Forest Policy and Economics 164 (2024) 103236

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

# Stakeholder perceptions in mangrove management in the Jaffna Peninsula, Sri Lanka

Thanne Walawwe Gedera Fathima Mafaziya Nijamdeen [a,b,c,1,*], Sofia Peruzzo [a,1], Kodikara Arachchilage Sunanda Kodikara [d], Hajaniaina Andrianavalonarivo Ratsimbazafy [a,e], Thenne Walawe Gedhara Fathima Ashara Nijamdeen [f], Thajudeen Thahira [g,h], Thasajini Sajeevan [b,i], Deluxeani Kugathasan [j,k], Jean Hugé [a,c,l,m,2], Farid Dahdouh-Guebas [a,l,n,o,2]

[a] Systems Ecology and Resource Management Research Unit, Department of Biology of Organisms, Université Libre de Bruxelles – ULB, Av. F.D. Roosevelt 50, Cpi 264/1, 1050 Brussels, Belgium
[b] Department of Biological Science, Faculty of Applied Science, South Eastern University of Sri Lanka, Sammanthurei, Sri Lanka
[c] Open University of the Netherlands, Valkenburgerweg 177, Heerlen 6419AT, the Netherlands
[d] Department of Botany, University of Ruhuna, Wellamadama, Matara, Sri Lanka
[e] Institut Halieutiques et des Sciences Marines, Université de Tuléar, Madagascar
[f] Faculty of Agriculture, University of Bonn, Bonn, Germany
[g] Department of Biosciences, COMSATS University, Islamabad, Pakistan
[h] Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka
[i] University of Pavia, Italy
[j] Department of Botany, Faculty of Science, University of Jaffna, Sri Lanka
[k] Postgraduate Institute of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka
[l] Ecology & Biodiversity, Laboratory of Plant Biology and Nature Management, Biology Department, Vrije Universiteit Brussel – VUB, Pleinlaan 2, VUB-APNA-WE, 1050 Brussels, Belgium
[m] Centre for Environmental Science, Hasselt University, Hasselt BE3500, Belgium
[n] MangroveSpecialist Group (MSG), Species Survival Commission (SSC), International Union for the Conservation of Nature (IUCN), Zoological Society of London, London, UK
[o] Interfaculty Institute of Social-Ecological Transitions, Université Libre de Bruxelles - ULB, Av. F.D. Roosevelt 50, CPi 264/1, Brussels 1050, Belgium

ARTICLE INFO

*Keywords:*
Conservation discourse
Forest conservation
Indian Ocean
Resource utilization
Wetlands

ABSTRACT

Mangroves are recognised as social-ecological systems where ecological dimensions constantly interact with human dimensions. In the Jaffna Peninsula of Sri Lanka, mangroves constitute the primary forest type. However, a destructive civil war spanning over 25 years, heavily affected the local vegetation and local inhabitants. Large patches of mangrove forests were damaged and remained inaccessible for a considerable time, compelling most of the population to temporarily abandon their land. This study aimed to investigate the main mangrove goods and services that the local population benefits from and gather opinions of mangrove management stakeholders regarding mangrove conservation in the Jaffna Peninsula through a mixed methods approach. Ethnobiological surveys were conducted with coastal communities, along with Q methodology, expert opinion surveys and additional semi-structured interviews with mangrove management stakeholders. Ethnobiological surveys revealed a significant distancing of local communities from mangrove goods and services. The Q methodology identified three discourses: community-oriented, government-oriented, and mangrove conservation oriented. Expert opinion surveys highlighted encroachment and pollution as major threats to mangroves. Issues raised in the semi structured interviews include challenges regarding land ownership permits during and after the war, weak interactions among different stakeholders with overlapping jurisdiction, failed replantation efforts and scarcity of scientific data for mangrove management. Addressing these issues is crucial not only for fostering

* Corresponding author at: Systems Ecology and Resource Management Research Unit (SERM), Department of Organism Biology, Université Libre de Bruxelles - ULB, Av. F.D. Roosevelt 50, CPi 264/1, Brussels, 1050, Belgium.
*E-mail address:* fathima.mafaziyanijamdeen@ou.nl (T.W.G.F.M. Nijamdeen).
[1] Co-first authors.
[2] Co-last authors.

https://doi.org/10.1016/j.forpol.2024.103236
Received 1 November 2022; Received in revised form 12 March 2024; Accepted 22 April 2024
Available online 13 May 2024

effective mangrove management and conservation in the Jaffna Peninsula but also for potentially benefiting other districts in Sri Lanka and beyond.

## 1. Introduction

Mangroves are plants that thrive in tropical, subtropical, and warm temperate latitudes along the intertidal land–sea interface. These plants along with their associated organisms and abiotic factors constitute the 'mangrove ecosystem' (Dahdouh-Guebas et al., 2021). Mangrove ecosystems significantly contribute to the livelihoods of local communities in numerous tropical and subtropical countries (Feller et al., 2010; Kodikara et al., 2017; Dahdouh-Guebas et al., 2021; Spalding and Leal, 2021). Therefore, these ecosystems can be considered as 'social-ecological systems', in which the ecological dimension is interlinked with the human (social and economic dimensions) (Santos et al., 2017; Dahdouh-Guebas et al., 2021).

In addition to playing crucial ecological roles worldwide, such as carbon sequestration and habitat provision for a multitude of species, mangroves provide a variety of goods, services, and functions to the population living within or in proximity to these ecosystems. Goods, services, and functions are material assets and non-material benefits that mangrove ecosystems directly or indirectly bring to human populations, such as wood, fishery products, shoreline protection and beyond. (Walters et al., 2008; Feller et al., 2010; Lee et al., 2014; Díaz et al., 2018; Dahdouh-Guebas et al., 2021). Mangrove ecosystems globally face threats from various anthropogenic factors, endangering the livelihoods of millions of people that depend on or benefit from them (Walters et al., 2008; Feller et al., 2010; Vande Velde et al., 2019). Major threats to mangroves degradation include climate change, over-harvesting, aquaculture activities, urbanisation, and coastal development (Walters et al., 2008; Vande Velde et al., 2019; Spalding and Leal, 2021).

Due to its troubled past, the Jaffna Peninsula in Sri Lanka has never been a focal point for ethnobiological research regarding the utilisation of mangrove goods and services. Indeed, in this region, mangrove ecosystems and communities have been affected by a civil war that lasted 25 years and concluded in 2009. The war inflicted severe damage on mangrove forests, prompting many families to temporarily abandon their homes and led to the establishment of inaccessible "*high-security zones*" (HSZ), on both land and in marine fishing areas (Soosai Siluvaithasan and Stokke, 2006; Suthakar and Bui, 2008; Dahdouh-Guebas et al., 2021). After 2009 mangrove restoration initiatives began to take place in the Northern province as well as in other coastal provinces of Sri Lanka. Furthermore, as noted by Kodikara et al. (2017), mangrove restoration projects in Sri Lanka often failed to succeed due to a lack of collaboration and insufficient communication among the different departments that cover mangrove jurisdiction, which brought us to further investigate this aspect with mangrove management stakeholders.

The literature lacks studies that approach Jaffna's mangrove ecosystem as a social-ecological system, and mangrove conservation efforts in this area have never been reported until present. Therefore, the overall aim of this study is to gain insights into conservation improvements of the mangrove social-ecological system in the Jaffna Peninsula, considering the perspectives of a multitude of stakeholders. To do so, our objectives are:

- to assess the main mangrove goods, services, and functions that the local population benefits from;
- to investigate the perception of the mangrove management stakeholders regarding mangrove ecosystems;
- to gather experts' experiences and opinions about mangrove management and conservation, assessing main issues and possible solutions.

## 2. Material and methods

### 2.1. Study site

#### 2.1.1. Jaffna Peninsula

Jaffna Peninsula, situated in the extreme north of Sri Lanka, is a district[3] of the Northern province of Sri Lanka, between the longitude of 079°54′-080°2′ E and latitude of 09°30′-09°50′ N. Covering an area of approximately 1126 $km^2$ with 160 km of coastline and encompasses three inland lagoons, collectively forming an inland lagoon system covering more than 100$km^2$ (Suthakar and Bui, 2008; Janen and Sivakumar, 2014; Gunaalan et al., 2018). Jaffna Peninsula is characterised by a dry tropical climate, with annual rainfall between 1204 and 1325 mm, 90% of which occurs between October and December, and an average temperature of 25–30° throughout the year (Suthakar and Bui, 2008; Gunaalan et al., 2018). Given the scarcity of consistent rivers and the presence of shallow limestone soils, underground water serves as the main source of freshwater for the local population and agricultural irrigation purposes in Jaffna Peninsula (Suthakar and Bui, 2008; Gunaalan et al., 2018). The aftermath of civil war significantly impacted the landscape of the Jaffna Peninsula. Damages to saltwater protection bunds, and extensive deforestation, including mangrove forests, exacerbated soil salinity levels in the study site (Suthakar and Bui, 2008).

#### 2.1.2. The Sri Lankan civil war

The Sri Lankan civil war is an armed conflict that unfolded between the LTTE (Liberation Tigers of Tamil Eelam) and the Sri Lankan Government (Soosai Siluvaithasan and Stokke, 2006; Samarathunga et al., 2020). Primarily impacting the Northern and Eastern provinces of Sri Lanka, where most of the Tamil population resided, the conflict arose from a longstanding history of social, political and religious inequality and misrepresentation of the Tamil minority (Ganguly, 2018; Samarathunga et al., 2020). The conflict started in 1983 and lasted almost three decades, during which several violent episodes occurred on both sides (Samarathunga et al., 2020). Throughout this period, a significant portion of the population faced forced relocation, with over 800,000 individuals displaced, and only part of it moved back to their original homes (UNHCR, 2003). The civil war reached its conclusion in 2009 (Ganguly, 2018).

#### 2.1.3. Mangroves in Jaffna Peninsula

In Sri Lanka, there are at least 20 mangrove species classified as true mangroves and 18 species as mangrove associates (Jayatissa et al., 2002; Arulnayagam et al., 2021). The mangrove forests in Northern Sri Lanka represent 16% of the total mangrove extent and rank as the second largest mangrove patch in the country (Arulnayagam, 2020a; Arulnayagam et al., 2021). *Avicennia marina* (Forssk.) Vierh., known for its adaptation to high soil salinity, stands as the most abundant mangrove species in Jaffna Peninsula (Amarasinghe and Perera, 2017; Priyashantha and Taufikurahman, 2020), followed by *Lumnitzera racemosa* Willd., *Rhizophora mucronata* Lam., *and Excoecaria agallocha* L. (Perera et al., 2013; Amarasinghe and Perera, 2017; Arulnayagam, 2020b; Priyashantha and Taufikurahman, 2020).

