Norges miljø- og biovitenskapelige universitet

Master's Thesis 2017 30 ECTS
Noragric

Social-Ecological Resilience of Mangroves and Coastal Households in Batticaloa District, Sri Lanka

Maja Jonsson
M-IES

Social-Ecological Resilience of Mangroves and Coastal Households in Batticaloa District, Sri Lanka

MSc Thesis

By Maja Jonsson, August 2017

Norwegian University of Life Sciences

Department of International and Environmental and Development Studies

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Title Photo: Mangrove Forest and water pond in Sathurukondan, Batticaloa (Photo: Maja Jonsson 2016)

majajo@nmbu.no

Noragric

Department of International Environment and Development Studies

The Faculty of Landscape and Society

P.O. Box 5003

N-1432 Ås

Norway

Tel.: +47 67 23 00 00

Internet: https://www.nmbu.no/fakultet/landsam/institutt/noragric

Declaration

I, Maja Jonsson, declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been appended. This work has not been previously submitted to any other university for award of any type of academic degree.

Signature……..

Date……

Acknowledgements

I would like to express my greatest gratitude to my supervisor Ian Bryceson, who gave me guidance and support throughout this research process and for making this master thesis completion possible through tragic times.

I would also deeply thank my field supervisor Dr T. Mathiventhan at the Eastern University of Sri Lanka (EUSL), who gave invaluably support and access to his network in Batticaloa and taking time to helping me familiarize with Batticaloa and its mangroves. I must also kindly thank Dr. T Jayasingam likewise for all his knowledge and input into my study.

A special thanks to my field assistants who got into the mud to help me and translators for connecting me to the locals but also for keeping me safe as your concern. I am forever grateful for all your efforts Prahadeesh Nagaretnam, Thayananth Selvarajah, Meschude Wellington, Kingston Shan, and Hasith Priyashantha.

All the staff at Sarvodaya, at the Department of Botany at the EUSL, and EUSL Guesthouse deserves all cred possible for making me feel part of your community and always cheering on me. I must also mention my designated driver Kirupairetnam, who knows all shortcuts and corners in the Districts, and Meerasaibo, Fouzia, and Anthamlebbe who made sure I was well fed before my field work. Also, thanks to family of Raja and Suki, and Nagaretnam and Punithavathy who included me in their families. I am very grateful and lucky to have met you all.

A very special and warm thanks to my own family who are always rock-solid in support me no matter what crazy adventures I get myself into, and in all difficulties we have to go through in life.

Lastly, I must thank my fellow student colleagues and study advisor Anette Virtanen at NMBU for helping, fixing, and mutually supporting through this research process.

Thank you, Nandri, Tack!

Abstract

This study compared two Social-Ecological Systems (SES) of mangroves and adjacent households, Sathurukondan and Nasivanthivu in Batticaloa District, with varied degrees of mangrove dependence, and different disturbance histories, but both involved in natural resource management projects. This study applied a mixed method approach, where ecological inventories were probability-sampled quantitatively and social dimensions were assessed qualitatively. Species diversity, forests characteristics, and structure data was derived from quadrats along transects perpendicular to the road and lagoon. The social data was collected through semi-structured interviews with households, key informants, and Fisheries Co-Operative Societies group discussions. The interviews were purposively sampled and thematically analyzed through coding and finally discussed in relation to principles of building SES resilience. The data indicate that insufficient tidal exchange in Sathurukondan cause dominancy of undesired mangrove species, *E. agallocha*, and mangrove associates that suggest ecological degradation. Nasivanthivu had higher functional mangrove species diversity caused by sound environmental conditions. Encroachment, accumulating waste, and erosion at lagoon edges were processes detracting from resilience at both locations. However, both mangrove forests are growing larger as a result from recent awareness program, replanting schemes, and increased monitoring. Most of these efforts are based on Participatory Coastal Zone Restoration and Sustainable Management Project that aims to restore coastal ecosystems through community participation and natural resource management. Further, as suggested from the context in Sathurukondan is access to urban areas increases substitution capacity in livelihood diversification and builds SES resilience. Further, social cohesion gives momentum to build resilience and adaptive capacity if properly embraced to wider governance networks for co-management or build capacity to self-organize in areas with low diversification flexibility, based from Nasivanthivu findings. There is large potential of building Social-Ecological-System resilience through diverse participation vertically and horizontally, sharing experience and information, open communication, mutual trust to maintain and agree upon desirable ecosystem services. However, incorporating participatory approaches and true local concerns may not be properly implemented, based from critique on hesitant devolution and internal social hierarchical structures within committees that sustain old top-down approaches.

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List of acronyms

ADB – Asian Development Bank

CBM – Community Based Management

CBO – Community Based Organization

CCA – Coast Conservation Act

CCC – Community Coordination and Committee

CC&CRMD – Coast Conservation & Coastal Resource Management Department

CEA – Central Environmental Authority

CZ – Coastal Zone

CZMP – Coastal Zone Management Plan

CNRM – Coastal Natural Resource Management

DBH – Diameter at Breast Height

DMC – Disaster Management Committee

DOFAR - Department of Fisheries and Aquatic Resources

FCS – Fishers Co-operative Society

FD – Forest Department

GN / GS – Grama Nildahari / Grama Sevaka (previous title)

GoSL – Government of Sri Lanka

IUCN – International Union for Conservation of Nature

IVP – Important Value Percentage, from IVI – Important Value Index

LMC – Lagoon Management Committee

LTTE – Liberation Tigers of Tamil Eelam

MAP – Mangrove Action Project

MCEC – Mangrove Conservation and Education Center

MMF – Mangroves For the Future

NCZ&CRMP - National Coastal Zone and Coastal Resource Management Plan

NECCDEP – North East Coastal Community Development Project

NGO – Non-Governmental Organization

NRM – Natural Resource Management

PCZRSMP – Participatory Coastal Zone Restoration and Sustainable Management Project in the Eastern Province of Post-Tsunami Sri Lanka

PALM – Participatory Action and Learning Management Foundation

RDS – Rural Development Society

SAM – Special Area of Management

SDG – Sustainable Development Goals

SLAF – Sri Lankan Armed Forces

TEK – Traditional Ecological Knowledge

1.0 INTRODUCTION

Mangrove forests decreased by 1 % annually between 1980 and 2005 (FAO 2007) and despite reduced global rate of mangrove forest destruction between 0.16 % and 0.39 % South Asia still experience heavy destruction rates between 3.58 % and 8.08 % among their largest forests (Giri et al. 2015; Hamilton & Casey 2016). The deforestation is mainly caused by aquaculture, coastal development, and timber or fuel extraction which threatens the provision of valuable ecosystem services for coastal communities (Alongi 2002; Duke et al. 2007; Polidoro et al. 2010; Richards & Friess 2016). Sri Lanka, as a biodiversity hotspot, has experienced similar impacts from increased population density, tourism and economic development since the cessation of civil war (Buultjens et al. 2016; NECCDEP 2010a). In addition to these human impacts are natural disasters as tsunami, cyclones and floods reasons to cause mangrove forest degradation (GreenTech 2010; NECCDEP 2010a) and loss of these protective coastal vegetation has negatively affected resource dependent coastal communities (Satyanarayana et al. 2013).

Loss of mangroves entails a loss of a range of valuable ecosystem services and functions that coastal households depend upon (Duke et al. 2007). Mangrove ecosystem as wooden vegetation between land and sea provides habitat for a variety of species of fish, crustaceans, molluscs, birds, mammals, and reptiles (Barbier et al. 2011). Mangroves also protect shorelines from erosion and reduce impacts from storms surges and tsunamis (Alongi 2008). Further, mangroves high productivity, sediment accretion, and accumulation of organic debris make them an important carbon sequester and sink, especially within the soil (Donato et al. 2011). In addition, mangroves can purify waters by bioremediation (Miththapala 2013) and further provide coastal communities with sources of marine organisms, wood, esthetics, and climate regulation (Barbier et al. 2011).

As a response to degrading mangrove ecosystems and coastal livelihood development, the Government of Sri Lanka (GoSL) enforced mangrove conservation management by enacting participatory and community-based management (CBM). While conservation might ensure high biodiversity, forest growth and provision of related ecosystem services as carbon sequestration as desirable, the negative side-effects, such as natural resource access restrictions may marginalize coastal resource dependent livelihoods if not properly implemented with these challenges in mind (Satyanarayana et al. 2013). Humans and mangroves are connected in a Social-Ecological System (SES), historically co-evolved from

traditional resource uses and knowledge passed down from generations within a community with cultural practices to sustain desired ecosystem services (Berkes et al. 1998; Berkes et al. 2003). Because of this link should a sustainable conservation management consult and involve local resource users that are part of the SES's social aspect. Further, it is hoped that sustainable natural resource management (NRM) may work in synergy with poverty alleviation and increase human security as communities' well-being are included in the management regime (Datta et al. 2012).

Community Based Natural Resource Management (CBNRM) approaches decentralizes rights, responsibilities, and authority from governments to local communities (Alcorn et al. 2002; Datta et al. 2012) and focus on empowerment, equitable access and benefit distribution among the local community (Riviera-Guieb 2002). To prevent individual marginalization is CBM of mangroves emerged in response to the rapid decrease in mangrove covers globally and increase coastal community livelihood security (Datta et al. 2012). Local NGOs and state initiatives in Sri Lanka have had the same shift in focus from centralized management regime to more local participatory approaches for sustainable resource management (De Silva et al. 2011; NECCDEP 2010b). However, despite the aspirations of participatory approaches in coastal NRM, Sri Lanka is still developing economically in a rapid phase where mangroves and other coastal vegetation are converted into other industrial, residential and recreational land uses (Buultjens et al. 2016; NECCDEP 2010a).

Poverty alleviation and coastal ecosystem restoration initiatives have increased in Batticaloa District since the end of the civil war, but understanding how such management regimes are realized on household level is not widely studied in Batticaloa in relation to mangrove ecosystems recently. SES resilience could help to identify the dynamics between humans and nature and threats and opportunities to provision of ecosystem services (ES) to local communities' livelihoods (Berkes et al. 2003).

1.1 Purpose of study and Research Objectives

The purpose of this study is to examine natural and social processes that builds or detracts the general SES resilience between coastal households and mangrove ecosystems at two sites in Batticaloa District. This study will hopefully bring further understanding to dynamics between humans and mangroves in Batticaloa. The following objectives are outlined in order to approach the accompanied research questions:

1 To investigate mangrove stand characteristics and identify observable processes influencing the present mangrove ecosystem conditions. What processes are influencing the system and how?

2 To investigate the households uses, perceptions, livelihood assets, and strategies in relation to mangroves, now and in the past. How are mangroves perceived and used by households now and in the past? What is the reason behind the changes and what were the households' strategies to cope with the changes? What are households perceived benefits from the mangroves?

3 To investigate the current mangrove management regime (based on the findings from the above mentioned objectives) and place the SES in respective phase of the adaptive cycle. How is management regime and implementation process affecting mangroves and coastal households? How is management regime relating to principles of building resilience? Are there risks for generating winners and losers? In what phase of the adaptive cycle is the SES?

1.2 Background: What are mangroves?

Mangroves are tropical coastal trees and shrubs growing in the intertidal zone in an environment between land and sea which experiences high salinity, wave action, inundation, strong winds, and muddy soils (Prasanna & Ranawana 2014). Mangroves have adapted both morphologically and physically in order to grow there by: stilt and aerial roots for gaseous exchange during high tides; viviparous seeds which germinate while still attached to the tree to later be dispersed by tidal action (McKee 2002); and the plants ability to secrete or exclude salt in roots and leaves (Prasanna & Ranawana 2014). Temperature, salinity, tidal fluctuation, sediment, and wave energy are factors that affect mangrove distribution. The tidal fluctuations are indirectly important for ecological functions in the mangrove ecosystems, such as bringing nutrients and sea water which creating saline soils which favor mangrove species over terrestrial plants (Lugo 1980; McKee 2002). However, too much salinity inhibits primary production where mangroves then need to use energy for regulating salt concentration and ionic balance. Also, anaerobic microbial activity in the soils produces toxic Hydrogen Sulfide (H_2S) and rainfall and upland freshwater exchange leaches out these salts and toxins in the soils to keep the chemical balance suitable for mangrove production (Kathiresan 2008). So the hydrology, tidal additives, and freshwater leaching in moderate levels are important for a healthy and productive mangrove ecosystem (Alongi 2009). Too strong tidal currents and wave energy however, prevent mangrove colonization and can cause shore erosion.

As a result of the productivity, location, and adaptation of mangroves, they contribute with a wide range of ES such as: stabilizing coastlines and reducing erosion (De Silva & De Silva 1998); filtering upland water runoff (Miththapala 2013); serving as habitat, nurseries and feeding grounds for important marine organisms as fish, crab, shrimp and off shore ecosystems (De Silva & De Silva 1998); storm and tsunami protection to coastal communities (Dahdouh-Guebas et al. 2005b; Mattsson et al. 2009); providing wood and multiple products to coastal communities (De Silva & De Silva 1998); sequester atmospheric carbon in biomass and soil (Donato et al. 2011); habitat for mammals and birds (McKee 2002).

1.2.1 Distinction between true mangroves and associates

There are around 70 mangrove species of true mangroves and associates in the world's approximately 181 000 km^2 of mangrove areas (Spalding et al. 1997) but their true numbers and classification is under debate, depending on the definition to distinguish between true and associate mangroves (De Silva & De Silva 1998). According to Tomilson's criteria (1986 cited in Wang et al. 2010) true mangroves possess all or most of the following features: (i) occurring only in mangrove environment and not extending into terrestrial communities; (ii) morphological specialization (aerial roots, vivipary); (iii) physiological mechanism for salt exclusion and/or salt excretion; (iv) taxonomic isolation from terrestrial relatives. However, fringing mangroves towards landward zones don't always fall under these clear distinctions as some true mangroves tolerate freshwater wetlands such as *Heritiera littoralis, Excoecaria agallocha,* and *Lumnitzera racemosa,* but are simply outcompeted with other freshwater species (De Silva & De Silva 1998). All of the above mentioned species are commonly classified as true mangroves, but the two first species were classified as mangrove associates by Wang et al. (2010) as they experience leaf traits and salt contents within similar ranges as mangrove associates. Wang et al. also found *Acanthus ilicifolius* more related to true mangroves than associates. With this debate in mind, this study will adopts the commonly used classification in Sri Lanka based on the national flora (Jayatissa et al. 2002; Jayatissa 2012) which originates from that of Tomilson (1986) with exception of *Acrostichum spp* which are classified as associates.

1.2.2 Mangrove forest characteristics

The mangrove ecosystems are developed as a result from long-term geomorphological processes connected by "*interaction with contiguous ecosystems in the regional mosaic*"

(Lugo & Snedaker 1974. p 60) from topography, hydrology, and tidal action. Mangrove ecosystems may be classified in geomorphological types where location determine their environmental condition within witch the mangrove forests grows and obtain specific characteristics and functions (Lugo 1980). The categories are: riverine, overwash, fringe, basin, dwarf, and hammock (De Silva & De Silva 2006 cited in Prasanna & Ranawana 2014; Lugo & Snedaker 1974) with inhibit conditions and long-term processes that influence the settings for the mangrove ecosystem. This is useful to identify favorable conditions in which a mangrove stand grow, and possible trajectories through the geomorphological changes (Lugo 1980).

