack of manpower - Inefficient and antique communication tools (especially letters) - Land demarcation issues between government and private land - Low financial assistance - Citizens often move land demarcation stones installed by the officers - Cutting mangroves for aquaculture, and encroachment, especially for saltern, prawn farms - mangroves are clearance by the fishermen to create temporary shelters from the sun - Pollution of the lagoons with untreated water - Illegal poaching - Increased urbanization 	<ul style="list-style-type: none"> - Implementation of more advanced technology for communication - Establishment of a common department - More facilities, staff, and infrastructures combined with more focused projects and with the development of sustainable tourism - Improve community engagement by increasing incentives 	<ul style="list-style-type: none"> - Most Mangrove replantation projects were successful - There was considerable community participation in mangrove replantation - Juvenile prawns were released in the lagoons as an incentive for fishermen to avoid cutting mangroves - Fishermen were left free to harvest the prawns and the project had a successful outcome to prevent mangroves from being cleared
Eastern Province	<ul style="list-style-type: none"> - Inexperience of officers and inequality in departments' power, and conflicts between officers - Lack of funding for mangrove conservation. - Mangrove cutting, clearing, and encroachment - Conversion of mangroves to other land uses - Illegal fishing activities (such as brush pile fishing and beach seines) - Coastal pollution 	<ul style="list-style-type: none"> - Meeting with mangrove stakeholders in a higher frequency - Enhancing collaboration and understanding among departments - Increasing the speed of information flow - Reduce coastal pollution - Unifying all stakeholders under one ministry 	<ul style="list-style-type: none"> - Mangroves were heavily affected by the civil war and by the 2004 tsunami - Most restoration projects failed - The officers recognized the profound - Mangroves are very important for the provision of ground for fish reproduction in lagoons, where the fishermen procure their catch during the off-season, and the extraction of dyes for fishnets

(continued on next page)

Table 6 (continued)

	Category 1 Challenges related to mangrove conservation	Category 2 Improvements to be made for better conservation	Category 3 Mangroves-related information and priorities
Southern Province	<ul style="list-style-type: none"> - Land and water pollution - Poor waste management - Encroachment - Lack of collaboration - Insufficient funding - Political influence - Poor methods of communication (i.e., letters) - Difficulties in gazetting as part of mangrove forests is located within private lands 	<ul style="list-style-type: none"> - Amending acts and rules that can be followed by all - Improve technology for communication - Have one department that interconnects all the others - Improving waste recycling and alternative usage of waste 	<ul style="list-style-type: none"> - Ecotourism projects are proposed to improve mangrove ecosystems by many departments - Mangroves are mostly cut to build hotel facilities - Some replantation projects were not effective, partly due to the lack of awareness of farmers that let the animals eat mangrove seedlings
Western Province	<ul style="list-style-type: none"> - Coastal Pollution - Encroachment - Lack of awareness about the importance of mangroves among coastal communities and stakeholders - Not enough funding 	<ul style="list-style-type: none"> - Improving more communication and collaborative work among stakeholders - Improving skills of persons involved in mangrove restoration projects and one - Separate unit only dedicated for mangroves 	<ul style="list-style-type: none"> - Mangrove lands are often converted to other land uses or illegal dumpsites or burned - Ecotourism projects are now being proposed on mangrove lands

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