This research is conducted in three villages located on the Jaffna Peninsula: Mandaitivu, Sarasalai, and Ponnalai, each with mangrove fringing communities. Additionally, the study encompasses Jaffna city, where government departments involved in mangrove management are

[3] District: administrative division, included in a province of Sri Lanka, which is managed by a district secretary.

located (Fig. 1). The three villages of our study, host mangrove forests at varying levels of degradation. In Mandaitivu, well preserved (not affected by war or human disturbance) mangrove forests are confined to a small area, while a major part of the mangroves was destroyed by the civil war. Since the the end of the civil war until now, the government has undertaken multiple mangrove replantation efforts in this area, focusing particularly on *R. mucronata* (Fig. 2B, C). In Sarasalai, an old[4] mangrove forest, which was not affected by the war, is still preserved (Fig. 2E), although mangroves have been partly removed for road construction (Fig. 2F). As for Ponnalai, characterised by high soil-salinity, it naturally hosts *A. marina*, while a replantation site, under the control of the Sri Lankan Navy and inaccessible to the public, has been, established with *R. mucronata* (Fig. 2H). Ponnalai also presents a dam and comprises pipelines for transporting domestic freshwater (Fig. 2A and G).

### 2.2. Research approach

The study comprises of two main steps: (i) Stakeholder identification, (ii) Data acquisition through various social-ecological surveys. We have employed a mixed methods approach to comprehensively understand the diverse dimensions of mangrove management in the Jaffna Peninsula, using multiple perspectives and angles of observation.

#### 2.2.1. Stakeholder identification

The stakeholders involved in our research can be categorised into two groups: (i) the mangrove-fringing communities ("community stakeholders") (residing within 10 km from the mangrove forest), selected through snowball sampling in three different villages. Among the 250 households encountered, 200 stated their lack of involvement to not be involved with mangroves and were not willing to participate further in the questionnaire. Consequently, we conducted interviews with 20 villagers from Sarasalai, 20 from Mandaitivu and 10 from Ponnalai; (ii) nineteen stakeholders involved in mangrove management and conservation ("mangrove management stakeholders"), including governmental departments, local and international NGOs, and the scientific community. The stakeholders in category (ii) were identified using a preliminary questionnaire (Appendix 1[5]) and with reference to Sri Lankan mangrove jurisdiction (Appendix 3) to identify the network of stakeholders and entities overseeing management in the study area. The stakeholder identification is supported by Nijamdeen et al. (2022), which identifies the governmental and non-governmental parties involved in mangrove management in Sri Lanka and defines the governmental structure for mangrove management at different levels of authorities (i.e., from divisional to national level) with relative jurisdiction for mangrove conservation.

In Sri Lanka, the protection of natural forests is directly overseen by several governmental departments spanning over forest, marine and aquatic jurisdictions, including the Department of Forest (DF), the Department of Wildlife Conservation (DW), the Coast Conservation and coastal resource management Department (CC), the Marine Environment Protection Authority (MP), Department of Fisheries and Aquatic Resources (FA), and the Central Environmental Authority (CE), connected with the local village councils and authorities (Nijamdeen et al., 2022; Nijamdeen et al., 2023a). Additional governmental stakeholders are directly or indirectly involved in mangrove management, through law enforcement (i.e., Police Department (PD), Army, Navy, Special Task Force (AN), advocacy for best practices (Mahaweli Authority of Sri Lanka (MA)), tourism (Sri Lanka Tourism Development Authority (ST)), involvement in aquatic ecosystem conservation and restoration (National Aquatic Resource and Development Agency (NR), and Rehabilitation Development Authority (RD)), development of fisheries and aquaculture (Department of Fisheries and Aquatic Resources (FA), National Aquaculture Development Authority of Sri Lanka (NQ)). Non-governmental organisations and university researchers are involved stakeholders due to the research and protection activities that they carry out in regard to the local mangrove ecosystem. Mangroves patches are found in both public and private lands, hence the inclusion of the Land use and Policy Planning Department (LP) and Private Enterprises (PE) (an exhaustive list of the category (ii) is presented in Table 1).

#### 2.2.2. Data acquisition through various social-ecological surveys

We used four different methodologies (1: Ethnobiological survey, 2: Q methodology, 3: Expert opinion survey, 4: Semi-structured interviews) to explore the dynamics and management of social-ecological systems, and management as depicted in Fig. 3 (Biggs et al., 2021). Results were ultimately integrated using a mixed-method approach.

For interactions with local communities, we used an *ethnobiological survey*, while for the perceptions of mangrove management stakeholders, we used both *Q methodology* and an *expert opinion survey*. Moreover, *Semi-structured interviews* were conducted with mangrove management stakeholders who consented to share more information regarding their experiences related mangrove management. Additional literature review and mangrove legislation in Northern Sri Lanka (Appendix 3) were integrated to complement our primary data and for the conclusion drawing process. Data collection of the ethnobiological questionnaire spanned from September 2020 and April 2021. Part of the expert opinion survey was submitted online and the remainder of the data collection of the Q methodology and the expert opinion survey was conducted in person between August 2021 and March 2022.

#### 2.2.3. Ethnobiological survey

The ethnobiological survey is composed of structured interviews and was adapted from previous studies (Dahdouh-Guebas et al., 2006; Satyanarayana et al., 2013) (Appendix 1). This survey is composed of four sections, which together investigate the main mangrove goods and services utilised by the community and their perceptions of the mangrove ecosystem.

The first section of the ethnobiological questionnaire, which was collected at the end of each interview, aimed to collect information on demographics (e.g., age, ethnicity, level of education, profession, the main source of income), characteristics of the housing (including the type of materials used to construct the house) and possession of assets and items (such as land, trees, cattle, bicycle and household appliances). The second section targeted the assessment of the ecosystem goods and services most utilised and appreciated by the community; major attention was directed toward the collection of fuelwood and construction wood, and usage of mangroves for medical, chemical, and alimentary purposes; species and quantities harvested as well as processing practices were investigated. The third section was related to fishery activities. This section assessed the most common methods used for fishing, principal species caught and consumed at present and in earlier times (including species of fish, bivalves, molluscs, crabs, and shrimps), as well as the percentage and price of fish catch sold. The fourth section assessed the perceptions and opinions of the respondents about the importance and evolution of mangrove ecosystems over the years. This section particularly investigated changes in mangrove vegetation and mangrove fauna over the past 10 years and predictions of these changes regarding the future.

#### 2.2.4. Q methodology

Q methodology is used to assess discourses within a group of participants, in which 'discourses' are defined as common and structured patterns of perceptions among stakeholders, regarding a specific topic. This methodology combines quantitative and qualitative data, categorizing participants' opinions into discourse clusters (Hugé et al., 2016; Mukherjee et al., 2018; Zabala et al., 2018; Vande Velde et al., 2019). The Q methodology is composed of four phases: *research design*, consists

[4] The locals referred to the forest as "old", which was not disturbed by war and remained the same for at least thirty years.

[5] All appendices are accessible in the supplementary data

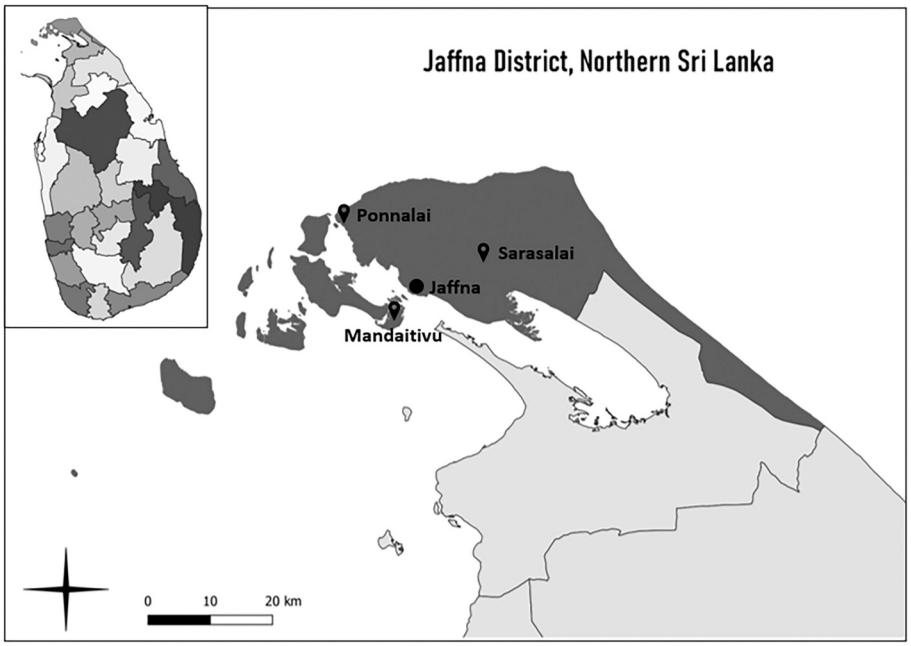


**Fig. 1.** Jaffna Peninsula in dark grey (right), located in the Northern Province of Sri Lanka; the three study sites and Jaffna city are indicated on the map. All Sri Lankan districts are shown with different shades of grey (top left).
Map created using the Free and Open Source QGIS Software, v3.20.3.

of the identification of main topics and elaboration of statements that will compose the Q-set; *data collection*, characterised by interviews where participants place the Q-set on a structured ranking grid; in this phase, the statements are placed in the boxes of the Q-grid, in the ranked column that corresponds to the level of agreement of the participant with the statement; the outcome of this step is called Q-sort, meaning a completed Q-grid in which the statements are filling all boxes; in the last phases of *analysis* and *interpretation* multivariate analysis is applied to identify the main discourses among participants (Fig. 4) (Mukherjee et al., 2018; Zabala et al., 2018).