Alongi (2008. p 5) states that in: *"[...] mangrove forests, stand composition and structure are the results of a complex interplay of physiological tolerances and competitive interactions leading to a mosaic of interrupted or arrested succession sequences in response to physical/chemical gradients and changes in geomorphology"*. The physical and chemical gradients are causing mangrove zonation which is the spatial variation of mangroves appearing in predictable bands parallel to the shoreline as horizontal bands with monospecific characteristics. Some factors determining their distribution are based on: plant succession due to land building; response to geomorphological factors; physiological adaptation to gradients across the intertidal zone; differential dispersal of propagules; differential predation on propagules across the intertidal; and interspecific competition (Smith 2002 p 7-8). The zones may vary between geographical locations but a common generalization in large and relatively undisturbed forests are usually *Rhizophora*, *Sonneratia*, and *Bruguiera* at the seaward zone, followed by a mixed mangrove community with *Avicennia*, *Lumnitzera*, and *Ceriops* species. However, *Lumnitzera* and *Avicennia* may also be found in the most landward zone, together with associate species due to restricted tidal action. The mangrove forests can further be very complex and inter-mixed due to frequent disturbances occurring at the coast (De Silva & De Silva 1998).

Complex stands and patches of different structure and composition are common in mangrove ecosystems where disturbances create such mosaic patterns in forest stands after canopy gaps triggering regeneration (Alongi 2009). Such gap created from lightning have been studied previously (Amir & Duke 2009) but local harvesting may create similar gaps causing mixed mangrove structure. The regeneration of a mangrove stand community that experiences a mosaic of successional stages is however often dependent on the initial stand structure (Alongi 2009). Competitive exclusion by canopy dominants has a big role in regulating

recruitment in gaps and subsequent forest succession characterized in disturbed mangrove forest, as local canopy cover species are more likely to recolonize available space than colonizing propagules dispersed with distance (Alongi 2009).

Mangroves high productivity and adaptations to thrive in extreme conditions on the coastal margins render them inherently resilient due to the diverse disturbances they historically have survived like: sea level rise from which mangrves have migrated in pace by accreting soils; patterns of recovery from storms and hurricanes with pioneer-phase characteristics and mosaic of interrupted successional stages from chemical, physical and landform changes; or generally being resilient to disturbances as obtaining large reservoir of below-ground nutrients, micrbial composition, complex and efficient biotic controls and feedbacks (Alongi 2008). However, mangroves are not easily regenerated on lands which have been significant and extensive converted as the initial conditions for mangrove settlement is lost.

1.2.3. Mangroves in Sri Lanka

Sri Lanka Island has lagoons, estuaries, and wetlands along its coasts that often host mangrove ecosystems (Kotagama & Bambaradeniya 2006). The national mangrove extent estimations in the past vary from 8 800 ha in 2005 (FAO 2007), 15 668 ha in 2010 (according to unpublished data in Forest Department in Sri Lanka in Prasanna and Ranawana2014), and 8 718 ha in 2014 by Coastal Conservation and Coastal Resource Management Department (CC&CRMD). There are around 20 to 23 true mangroves and around 18 associate species in Sri Lanka (Jayatissa et al. 2002; Jayatissa 2012). The largest mangrove forests are in northeast consists mostly of fringing and riverine mangrove types (De Silva & De Silva 1998). The differences between fringing and riverine types is the low- or high-saline conditions that limits the mangrove species distribution caused by the seasonal rains and freshwater discharge between the wet zone and dry zone, but also upstream (riverine) and downstream (fringing) mangroves respectively (De Silva & De Silva 1998). There are also areas where mangroves that experienced over-harvesting or reduced tidal fluctuation, caused from bridge and dam constructions, has turned into shrub mangroves (CEA et al. 2006; Karunathilake 2003).

The tropical climatic conditions in Sri Lanka have relatively even temperatures ranging between 26.5 °C to 28.5°C in the lowlands and decreasing temperatures in the highlands (15.9 °C mean annual) (Department of Meteorology 2016). The climatic seasonality in Sri Lanka depends mainly on the distribution of the rainfall and topography which gives the country two monsoon seasons where southwestern and northeastern parts of the country, where the

southwestern monsoon occurs from May to September with precipitations ranging between 100 mm to over 3000 mm. The northeastern monsoon initiates around December to February but the rain usually starts as early as October in Batticaloa District, with average 320 mm per month. The amount of rainfall and topography distribution in Sri Lanka creates wet and dry zones where the former is the south western parts, Negombo to Hambantota, together with the highlands and all the rest exists in the dry zone (Department of Meteorology 2016). Batticaloa Lagoon in the east coasts is one of the largest water bodies in the country with salinity ranging from 6 to 40 ppt with fringing mangroves but also riverine mangroves in upstream rivers. Local mangrove stands in Batticaloa District have no clear zonation in the species gradient due to low tidal amplitude of 10 cm (CEA et al. 2006) and the stands don't grow as tall compared to other Asian mangroves due to the influences from human disturbances making inter-mixed mangrove stands (De Silva & De Silva 1998).

Mangrove ES and resources uses by coastal communities in Sri Lanka have been: medicines, food, and wood for construction, firewood, boats, fishnet dye, and brush piles[1] (Bandaranayake 1998; De Silva & De Silva 1998). In addition, mangrove forests have been converted to other land uses due to: tourism expansion; coastal infrastructure development; coconut, cinnamon and rubber plantations; and extensive shrimp farming (Buultjens et al. 2016; De Silva & De Silva 1998; NECCDEP 2010a). In the late 1970s, Batticaloa had the most commercial-scale shrimp farms with high profit which attracted many investors into the early 1980 (Galappaththi & Berkes 2014). However, while the governments promoted continued commercialization and small-scale shrimp farms all around the country, it became restricted in the northeast due to the emerging civil war, which was also why many shrimp farms were abandoned (Galappaththi & Berkes 2014; Mathiventhan 2007).

1.3 Contextual background of Sri Lanka

The Democratic Socialist Republic of Sri Lanka is divided into nine provinces which are further divided into 25 Districts, each of which having an appointed District Secretary that are comprised of a number of Divisional Secretary's Divisions (total 256) (Kruse 2007; Landstrom 2006). Further subunits of the Divisional Secretariats are called Grama Niladhari Divisions that is comprised of a number of Villages. The Grama Niladhari (GS – former name was Grama Sevaka and still commonly used by local villagers) subunit is the lowest

[1] Brush piling is a traditional fishing technique where mangrove branches are left under the water to create a food web that attract marine and lagoon organisms that later on can be trapped by surrounding the whole pile with fishing net to trap the fish.

appointed governmental officer with duty to report and issue permits, gather statistics and taxes, maintain voter registry, and keeping peace among personal disputes (Landstrom 2006). The electoral memberships in Sri Lanka have three layers of governance: Parliament (national); Provincial councils (regional), and the local authorities (local). The provincial councils were established as a demand from the LTTE in 1987 to provide some degree of power sharing from the central government (Widmalm 2002 cited in Landstrom 2006). Further, three types of authorities operate on local level: Municipal Councils (urban and towns); Urban Councils (less urbanized centers); and Pradeshiya Sabha (village councils) (Leitan 1997; United Nations Economic and Social Commission for Asia and the Pacific 2003 cited in Landstrom 2006). The Divisional Secretary's Divisions are the main unit of government administration who are responsible for implementing decentralized initiatives from Ministries, Provincial councils and local authorities (Landstrom 2006).

The economy of Sri Lanka after independence in 1948 was largely based on agriculture, but the major GDP generation today comes from the service sector, especially since the end of the civil war when economy have grown annually (World Bank 2015). The share of value added and the employment have decreased in the agricultural sector and increased in the industrial sector between the years 2000 – 2013. The service, agriculture, and industry sectors today contribute with 56.5 %, 7.1 %, and 26.8 % share of GDP respectively (Ministry of Finance 2017). To name a few major activities: marine fishing and aquaculture, coconut, rubber, and tea are the largest contributors to GDP within fishing, forestry and agricultural sector. Construction, food and tobacco products, textile, and mining within the industrial sector; and transport of goods and passengers, retail and wholesale, and personal service activities are the largest components contributing to GDP within the service sector in respective order of magnitude within the sectors (Ministry of Finance 2017). A lot of these economic activities occur along the coasts of Sri Lanka which attracts more people to settle and re-settle after the civil war (Buultjens et al. 2016).

1.3.1 The civil war (1983-2009) and the tsunami (2004)

In 2012, Sri Lanka had 20 million inhabitants where Sinhalese make up 75 % as the largest ethnic group followed by 11 % Tamils, and 9 % Muslims (Sri Lankan Department of Census and Statistics 2012). The Tamils are for the most part concentrated along the east and north coasts and around the estate sectors in the highlands (World Bank 2015). Since the independence from the British in 1948 it was suggested that challenges in provision of social

inclusion lead to Tamils feeling disenfranchised from economic benefits and development (World Bank 2015; Abeyratne 2004 cited in Buultjens et al. 2016). Armed formations mobilized eventually, called the Liberation Tigers of Tamil Eelam (LTTE), who wanted independence over the Tamil concentrated areas in the northeastern parts of Sri Lanka which became the agenda of the violent civil war (Bohle & Fünfgeld 2007).

Batticaloa Lagoon was one space of contested power during the war where the Sri Lankan Armed Forces (SLAF) strictly controlled the coastal strips as no-go zones, whereas the LTTE in contrast administered the landward strips though taxation and civilian control (Bohle & Fünfgeld 2007). Another contrast was LTTEs strategy to protect mangroves but also issued permits for sustainable mangroves usage (Mathiventhan 2007) whereas the SLAF cleared away whole mangrove forests to prevent hiding areas for LTTE (GreenTech 2010). Further, the SLAF had altered the natural processes in Batticaloa Lagoon by opening the only bar mount, which reduced the lagoon water level and hampered seasonal migration of fish and crustaceans. This increased the salinity within the lagoon, adjacent paddy fields, and water wells as the seasonal bar closing was lost (Bohle & Fünfgeld 2007). The already high fishing competition among the lagoon fishers increased and further security regulations of restricted access to fishing grounds pressured resources-dependent fishers (Calatharan 2007; NECCDEP 2010a). Bohle and Fünfgeld (2007. p 677) wrote: "*Environmental destruction, as a consequence of violence in the area, thus has also led to structural violence in the form of livelihood insecurity through a process of declining environmental entitlements among the already marginalized lagoon fishermen*".

In addition, the Indian Ocean tsunami on 26th December, 2004 caused a natural crisis with devastating human implication. While disasters are indiscriminate, the people most affected in the east were largely those already marginalized economically, politically and socially in the context of a civil war (Risvoll 2006; Walker 2013). Walker (2016) argues that in the tsunami created a space of opportunity to create peace as previous boundaries literally were washed away and the ethical differences were overruled to save one another despite the war. However, the reconciliation opportunity between the LTTE and GoSL was brief and lost instead of used by humanitarian organization to provide disaster aid also to victims of the conflict who otherwise were unreachable (Walker 2013). A thorough study by Risvoll (2006) found that this lost opportunity was partly derived from a failure to impose a shared mechanism for tsunami relief and reconstruction called Post-Tsunami Operation Management Structure (P-TOMS). This failure contributed to the continuation of the competitive politics

between the conflicting actors in Sri Lanka. Risvoll (2006) further argues how power centralization at District and National level bypassed local authorities which resulted in inappropriate assistance that lacked ground-reality-knowledge due to absent local level interactions. In addition, lack of coordination between actors working in the relief and reconstruction process neglected the vulnerability context within Batticaloa District due to the civil war. The resulting insensitive approaches that followed were derived from INGOs pursuing their own agendas of result-driven-work, together with gaps in communication and coordination between INGO and local actors (Risvoll 2006).

Some fishers were put in a more vulnerable position where the given aid was unsuitable to secure the local livelihoods, such as unsafe fishing boats and small mesh-sized fishing nets and bureaucratic regulations prevented beneficiaries to be given aid more than once (Risvoll 2006). If one is to allow any optimism from the tsunami after-math, one positive outcome in terms of social-ecological resilience was the highlighted importance of the coastal vegetation, such as mangroves, as protecting villages from natural disasters (Dahdouh-Guebas et al. 2005b; Mattsson et al. 2009). In terms of coastal ecosystem governance, the tsunami aftermath increasing numbers of donors and facilitators amplified the role of civil society and international community that could risk fragmentation in governance responsibility over natural resources (Ashiln 2012).

1.3.2 Mangrove management in Sri Lanka

Mangrove's unique placement between land and sea causes its management responsibility to vary, depending on specific locations along the Sri Lankan coast. Many governmental agencies regulate a range of activities in the coastal zone and its diverse natural resources which attracts many activities (NECCDEP 2010a) such as: coastal environmental protection; housing and infrastructure development; urban area management; tourism activities; and fishing and industrial activities (De Silva et al. 2011). According to the Forest Ordinance from 1885 are mangroves protected state-owned forests under the jurisdiction and responsibility of the Forest Department (FD) (Parliament of the Democratic Socialist Republic of Sri Lanka 1885; 2009). However, Coast Conservation and Coastal Resource Management Department (CC&CRMD) have the mandate to conserve and manage the environmental resources within

the coastal zone[2] (CZ) under the Coastal Conservation Act (Parliament of the Democratic Socialist Republic of Sri Lanka 1981).

The CC&CRMD has the main legal foundation for regulating activities in the CZ as the compilers of the Coastal Zone Management Plan (CZMP) where management policies and implementing strategies are formulated based on identified issues (CC&CRMD 2004; De Silva et al. 2011). The CZMP further emphasize Special Area of Management (SAM) where resource management promotes high community participation and flexible and adaptive approaches within a declared geographical area (Landstrom 2006). As the coastal areas have many resources and stakeholder interests, balancing the local livelihoods and commercial interests is the key for sustainable use and resource conservation in the CZMP and SAM outlays (NECCDEP 2010b). Most regulations emphasize participatory and sustainable conservation management (Parliament of the Democratic Socialist Republic of Sri Lanka 1885; 2009) but this sector-based administrative system has yet to prove efficiency as it lacks affordable tools in the legal framework to harmonize the priorities and operations of diverse state actors (De Silva et al. 2011).

Local and international NGOs often work as implementing partners in projects for community based sustainable coastal natural resource management to address these issues and incorporate the strategies of SAM and CZMP. Previously, such project were lacking from Batticaloa Districts due to the civil war (Mathiventhan 2007), or the projects focused on mangrove dependency only in one perspective of contributing to livelihood security, or discarded crucial environmental conditions to sustain an ecosystem (Ekaratne & Vidanage 2013). The most recent CCA highlights the sector linkages necessity for dynamic, interdisciplinary, and iterative process to promote sustainable management of coastal zones, but also for controlling and preventing risks threatening the coast lines (Katupotha 2016). The newest CZMP from 2016 also highlight participatory design and inclusive co-management processes in order to ensure sustainable and long-term use of coastal environment and resources to be consistent with the national development goals (CC&CRMD 2016).