The Q-set used in this study was elaborated through peer-reviewed literature and governmental annual reports regarding mangroves in Sri Lanka. Web of Science and ScienceDirect platforms were used for literature research, using keyword searches such as 'Sri Lanka AND management', 'Sri Lanka AND mangrove'. The initial concourse was composed of 145 statements which were reduced to 50 by identifying key themes within the concourse. A pilot test was conducted with 15 members of governmental departments and the scientific community. Statements were reduced and adjusted according to the responses received and 37 statements were finally identified to constitute the final Q-set used in this study (Appendix 1). The 37 statements composing the final Q-set cover topics regarding mangrove conservation and restoration in the Jaffna peninsula, including the present regulation of mangrove forests, responsibilities of the different stakeholders, community involvement and mangrove ecosystem services, and good practices for mangrove conservations or restoration projects. The ranking grid is numbered from −3, which represents the strongest degree of disagreement of the participant with the statement, to +3, which represents the strongest degree of agreement (Fig. A1, Appendix 2).

#### 2.2.5. Expert opinion survey

The expert opinion survey (Appendix 1) is developed to assess the opinions of stakeholders considered experts in mangrove management and conservation and to investigate whether consensus exists among them (Šimović et al., 2014; Pfeifer et al., 2020). The questionnaire was based on a literature review regarding mangrove ecology and conservation in Sri Lanka, performed on Google Scholar and ScienceDirect using keyword searches such as 'Sri Lanka AND conservation', 'Sri Lanka AND mangrove'. The stakeholders were chosen according to Section 2.2. The survey is composed of four different sections: Sections 1 and 2 deal with assessing mangrove goods and services and the current state of degradation of the mangrove forests in the Jaffna Peninsula; Sections 3 and 4, meanwhile, investigate the roles and challenges of stakeholders involved in mangroves management and possible solutions. Different types of question setups were included in the questionnaire, such as ranking questions (ranking the top three choices), 1–5 Likert-scale questions, multiple choice questions, and open questions.

#### 2.2.6. Semi-structured interviews

The semi-structured interviews were conducted to identify challenges and solutions in mangrove management and conservation, along with other related topics according to the participant's expertise and experience. Initially, guiding questions were provided, but the interviews remained open ended, allowing respondents to freely express their insights and knowledge on topics connected with mangroves in the Jaffna Peninsula (Biggs et al., 2021). A total of 13 participants showed willingness to further share personal experiences regarding mangrove ecosystems in the study area. However, due to relatively small sample size, these insights and opinions carried less weight in the final conclusions.

### 2.3. Data analysis

#### 2.3.1. Ethnobiological survey

A Microsoft Excel spreadsheet was compiled with responses from the participants, and frequency tables were produced to summarise the answers and sort proportions. Due to the high number of absent responses in Sections 2 and 3, data analysis was applied only to Sections 1 and 4. The socio-demographic profile of the participants was outlined with frequency distributions and percentages. Variables were distinguished into independent variables (socio-demographic and economic traits) and dependent variables (respondents' perspectives) (Table A1, Appendix 2). The Chi-square test and the correspondent G-test were performed to assess differences between dependent variables. Four indices were built on different questions to assess participants' knowledge about mangrove ecology and legislation, and their perceptions

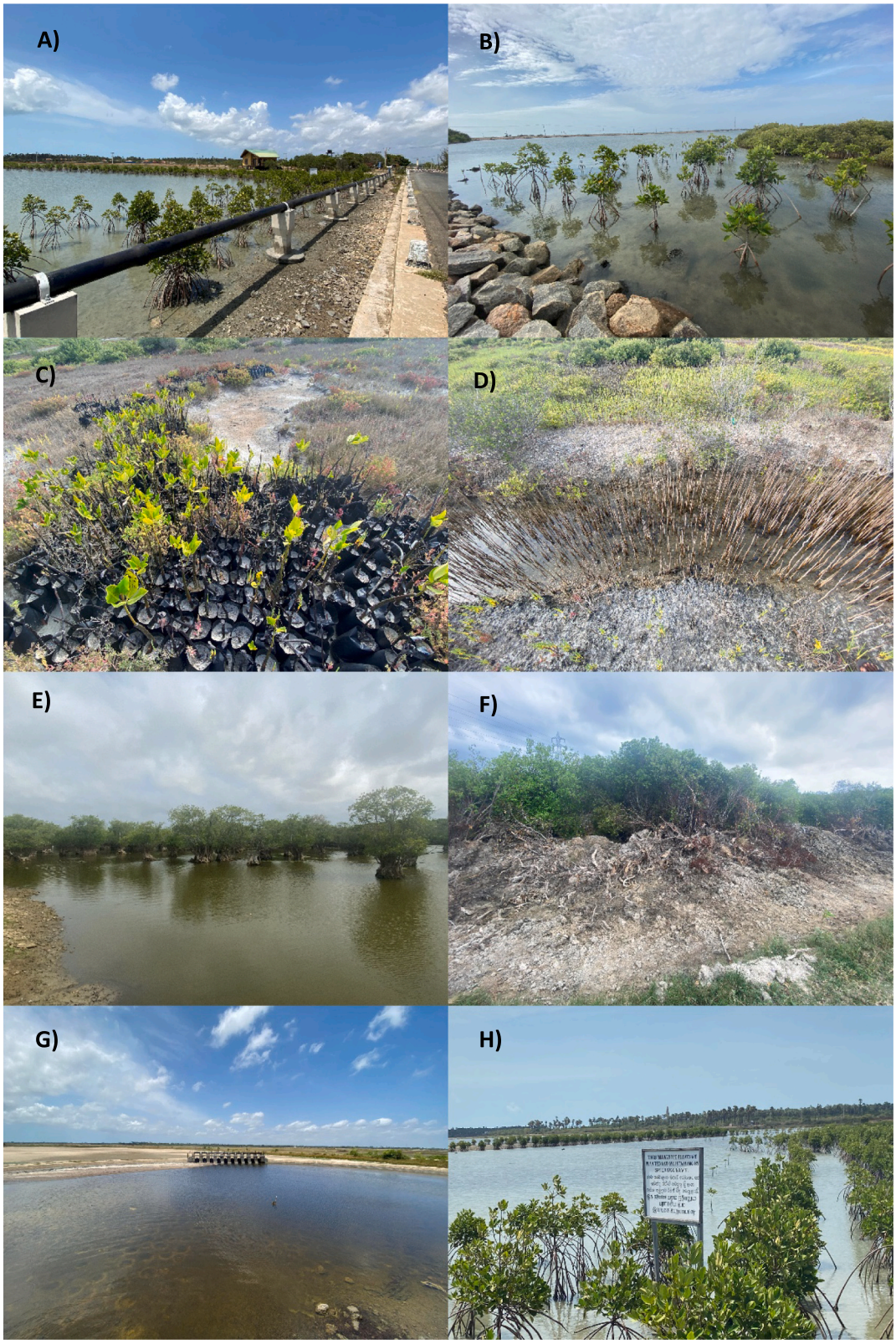


**Fig. 2.** A) Pipelines that transport groundwater to local habitations in Ponnalai. B) Newly planted *Rhizophora mucronata* in Mandaitivu, after the destruction of the mangrove forest due to the war. C) Leftover seedlings of *R. mucronata* in an abandoned nursery in Mandaitivu. D) *Avicennia marina* aerial roots (pneumatophores) and mangrove associates *Salicornia* spp. and *Halosarcenia* spp. in Mandaitivu. E) Preserved mangrove forest in Sarasalai. F) Destruction of mangroves in Sarasalai for road construction purposes. G) Water dam in Ponnalai. H) Non-accessible area in Ponnalai controlled by the Sri Lankan Navy, which is in charge of replantation of *R. mucronata.* Source: own pictures, August 2021.

**Table 1**
List of stakeholders of the category (ii), identified as stakeholders involved in mangrove management and conservation (or 'mangrove management stakeholders'), with relative abbreviation and division (GOV: governmental authority, LOC: local authority, PRI: private division, SCI: scientific community).

| *Stakeholder* | *Division* |
|---|---|
| Department of Forest (DF) | GOV |
| Irrigation Department (ID) | GOV |
| Central Environmental Authority (CE) | GOV |
| Department of Wildlife Conservation (DW) | GOV |
| Department of Fisheries and Aquatic Resources (FA) | GOV |
| Marine Environment Protection Authority (MP) | GOV |
| Coast Conservation and coastal resource management Department (CC) | GOV |
| Land use and Policy Planning Department (LP) | GOV |
| Mahaweli Authority of Sri Lanka (MA) | GOV |
| Sri Lanka Tourism Development Authority (ST) | GOV |
| Rehabilitation Development Authority (RD) | GOV |
| National Aquatic Resource and Development Agency (NR) | GOV |
| National Aquaculture Development Authority of Sri Lanka (NQ) | GOV |
| Police Department (PD) | GOV |
| Army, Navy, Special Task Force (AN) | GOV |
| Local authorities: Village councils, Gramasevaka, Districts secretariat, Divisional secretariat (LA) | LOC |
| Non Governmental Organisations (NGO) | PRI |
| Private enterprises (PE) | PRI |
| Universities (UNI) | SCI |

about mangrove evolution in the past and the future (Frank et al., 2017) (index scoring tool in Table A2, Appendix 2). We built a "knowledge index" (KI) on questions Q19 and Q20 to analyse respondents' level of knowledge about the local mangrove ecosystem. An "awareness index" (AI) was built on questions Q61 and Q63 to analyse participants' awareness of mangroves importance and knowledge of mangrove-related legislation. A "mangrove evolution index" (MEI) was built on questions Q65, Q66, Q68 and Q69 to analyse respondents' perception of the evolution of the mangrove ecosystem and related aspects in the past 10 years. Question Q64 was used as an index of participants' perceptions about mangrove evolution in the future. Indices were used as qualitative variables to categorise respondents into groups (Table A3, Appendix 2). For KI and LAI participants were classified, according to their scores, in the categories "None", "Low", "Medium" and "High". For MEI and Q64, participants were classified as "Decreased", "Unchanged" or "Increased". Ultimately, the Chi-square test was used to assess dependency between the four indices and independent variables (religion, age class, education level, occupation), and was applied to assess relations among indices. All data were analysed with R 4.1.1 software.

### 2.3.2. *Q methodology*

The 21 Q-sorts were gathered and inserted in PQMethod software (v2.35 Schmolck, 2014; Hugé et al., 2016) (participants and relative departments in Table A6, Appendix 2) and analysed in R, through

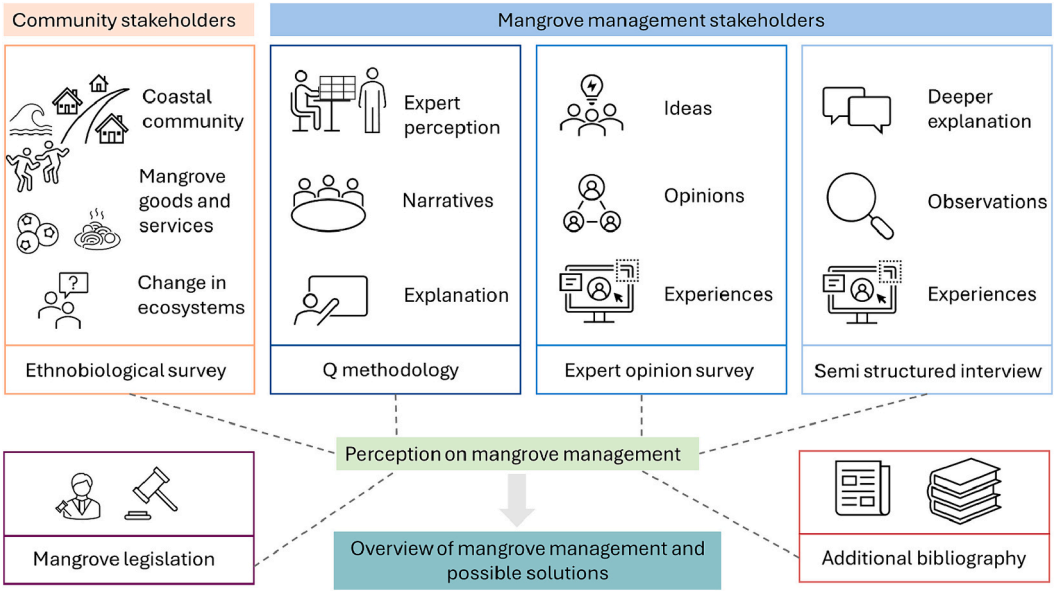


**Fig. 3.** Figure describing the study's main steps: ethnobiological survey, Q methodology, expert opinion survey, semi structured interviews along with the addition of legislation and bibliography with relative outcomes, and integration of all steps for a common final goal. Mangrove legislation and additional literature were consulted as the final step to draw consistent conclusions on mangrove management in Jaffna Peninsula, Sri Lanka.

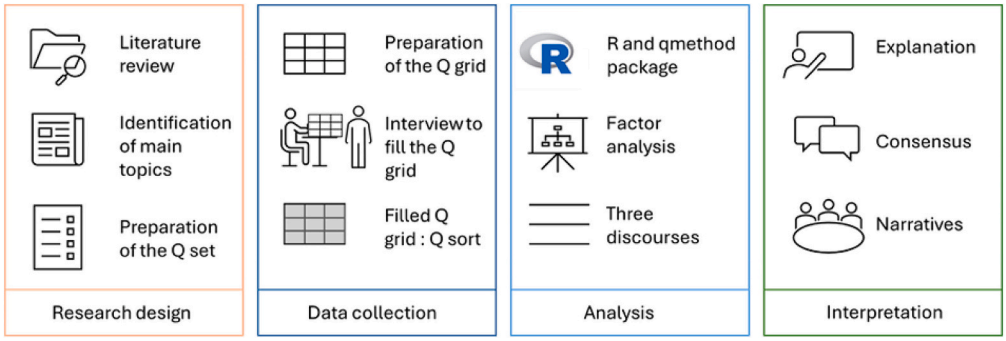


**Fig. 4.** Figure describing the steps involved in the four phases of the Q methodology: research design, data collection, analysis, and interpretation.

'qmethod' package (v1.8; Zabala, 2014). A correlation matrix was initially generated, using Pearson coefficient. Multivariate analysis for factor extraction was performed using PCA, with extraction of three factors (eigenvalues >3.95, 57% of the variance explained). Factor rotation was performed with varimax rotation including the three factors extracted, and automatic flagging was performed on the outcome. Q-sorts with significant factor loading (p-value <0.05) were attributed to the three factors according to their loadings. *Z*-scores were calculated and plotted to compare opinions and consensus about each statement in the different factors (Zabala, 2014; Hugé et al., 2016). A crib sheet was created in R to identify statements that were given the highest and the lowest values (+3 and − 3) for each factor and to determine the main differences among factors. Factor interpretation was performed using results from the crib sheet, factor rounded scores and z-score values (Zabala et al., 2018). Finally, a narrative process was implemented to disentangle the results and to present the three main points of view of the participants (discourses) corresponding to the three factors; additional qualitative results were included at this stage, especially for significant Q-sort loadings (Hugé et al., 2016).

#### 2.3.3. Expert opinion survey

Outcomes from the expert opinion survey were entered in Microsoft Word, for open questions, and in Microsoft Excel, for the rest of the results. A summary statistic was applied to analyse 1–5 Likert-scale questions: mean score, median and level of dispersion through standard deviation (SD) and interquartile range (IQR) were calculated (Šimović et al., 2014; Pfeifer et al., 2020). The mean and the median were used to find the point of consensus among participants, although consensus was considered achieved with IQR <1. In ranking questions, the order of importance of the options was determined through weighted frequencies of choices, calculated by giving a weight according to the ranking given by the respondents (scoring points for weighted frequencies calculation in Table A10, Appendix 2). For the two questions that required choosing the entities involved in mangrove management, frequencies and percentages of selection for each entity were calculated in Microsoft Excel. A percentage equal to or higher than 50% was used as an indicator of consensus among the participants. Finally, open questions were analysed using content analysis with NVIVO software (content analysis explained in Section 2.3.4).

#### 2.3.4. Semi-structured interviews

Semi-structured interviews were analysed using content analysis. Qualitative content analysis is a methodology used to analyse qualitative data such as interviews and images while classifying sections of the texts into categories and extracting common perspectives (Elo and Kyngäs, 2008; Vaismoradi et al., 2013). The data was entered and analysed with NVIVO software, and prior data screening was effectuated to establish preliminary codes. The coding process led us to the identification of 12 final codes (Table A16, Appendix 2). Through word queries and thematic grouping, we moved forward with the abstraction process, during which code contents were revised, compared and combined (Elo and Kyngäs, 2008). A final storytelling process was performed by the researcher while including the obtained results in a coherent storyline. The 12 codes were merged into three final categories, identified as "issues in mangroves management and conservation", "evolution of mangrove ecosystems in Jaffna Peninsula", "possible improvement for mangrove conservation". The whole process is strongly dependent on the researcher's subjectivity and interpretation, and it is followed by integration with existing literature (Elo and Kyngäs, 2008; Vaismoradi et al., 2013).

#### 2.3.5. Data integration

Mixed-method research is an approach commonly used for addressing issues inherent in complex systems such as the mangrove social-ecological systems. The approach involves integrating qualitative and quantitative methodologies to comprehensively address the problem from different viewpoints (Biggs et al., 2021). Therefore, for this study, the data from all methodologies used with the mangrove management stakeholders as well as additional qualitative data and bibliography were combined with a mixed-method approach. Topic categories were identified among the totality of the results and, for each category, outcomes from different methodologies were compared to identify common patterns and divergences. The process brought us to the drafting of the discussion Section 4.3.

## 3. Results

### 3.1. Ethnobiological survey

#### 3.1.1. Socio-demographic profile of the participants

All the participants are Tamil speaking, with 50% males and 50% females with 64% Hindus and 36% Christians. At least 13 participants are representing each of the age classes older than 20 years old and 58% of the participants are native of the village of residence. The higher educational level attained by most of the participants is a high school degree (Advanced Level) (46%), while 12% are retired and 28% declared as not currently having a job; of the remaining, 20% are farmers, 10% are involved in fishery activities, 8% are shop owners and 22% are students or have different types of employment such as teachers or gardeners. Half of the participants own land and fruit trees, and most of them possess assets such as bicycles, motorcycles, televisions, and gas cookers (additional details in Table A4, Appendix 2).

#### 3.1.2. Utilisation of mangrove goods and services

One person uses *Rhizophora* spp. stems as a source of fuelwood, in combination with gas; 19 use other sources of wood (non-mangrove wood sources, such as *Thespesia* spp. Sol. *ex Corrêa* or parts of the local palm and coconut trees) and the remainder use gas or a combination of gas and plant species mentioned above.Two people currently use mangroves (*Aegiceras corniculatum* L. and *Rhizophora* spp.) for construction purposes (mainly for fences). Only 5 people still employ mangrove preparations to cure not specifically specified injuries and illnesses (*Rhizophora* spp. boiled and grounded to apply on injuries; *Acanthus ilicifolius* L. boiled and drunk against sickness). The use mangroves as a source of food or drinks was not recorded. Concerning fishery activities, two people declared to fish among mangroves, especially fish, crabs, and shrimps, using nets or traps (average catch of 5-10 kg/day, sold for 200-300LKR/kg).

#### 3.1.3. Community perception of the mangrove ecosystem

Results from the "knowledge index" (KI) reveal that 78% of the respondents have a low understanding of mangrove diversity and ecosystem. Only 20% of the participants could specify at least one species of mangroves or mangrove associates; the species mentioned more often include *Rhizophora* spp., *Avicennia* spp., and *Excoecaria* spp., followed by *Acanthus* spp. and *Aegiceras* spp. Significant relation was found from Chi-square tests performed on KI with age groups ($\chi^2 = 7.1707$, df = 6, p-value = 0.02773) and occupation ($\chi^2 = 30.41$, df = 10, p-value = 0.00073), where people older than 60 years old and retired people had the highest scores of mangrove knowledge. A total of 56% of the respondents scored in the "Medium" category for the "awareness index" (AI), but only 30% could mention at least one jurisdiction, mostly related to fishery activities. Chi-square test results show no specific trends in the relation between awareness levels and age group, occupation, or educational level. For the "mangrove evolution index" (MEI), 82% of the participants fell under the "Increased" category of mangrove ecosystem area, while 14% scored as "Decreased". The main reasons mentioned for mangrove expansion are replantation, proper maintenance, and stricter rules about mangrove damaging, while reasons for reduction in mangrove areas were not provided. From the "mangrove in the future index" (Q64), a total of 60% predicted continuous increase of the mangrove vegetation area but most of the respondents have a low

understanding of (possible future trends of) sea-level rise (complete indices results in Table A5, Appendix 2). Relation was found between MEI and age classes ($\chi^2 = 13.23$, df = 6, p-value = 0.03952), showing a perception of increasing mangrove ecosystem area mostly for participants older than 40 years old, and no specific trend was encountered regarding the perception of mangrove evolution in the future. Chi-square tests were also performed among indices. Correlation was identified between MEI and Q64 ($\chi^2 = 18.99$, df = 4, p-value = 0.00079), showing similar trends of perceptions in mangrove ecosystem evolution in the past and toward the future.