Sri Lanka have a history of collaborative NRM as governance structure became more decentralized and as sustainable solutions required wider participation. Ashlin (2012) argues

[2] The Coastal Zone is defined as the area 300 m landward Mean High Water Line (MHWL) and 2 km seaward from the Mean Low Water Line (MLWL). In the case of any waterbody connected to the sea (permanently or periodically), the landward limit extents to 2 km landward, perpendicular to the natural entrance point. Special Area Management (SAM) in the CZ gives CC&CRMD mandate to facilitate and consult management design.

that NRM along the Sri Lankan coasts became decentralized since the 1990s through a seminal document called *Coastal 2000* which focused on integrating socio-economic and ecological factors in the resource management as well as multilevel scales and among multiple institutions (Ashlin 2012). More recently after the installation of a new President after the 2015 elections, constitution amendments with governance reforms reduced presidential power towards the provinces and provide more internal checks and accountability mechanisms (World Bank 2015).

There are earlier traditions of community-based management (CBM) of natural resources connected on local level that is connected to local authorities for co-management (Amarasinghe & De Silva 1999; Galappaththi & Berkes 2014). Collectively, the Fisheries Co-operative Societies (FCS) is one example between government agency Department of Fisheries and Aquatic Resources (DOFAR) and local fishers that are members in the organization on a local scale. FCS represents people engaged in the fishing sector within each Divisional Secretariat and focus on development within economic, social, and cultural aspect of the fishing community as well advising the Fishing Ministry (Sri Lanka National Federation of Fisheries Co-operative Societies Ltd 2016; Risvoll 2006). As these societies can be useful for project implementation and NRM collaboration, extensive initiatives including mangrove ecosystems were not too common on the east coast until after the tsunami.

1.3.3 Recent initiatives and institutions on mangrove and coastal livelihoods

Several large-scale programs emerged in Sri Lanka and in Batticaloa District after the tsunami as the mangrove ecosystems gained more recognition as coastal protection. Many restoration projects consisted of unsuccessful and unsuitable mangrove replanting schemes which were not properly monitored. As a response, Sri Lankan NGO, Sewalanka Foundation, together with Mangrove Action Project (MAP) held two workshops in 2007 focused on sharing and exchanging knowledges on mangrove replanting initiatives outcomes in the past which ended in a creation of principles of successful mangrove restoration (Ashlin 2012; Mangrove Action Project & Sewalanka Foundation 2007). They concluded that a national mangrove network was necessary to monitor and govern existing mangroves in the country. At the same time, Sri Lanka became a member of Mangroves for the Future (MFF) in 2006, a multi-partnership[3] between tsunami affected countries in South East Asia that aimed to promote resource-

[3] Food and Agriculture Organization (FAO), Wetlands International (WI), CARE, United Nations -Development programme, and -Environment Programme, International Union for Conservation of Nature (IUCN), SIDA, NORAD, and DANIDA

dependent coastal communities' resilience by securing healthy coastal ecosystems through long-term sustainable management. Each country coordinator, consisting of representatives from NGO, government, and private sectors, offer grants to initiatives or projects with the purpose to generate knowledge, empower local communities, and promote best practice policies in integrated coastal management (Ekaratne & Vidanage 2013).

In addition, North East Coastal Community Development Project (NECCDEP) was a funded project from Asian Development Bank (ADB) in 2004 to 2010 that aimed to reduce poverty by promoting sustainable livelihoods and implement sound NRM (NECCDEP 2010a). NRM was emphasized as the key to sustainable development. With the objective to create an information base, it further recommended state and district governments on Integrated Coastal Zone Resource Management (ICZRM) and Special Area Management (SAM) strategies. The project had several focus areas around the Eastern Province and used several stakeholders for the assessments and evaluation of the coastal natural resources. The main approach in NECCDEP had been ecological assessments but it acknowledged that for sustainability it would have to further empower vulnerable communities by participation and engaging them in NRM.

Further, MFF acknowledge that collaboration between agencies and actors on different scales and across countries are considered necessary through sharing knowledge and best practices for the purpose of accountability and transparency (Ekaratne & Vidanage 2013). All collaborations promote local NGOs as implementing partners who often have useful local knowledge. The MFF initiatives carried out in Batticaloa District with support from local NGOs such as MANDRU, Green Movement Sri Lanka, and Sewalanka included: mangrove replanting; coastal ecosystem awareness raising; home garden development, crop cultivation, and training; ecosystem assessments; and other alternative livelihoods training such as business training and micro-credit loans (Ekaratne & Vidanage 2013). The institutional richness from MFF, NECCDEP, Sewalanka and MAP initiatives produced a valuable platform to share best practices and lessons learnt from past initiatives regarding mangrove management and restoration (IUCN 2011) and coastal management (De Silva et al. 2011). This collaboration could prevent what Chapin (2004) argued as a threat when large conservationist players simply claim important areas for strict conservation that exclude traditional and local practices and livelihoods that are dependent on those areas' resources.

Bringing to light the most recent national initiative regarding mangroves came from Seacology, an INGO, who together with Sudeesa, a local NGO, received a *Global Resilience Challenge* grant[4], for their *Mangrove Conservation Project* which aim to conserve, restore, and replant mangroves all over in Sri Lanka (Seacology 2015). In addition to conserving and replanting mangroves, the project aim to set up several nurseries around the country and gives job-training and microfinances to women-headed households to protect existing mangrove forest. With the recent grant the project will extent into the north and east coasts which have been absent previously. All these past initiatives shed light to the institutional richness and opportunities on mangrove ecosystem management with local participation to strengthen the social-ecological resilience in Batticaloa District. However, the perceptions of this management experienced in practice are not recently documented among the coastal populations in Batticaloa District, and the management seems to continue to promote ecological restoration and conservation rather than sustainable use of mangrove resources.

1.4 Justification of study

Sustainable use may not be on the agenda in Batticaloa as the District has the highest reduction of mangroves in Sri Lanka from 1 855 in 2006 and 1 421 ha in 2014 due to flawed participatory and sustainable environmental governance in the past such as: lack of law enforcement and monitoring on mangrove conservation (Mathiventhan 2007; Senaratne et al. 2009); lack of state officials engagement from each Divisional Secretariat; and community participation and representation (NECCDEP 2010b). Studies form Mathiventhan (2007) and Mathanraj and Kaleel (2015) both found the governmental responsibility and monitoring over the mangrove ecosystem extent to be insufficient and inefficient at their study sites around Batticaloa Lagoon. In Mathiventhan's (2007) study was Sathurukondan already considered important as a Bird Sanctuary that could attract tourists if it would become protected, but at that time it had been heavily exploited by local uses, security clearing, and shrimp farms and land use conversions in the past.

In Batticaloa District, coastal livelihoods are mostly dependent on coastal, deep sea, and lagoon fishing, or on agriculture and aquaculture (Calatharan 2007; Mathiventhan 2007; Risvoll 2006). Adger (2000) argues that resource dependent coastal communities are inherently resilient as multiple resources and ES provisions from integrated coastal

[4] A competition hosted by the Global Resilience Partnership (https://www.seacology.org/uncategorized/sri-lanka-project-wins-international-funding-competition/ [accessed 09.06.2017])

ecosystems attract diverse activities and economies to coastal areas for diversified coastal livelihoods. However, institutions govern the social system as well as the diversity of the ecosystem and hence its resilience. For example, NGOs and Government response efforts in the tsunami after-math eventuated coastal households more vulnerable by localizing rescue camps on flood-prone areas that had been cleared from mangroves (Risvoll 2006). Learning from the recent ambitious projects is important to investigate if management aims to include poverty reduction and community development in CBM, as highlighted from MFF and MAP initiatives (Ashlin 2012) but also to include the local perspective and potential challenges that individuals may face from such management regimes.

Batticaloa District was chosen as a study region as there are opportunities within the institutional richness here and in Sri Lanka on NRM in terms of building SES resilience and the adaptive capacity. Ashlin (2012) concluded that since the 2004 tsunami, the governing institutions of coastal natural resources have adaptive components expressed as: collaborating stakeholders and cross-scale network cooperation through demonstrated MFF initiatives; sharing and learning between stakeholders at workshops and conferences; and learning by doing and adaptation evidenced by formal and informal institutional changes which became much more complex after the tsunami. However, she further arguments that this institutional structure may also weaken the governance as the responsibility becomes fragmented or overlapped without any central coordinating mechanism over all the initiatives. Further, as each location is unique in its context and settings that shape SES resilience, assessing the processes that influences the SES and maintain desired ES shed light to a purposeful management regime that further can adapt in the face of future perturbations and disruptions.

2.0 CONCEPTUAL FRAMEWORK

This study uses concepts derived within Social-Ecological Systems (SES) Resilience to explain nature and human dynamics, and the livelihood concept was included because households in natural resource dependent communities respond to changes resources access and disturbances through their livelihoods (Orchard et al. 2016) and social infrastructure (Adger 2000). Here follows an explanation on resilience theory from the literature.

2.1 Social Ecological System Resilience

Resilience is founded on a perception that ecosystems are constantly changing and that nature is not centered on a stable equilibrium but within a domain of attraction (Holling 1973; Holling 1986). The definition of resilience is: the magnitude of disturbance the system can absorb and retain the same function, structure, and identity. Further it is the ability of the system to self-organize, learn, and its' adaptive capacity (Gunderson & Holling 2002; Resilience Alliance 2017b; Walker et al. 2004). A system is more likely to tolerate disturbance events without tipping over to another domain of attraction with another set of processes if the resilience is enhanced. Contrastingly, reduced resilience makes the system vulnerable to disturbances or gradual changes where a threshold of some conditions is surpassed that triggers an abrupt change in the system regime and provision of ecosystem services (ES) (Resilience Alliance 2017b). For example, from a clear lake to a turbid lake due to nutrient loading (Folke et al. 2004). This change can be in a socially undesired state where restoration may have to set back conditions to what they were well back before the regime shift (Folke et al. 2004; Resilience Alliance 2017b). The chances of maintaining a system in a desired resilient state increases if slow and gradual changes and variables underlying the systems are understood (Folke et al. 2004; Walker et al. 2004). Resilience is a property of a system, and in Social-Ecological Systems (SES), humans have the added capacity to anticipate change to some degree and influence future paths (Resilience Alliance 2017b).

SES perspective views linkages between social and ecological systems through co-evolution and humans as an intrinsic part of nature with mutual influences (Berkes et al. 1998; Berkes et al. 2003). Ecosystems are basically environments in which organisms and animals interact with one another in self-regulated communities (Berkes et al. 2003). Through the organism's interactions and processes are ecosystem services (ES) generated which provides benefits to surrounding environments and populations (Millennium Ecosystem Assessment 2003). Social

systems, such as local communities depending on these ES, contain cultural practices based on Traditional Ecological Knowledge (TEK) embedded in institutions and cultural values to sustain the ES they depend on (Berkes et al. 1998). A sustainable management assumes that societies interpret environmental signals as precursor to a change which is then acted upon (Berkes et al. 1998).

2.1.1 The adaptive cycle and panarchy

The dynamic changes in SES trajectories can be explained in the adaptive cycle, a framework developed by Holling (1986). The SES goes through cycles of exploitation (r), conservation (K), release (Ω), and reorganization (α) and repeated loops generate an ecosystem to become more resilient (see Figure 1) (Holling 1986). In an ecosystem, the r phase is where pioneer species are established, followed by the K phase where species diversity is consolidated and where biomass and stored nutrient peaks. This relatively stable stage depend on conditions remaining constant as it experiences high connectivity, but can in fact make it brittle to disturbances and surprises. The climax is disrupted by a perturbation or disturbance and the SES changes and enters the Ω phase. This stage is rapid, as all the fixed nutrients and accumulated capital are then released. The final phase is α phase where nutrients becomes opportunities and used by the actors or species left in the ecosystem for reorganization, before a new exploitation phase is entered again, either as the same system configuration or into a new system regime with different set of processes and functions as illustrated by the X path to the left corner (see Figure 1) (Berkes et al. 1998; Berkes et al. 2003). Further, the adaptive

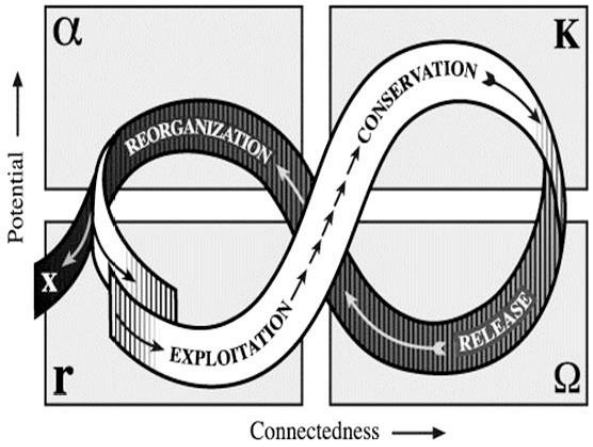

Figure 1. The adaptive cycle. The foreloop process is the exploitation (r) and conservation (K) phases. The backloop is the release (Ω) and reorganization (α) phases. Source: http://www.resalliance.org/adaptive-cycle

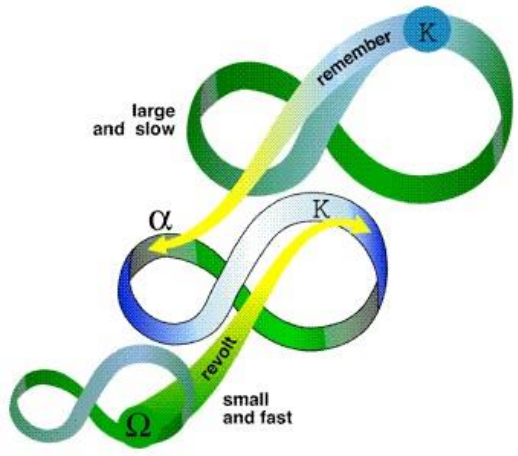

Figure 2. Panarchy. Connected SES operating at multiple scales of space, time and social organization. Small-scale SES may influence large-scale slower processes by *revolt*. Large-scale processes influence small-scale by *remember*. Source: http://www.resalliance.org/panarchy

cycle is nested within in a hierarchy of adaptive cycles, a concept called *Panarchy* (Gunderson & Holling 2002) (see Figure 2). Panarchy explains how small, fast systems are hierarchically nested, and connected through remember and revolt, to larger and slower systems. If a small level change collapses, large level mechanisms can reorganize the area (remember), or the collapse may spread to higher hierarchy and contributing to new set of conditions or innovation (revolt) (Gunderson & Holling 2002) (see Figure 2).

2.1.2 Components and principles building SES resilience

This study on SES will seek to identify factors and processes that build or detract from resilience mostly by comparing the attributes with Biggs et al. (2012) seven consolidated principles that build resilience of ES in SES that are based on previous literature in SES resilience theory introduced further below (Berkes et al. 2003; Folke et al. 2005): maintaining biodiversity and redundancy (1); managing connectivity (2); managing slow variables and feedbacks (3); fostering complex adaptive system thinking (4) (through adaptive cycle); encourage learning (5); broaden participation (6); and promoting polycentric governance system (7).

SES becomes resilient by accumulating memory from past experiences which increase its adaptive capacity to reorganize and *"re-configure without significant changes in crucial function or declines in the ecosystem services"* (Resilience Alliance 2017a. Key concepts: Adaptive Capacity). The survival and adaptation capacity lies within the ability to respond to renewal and opportunity from learning to live with change and uncertainty that increase SES resilience of the life-support system (Biggs et al. 2010; Folke et al. 2003). Cyclic changes generate adaptation by the system components and increase system resilience by accumulation of experience, knowledge, and creation of institutions on how to respond and maintain components that can cope with change (Berkes et al. 1998; Berkes et al. 2003; Holling 1986). Likewise, memory and diversity are two component core to both remember and revolt processes' reorganization capacity, and building SES resilience.

Diversity contributes to adaptive capacity both in ecological and the social dimension. Biodiversity in ecosystems builds resilience through functional redundancy and response diversity (Biggs et al. 2012; Carpenter et al. 2001; Folke et al. 2004). A high biodiversity may provide a variety of services and functions as well as responding to disturbances by restarting reorganization to provide previous services and functions (Barbier et al. 1994; Folke et al.

2004). The biodiversity is the ecological memory within the ecosystems and entails the distribution of species that persist after a disturbance, including latent responses, and connection to sources in order to reorganize the system in a heterogenic landscape mosaic (Berkes et al. 2003). Resilience is enhanced where biodiversity and functional redundancy are stored in ecological pockets of memory connected in a landscape to disperse and recolonize disturbed patches so to maintain the provision of ES (Biggs et al. 2012).

The social dimension also relates to memory and diversity (Carpenter et al. 2001; Folke et al. 2004) where memory is embedded in TEK among local communities and may be passed down from generations which are accumulated into practices and community cultures (Berkes et al. 1998; Gómez-Baggethun et al. 2012). And diverse actors connected in networks of structures and institutions are important to consider as they create flexible problem solving and balancing power relations linked to social resilience and its' adaptive capacity (Adger 2000; Boyd & Folke 2012; Carpenter et al. 2001). However institutions and structures could also be restrictive for people or specific uses which are observable through social exclusion and marginalization (Adger 2000). Due to the presence or absence of cultural structures and institutions, one cannot assume that a resilient ecosystem generates resilient communities that depend on that ecosystem (Adger 2000).

Environmental governance can cause or prevent structural exclusion or marginalization where policies or regulations determine access to natural resources which influence the social dimension of SES resilience (Lebel et al. 2006). Governance is defined as the deliberation and decision-making authority to act and is practiced through a variety of organizational forms among groups such as non-profit organization, watershed council, or state department (Biggs et al. 2012). Polycentric governance system is defined as a governance system with multiple governing authorities at different scales where each governance unit have independent domain of authority over a geographical area. Each unit may link with others horizontally and vertically but one key principle is to match governance levels to the scale of the problem, referring to a multi-layered system.

Biggs et al. (2012) and Lebel et al. (2006) argue that governance can help understand power distribution across institutions and actors and how it influence SES resilience through: diverse participation for open communication and deliberation to build mutual trust and understanding; accountable authorities who pursue social justice and securing livelihood for most vulnerable groups; and flexible polycentric and multi-layered governance systems to

create opportunities for learning and decision-making that match the social and ecological context-scale.

2.1.3 Assessing SES resilience

Carpenter et al. (2001) argues that any resilience analysis must delineate the boundaries of the investigation object (*of what*) and the premises of resilience (*to what).* This study aim to investigate the SES consisting of two mangrove forest ecosystem located at the east coast of Sri Lanka and the adjacent households to respective mangrove ecosystem. The *general* resilience characteristic is studied to invite a wider spectrum of possible influences on the SES resilience to be identified, as opposed to assessments where the resilience *to what* is *specified* (Brown 2016; Carpenter et al. 2001; Resilience Alliance 2010).

Further is the ES a useful concept to link the benefits of ecosystem processes to human well-being and how human behavior affects ES provisions and biodiversity (Millennium Ecosystem Assessment 2005). However, a desired resilient state assumes that the ecosystem provides desirable ES, such as the clear water lake that can support fish population, bathing, and drinking water as opposed to turbid and eutrophic lake. The desirability of ES are normative and political and hence one must further ask resilience *to whom* within the SES resilience investigation (Lebel et al. 2006) by including governance implementation process and structure which previous resilience literature have been criticized to not recognize (Bousquet et al. 2015; Brown 2016).

Further, different sectors and stakeholders often value and demand different ES, and Biggs et al. (2012) and Robbins (2012) argues therefore that decisions regarding ES and the environment are inherently political. Hein et al. (2006) explain how ES are generated and operates at different natural, spatial, and administrative scales that further complicate just and equal governance of ES where trade-offs often occurrs within or between scales, for example between timber harvesting at local scale and carbon storage at global scale (Biggs et al. 2012). Again, analysing ES highlighted in management efforts and outcomes needs to consider *by whom* the ES are declared desireable for and whether there is any disenfranscied groups generated by such an management regime (Robbins 2012).

Previous interdisciplinary studies on SES resilience incorporated an ES approach and livelihood approach in the resilience analysis to include the local ES preferences and restrictions (Armitage et al. 2012; Orchard et al. 2016). The identified ES mentioned by the

respondents in this study are cateorized into provision, regulating, cultural, and supporting (Millennium Ecosystem Assessment 2005) to explore the ES characteristics and facilitate understanding of how it influences the SES resilience (Biggs et al. 2012). The categorizations allows comparison between households' livelihood strategies shaped by the past strategies as a resopnse to mangrove ecosystem changes (Orchard et al. 2016).

2.2 Sustainable livelihood framework

Livelihoods can broadly be defined as "*the capabilities, assets (including both material and social resources) and activities required for a means of living"* (Chambers & Conway 1992 cited and adapted in DFID 1999. p 1). A sustainable livelihood can further cope and recover from stresses and maintain its assets both now and in the future while not undermining the natural resource base (Scoones 1998). A sustainable livelihood approach puts people at the center but also acknowledge the vulnerability context which affects the access to certain assets. The sustainable livelihood framework visualize the categorized assets that affects peoples livelihoods and how they are linked. These assets are categorized: Human; Social; Natural; Financial; and Physical [5], which: "*influences the livelihood strategies that are open to people in pursuit of beneficial livelihood outcomes that meet their own livelihood objectives"* (DFID 1999. p1). Livelihood strategy is the mix of assets and activities households uses and the liveilhood approach firstly gives an understanding of how people use assets to create positive livelihood outcomes.

A sustainable livelihood approach resonates with resilience theory where systems ability to withstand shocks and perturbations, similarily to households liveilhoods ability to cope and recover from stresses and shocks and maintain its assets (Orchard et al. 2016). Marschke and Berkes (2006) and Berkes and Seixas (2005) argue that to build livelihood security and resilience, livelihoods must build capacity to build flexibility through combining skills and adaptability, coupled with access to natural resources. Such skills and adaptability entails livelihood diversification, capacity to build good relations, knowledge, and problem solving thinking.

[5] Human: skills, knowledge, ability to labour, and good health. Social: netorks, connectedness, group membership, relationships, reciprocity, and exchanges. Natural: resources as biodiversity, goods for production (trees, land, fish). Physical: infrastructure, affordable transport, buildings, water, sanitation, energy. Financial: savings in cash, bank deposit, or livestock, earned income, pension, or remittances.

3.0 METHODS

3.1 Mixed-methods approach

This research is conducted through a mixed approach, to generate meaningful information to the different study objectives (Bryman 2012). In order to gain a representative sample as possible were both probability and purposive sampling conducted. The mangrove inventory is predominantly investigated through a quantitative approach generating descriptive statistics of the forest species composition and structure. The social and managerial system is investigated through a qualitative approach, by semi-structured interviews and focus-group discussions. Secondary data from scientific literature, grey literature (such as project reports) and previous studies are also included in the discussion and background information.

This study compares two cases of SES allowing us to distinguish site specific characteristics, and highlighting the similarities influencing the systems resilience (Bryman 2012). This methodology was adapted from earlier studies on socio-ecological systems resilience on mangroves and coastal communities both in Zanzibar (Othman 2005) and in Batticaloa Lagoon (Mathiventhan 2007). The latter is relevant for longitudinal comparison as the present time frame is absent from influences from the civil war. Both studies' methodology were replicated and adapted to fit a shorter time-frame for conducting field work and to the conditions met at the chosen study sites. However, similar ecological indices and social data were collected and investigated. By using similar approaches, impact of past conservation development and management regimes in Sri Lanka are recognizable. In light of recent resilience theory, discussing adaptive capacity and possible transformability is valuable for maintaining sustainable traits and processes (Brown 2016).

3.2 Overview of the study region: Batticaloa District

The tropical savannah climate on the east coasts of Sri Lanka have a more pronounced northeast monsoon from October until December which contributes most to the annual rainfall in Batticaloa District, averaging of 320 mm per month to the total of 1 828 mm per year (World Bank Group 2015). Recent records indicates a delayed onset in the northeast monsoon (in November instead of October) and increased average amount in November and December precipitation (World Bank Group 2015) which causes annual floods and uncertain prediction of the monsoon onset. Further, Batticaloa District has experienced an increase in

population density since 1981 until 2012 from 134 to 202 persons per km^{-2} (Sri Lanka Department of Census and Statistics 2012). The majority of the population resides along the coastal areas and urban centers since economic activities and opportunities are found there (Nayanananda 2007) and 52 % of the District's population are coastal dwellers (Sri Lanka Department of Census and Statistics 2012). Batticaloa District also has a rich coastal biodiversity with mangroves, and coral reefs that support habitats for many commercially important species of fish, shrimps, and crabs (Gunatilleke & Gunatilleke 1990; NECCDEP 2010a).

3.2.1 Criteria for comparative study sites

For this comparative study, locations should inhabit mangrove forest adjacent to households and through consultation with field supervisor, Dr. T. Mathiventhan, and background research were two mangrove sites selected based on the following criteria:

- SES differences in villages' mangrove dependency
- SES under proposed mangrove management, livelihood improvement, or project influencing the management design
- SES experienced historical impacts from war or natural disasters (disturbances)
- SES located at short distance from Batticaloa Town, due to practical reasons
- Accessibility and permission to research on site and presence on historical information (either among community memory or from previous studies)

Sathurukondan and Nasivanthivu villages were selected (see Figure 3) and are described in more detail below. Both areas are replication sites from a wider ecosystem restoration project but they differ in distance to urban clusters and dependency on mangroves where Nasivanthivu inhibits more fishing dependent households (indirect dependent on mangroves as fish habitat) and are located further away from urban center.

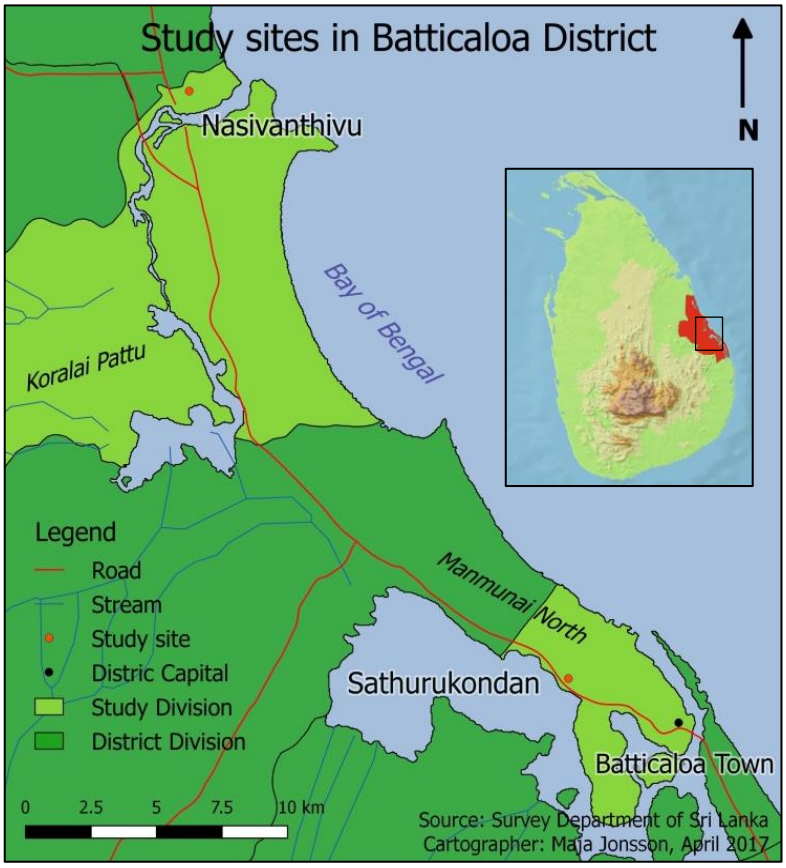

Figure 3 Overview map over the study locations within Batticaloa District. The insert map illustrates the districts location within Sri Lanka. Cartographer: Maja Jonsson April 2017.

Sathurukondan Village

Sathurukondan have a majority of fringing mangroves that are stretched along A15 highway from Batticaloa town towards Trincomalee in Manmunai North Division. The total mangrove extent is 84.94 ha, with patches along the roadside (see Figure 4). A large mangrove patch borders another village called Kokuvil[6]. This patch is on the landward side of the road (opposite of Batticaloa Lagoon side) exhibiting waterbodies even in the dry season, where fishers use cast nets. The mangroves along the road towards the lagoon have diminished due to the road construction and shoreline erosion (Ms Environmental Engineering Consultants 1992). Despite the incremental erosion were mangroves not much affected by the tsunami in 2004 but it has a destructive history from the cyclone in 1978 and the SLAF mangrove clearances (Mathiventhan 2007).

[6] The mangrove forest under investigation stretches also into Kokuvil village. In this study, Sathurukondan is only expresses since that village hosts the majority of the stretched patches of mangroves and household respondents.