### 3.2. Q methodology

Each of the three factors explains about 19% of the data variance, with five to nine Q-sorts significantly associated with each factor (Table A7, Appendix 2). The factor matrix obtained is shown in Table 2, which highlights the Q-sorts with loadings at p-value <0.05. *Z*-score values, rounded scores and additional results are presented in Table A9, Table A10 and Fig. A2, Appendix 2. The three main discourses regarding mangrove conservation and management, extracted from the three factors, are labelled and presented below. Although correlation among factors is relatively high (Table A7, Appendix 2), we decided to conduct the factor interpretation with three different perspectives, as carried out by Hugé et al. (2016). The three factors correspond to the three discourses delineated in Sections 3.2.1, 3.2.2, 3.2.3.

#### 3.2.1. Discourse 1: "Community Oriented" – communities as an integral part of mangrove conservation

The first discourse, extracted from factor 1, captures a scene positively oriented to the local communities involvement in mangrove conservation and to the benefits that they can draw from effective mangrove management. The highest scores were given to S13 and S22, underlining orientation toward community involvement and school awareness programmes in mangrove conservation, and to S10 and S26, implying the importance of mangrove restoration for population's subsistence and preservation of traditional knowledge. Moreover, S14 emphasises the importance of women's involvement in mangrove replantation projects, while the positive score given to S31 shows the importance for local people to oversee replanted mangroves, knowing the benefit that they can draw from this ecosystem. This perspective also implies an important role of local communities in the enhancement of mangrove management, shown by the negative score attributed to S16. According to scores given to S14, S18, and S20, the main cause for ineffectiveness of mangrove restoration programmes was attributed to lack of post-care and missing data regarding the consequences of mangrove replantation, rather than wrong species chosen for the replantation. Finally, this is the only discourse highlighting possible positive effects of ecotourism and media awareness for mangrove conservation (S23 and S15).

**Table 2**
Factor matrix with factor loadings from extraction and rotation performed with automatic rotation and flagging (executed in R with qmethod package); (*) indicates loading Q-sorts with p < 0.05 which were attributed to the relative factors.

| Q sort Number (N) | Factor 1 (Community Oriented) | Factor 2 (Government Oriented) | Factor 3 (Mangrove Conservation) |
|---|---|---|---|
| 1 | −0.05 | *0.61 | 0.01 |
| 2 | 0.17 | *0.80 | 0.24 |
| 3 | 0.57 | 0.46 | 0.36 |
| 4 | *0.80 | 0.14 | −0.26 |
| 5 | *0.75 | 0.30 | 0.24 |
| 6 | 0.41 | 0.19 | 0.45 |
| 7 | −0.18 | *−0.58 | −0.25 |
| 8 | −0.16 | *−0.62 | 0.24 |
| 9 | 0.34 | 0.09 | *0.63 |
| 10 | 0.05 | 0.12 | *0.80 |
| 11 | 0.21 | 0.00 | *0.74 |
| 12 | 0.30 | *0.53 | 0.41 |
| 13 | *0.81 | −0.06 | 0.36 |
| 14 | *0.73 | 0.09 | 0.46 |
| 15 | 0.04 | 0.40 | *0.63 |
| 16 | 0.41 | 0.30 | *0.54 |
| 17 | 0.43 | 0.20 | *0.49 |
| 18 | −0.11 | *0.56 | 0.40 |
| 19 | *0.52 | 0.41 | 0.26 |
| 20 | 0.28 | *0.58 | 0.12 |
| 21 | 0.32 | *0.68 | 0.23 |

#### 3.2.2. Discourse 2: "Government Oriented" – government as the main responsible for improving mangrove conservation

The second discourse, drawn from factor 2, places the emphasis on actions that should be implemented by the state to assure improvement in mangrove restoration and conservation. In particular, the government should reinforce policies related to illegal activities, such as encroachment and logging (S1 and S3), strongly considering scientific advice (S2) to restore mangroves to their initial state before degradation (S7). Moreover, high score given to S4 underlines the importance of governmental engagement to solve land ownership issues and S8 highlights the existing problem of overlapping responsibilities of different governmental departments over the mangrove ecosystems. However, this perspective also considers the relevance of community involvement and the benefits that the local population can draw from effective mangrove management (S10, S12, S14, S17, S22). Contradictory scores were encountered regarding effectiveness of mangrove restoration against replantation (S29 and S30); a higher number of neutral or weaker scores were given for topics regarding mangrove knowledge (S20, S26, S27, S32 and S36) and improvement of mangrove restoration (S23 and S24).

#### 3.2.3. Discourse 3: "Mangrove Conservation Oriented" – a middle ground between discourse 1 and 2

The last discourse, extracted from factor 3, emphasises the concept of protecting and restoring mangroves to their initial state for their ecosystem services, including community subsistence and establishment of habitats for aquatic species (S7, S10 and S33), and for their inherent value (S27). Awareness programmes in schools are considered crucial for effective mangrove conservation (S22); nevertheless, poor confidence is expressed regarding community involvement in mangrove management (S14 and S16). Wrong species selected for mangrove replantation is considered as the main cause for failure of replantation projects (S18) rather than lack of post-care of replantation sites (S19), followed by abandonment of projects due to lack of funding (S24) and poor mangrove-related literature (S20 and S21). Replantation is considered as a key aspect for mangrove restoration (S29), although shoreline protection should not be the sole driving factor (S37). Encroachment, logging and overlapping responsibilities among governmental departments are not considered as jeopardising aspects for mangrove conservation (S1 and S8) but the government is expected to implement stricter rules following scientific advice (S2 and S3) to enhance mangrove conservation.

#### 3.2.4. Consensus among discourses

The lowest scores were attributed to the same four statements for the three factors. Therefore, the participants agree on the present need for mangrove restoration in Jaffna's lagoons (S28), and the focus of this restoration is expected to be far from development activities such as the establishment of industrial, touristic or agricultural areas because this would have negative consequences on the aquatic fauna (S6 and S32). Moreover, consensus was reached for S34, which expresses little concern for inland mangrove colonisation in case of sea-level rise, and for S25, which received negative scores indicating dissatisfaction among the stakeholders with the post-monitoring process carried out after restoration projects.

### 3.3. Expert opinion survey

Results from Likert-scale questions (Fig. 5 and Table A11, Appendix 2) show that consensus was reached only for question 2.1, with which participants agree regarding the degree of degradation of the mangrove forests in the Jaffna Peninsula. Results from question 1.2 indicate, from first to third, fishing equipment (*e*), nursery for fishery and seafood (*f*) and food purposes (*d*) as main goods and services appreciated by the communities. Outcome from question 2.2 expresses villages' expansion and development activities (*c*), encroachment (*b*) and pollution (*a*) as main challenges for mangrove ecosystems in the Jaffna Peninsula. Question 4.6, which assesses solutions to overcome challenges in mangrove management, sees 'increasing in research projects' and 'local community involvement' (*a* and *c*) as first choices with equal scores, and 'decrease in language barrier' (*d*) as second choice. Ranking questions Q3.2 and 3.3 received a lower amount or responses, therefore results were included in discussion considering this flaw (additional information about ranking questions in Table A12 and Fig. A3, Appendix 2). Concerning the two questions related to entities' involvement in mangrove management, in question 3.1, agreement was reached for four roles regarding only a few entities: 'production of new knowledge', regarding the entities ENV[6] and MAR,[7] the entity NGO for 'funding', the entity ENV for 'promotion of environmental awareness' and the entity FOR[8] for 'revision of measures' (more details in Table A13, Appendix 2); in question 4.1, 12 entities were indicated by 50% or more of the respondents, with a higher agreement (>70%) in regard to five entities (Table A14, Appendix 2). To conclude, results from content analysis applied on open questions reveal that mangroves are recognised as important for the ecosystem processes and coastal protection. However, while part of the participants declared that mangroves are still used by the communities for fishing, food and construction purposes, the other part agrees on the fact that local communities nowadays stopped using mangrove goods and services. Opinions are dissenting also regarding community awareness of mangrove importance and effectiveness of the ban against mangrove cutting (additional information in Table A15, Appendix 2).

### 3.4. Content analysis on semi-structured interviews to delineate stakeholder views on mangrove management

During the abstraction process of the content analysis applied to semi-structured interviews, 12 initial codes were merged in three final categories (Section 2.3.4). For the first category, management of land properties resulted to be a primary issue jeopardising proper mangrove conservation, due to multiple modifications of land ownership permits during and after the war. Other major problems, cited by three or more participants, include poor communication among and within departments (partly due to language barrier), lack of environmental awareness by governmental stakeholders, lack of manpower and power inequality among different departments. Ultimately, the lack of environmental data led to ineffective mangrove restoration and NGOs struggled with obtaining new funding for further restoration projects. For the second category, several participants stated that mangroves were heavily affected by the civil war, even though they started to naturally regenerate after the war. In actual state, *Avicennia marina* is indicated as the prevalent species, followed by *Rhizophora* spp. and *Excoecaria* spp. Information about the three study areas and related mangrove restoration projects emerged. Mandaitivu currently hosts a mangrove nursery, in which wrong guidelines about seed treatment led to an initial failure of mangrove growth. In Ponnalai, a high soil-salinity site, the Sri Lankan Navy was ordered to plant *Rhizophora* spp. seedlings, but only a small amount entirely survived to the dry season. Finally, part of the Sarasalai area (in Tamil called 'Kuruvikkadu') was declared a social forest and bird sanctuary, where local people used to collect fuelwood, fish among the mangroves and cattle farming. In this area, mangroves were less affected by the war but are currently threatened by development activities. For the last category, suggestions were given by the respondents to enhance mangrove conservation. The scenario of having all environmental-related organisations under the same ministry was proposed by four respondents; moreover, workshops were proposed as a better way for active participation rather than classic reunions. Promoting awareness among citizens was also considered an important solution to reduce mangrove degradation (i.e., through projects carried out in schools), as well as enhancing focused research projects (complete results in Table A17, Appendix 2).