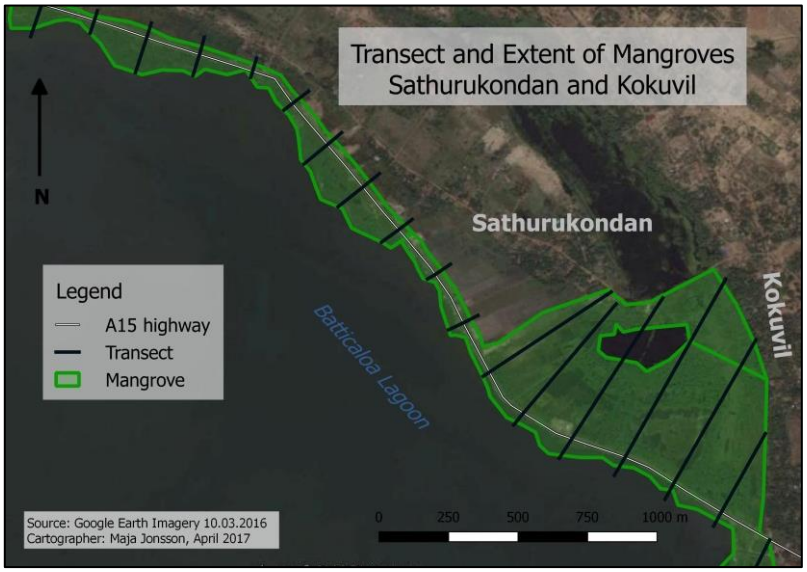

Figure 4 Map of mangroves and study transects in Sathurukondan and Kokuvil. The landward mangrove patch in the lower right corner contained several waterbodies and paths to cross the forest. Source: Google Earth Imagery from 5th of August 2014. Cartographer: Maja Jonsson

The mangrove forest hosts many migrating birds and has been a popular bird-watching area (Kishoran et al. 2017; Mathiventhan 2007). There are 1 677 residents in Sathurukondan (Sri Lankan Department of Census and Statistics 2012) and as an urban wetland 5 km away from Batticaloa town, the households have access to varied job opportunities such as: fishing; governmental sector; construction and masonry; agriculture; teaching; business sector; and NGOs (Grama Nildahari of Sathurukondan. Personal Communication. 4th November 2016). This site was under investigation by a similar SES resilience study a decade ago (Mathiventhan 2007).

Nasivanthivu village

Being an island, Nasivanthivu village is surrounded by fringing mangrove forest. The exact study site was located at the western bank and across-river on landward bank that hosts a mangrove cover of 27.94 ha (see Figure 5). Valaichchenai Lagoon borders to the south and Nasivanthivu Lagoon in the north which are joined at a bridge where the only road exists to enter the island. Both lagoons consist of brackish water and modest tidal fluctuations. Tsunami, cyclone and the civil war had a severe impact on the mangroves all over the island. The mainland north of the island is used for paddy fields, coconut plantations and brickmaking, while the island hosts some coconut plantations.

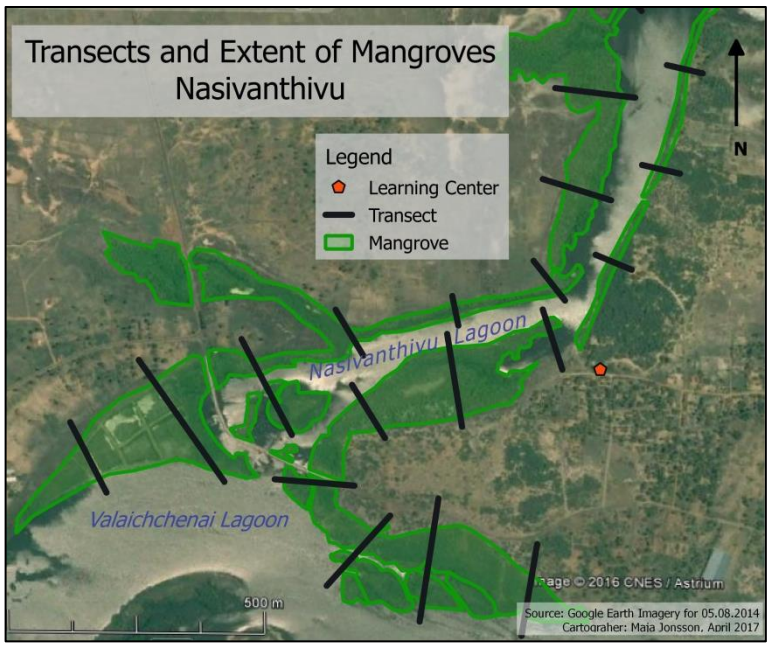

Figure 5 Map of mangroves and study transects in Nasivanthivu. The red dot indicates the Mangrove Conservation and Education Center (MCEC). Source: Google Earth Imagery from 5th of August 2014. Cartographer: Maja Jonsson April 2017.

The majority of the 1 037 residents in Nasivanthivu are fishers (Sri Lankan Department of Census and Statistics 2012) but few also carry out daily labor of different activities such as: paddy field worker; carpenter; construction and masonry. Very few families are involved in governmental or NGO professions (Grama Nildahari of Nasivanthivu. Personal Communication. 1st November 2016). The area is hosting recently build Mangrove Conservation and Education Center (MCEC) built in 2014.

3.3 Ecosystem inventory in the mangrove forest

Field work carried out in September to November 2016 started with ecosystem inventory in Sathurukondan and then Nasivanthivu respectively. The mangrove forest was investigated by a probability sampling approach placing 10 X 10 m plots systematically along transects at 5 meters interval, perpendicular to the road or river into the mangrove forests. The data recorded from each plot was registered in pre-designed data-sheets (Appendix 1) on: species; plant life form (Tree, Shrub, Fern, Grass, Liana); diameter; height; status; number of saplings and seedlings; and dead, respectively regenerating stumps and cuts. A Garmin eTrex 30x GPS, tree caliper, an inclinometer, a premeasured pole, and diameter tape were used.

Additionally, other qualitative observations from the surrounding environment were noted down to give fuller insight and description of the mangrove ecosystem such as: encountered animals; pollution; and noticeable environmental patterns. Additional resource walk and canoe trip was performed together with local fishers to triangulate mangrove species, characteristics, history, and usages across the sites. The data from the field sampling in

Sathurukondan and Nasivanthivu were further processed and analyzed to generate indices in the analysis.

3.3.1 Analysis of ecosystem data

The descriptive statistics from the ecological inventory give information on plant biodiversity indices such as: Species Richness, Species Evenness, and Shannon's Diversity Index (Appendix 2) where the latter shows the internal distribution of all species within the sample, by accounting the population number and not only number of species and total number of individuals. Further, for true mangrove species were Important Value Index Percentages calculated as an indication of the species dominance. The generation and disturbance indices was assessed by calculating percentage of juvenile, and densities of seedlings, saplings, dead and regenerating stumps and cuts within respective species. The indices give an indication of the forest characteristics, structure, composition, and can give evidence of disturbance and regeneration patterns.

Despite no evident direct positive relationship between high biodiversity and high resilience as mentioned by Adger (2000) the two are rather connected to functional redundancy and response diversity to disasters and change (Biggs et al. 2012). This study founds on the assumption that high biodiversity builds resilience as a kind of insurance where other species may take over an ecosystem function in case key functional species is vanished after a disturbance and maintain the provisioning of ES (Biggs et al. 2012; Folke et al. 2004).

3.4 Social system inventory with village households and key informants

Opposed to the ecological assessment was a predominant qualitative method applied for the social resilience assessment. It undertook on a non-probability sampling approach including 12 key informants, 53 household interviews (27 in Sathurukondan and 26 in Nasivanthivu), and one focus-group discussion at each location. The household respondents were sampled with some element of snowball and convenience approach depending on who was at home during the day of the sampling time. The sampling approach was aimed to get a varied range of perceptions and uses of mangroves as possible since the field time was limited. Purposive sampling is efficient to gain this wide range and as local villagers know their villages better (Bryman 2012).

Semi-structured interviews were conducted with households so respondents would answer freely but within a given topic. Interview guides (Appendix 3) allowed the same question

being asked to all the households and inviting probing and follow-up questions (Bryman 2012). The interviews purpose was to map out households mangrove dependency and livelihood strategies so the interview guide covered topics on: present and historical mangrove uses; history of the mangrove forest; alternatives and replacements for mangrove resources; thoughts about the mangrove management regimes; perception of benefits and valued ecosystem benefits; and their perception of future opportunities in relation to the mangrove management. Each interview guide initiated with some basic quantifiable questions on income level, income sources, and education, in order to map out basic livelihood assets. All the household respondent correspondence carried out through a translator, and since the interviews were not recorded, answers were written down in the pre-designed interview guides with space to allow for additional information that the respondents wished to share.

Key informants interviews were purposively- and snowball- sampled as they gave insight to the managerial situation and issues at different administrative level. The informants were active within: Forest Department, Department of Fisheries and Aquatic Resources, Village Leaders (Grama Nildahari, GS), Coastal Conservation Department, local NGOs, and Academics (Appendix 4). The interview guides had same function as for the household interviews, but the topics covered their perspectives on: management objective; perception of benefits and valued ecosystem benefits; responsibilities; changes and reason behind them; regulations; influences in policy-making; and procedures for any development and management project (Appendix 5). Additionally, informal talks with Governmental Officers, fishers, and random villagers were conducted during field visits.

Focus group discussions were held with the Fisheries Co-Operative Societies at both locations. The group discussions were performed as to triangulate the information but also to further allow additional insights from fishers interacting between each other (Bryman 2012). The topics covered were very similar to the household interviews in addition to more focus on mangrove management perceptions and history (Appendix 6). The information was used to cross-check information from interviews on management practices and outcomes. Nearly all the key informant interviews and focus-group discussions were recorded when appropriate and transcribed.

3.4.1 Analysis of social data

The transcriptions and the household notes and data were thematically analyzed. The thematic analysis gives insight and overview of key informants and respondents' narratives and

perceptions of mangroves and management at each location and what influenced changes through time. The thematic analysis findings will be discussed with traits that influence resilience derived from principles (Berkes et al. 2003; Biggs et al. 2012) and used for placing the SES in the adaptive cycle. These resilience traits are derived from semi-structured interviews rather than quantitative questionnaires as individual experiences from each household could be grasped. Also, in-depth and semi-structured interviews welcomed opportunities of conflicting themes or other concerns from the respondents. This method allowed a wide spectrum of issues to emerge.

3.5 Limitations to study

The first limitation to this study is the delineation of only encapsulating the SES processes that people know and share from their memory of the recent past and from field observations. This means that large scale processes on global scale or very slow variables may not be identified.

3.5.1 Species-specific measurements

The species encountered in field varied greatly in structure and for time saving reasons were specific measuring methods derived. The existing main stem was measured at breast height, but if the trunk was branched or split the point of measurement was adjusted. *Excoecaria. agallocha*, have multiple stems united at the roots but each stem was measured as a single tree as they expects to grow as a single tree. In contrast, the *Avicennia marina* and *Lumnitzera. racemosa* are recorded as shrubs and exhibit multiple split branches usually much lower than at breast height. But in this case the diameter was measured at first branch and number of branched stems were recorded. Ferns and very dense shrubs (*Acrostichum aureum* and *Clerodentron inerme*) were measured diameter of ground cover. Grasses and *Acanthus ilicifolius* were classified by cover from 1 to 5 and their frequency were used for the diversity calculation. Also, the sampling transects were either initiated at the road (Sathurukondan) or from the first plot with present mangrove species (Nasivanthivu and Sathurukondan). If sampling would have occurred more landward it would have been further dominated by mangrove associates. As this study focus on mangroves were the associates only recorded by number (or frequency for dense covered plants) and not measured in height or diameter (appart from *C.inerme, A. aureum,* and *Cerbera manghas*).

Further, fern measurements taken at ground level and breast height for trees don't account for the actual light penetration to the ground covers tree as crown cover at higher level. Further, it influences the encountered numbers for *A. marina* and *L. racemosa* in relation to trees as the shrubs may be underestimated due to their recordings at first branch. Counting shrub branches as stems (the significant large branches) could have been an alternative and probably had a slight impact on the evenness index too in Sathurukondan and perhaps decrease evenness in Nasivanthivu as it already is most dominated by shrub *L. racemosa*. These standardized methods were adapted with consultation of my field supervisor based upon sound local and topical knowledge for measuring the mangrove plants and associates in both study sites. I am attempting to describe the methodology in a transparent matter so that compromises could be acknowledged by others if that would be the case.

3.5.2 Considerations in the social dimension

This study has limitations regarding language barriers and time in field for data collection. The time restriction did not allow a more thorough data collection for advanced statistical analysis at each site. Neither could it encapsulate the seasonal differences the ecosystem may experience as I only visited the site during one season which was just before the initiation of the northeast monsoon (September to November). The descriptive data and the respondents' narrative will however shine light on the seasonal traits to compensate this shortcoming. Also, time constraints prevented a larger number of interviews from being conducted and longer in-depth interviews with the households. Further and perhaps the biggest limitation was the necessity of translators which limited unprocessed information from reaching me as I would later analyze the data. The availability of translators was further limited and based from pilot interviews were the two first translators replaced due to language and their availability difficulties. Further on, I made contact with three translators that were available to help out and provide as fair amount of a sample as possible.

This limitation may affect the trustworthiness of the data as the translation process of the interview may be subject to transferability issues (Bryman 2012). This is a disadvantage of not having one translator to ask the exact questions to every respondent regardless of careful and exact instructions and debriefing with every translator before and after every interview. Further, I could not be too picky about the translators as my time in field was limited and therefore had to use translators with sufficient English and Tamil knowledge and not necessarily scientific knowledge and terminology related to botany and social sciences. To

overcome some of these limitations were respondents asked to explain details regarding certain plants and trees they mentioned and make drawings in note books or in the sand. Also, using more than one translator could also give way to nuanced interpretation and preventing one translation for using similar (but different) expressions from different respondents. In considerations in future field work I would allow more time and resources to find translators.

Moreover, the social system inventory has some elements affecting the credibility of the household interviews as interviews was approached through some convenience sampling to initiate the sampling strategy. Later on, respondents were requested to mention other respondents through snowball sampling which reduced the convenience sampled respondents and led the process forwards to gain a wide spectrum of perspectives and mangrove uses. Besides, the time constrained complete saturation in the gained data but adequate information was derived for a useful thematic analysis.

Details on the current management progress may not be fully represented in this study as the data collection was carried out just at the project end and no finalization report existed yet. The findings are based on the key informants' answers in order to map out the management process, structure, objectives, and outcomes. The risk of only basing the information on recollection in human memory is that the full picture may be lost or components not mentioned by anyone of the key informants. The interview usually went on for 30 min to 1.5 hours and may still not have been enough to include all project details. However, when possible was information supplemented with secondary sources such as supervision and mid-assessment reports. After returning to Norway from Sri Lanka it was still possible to reach out to some key informants for further clarifications and complementary information to a limited extent.

Ethical issues on the social dimension emerged as I could not share my derived findings with household respondents for validation. Also, I visited the sites as often as I could and spend time around the study sites to familiarize with the villagers and practices carried out there. During the time of the interviews I also asked each respondent for oral consent and option to anonymity and withdraw participation in the study at any time through a local number. Though the topic may not be perceived as very controversial, it may still be a risk of credibility issues as I may have been perceived as an outsider to the villagers whom may have difficulties to confide to me, which could affect my representation of their true opinions, perceptions, and difficulties regarding mangrove management or any issue.

4.0 RESULTS

4.1 Status of the Mangrove forest ecosystem

4.1.2 Past influences on mangrove forest narrated by respondents

Natural influences

The mangrove forest in Sathurukondan and Nasivanthivu were both severely disturbed during the 1978 cyclone, felling much of the fringing *Rhizophora apiculata* along both lagoons. As *Rhizophora* declined in extent in Sathurukondan, *Excoecaria agallocha* and *Acrostichum aureum* expanded. Contrastingly, Nasivanthivu had a much larger impact from the 2004 Indian Ocean tsunami that reduced mangrove forest extent. Also here, *R. apiculata* decreased the most as it was first exposed to the wave energy as a fringing mangrove. Since the cyclone and tsunami, the shorelines started to erode, swiping away remaining mangroves slowly from both study sites. In addition, recently there are annual floods occurring, which submerge the roads and inhibit access and escape:

> *"In 2013 there was a heavy flood that lasted for 6 days and they couldn't escape then. The navy came and provided food. Now every year there is a 3 days flood when the bridge is blocked, submerged under water."* (respondent 23, Nasivanthivu).

Further, floods destroy fences so gardens and crops are spoiled by animals, and saplings from replanting schemes are washed away. In Nasivanthivu, erosion was amplified after harbor development in Valaichchenai city south of the island and deepening of the lagoon bottom by sediment removal. The removed bottom sediment was piled at the sea mouth but waves eroded it and deposited sand back into the lagoon, but at different locations. Interviews revealed that it was perceived as the mangroves are rooted from the shore but float across the lagoon and regenerates at the landing sites (see Figure 6).

Figure 6 Google Earth remote sensed imagery over Nasivanthivu bridge and mangrove cover changes between 2004 (left) and 2016 (right). The red circles indicate erosion along the bottommost lagoon (Valaichchenai Lagoon) shoreline and 2 small islands have disappeared in the upper left corner. The patches just above the road have experienced increased mangrove cover.

Anthropogenic influences, direct and indirect mangrove impact

Before the civil war there mangrove forest in Sathurukondan hosted several shrimp farms around 1970-80ies, as a widespread occupation among the villagers. The war grew violent into the 1990-ies, when many fled or fell victim to the war, and the farms became abandoned. Mangroves were also cut and cleared by SLAF to prevent them being used as hiding grounds for the LTTE. In Nasivanthivu had mangroves also been subject to SLAF clearances in addition to widespread paddies and coconut plantations. Households at both sites had taken advantage of cutting mangrove wood in their surroundings, but they were also forced by the army to cut the mangrove trees:

> *"Before the war, the mangroves were even bigger than now. Then the army was cutting them, and they even told us villagers to cut the mangroves. If we didn't cut we would be beaten by the army. So we started to cut the mangroves and use the wood for different purposes as firewood, building houses and fences. So we got dependent on the mangrove wood and started cutting the mangroves to sustain that livelihood"* (respondent 6, Nasivanthivu).

The mangrove was considered at its minimum extent just after the tsunami hit, but shortly after, NGOs constructed brick houses in Nasivanthivu and mobilized villages and praised the protective capacity of mangroves. Mangrove replantation projects were implemented in tsunami affected areas: *"After the tsunami people living along the coasts were not aware about the mangroves as protecting from the waves. Also NGOs came and gave awareness about the mangroves and gave funding to replant them"* (respondent 1, Sathurukondan). Still today, Government is conducting replanting schemes and awareness programs for the local

households, explaining ecological benefits, mangrove importance as habitats and coastal protection but also to highlight the enforced legal protection over mangrove forests. Villagers from both sites explain that mangroves have been regenerating due to reduced cutting from the Government's efforts to reinforce mangrove protection. Both mangrove areas are now predominantly state-owned, with minor private areas fenced for paddy, coconut, and banana cultivations.

4.2 Observations in field

4.2.1 Patterns, pollutions, and fauna

In Sathurukondan grow many mangrove associates along the forest edges and along paths running through the forest, such as *A. aureum, Cerbera manghas*, and *Clerodentron inerrme*. In these areas, trees had high presence of cuts and lots of dumped waste on the grounds. However, deeper into the forest with complicated accessibility, there were less stumps and cuts, higher trees, and thicker tree stems. The mangroves here were often intertwined with climbers as *Derris scandens*, creating a very dense forest. In these locations there were less small plants and saplings on the substrate. At sunny patches, there were more regenerating stumps, juveniles and saplings on the ground and on the trees. Aquatic fauna was present, often dead on dried mud bed such as *Melanoides tuberculata*, *Casidula mustelina*, and *Littoraria undulata*. In the presence of water were crabs such as *Periesesarma bidens*, and *Metopograpsus messor* found. Lots of different birds, lizards, turtles, and crocodile (see Figure 7) were also encountered animals. There were both mature and replanted *Terminalia ajunga*, along the roads and juvenile *Pandanus* and *Pongamia pinnata*.

Figure 7 Crocodile encounter in Sathurukondan mangrove forest

In Nasivanthivu, *R. apiculata* fringed the lagoon waters while *Avicennia marina, C. inerrme, Phoenix pusilla,* and *Hibiscus tiliaceus* grows in upper littoral zone. *Lumnitzera racemosa* was predominant everywhere and *Acanthus ilicifolius* was present on the substrate of some plots as opposed to *A. aureum* and *Typha angustifolia* in Sathurukondan. The mangrove stretches are between 1. 5 m – 150 m wide just before zoning into terrestrial vegetation. There was no obvious pattern for where dead or regenerating stumps occurred in the very dry conditions. Solid wastes were predominant among the mangroves (see Figure 8). A lot more living aquatic fauna was present than compared to Sathurukondan, such as crustaceans *Periesesarma bidens, Metopograpsus thukuhar, Uca annulipes, Thalassina anomala* (mud lobster), and hermit crabs (*Diogenes spp).* Molluscs such as *Terebralia palustris, Telescopium telescopium, Certhidea cingulata,* and *Nerita polita* was also encountered. Other animals encountered were birds, lizards, mongoose, monkeys, water-snakes, and rabbit.

Figure 8 Solid wastes dumped in Nasivanthivu

4.2.2 Mangrove destruction

In Sathurukondan was occasional tree felling inside the mangroves forest observed (see Figure 9) as well as brush piles in the nearby lagoon. There are cuts and stumps available on all tree species, most on the *E. agallocha,* and some trees were scorched close to village edge from a big fire one year ago. In Nasivanthivu a bridge reconstruction was underway to

Figure 9 Extensive destruction of mangroves in Sathurukondan (left) and Nasivanthivu (right). Left photo, felled E. agallocha by private persons and wood left to dry. Right photo, lots of mangrove clearing during the construction process of a bridge, just north of Nasivanthivu.

promote better water flow in a creek surrounded by mangroves. In the construction process, there had to be many mangroves sacrificed though (see Figure 9).

4.2.3 Encroachment or land claims

Encroachment terminology was first introduced by key informants and there was evidence of encroachment happening just next to the road on state claimed land during the field work in Sathurukondan (see Figure 10). This particular land use converser had been brought to court due to this encroachment as a result of old or illegal land deeds. In Nasivanthivu, mangroves are burned on the northern bank which could indicate efforts to expand the paddy fields into the lagoon by such deliberate impacts on fringing mangroves.

Figure 10. Encroaching on state claimed land in Sathurukondan. The leftmost photo taken in September 2016, and the rightmost photo taken in November 2016. The red circles indicate the same *E. agallocha* bush.

4.3 Statistical description of mangrove ecosystems

4.3.1 Species list with Important Value Percentages

A total of 31 species were recorded in Sathurukondan and 27 in Nasivanthivu (see Appendix 7) with 5 and 8 true mangrove species encountered respectively (see Table 1). *E. agallocha* and *L. racemosa* were most common mangroves at both sites, but more dominance of the former one in Sathurukondan. Continuing in Sathurukondan, *A. aureum*, becomes second most common in the mangrove area when including mangrove associates in the calculations. In Nasivanthivu, *C. inerrme* is the most common species leaving *L. racemosa* at a second place, closely followed by *E. agallocha. R. apiculata* was common in Nasivanthivu whereas it was rare in Sathurukondan. Further, while *R. apiculata* was encountered in more numbers

compared to *S. caseolaris* in Sathurukondan, they had smaller basal area resulting in the relatively similar IVP of 2.9 % and 3.0 % respectively.

Table 1. Encountered true mangroves species and Important Value Percentage (IVP).

Species	Family	Sathurukondan	Number counted	Nasivanthivu	Number counted
Avicennia marina, S	Avicenniaceae	5.8% (3.0)	270	17.3 % (9.8)	434
Bruguiera gymnorhiza, T	Rhizophoraceae			2.6 % (2.3)	72
Ceriops tagal, T	Rhizophoraceae			1.5 % (1.3)	45
Excoecaria agallocha, T	Euphorbiaceae	81.6 % (44.6)	15 322	25.0 % (17.7)	1871
Heretiera litterolaris, T	Sterculiaceae			1.0 % (0.8)	33
Lumnitzera racemosa, S	Combretaceae	7.0 % (4.3)	436	32.6 % (19.7)	1542
Rhizophora apiculata, T	Rhizophoraceae	2.9 % (1.8)	118	18.8 % (11.0)	674
Sonneratia caseolaris, T	Sonneratiaceae	3.0 % (1.7)	43	1.2 % (1.1)	27
(Cerbera manghas, T)	Apocyanaceae	(0.8)	(47)		
(Acrostichum aureum, F)	Polipodiaceae	(39.9)	(509)		
(Clerodentron inerrme, S)	Capparidaceae	(3.9)	(43)	(36.3 %)	(151)
Total		5 (8)	16 189 (16 725)	8 (9)	4 698 (4 849)

4.3.2 Ecological indices

Though the amount of different species was higher in Sathurukondan, the species diversity is higher in Nasivanthivu (Table 2). Since Sathurukondan also are extremely dominant of *E. agallocha* and *A. aureum*, it has lower evenness than Nasivanthivu. The sampled area in Sathurukondan is larger and has higher density and average height of mangrove species compared to Nasivanthivu (maximum height 10 m and 9 m respectively). However, the stems are slightly thicker in Nasivanthivu. There are substantial amount of liana and shrub covers of *D. scandens* and *A. ilicifolius* (Table 3) in each location which is presented by their frequency in percentage of cover.

4.3.3 Lifeform distribution

The life forms of the species present in the forest at each location are predominantly trees, 91.1 % and 58.9% in Sathurukondan and Nasivanthivu respectively. The high presence of *L. racemosa, A. marina* and *C. inerrme* in Nasivanthivu contribute to 38 % proportion of shrubs, but the collective numbers of *E. agallocha, R. apiculata,* and especially mangrove associate

H. tiliaceus jack up the tree numbers to a majority (Appendix 7). Sathurukondan recorded 4.6 % shrubs. 3.3 % ferns, 1 % climbers and grass. Nasivanthivu recorded 1.8 % ferns, 1.4 % climbers, grass, and herbs.

Table 2 Forest structure and diversity indices between the mangrove species in both sites.

All Species	Sathurukondan	Nasivanthivu
Species Richness	3.08	3.12
Species Diversity	0.60	2.00
Species Evenness	0.17	0.60
Density of true mangroves	666 214 / km^2	465 149 / km^2
Average DBH (± sd)	4.3 cm (2.9 cm)	5.1 cm (3.5 cm)
Average Height (± sd)	3.4 m (1.5 m)	2.9 m (1.5 m)

Table 3 Frequency of *Derris scandens* and *Acanthus ilicifolius* cover in both sites.

	Sathurukkundan		Nasivanthivu	
Plot cover	*D. scandens*	*A. ilicifolius*	*D. scandens*	*A. ilicifolius*
< 5 %	30	3	4	5
5 - 20 %	15	1	10	2
20 - 35 %	21	3	7	2
35 - 50 %	20	1	1	4
> 50 %	3	0	1	2
Total frequency	**89**	**8**	**23**	**15**

4.3.4 Disturbance and regeneration densities

In Sathurukondan were 1.5 % of all mangrove species juveniles (Table 4), where *E. agallocha* as the most dominant had the highest number of saplings, dead, and regenerating cuts and stumps. Density of saplings, dead cuts and stumps, and regenerating ones are higher in Sathurukondan than recorded in Nasivanthivu, but both locations experience more dead than regenerating stumps and cuts.

In Nasivanthivu, 9.8 % of all mangroves recorded were juveniles where *A. marina* has highest proportion, but *L. racemosa* being the highest in true numbers. Interestingly, there are more dead stumps of *L. racemosa* than *E. agallocha*, but the latter experience higher density of regenerating stumps. All species except *E. agallocha* had higher density in Nasivanthivu, even though sapling density was highest in Sathurukondan.

Table 4 Densities of regeneration and disturbance present at each location (km^{-2}) and juvenile percentage by each species. The total number counted is presented in parentheses.

Mangrove Species	Sathurukondan (km^{-2})				Nasivanthivu (km^{-2})			
	Juvenile (%)	Dead stump	Regenerating stump	Sapling	Juvenile (%)	Dead stump	Regenerating stump	Sapling
A. marina	5.9 (16)	16 049 (390)	5 473 (133)	6 584 (160)	25.6 (111)	20 396 (206)	4 455 (45)	33 762 (341)
B. gymnorhiza					15.3 (11)	1 287 (13)	0	198 (2)
C. tagal					6.7 (3)	495 (5)	99 (1)	495 (5)
E. agallocha	1.2 (179)	345 638 (8 399)	122 058 (2 966)	83 292 (2 024)	6.6 (123)	43 069 (435)	22 574 (228)	5 149 (52)
H. litterolaris					15.2 (5)	1 683 (17)	396 (4)	0
L. racemosa	9.2 (40)	17 037 (414)	1 687 (41)	1 523 (37)	10.8 (167)	121 980 (1 232)	18 614 (188)	13 861 (140)
R. apiculata	0	1 193 (29)	0	617 (15)	5.9 (40)	25 149 (254)	792 (8)	11 188 (113)
S. caseolaris	7.0 (3)	329 (8)	165 (4)	41 (1)	0	99 (1)	0	990 (10)
Total	**1.5 %**	**380 247**	**129 383**	**92 058**	**9.8 %**	**214 158**	**46 931**	**65 644**

4.4 Household's status, mangrove uses, and dependency

4.4.1 Livelihood diversification and change in income

Approximate monthly income is lower for the highest proportion of villagers in Nasivanthivu (54 % in 10 – 20 000 LKR) than in Sathurukondan (37 % in 30 – 34 000 LKR) (see Figure 11A). Villagers in Sathurukondan and Nasivanthivu are both involved in fishing, but Nasivanthivu have a higher proportion of respondent dependent on fishing for livelihood (see Figure 11B). In addition, majority of Sathurukondan villagers shift between two jobs depending on the season and availability of work (see Figure 11C), whereas the majority in Nasivanthivu mostly has one income source throughout the year, however, the graph does not reveal if the full-time fishers possibility shift between lagoon and sea fishing seasonally. The majority of respondents have primary or secondary education (41 % in Sathurukondan and 62 % in Nasivanthivu) but more respondents had obtained Ordinary and Advanced level examination in Sathurukondan (15 % and 37 %) than in Nasivanthivu (8 % and 4 %) (see Figure 11D).