## 4. Discussion

### 4.1. Mangrove goods and services in Jaffna Peninsula – detachment of the communities of Jaffna Peninsula from mangroves goods and services

Our study demonstrates a significant detachment of the communities of Jaffna Peninsula from the usage of goods and services provided by the local mangrove ecosystems, along with a redirection toward the use of other non-mangrove-based goods and services. Several studies show that mangrove ecosystems represent important elements for community's subsistence in tropical countries, including India (Dahdouh-Guebas et al., 2006), Brazil (Santos et al., 2017), Malaysia (Hugé et al., 2016), Indonesia (Rizal et al., 2018), Kenya (Dahdouh-Guebas et al., 2000), and Senegal (Gallup et al., 2020; Arumugam et al., 2021). Likewise, studies conducted in different Sri Lankan provinces illustrate that local communities continue to rely on the mangrove ecosystems for their livelihood, especially for fishery products and wood consumption (Satyanarayana et al., 2013; Rubiera Rodriguez, 2020; Ngendahimana, 2021). A smaller proportion of the participants interviewed for this study (20%) is still relying on the mangrove ecosystems. Mangrove goods that are commonly used by local communities fall under the categories of "food production", such as "fish, game, crops, nuts, fruits", "raw materials" such as "lumber, fuel, or fodder", and "genetic resources" including medicinal purposes (Vo et al., 2012). In this study, the main goods that are used by the local communities of the Jaffna Peninsula are fuelwood, construction wood, fish production and mangrove preparation to cure injuries or illnesses. Mangrove services are diverse and often misconceived, making them harder to identify and categorise for people (Dahdouh-Guebas et al., 2020). In this study, the main mangrove service that the participants recognised is the creation of habitat for "locally harvested species" (Vo et al., 2012), such as fish and crustaceans". Nonetheless, the majority of the participants (80%) is not using goods and services from the mangrove ecosystems of Jaffna Peninsula, and 80% of the households initially encountered directly declared to not use mangrove goods and services, refusing to continue with the survey. Recent studies have shown that there is an increasing awareness and recognition of the importance of coastal ecosystems among coastal communities in the Northern province due to the influence of social media (Suresh, 2024). Moreover, the alteration in community demographics along the northern coast due to emigration (due to the civil war) which has led to a transitional state, during which the current community is adapting to and learning to utilize mangrove ecosystem goods and services (Nijamdeen et al., 2022). A less intense decrease in utilisation of mangrove goods and services was also observed in other Sri Lankan provinces; for example, in the Eastern province (Rubiera Rodriguez, 2020), and partly in the Southern and North-Western provinces (Satyanarayana et al., 2013; Ngendahimana, 2021; Nijamdeen et al., 2023b), the causes behind this phenomenon were attributed to increasing urbanisation, environmental awareness and availability of sustainable alternatives. In Jaffna Peninsula, the civil war led to the temporary or permanent migration of a large part of the local

[6] ENV: Environmental related stakeholders (CE, LP, RD and MA)
[7] MAR: Marine and coastal related stakeholders (MP and CC)
[8] FOR: Forestry related stakeholders (DF and DW)

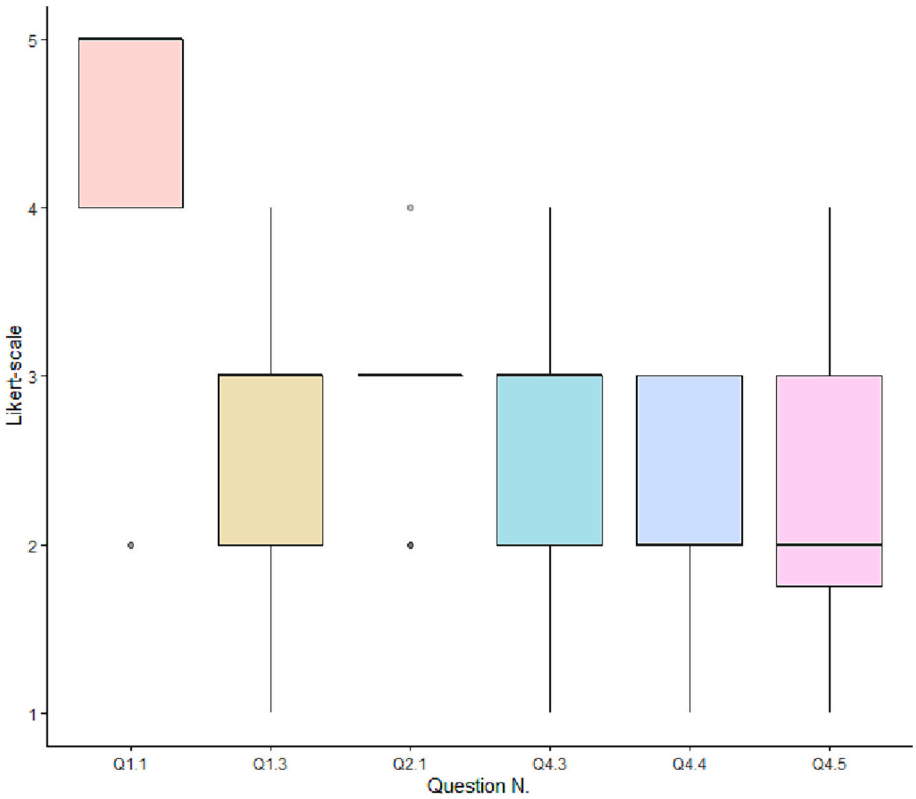


**Fig. 5.** Visualisation of results from Likert-scale questions. The graph shows box-plots representing interquartile ranges of participants' answers to Likert-scale questions. The black line represents the median value, used as the point of consensus. Q2.1 is the only question in which consensus was reached. Dots in Q1.1 and Q2.1 represent single participants giving a rank outside the interquartile range (for Q1.1) or different from the mean (for Q2.1).

population; moreover, the establishment of "*high-security zones*" (HSZ), due to presence of unexploded landmines, for different decades denied access for the communities to several mangrove areas (Soosai Siluvaithasan and Stokke, 2006; Suthakar and Bui, 2008; Dahdouh-Guebas et al., 2021). This combination of factors could partly explain the communities' scarce utilisation of the mangrove ecosystem services that have been encountered in this study. On the other hand, mangroves that for a long time have been in an inaccessible area were less exposed to anthropogenic threats such as village development and pollution, and therefore, they are more likely well preserved and suitable for mangrove conservation.

### *4.2. Community perception of the mangrove ecosystem – low understanding of the local mangrove ecosystems combined with perceived increase in mangrove area*

Results reveal that the majority of the respondents (82%) have noticed a progressive increase of the mangrove cover of Jaffna Peninsula throughout the time. Moreover, most of the community's participants (78%) showed to have a poor understanding of the local mangrove ecosystem, a situation that was not encountered in other Sri Lankan provinces (i.e., Rubiera Rodriguez, 2020). Nevertheless, elderly and retired people proved to have a higher understanding of the mangrove ecosystem, which can be connected to the fact that they used mangrove goods and services during their childhood. Older participants were also more aware of changes in mangrove cover throughout the years and more inclined to believe in a continued expansion in the following years. Literature is scarce regarding the comparison between past and present state of the mangrove ecosystems in Jaffna Peninsula, therefore we are not able to state with certainty whether the perception of the local population reflects reality. Changes in local mangrove area and composition have been observed by different communities living in other Sri Lankan districts (i.e., Satyanarayana et al., 2013). However, erroneous perception of increase in mangrove area is not uncommon among communities (Dahdouh-Guebas et al., 2006). Difficulty in recognising changes in vegetation composition can be due to 'cryptic ecological degradation', as suggested by Dahdouh-Guebas et al. (2005); this process can imply increase in mangrove area although with shifts from functional to non-functional vegetation composition, which can remain hidden to the local population. Finally, the detachment of most of the community's members from mangrove goods and services could explain their poor understanding of the mangrove ecosystem encountered in this study.

### *4.3. Opinions from mangrove management stakeholders – poor communication among governmental departments combined with lack of environmental data*

The combination of results obtained from mangrove management stakeholders occasionally expresses opposing opinions while, in other cases, a common perspective is reached among the participants. Some respondents are in favour of a scenario in which communities of the Jaffna Peninsula keep depending on mangrove goods and services and highly recognise mangrove importance, while the contrasting perspective claims that communities abandoned the utilisation of mangrove goods and services, and lost interest in protecting this ecosystem. As seen in Section 4.1, our results confirm the second scenario. Consensus is reached regarding the partially degraded state of mangroves in the peninsula, initially due to the civil war, and afterwards exacerbated by development activities and industrialisation. The destructive impact that wars can have on mangrove forests is well documented by Van et al. (2015), which reports similar patterns in mangrove destruction due to the Vietnam War. Likewise, urbanisation has been reported by several studies as a major threat to the mangrove ecosystems (i.e., Tuholske

et al., 2017), although other studies are positive regarding the incorporation of mangrove conservation in an urban environment (Vande Velde et al., 2019). Issues in the communication between different governmental stakeholders and failure of restoration programmes have been identified as main jeopardising elements for effective mangrove management and conservation. Poor coordination among governmental departments appears to be mainly due to overlapping policies regarding the mangrove ecosystem, as well as language barriers between local Tamil speaking and Sinhala speaking officers, and outdated means of communication. Difficulties in the management of mangrove ecosystems as an intertidal system are not uncommon, due to the necessity of coordinating different governmental departments which have overlapping jurisdiction over this ecosystem (Iftekhar, 2008; Carter et al., 2015; Rog and Cook, 2017). Additionally, the three-decades-long civil war that affected the Jaffna Peninsula has caused high levels of distress on the local population and is likely to have influenced stakeholder's perceptions in relation to the local ecosystems (Thomas et al., 2022).

The participants have reached a consensus regarding absence of funding and unsatisfying post-monitoring process as causes of failure of replantation projects. indeed, the importance of post-care of replantation sites was mentioned by other studies as a crucial step in avoiding a high mortality rate (i.e., Gallup et al., 2020). Lack of scientific procedure and preliminary research, as well as improper species selection were identified as additional causes of failure, as encountered by Kodikara et al. (2017) for several restoration projects in other Sri Lankan districts. Natural regeneration has been observed in Jaffna's mangroves by participants belonging to governmental departments, which could explain the discordance on replantation practices for mangrove conservation. Other research observed natural regeneration processes after mangrove clearing, although solely in proximity to the propagule source (Van et al., 2015). On the other hand, replantation can be a powerful tool to restore larger areas of eradicated mangroves, bearing in mind that natural colonisation of original species can take considerable time and restoration of original functionality is not always guaranteed (Walton et al., 2006; Van et al., 2015). To conclude, solutions for these challenges have been proposed by the respondents and documented by literature for other tropical countries. Participation of local communities in mangrove replantation programmes can be a potent tool for effective mangrove restoration (Walton et al., 2006; Gallup et al., 2020) and reconciling mangroves-related departments under a unique entity or establishment of binding policies for mangrove-related departments (Kodikara et al., 2017) can be powerful moves for enhancing mangrove management, together with incentivising mangrove research projects with the scientific community (Iftekhar, 2008; Kodikara et al., 2017) and ecotourism activities for fund collection (Iftekhar, 2008).

### 4.4. Strengths and weaknesses of this study

The combination of qualitative and quantitative data with a multimethod approach is the main strength of this study, followed by the merging of perspectives from a wide variety of stakeholders. Indeed, Biggs et al. (2021) suggests the combination of multiple methods as a powerful practice to disentangle complex topics, such as issues related to social-ecological systems. However, the sample size of respondents participating in the ethnobiological survey was considerably smaller compared to similar ethnobiological studies (i.e., Dahdouh-Guebas et al., 2006), due to 200 encountered households (out of 250) that declared to not use mangroves for any purposes and were not willing to share their socio-demographic data. The sample size (50) may not be representative of the mangrove fringing community of the study site. Moreover, participants from the three villages were considered as a unique community, and differences among villages were not investigated, due to the scarce utilisation of mangrove goods and services. Likewise, this study considers governmental departments, NGOs, universities and private enterprises as a unified group of stakeholders involved in mangrove management, defined as category (ii) in Section 2.2.1 Hence, results were not studied in linkage with the stakeholder of origin. Remote sensing data and other relevant observational studies need to be carried out to verify the stakeholder and communities' perception of mangrove cover change. Finally, effects of the pandemic and of the Sri Lankan economic crisis on the topics addressed in the research were not investigated, which could have partly impacted participants' interactions and motivation to participate in the study.

## 5. Conclusion

While literature reports that mangroves goods and services continue to be essential for the livelihood of communities in several tropical countries, little research has been carried out in Northern Sri Lanka's mangrove social-ecological systems. With this study, we examined the main mangrove goods and services derived from mangroves that benefit the local population of Jaffna Peninsula, as well as the community's perception of the mangrove ecosystem. We found that a small fraction of the community continues to actively utilize mangrove goods and services and to have a good understanding of the local mangrove ecosystems. This could be due to the temporary migration of a large part of the Jaffna population during the civil war combined with the increasing availability of alternative non-mangrove-options, but the factors lying behind the redirection toward alternative solutions require further investigation. However, we mean to highlight the significance of this ecosystem, independently of the scarcity of direct benefits perceived by the neighbouring communities. The utilisation of multiple methodologies showed to be a powerful approach to address complex issues regarding ecosystems that are managed and protected by several entities. Q methodology, a semi-quantitative method, combined with an expert opinion survey and semi-structured interviews, provided us with a multitude of qualitative and quantitative data on experts' perspectives. The Q methodology revealed discourses related to community-oriented, government -oriented and mangrove conservation-oriented. Semi structured interviews brought out challenges to mangroves regarding and ownership, lack of collaboration among stakeholders, overlapping jurisdiction and insufficient scientific input in mangrove management. Experts opinion surveys highlighted the major threats such as pollution and encroachment. The investigation of perspectives with experts in mangrove management and conservation brought us to discover the main challenges that can jeopardise mangrove conservation in Jaffna Peninsula, and possible solutions to these issues. Our results show that more research is required to ensure the establishment of proper measures for effective mangrove conservation in Jaffna Peninsula. It is essential to document environmental data and good practices for mangrove replantation, and weak interactions among departments need to be addressed. Mangrove ecosystems should be clearly defined by jurisdiction and managed by relevant departments to minimize overlapping jurisdictions. It is imperative to clarify land ownership issues before initiating mangrove management projects. Local universities and research institutions may increase their involvement in mangrove management trajectories in the Northern province of Sri Lanka. This study can serve as an example applicable to mangrove ecosystems in several other countries and to different systems found under the jurisdiction of multiple entities, as a potential approach to disentangle weaknesses in management and start acting toward more effective environmental conservation.

## CRediT authorship contribution statement

**Thanne Walawwe Gedera Fathima Mafaziya Nijamdeen:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Validation, Writing – original draft, Writing – review & editing. **Sofia Peruzzo:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Validation, Writing – original draft, Writing – review & editing. **Kodikara Arachchilage**

**Sunanda Kodikara:** Supervision, Writing – review & editing. **Hajaniaina Andrianavalonarivo Ratsimbazafy:** Conceptualization, Methodology, Writing – review & editing. **Thenne Walawe Gedhara Fathima Ashara Nijamdeen:** Investigation, Writing – review & editing. **Thajudeen Thahira:** Investigation, Writing – review & editing. **Thasajini Sajeevan:** Investigation, Writing – review & editing. **Deluxeani Kugathasan:** Investigation, Writing – review & editing. **Jean Hugé:** Validation, Writing – review & editing, Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Supervision. **Farid Dahdouh-Guebas:** Conceptualization, Data curation, Funding acquisition, Validation, Writing – review & editing, Methodology, 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.

## Acknowledgments

This research was carried out under the research permits/permissions/ethical clearance from the Ruhuna University of Sri Lanka and the South Eastern University of Sri Lanka. This research was financed by the University Grants Commission of Sri Lanka (UGC/VC/DRIC/PG2019 (1)/SEUSL/01), Erasmus Mundus, and University Libre De Bruxelles.

## Appendix 1. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.forpol.2024.103236.

## References

Amarasinghe, M., Perera, R., 2017. Ecological biogeography of mangroves in Sri Lanka. Ceylon J. Sci. 46, 119. https://doi.org/10.4038/cjs.v46i5.7459.

Arulnayagam, A., 2020a. Floral distribution, abundance and diversity of mangroves in Sangupiddy, Kilinochchi, the northern coast of Sri Lanka. GSJ 8 (2).

Arulnayagam, A., 2020b. Floral distribution, diversity, and ecology of mangrove forests in Mandaitivu and Arali, Sri Lanka. Indones. J. Soc. Environ. Issues (IJSEI) 1 (3), 151–160.

Arulnayagam, A., Khim, J.-S., Park, J., 2021. Floral and faunal diversity in Sri Lankan mangrove forests: a systematic review. Sustainability 13, 9487.

Arumugam, M., Niyomugabo, R., Dahdouh-Guebas, F., Hugé, J., 2021. The perceptions of stakeholders on current management of mangroves in the sine-Saloum Delta, Senegal. Estuar. Coast. Shelf Sci. 248, 107160.

Biggs, R., de Vos, A., Preiser, R., Clements, H., Maciejewski, K., Schlüter, M., 2021. The Routledge Handbook of Research Methods for Social-Ecological Systems. Taylor & Francis.

Carter, H.N., Schmidt, S.W., Hirons, A.C., 2015. An international assessment of mangrove management: incorporation in integrated coastal zone management. Diversity 7, 74–104.

Dahdouh-Guebas, F., Mathenge, C., Kairo, J.G., Koedam, N., 2000. Utilization of mangrove wood products around Mida Creek (Kenya) amongst subsistence and commercial users. Econ. Bot. 54, 513–527.

Dahdouh-Guebas, F., Hettiarachchi, S., Lo Seen, D., Batelaan, O., Sooriyarachchi, S., Jayatissa, L.P., Koedam, N., 2005. Transitions in ancient inland freshwater resource Management in Sri Lanka Affect Biota and Human Populations in and around coastal lagoons. Curr. Biol. 15, 579–586. https://doi.org/10.1016/j.cub.2005.01.053.

Dahdouh-Guebas, F., Collin, S., Lo Seen, D., Rönnbäck, P., Depommier, D., Ravishankar, T., Koedam, N., 2006. Analysing ethnobotanical and fishery-related importance of mangroves of the East-Godavari Delta (Andhra Pradesh, India) for conservation and management purposes. J. Ethnobiol. Ethnomed. 2, 1–22. https://doi.org/10.1186/1746-4269-2-24.

Dahdouh-Guebas, F., Ajonina, G.N., Amir, A.A., Andradi-Brown, D.A., Aziz, I., Balke, T., Friess, D.A., 2020. Public perceptions of mangrove forests matter for their conservation. Front. Mar. Sci. 901.

Dahdouh-Guebas, F., Hugé, J., Abuchahla, G.M.O., Cannicci, S., Jayatissa, L.P., Kairo, J. G., Arachchilage, S.K., Koedam, N., Nijamdeen, T.W.G.F.M., Mukherjee, N., Poti, M., Prabakaran, N., Ratsimbazafy, H.A., Satyanarayana, B., Thavanayagam, M., Vande Velde, K., Wodehouse, D., 2021. Reconciling nature, people and policy in the mangrove social-ecological system through the adaptive cycle heuristic. Estuar. Coast. Shelf Sci. 248, 106942.

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R.T., Molnár, Z., Shirayama, Y., 2018. Assessing nature's contributions to people. Science 359 (6373), 270–272.

Elo, S., Kyngäs, H., 2008. The qualitative content analysis process. J. Adv. Nurs. 62, 107–115.

Feller, I.C., Lovelock, C.E., Berger, U., McKee, K.L., Joye, S.B., Ball, M.C., 2010. Biocomplexity in mangrove ecosystems. Annu. Rev. Mar. Sci. 2, 395–417.

Frank, C., Kairo, J.G., Bosire, J.O., Mohamed, M.O., Dahdouh-Guebas, F., Koedam, N., 2017. Involvement, knowledge and perception in a natural reserve under participatory management: Mida Creek, Kenya. Ocean Coast. Manag. 142, 28–36.