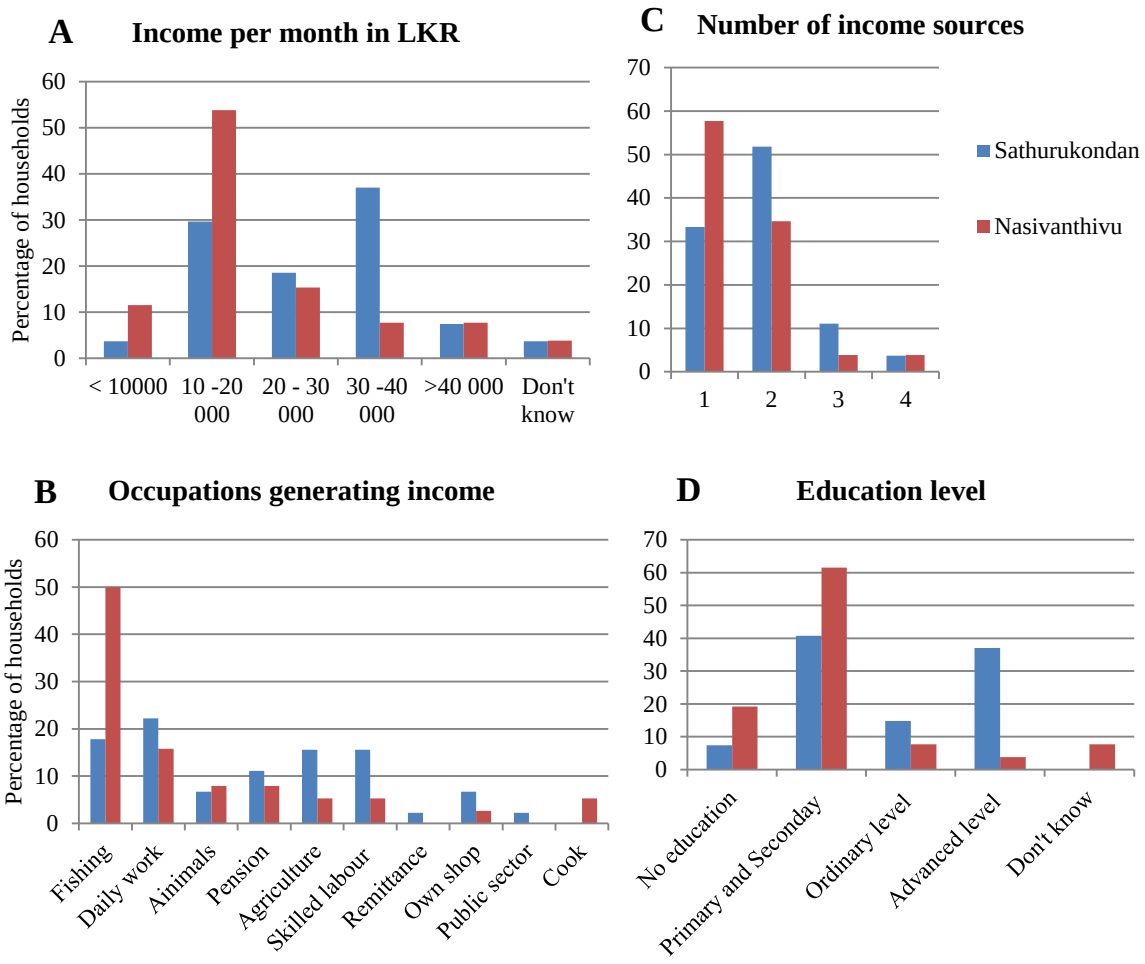

Figure 11 Histograms of percentages distribution between household respondents in Sathurukondan and Nasivanthivu. Distribution of income in LKR (**A**), number of sources (**B**), occupations generating income (**C**), and educational level (**D**).

Seasonal shifts between occupations were common, especially in Sathurukondan where demand for daily workers such as, construction, masonry, or painting is high in the dry season (February – September). Many do not have long term contract, yet generate more income compared to fishing, and some considered fishing a last resort in times of hardship or decreased demand for daily work.

The onset of monsoon determines when agriculture and paddy fields start planting, and when more fish and shrimp species exist in the lagoon. Some daily workers turn to fishing only because the rain impedes construction and painting activities as fishery income is less stable and depend on factors such as effort, gear, price on species, and species available. It is also more dangerous work as fishers are exposed to crocodiles. In addition, too much rain flood the villages and roads which prohibits access to work, electricity available, or dispel lagoon

species as the brackish water become more diluted: *"It is more difficult to gain an income during the heavy rains. The bridge is then blocked and they cannot go anywhere. There are only small fishes that they catch. Different fishes from what they catch normally"* (respondent 26, Nasivanthivu). Skilled laborers, such as business persons, welders, and teachers, on a long-term contract have more stable income and thus not affected other than accessibility. The reason for changes in income were similar in both locations, but households had more stable income alternatives available in Sathurukondan.

4.4.2 Mangrove resource uses stated by household respondents

Past and Present uses of mangrove resources

Previously, Sathurukondan and Nasivanthivu villagers used *L.racemosa* and *R.apiculata* for fencing and construction as the wood is very strong. Other uses would be firewood, poles to support plants in home gardens, bark to make rope, or dye for fishnets. Some would sell the wood and get a monetary income. Respondents at both locations did not prefer *E.agallocha* for its poisonous sap, other than floating pole supporting traditional canoes in Nasivanthivu. But due to its dominancy in Sathurukondan it was used for construction previously. *S. caseolaris* is important for collecting mangrove apples for sale and consumption or the roots for corking bottles. See Table 5 for all mentioned uses in ES categorizations.

Today, direct mangroves resources were used to a much smaller extent: for ornamental purposes for festivals (flowers from *H. tiliaceus* and *T. populllnea)*, plants for medicine (*C. inerrme*), or firewood (any dead wood). *C. inerrme* was more commonly used in Nasivanthivu as complement to modern medicine, however in decreasing trend where the plants' sap sooth rashes or body pains, for example from the sap of *E. agallocha*. Nevertheless, cutting mangroves has nearly stopped as cutting of mangroves became banned at both sites. Few respondents mentioned a fear of being arrested as motivating their decreased mangrove use in Nasivanthivu. However, just above 50 % of the respondents at both sites appreciated the mangrove conservation benefits, either for the sake of fish and bird habitat or for the wider village:

> *"The mangroves are important for the fishes, crabs and prawns as breeding stations. Mangroves are also important as lodge for the birds [...] So the reason the mangroves are used as a breeding station and that is why they [Government] want to protect the mangroves"* (respondent 4, Sathurukondan).

Table 5 Mangrove Ecosystem Services mentioned from household respondents in Sathurukondan (*) and Nasivanthivu (¤).

Provisioning	**Cultural**
BEFORE: - Wood: firewood, fence, constructing, fish, dye*¤, sales ¤ - Shells, oysters for chalk production and shrimp fertilizers ¤ - Agricultural land ¤ NOW: - Food (fruits, marine animals, plants) *¤ - Harvesting fish, shrimp, crab *¤ - Bird and egg harvesting * - Products for sale (wood, fruit, plants, herbs)*¤ (saplings) ¤ - Branches or sticks to support vegetable plants*¤ - Wood for fence *¤, firewood, boats, coffin ¤ - Dead wood for firewood *¤ - Sticks for fish and crab cages *¤, cane* - Flowers (ornaments) *¤ - Bark for rope *¤ - Plants and herbs for medicine *¤ - Phnemaphores for bottle caps * - Branches for brush piles (fishing method) * - Dumpsite * - Feed for cows and goats ¤ - Seedling and sapling for nursery ¤ - Plants and leaves for mats ¤	BEFORE: - Collecting wood in groups *¤ NOW: - Beautiful to observe *¤ - Recreational to observe animals (birds) and attract tourism *¤ - Flowers used for decorating and worshiping Tamil gods in Kovil * - Nature will survive through time for future generation to enjoy *¤ - Cultural heritage for fishers and their traditional livelihood *¤ and identity of fishing village ¤ - Ghosts among dense mangrove forest * - Scary place that invite bad and illegal activities * - Witchery in graveyard ¤ - Hindu Sanskrit timing on wood harvesting ¤ - Village replanting ¤ - Clean environment provides feeling of freedom ¤
Regulating	**Supporting**
BEFORE: - Hiding area, dispose bodies *¤, rubbish * NOW: - Regulate heat, wind, air, wave energy, (humidity) rain *¤ - Flood regulation *¤ and groundwater recharge * - Protection against strong wind, storms, soil erosion*¤, tsunami ¤ - Sequester carbon from air * - Provide drinking water ¤ - Give shade for animals and humans *¤ - Filter dirty water ¤	BEFORE: -Habitat conditions for shrimp farming ¤ NOW: - Bird habitat *¤ - Fish habitat *¤ - Crab and shrimp habitat *¤ - Habitat for scary and dangerous animals *¤ - Habitat for mosquitoes ¤

However, both sites mentioned that small mangrove cutting still happens by poor people as they still have needs and most don't blame them or tell on them, because it happens at such a decreased scale. Few respondents in Nasivanthivu only use mangroves as a last resort but prioritize alternative sources. Also, it was mentioned that people from other villages still cut

the mangroves: *"The village people who are using mangroves has decreased. But now people from outside the village are using the mangroves"* (respondent 18, Sathurukondan). And some still use *R. apiculata* for traditional uses and for lack of finances to alternatives:

> *"Ancestors have done this tradition. They cut 5 sticks of kanna [R. apiculata] and use for one small bed. Because they cannot afford to buy a coffin, as the people with money can. They use this tree because it is strong wood. But even if they are poor, the law will not leave them be. If they catch them the law will still apply as harsh to them as to anyone. The law is the law"* (respondent 5, Nasivanthivu).

Further, *R. apiculata* was most often mentioned as important for fish production among respondents in both sites. Even though there were additional three true mangrove species present in Nasivanthivu, its usefulness for fish production was not declared by respondents (i.e. *Bruguiera gymnorhiza, Ceriops tagal, and Heretiera litterolaris*). *E. agallocha* was explained as very productive and persistent tree: *"Thillai [E. agallocha] marangal will regenerate very quickly. It will regenerate even if you cut it down to the roots the trees will keep growing from the remaining roots. [...] If you cut one stem, 10 new will grow"* (respondent 6, Sathurukondan). But it is not a wanted tree: *"The tree [E. agallocha] is no helpful at all. It is not as useful as Kanna [R. apiculata] for fish production or preventing soil from erosion"* (respondent 21, Sathurukondan). Other species mentioned by fishers as beneficial for the fish production, coastal erosion, and storm protection were *S. caseolaris, A. marina,* and *L. racemosa* due to their root systems.

4.4.3 Mentioned strategies to replace mangroves by household respondents

In replacing mangrove resources were firewood mostly replaced by buying wood from shops, collecting wood at more distant places, or whatever found on own land. In Sathurukondan, many households have gas stoves to replace firewood altogether, which is not as common yet in Nasivanthivu. To replace fencing, coconut or palmyrah leaves are used between concrete poles which are more permanent, but costly. The decayed leaves would then be used for firewood. In Nasivanthivu would many women collect dead or rotten wood for cooking and fencing from terrestrial jungles. Some replacements have required own finances among the respondents, which not all possess: *"But those who can afford to buy concrete posts, they will buy that. The poor ones will use the wood from the mangroves"* (respondent 25, Sathurukondan). Some organizations have given out concrete poles, timber and tree plants for

home gardens, but the support is not supplied frequently. However, brick-house donations from INGOs after the tsunami greatly decreased demand of wood for building cottages and roofs in Nasivanthivu.

Few respondents mention to have personal savings when income is high to support the household through difficult times. Those without savings would take loans or borrow on credit. Even begging was mentioned as a strategy in Nasivanthivu, if they were unable to find a job. Those with experience can find work, but in Nasivanthivu there not too much options available in the village as mentioned in Sathurukondan:

> *"I used to fish for 100 % of the time but now I have two jobs as there are more job opportunities to find other sources of income. Many others have also gone to do other jobs at part time. The fish production has reduced, but other job opportunities are rising and are easy and permanent. Fishing is not as secure. Alternatives for jobs exists if they have to change job, which is good"* (respondent 1, Sathurukondan).

Many respondents had ambitions to support their children into good education and good jobs. As mostly expressed in Sathurukondan, children would not need to partake in traditional work. Nasivanthivu villagers also wished good education and job for their children, but it was more emphasis on teaching the ecological knowledge and the fishing village identity down the generations too: *"If I would pass away, my children and grandchildren will still protect the mangroves too. [...] I am happy with this. The future generation will also protect the mangroves and the future for the village"* (respondent 12, Nasivanthivu).

4.4.4 Perceptions of mangrove benefits by household respondents

Fishers in general at both sites were much aware and detailed about how mangroves are protecting the fish resources. From fishers own observation they experience an increase in fishes as a result from more and bigger mangroves at both locations. The majority of them would not disturb the mangrove forest and would report those who do. In Nasivanthivu however, some fishers and respondents understand those still using mangrove resources due to poverty. Further, fishers in Nasivanthivu expressed more own responsibility over the lagoon resources in connection to their identity as a fishing village:

> *"The fish are nesting among the roots and it provides us with our livelihood and work. We are saving and loving these trees. The trees are good because it gives*

the fishermen occupation, fish, prawns and crabs. If they are cut, we don't have any jobs because the fish will be reduced. It is the main investment of our life. We depend on this" (respondent 12, Nasivanthivu).

Some women in Sathurukondan on the other hand were not optimistic of the increased forest cover. They feared increased crocodiles, snakes, lizards, mosquitoes, and more hiding area for thieves and other illegal activities. Furthermore, people dump all sorts of rubbish and leftovers there at night time, leaving a bad smell: *"After six pm in the nighttime they cannot go into this area because thieves steal necklaces and purses. They also throw garbage and pollutes in the nighttime. They throw chicken intestines and leftovers from restaurants. It is very dirty"* (respondent 27, Sathurukondan). Such comments on aesthetics were also common on the beauty of mangroves.

Several respondents at both locations had romantic expressions about the esthetics provided by mangrove forest: "*The decorations of flowers and leaves are beautiful"* (respondent 18, Sathurukondan). Also, benefits in the natural environment were generally acknowledged at both sites: *"The forest need to be increased and clean the air from the sea and make it more a feeling of freedom and is healthier"* (respondent 9, Nasivanthivu). Increased mangrove forest had cooled down the air and decreased the wind speed. The mangroves were further retaining the flood water from entering the villages, recharging well-waters, and preventing shore erosion. Different mangrove species and characteristics were perceived as common knowledge and taught down from generations at both sites, especially among fishers. Medical uses were derived from village doctors or mothers and grandmothers when someone needed medical help.

4.5 The Mangrove Management Implementation Process and Involvement

The contemporary Government administration under President Maithripala Sirisena emphasize and support environmental conservation and local participation to achieve sustainable development more than the previous president, as perceived by interviewed Governmental officers and NGO representatives. This discourse was mirrored in explanations describing implementation of environmental management through the Participatory Coastal Zone Restoration and Sustainable Management Project (PCZRSMP) in the Eastern Province of Post-Tsunami Sri Lanka, active at both locations and funded by the International Fund for Agricultural Development (IFAD) and the Global Environment Facility (GEF) and regionally facilitated by CC&CRMD. The participatory component entails cyclic top-down and bottom-

up processes for baseline surveys and management design through new and existing institutions such as the local village (GS) and village organizations. Co-management and participation is highlighted among Governmental officers and local NGO's.