Gallup, L., Sonnenfeld, D.A., Dahdouh-Guebas, F., 2020. Mangrove use and management within the Sine-Saloum Delta, Senegal. Ocean Coast. Manag. 185, 105001.

Ganguly, S., 2018. Ending the Sri Lankan civil war. Daedalus 147 (1), 78–89.

Gunaalan, K., Ranagalage, M., Gunarathna, M.H.J.P., Kumari, M.K.N., Vithanage, M., Srivaratharasan, T., Saravanan, S., Warnasuriya, T.W.S., 2018. Application of geospatial techniques for groundwater quality and availability assessment: a case study in Jaffna Peninsula, Sri Lanka. ISPRS Int. J. Geo Inf. 7, 20. https://doi.org/10.3390/ijgi7010020.

Hugé, J., Vande Velde, K., Benitez-Capistros, F., Japay, J.H., Satyanarayana, B., Nazrin Ishak, M., Quispe-Zuniga, M., Mohd Lokman, B.H., Sulong, I., Koedam, N., Dahdouh-Guebas, F., 2016. Mapping discourses using Q methodology in Matang Mangrove Forest, Malaysia. J. Environ. Manag. 183, 988–997. https://doi.org/10.1016/j.jenvman.2016.09.046.

Iftekhar, M.S., 2008. An overview of mangrove management strategies in three South Asian countries: Bangladesh, India and Sri Lanka. Int. For. Rev. 10, 38–51.

Janen, S.S., Sivakumar, S.S., 2014. Groundwater quality improvement of Jaffna Peninsula of Sri Lanka by regulating water flow in the lagoon mouths. Int. J. Sci. Eng. Res. 5 (4), 973–978.

Jayatissa, L.P., Dahdouh-Guebas, F., Koedam, N., 2002. A review of the floral composition and distribution of mangroves in Sri Lanka. Bot. J. Linn. Soc. 138, 29–43. https://doi.org/10.1046/j.1095-8339.2002.00002.x.

Kodikara, K.A.S., Mukherjee, N., Jayatissa, L.P., Dahdouh-Guebas, F., Koedam, N., 2017. Have mangrove restoration projects worked? An in-depth study in Sri Lanka. Restor. Ecol. 25, 705–716.

Lee, S.Y., Primavera, J.H., Dahdouh-Guebas, F., McKee, K., Bosire, J.O., Cannicci, S., Diele, K., Fromard, F., Koedam, N., Marchand, C., 2014. Ecological role and services of tropical mangrove ecosystems: a reassessment. Glob. Ecol. Biogeogr. 23, 726–743.

Mukherjee, N., Zabala, A., Huge, J., Nyumba, T.O., Adem Esmail, B., Sutherland, W.J., 2018. Comparison of techniques for eliciting views and judgements in decision-making. Methods Ecol. Evol. 9, 54–63.

Ngendahimana, E., 2021. Mangrove Ecosystem Functions, Goods, and Services in Southern and North-Western Sri Lanka; Insight towards Ethnobiology and Mangrove Conservation. Master thesis.. Université Libre de Bruxelles, Vrije Universiteit Brussel, Brussels.

Nijamdeen, T.M., Hugé, J., Ratsimbazafy, H.A., Kodikara, K.A.S., Dahdouh-Guebas, F., 2022. A social network analysis of mangrove management stakeholders in Sri Lanka's Northern Province. Ocean Coast. Manag. 228, 106308.

Nijamdeen, T.W.G.F.M., Ratsimbazafy, H.A., Kodikara, K.A.S., Nijamdeen, T.W.G.F.A., Thahira, T., Peruzzo, S., Hugé, J., 2023a. Mangrove management in Sri Lanka and stakeholder collaboration: a social network perspective. J. Environ. Manag. 330, 117116.

Nijamdeen, T.W.G.F. Mafaziya, et al., 2023b. Understanding the ethnobiological importance of mangroves to coastal communities: a case study from Southern and North-western Sri Lanka. Mar. Policy 147, 105391.

Perera, K.A.R.S., Amarasinghe, M.D., Somaratna, S., 2013. Vegetation structure and species distribution of mangroves along a soil salinity gradient in a micro-tidal estuary on the North-western coast of Sri Lanka. Am. J. Mar. Sci. 1 (1), 7–15.

Pfeifer, R., Kalbas, Y., Coimbra, R., Leenen, L., Komadina, R., Hildebrand, F., Halvachizadeh, S., Akhtar, M., Peralta, R., Fattori, L., 2020. Indications and interventions of damage control orthopedic surgeries: an expert opinion survey. Eur. J. Trauma Emerg. Surg. 1–12.

Priyashantha, A.K.H., Taufikurahman, T., 2020. Mangroves of Sri Lanka: distribution, status and conservation requirements. Trop. Plant Res. 7, 654–668.

Rizal, A., Sahidin, A., Herawati, H., 2018. Economic value estimation of mangrove ecosystems in Indonesia. Biodiv. Int. J. 2, 98–100.

Rog, S.M., Cook, C.N., 2017. Strengthening governance for intertidal ecosystems requires a consistent definition of boundaries between land and sea. J. Environ. Manag. 197, 694–705.

Rubiera Rodriguez, S., 2020. Exploring the Ethnobiological Importance of Mangrove Social-Ecological Systems on the Eastern Coast of Sri Lanka for Conservation, Management, and Well-Being. Master thesis.. Université Libre de Bruxelles, Brussels.

Samarathunga, W., Cheng, L., Weerathunga, P.R., 2020. Transitional domestic tourist gaze in a post-war destination: a case study of Jaffna, Sri Lanka. Tour. Manag. Perspect. 35, 100693.

Santos, L.C.M., Gasalla, M.A., Dahdouh-Guebas, F., Bitencourt, M.D., 2017. Socio-ecological assessment for environmental planning in coastal fishery areas: a case study in Brazilian mangroves. Ocean Coast. Manag. 138, 60–69. https://doi.org/10.1016/j.ocecoaman.2017.01.009.

Satyanarayana, B., Mulder, S., Loku Pulukkuttige, J., Dahdouh-Guebas, F., 2013. Are the mangroves in the Galle-Unawatuna area (Sri Lanka) at risk? A social-ecological approach involving local stakeholders for a better conservation policy. Ocean Coast. Manag. 71, 225–237. https://doi.org/10.1016/j.ocecoaman.2012.10.008.

Schmolck, P., 2014. PQ Method Software, v2.35. Available at: http://schmolck.userweb.mwn.de/qmethod/.
Šimović, H., Blažić, H., Štambuk, A., 2014. Perspectives of tax reforms in Croatia: expert opinion survey. Finan. Theory Pract. 38, 405–439.
Soosai Siluvaithasan, A., Stokke, K., 2006. Fisheries under fire: impacts of war and challenges of reconstruction and development in Jaffna fisheries, Sri Lanka. Norsk Geogr. Tidsskrift-Norw. J. Geogr. 60, 240–248.
Spalding, M., Leal, M., 2021. The State of the world's Mangroves 2021. Global Mangrove Alliance.
Suresh, A., 2024. Coast and the community: understanding public perceptions towards coastal ecosystems in the Northern Province, Sri Lanka. J. Coast. Conserv. 28 (1), 33.
Suthakar, K., Bui, E.N., 2008. Land use/cover changes in the war-ravaged Jaffna peninsula, Sri Lanka, 1984–early 2004. Singap. J. Trop. Geogr. 29, 205–220. https://doi.org/10.1111/j.1467-9493.2008.00329.x.
Thomas, F.C., Coulombe, S., Girard, T.A., Hart, T.L., Doherty, S., Dass, G., Wickramage, K., Siriwardhana, C., Surenthirakumaran, R., McShane, K., 2022. Displacement-related stressors in a Sri Lankan war-affected community: identifying the impact of war exposure and ongoing stressors on trauma symptom severity. SSM - Mental Health 2, 2666–5603.
Tuholske, C., Tane, Z., López-Carr, D., Roberts, D., Cassels, S., 2017. Thirty years of land use/cover change in the Caribbean: assessing the relationship between urbanization and mangrove loss in Roatán, Honduras. Appl. Geogr. 88, 84–93.
UNHCR, 2003. The UN Refugee Agency. Retrieved from. www.unhcr.org/news/latest/2003/1/3e26e8f84/unhcr-talks-sri-lankans-uprooted-civil-war.html (accessed on 06/07/2022).
Vaismoradi, M., Turunen, H., Bondas, T., 2013. Content analysis and thematic analysis: implications for conducting a qualitative descriptive study. Nurs. Health Sci. 15, 398–405.
Van, T.T., Wilson, N., Thanh-Tung, H., Quisthoudt, K., Quang-Minh, V., Xuan-Tuan, L., Dahdouh-Guebas, F., Koedam, N., 2015. Changes in mangrove vegetation area and character in a war and land use change affected region of Vietnam (Mui Ca Mau) over six decades. Acta Oecol. 63, 71–81.
Vande Velde, K., Hugé, J., Friess, D.A., Koedam, N., Dahdouh-Guebas, F., 2019. Stakeholder discourses on urban mangrove conservation and management. Ocean Coast. Manag. 178, 104810 https://doi.org/10.1016/j.ocecoaman.2019.05.012.
Vo, Q.T., Künzer, C., Vo, Q.M., Moder, F., Oppelt, N., 2012. Review of valuation methods for mangrove ecosystem services. Ecol. Indic. 23, 431–446.
Walters, B.B., Rönnbäck, P., Kovacs, J.M., Crona, B., Hussain, S.A., Badola, R., Primavera, J.H., Barbier, E., Dahdouh-Guebas, F., 2008. Ethnobiology, socio-economics and management of mangrove forests: a review. Aquat. Bot. 89, 220–236.
Walton, M.E., Samonte-Tan, G.P., Primavera, J.H., Edwards-Jones, G., Le Vay, L., 2006. Are mangroves worth replanting? The direct economic benefits of a community-based reforestation project. Environ. Conserv. 33 (4), 335–343. https://doi.org/10.1017/S0376892906003341.
Zabala, A., 2014. Qmethod: An R Package to Analyse Q Method Data. University of Cambridge, Cambridge, UK, p. 163.
Zabala, A., Sandbrook, C., Mukherjee, N., 2018. When and how to use Q methodology to understand perspectives in conservation research. Conserv. Biol. 32, 1185–1194. https://doi.org/10.1111/cobi.13123.