4.5.1 The PCZRSMP aim and objectives as explained by key informants

The project aimed to restore tsunami effected ecosystems and promote community livelihood options and promote disaster risk reduction measures. Nasivanthivu and Sathurukondan were recognized for their high ecological value and were selected as replication sites where management design and implementation had been initiated but monitoring would end with the project in December 2016. After stakeholder consultation on District and Divisional level are all villagers invited for project briefing, and thereafter are CBOs (such as: Rural Development Society, RDS; Samourdhi, Women RDS, and FCS) consulted about issues and support for the project plan. The wider objective of the project was to restore and conserve the coastal ecosystems to maintain the provision of the beneficial mangrove ES to mitigate climate change impacts and natural disasters on the coastal zone and communities. The expected outcome of the project is to gazette a local Committee consisting of villages which are to be registered at the Divisional Secretariat, which would give them legal ownership and responsibility for managing a demarcated area and its natural resources. Through the Divisional Secretariat has the project also established Community Coordination and Committee (CCC) forums, where major stakeholders such as FSC, Women RDS and RDS, and Farmers co-manage the natural resources in partnership with Government officers and chairpersons (GS or CEA). The CCC are recommended to have monthly meetings to increase the members awareness and to discuss ecotourism, sanitation, and micro-credit for women. In addition, the CCC is an important mechanism to sustain the coastal ecosystem restoration works within the hand of the communities and sustaining good practices between the local and state. However, meetings are not held as frequently as anticipated according to key informants from CC&CRMD and FD.

Sathurukondan issues and solutions

Sathurukondan mangroves and wetland is often highlighted as important nesting grounds for several different migrating birds and fishes. The collectively identified issues from key informants were: garbage dumping; encroachments; illegal cutting; increased fishing pressure (including traditional brush piling methods); and reduced water exchange into mangroves due to unplanned infrastructure development. The FD had previously replanted mangroves in the

area with low survival rate, but through the recent project the FD and CC&CRMD have replanted mangroves associates as a bio-fence along the road in Sathurukondan, together with concrete pillars and held awareness meetings with the villagers in 2014. The mangrove cutting has decreased substantially since then, but it did not stop solid waste dumping. Thereafter, CC&CRMD provided some households with compost bins and training in organic home-gardening to prevent more garbage being thrown into the mangroves. Further, the land encroachment into the area was neither stopped and most land disputes in Sathurukondan are caused by outdated or illegal land deeds and leases, but other root causes of encroachments mentioned still existed as: increased population, re-settlement of war refugees, or small efforts to expand land. Only legal protection would prevent continued dumping, encroachment, and mangrove cutting according to key informants. Conservationists on the Government side do not wish to ban traditional fishing methods such as brush piling which entails cutting mangrove branches, but neither do they promote it. It is an efficient method to catch fish as fishing competition is high, but its use has been decreased as an effect of the awareness programs.

Gazetting the Wetland Committee as mangrove managers by PCZRSMP

The project created a Wetland Committee mobilized with the assistance of the GS, Central Environmental Authority (CEA), WRDS, RDS, FD, Road Development Authority, and FCS. The Committee composed of 50 % women and representatives from both local organizations and governmental agencies and all elected a local president to be responsible to report any illegal activities. The committee president had been sent on exposure trips to learn lessons and share knowledge with other village leaders on Community Based Disaster Reduction Management. The sustainable mechanisms involved to ensure future progress even without contribution from project is to train the members properly, and involving GS, CEA, and Divisional Secretariat as chairpersons in the Committee. Governmental officers are meant to give continued advice and support after end of project, but so far their participation is voluntary and not secured, according to representatives from PCZRSMP.

The Wetland Committee had yet to write a management plan over a clear demarked mangrove area which is to be gazetted in the Parliament. The main step forwards is to protect the mangroves and the wetland area through gazetting which gives more legal power and ownership. Even gazetting the area as a Bird Sanctuary under Wildlife Department, or Reserved Forest under FD are mentioned options for enforcing the protection status.

Depending on the owner and its' objectives after gazetting, access into the area may become strictly prohibited. So far, FD has only given warnings to arrested violators on humanitarian grounds as the reason for cutting mangroves is poverty.

Nasivanthivu issues and solutions

Nasivanthivu has a high variety of mangrove species, scenic beauty, and a population highly dependent on lagoon fishing resources. The island is flat and exposed to natural hazards which threaten the fishing villagers' livelihoods. Representatives from PCZRMSP claimed that mangroves needed to be protected and replanted in order to support increased fish stocks and alternative income sources for household's livelihoods. Awareness programs to conserve the remaining mangroves and increase cover, with a mangrove nursery and replanting were initiated in Nasivanthivu in 2014. Villagers were asked to collect seedlings and grow them, to later be sold and replanted either in Nasivanthivu or other coastal areas. At first, NGOs facilitated by FD and PCZRSMP carried out these efforts and participating villagers got food items in return. Due to its success the event has continued since then, but under supervision of local CBOs (WRDS, RDS, GS, and FCS) instead of the project founders. Also, alternative tree species were given to villagers for firewood. These inputs reduced mangrove cutting to a large extent, but mangrove resources for medicine, flowers, and fruits are considered legal uses and can continue.

Disaster Management Committee by PCZRSMP

In 2012, villagers were mobilized by GS, representatives from Disaster Risk Reduction Management Department, and PCZRSMP to form a Disaster Management Committee (DMC) with local members. The Committee elected a president among the villagers and they were given life-jackets, engine boats, speakers, and first-aid-kits. The members were trained on procedures to help villagers during a disaster to find shelter and give medical treatment. The motorboat provided generates income as a taxi, where revenues should be reinvested into the continued management process after the project cessation. Protecting mangroves was a main component in disaster reduction as the trees reduce strong winds and waves energy from destroying the village. The committee president and members were to report any illegal cutting inside the mangroves. Further, the president was sent to exposure trips along with other village Committees' presidents to share experiences and learn from mangrove conservation projects and management at other locations. The Committee members had created a 5-year management plan where they aim to meet every month to discuss the needs

and decisions needed. This plan was signed by FD and the MCEC building was built to continue to host awareness programs, meetings, student mangrove education, and replanting schemes. The Participatory Action and Learning Methodology (PALM) Foundation, a local NGO, has also done extensive work in cooperation with the Governmental officers and villagers in Nasivanthivu regarding lagoon resource management.

Sustainable Lagoon and Livelihood Lagoon Project by PALM Foundation

The PALM Foundations were implementing partners with the PCZRSMP and DOFAR operating in Nasivanthivu to sustainable manage lagoon resources for future generations in their project: *Sustainable Lagoon and Livelihood*. They contributed with preparing baseline surveys in 2013 and mobilizing the village election of the local Committees. The DMC can be regarded as a part of the wider Lagoon Management Plan for Nasivanthivu, where a Lagoon Management Committee (LMC) functions autonomously for the wider lagoon. The LMC will have a written legal framework to sustainably manage lagoon resource and financially support fisher families to alternative livelihood opportunities. Early 2016, the chairpersons and department representatives in the Committee met to discuss regulations and management set-up with CCC resulting in a Lagoon Management Area Declaration for Valaichchenai and Nasivanthivu Lagoon. The reservation area and regulations will hopefully come in effect 2017 and consider the lagoon waters and 10- 30 meter landward. The details of the decided regulations and plan from the meeting were not obtained during the field study.

4.5.2 Sectoral and Institutional partnership

Other NGOs such as Sevalanka Foundation, and World Vision had worked together with Government and villagers as facilitators and implementing partners in previous projects and management implementation. In the case of PALM's project, who intended to create a platform for collaboration between lagoon users and rulers, further stated that cooperation between NGOs and Government institutions should not be taken for granted as a success. Such cooperation or co-management at different administrative levels and with Government representatives are not always ready to take on more responsibility which put more efforts in the hands on the NGOs. Differing issues attract the attention of stakeholders differently, for example, illegal fishing gear and land ownership disputes was mostly mentioned by Sathurukondan fishers, whereas land ownership disputes was not given too much attention in Nasivanthivu. On a positive note, many key informants expressed increased effort of cross-

sectoral communication and cooperation within the recent project of PCZRSMP and PALM Foundation efforts as an opportunity and positive change.

4.6 Households' and Fisheries Co-Operative Societies' perceptions and involvement in mangrove management

The mangrove conservation management as enforced at both locations was followed and positively met among most villagers. In both study locations, the project reached out mostly via the existing CBOs through GS:

> *"GS created a group and informed them not to destroy the mangrove forest or disturb them. The organization members are then sharing this information with other villagers in the community. The group has a leader and members inform the leader in case they observe any destruction. The leader then informs the GS. This is the established system by the government. We are not members but got this information from our neighbor"* (respondent 14, Sathurukondan).

Those not involved in organizations are informed by neighbors as an informal information sharing network. As Table 6 display were respondents widely organized in Nasivanthivu, but not necessarily getting mangrove awareness through their membership. 42 % of the organized respondents in Nasivanthivu had participated in a mangrove related project.

Table 6. Respondents' membership in local village organizations. Sathurukondan were members to a much lower degree than Nasivanthivu villagers. Mentioned organizations were Samourdhi, WRDS, RDS, Fisheries Co-Operative Societies. The latter was very common in Nasivanthivu.

	Sathurukondan (%)	Nasivanthivu (%)
Member of local organization		
• Yes (mangrove projects)	37 (40)	73 (42)
• No	56	27

In Sathurukondan, villagers were also made aware about the mangroves through notice boards surrounding the mangrove forest. The boards share information on mangrove's importance for migrating birds. Despite these efforts to increase mangrove awareness, some respondents were still not aware of any mangrove project or ban. The mangrove conservation perception the respondent had seemed to vary in the manner information was given out.

The FCS respondents were very supportive of mangrove conservation and they were often involved in the governments' awareness programs, both through their connection to GS and

DOFAR. FCS were mentioned as very resourceful groups because its members depend and have good knowledge of lagoon resources:

> "*The Fishery Department and the Fishery Association*[7] *are connected by the one association leader and nine executive members. All information goes between them and plans have to be approved by the associations"* (respondent 1, Sathurukondan).

In Sathurukondan, about a third of the respondents did not recognize any benefits of the mangrove protection for their households, or considered that the benefits were only for the migrated birds:

> *"Government only told them to protect them [mangroves] and not to cut them. Not why they are only protecting. They didn't explain the benefits of the protection of the mangroves being beneficial. [...] If they could tell us why it is important to protect it we could know the benefits and I would be interested to hear it"* (respondent 4, Sathurukondan).

Negative perceptions on the management regime emerged at both sites. As mentioned earlier, some women in Sathurukondan were negative to the forest inviting illegal activities and dangerous, that men would not have to worry about. Also, despite these efforts from politicians, GS, RDS and FD, few villagers perceived these actors as only giving empty vows during election times. One respondent said that Nasivanthivu villagers could agree on project conditions, but as authorities left the island the cutting would resume in as before. A couple of villagers in Nasivanthivu perceived the support given from the NGOs and Government programs, being distributed unequally and insufficiently: *"Both poor and wealthy are given support but still there are many poor that are left without any help"* (respondent 4, Nasivanthivu). Again, many respondents in Nasivanthivu recognized that poverty needs to be addressed in order to stop mangrove cutting:

> *"Some people who are still using it [mangroves] after the banning of cutting, don't fully realize the benefits of mangroves. I have stopped to cut the mangroves because I realize the benefits it will bring the village to let the mangroves grow. Because there are many fishermen in this village and*

[7] Fishery Association is used as a synonym for Fisheries Co-Operative Societies as respondent often mentioned the former, but after clarification of details on this organization it had same activities.

increasing mangrove will increase the fish production. The problem is poverty. They cut and don't see, or realize or cannot realize the long term benefits of the trees. They have the needs today" (respondent 5, Nasivanthivu).

Further, the interviews revealed that respondents did care and felt the ecological benefits of mangroves and were positive to conserve it if participated in replanting schemes, awareness programs or gotten this knowledge in person from NGO staff or Governmental officers, or having own close observations of mangroves. Obtaining the information from a board or through village members did not always seem to generate as high concern for mangrove conservation benefits. Also, those who were not keen to protect standing mangrove forest were not necessarily aware of the outspoken benefits mentioned in the meetings by the government and not forwarded in the informal village communication networks. Further, few household respondents mentioned that they do not consider small cutting inside the mangroves as destructive while also understand the importance of mangroves for the fish production.

4.7 Remaining issues according to key informants

Several issues remain to be addressed which have been insufficient or not considered for reaching a sustainable mangrove management at each site.

- **The A15 highway and water exchange in Sathurukondan wetland** impedes sufficient water exchange for the mangrove forest. The highway used to be smaller 15 years ago, but the current culvers are the only path allowing water exchange between the big mangrove patch and the lagoon. Apart, from the floods in the rainy season that contribute to soil humidity, the extent of sufficient exchange is not well known among managers or scientists. However, the current state is perceived to deplete mangrove productivity and feeding ground for fish in the long-term.
- **The Monsoon floods** that inundate the mangroves to extreme levels have uncertain but perceived negative impact the mangrove forest ecosystem. A changed pattern of delayed onset and large amount of rain under short time has result in recent extreme floods. The mangroves become inundated with freshwater to a high level for a long time. In addition, dirt and rubbish are accumulated among the mangroves as the flood water wanes. Accumulation of toxins and chemicals from runoff and garbage may change forest biology, chemistry, features, and functions.

- **Climate change and large scale processes** impacts the monsoon pattern in addition to sea level rise threats. Geomorphology, available space, and suitable conditions inland determined the mangrove migratory pattern for adaptation, which is not well known at either site. Actually, the Sathurukondan wetland today was mentioned to be a remnant from when Batticaloa was an estuary, where the floods may be crucial factor that maintain the ecosystem a wetland.
- **Bribes within political decisions** impact natural ecosystems. Approval of construction processes was mentioned to be discarded with bribes resulting in mangrove clearances. Any activities have to go through and be supported by CEA, GS, local organizations, and villagers, as common procedure according to key informants. On a positive note, this structure had been successful in a case where a hotel construction was stopped as local villagers in another location opposed a hotel proposal which threatened the mangrove cover.
- **Working across sectors and scales** is perceived a big problem among those working with mangrove management implementation at Divisional, District and National level. This creates conflicting processes, unsuitable management implementations, and mangrove responsibility uncertainty between governmental agencies. As example, the A15 highway as constructed by Road Development Authority removed protective mangroves and today spends millions on gabions to prevent erosion on the road (Figure 12). More lateral coordination at administrative level and preventive consulting through relevant Departments and Ministries would prevent wasting money on unsuitable management and unsuccessful projects. One successful example, before initiating any activity one must seek approval and guidance from related Ministry and Governmental agency, based on lesson learnt from failed mangrove replanting programs in the past.

Figure 12 Gabions protecting the A15 highway from shore erosion in Sathurukondan.

- **NGOs experience decreased funding availability** (according to Sewalanka Foundation, PALM Foundation, and SOND who all are local NGOs with previous experience in mangrove related projects). The decreased trend, as suggested by NGO

representatives at Sewalanka Foundation, is caused by Sri Lanka being declared a middle income-country based on efforts from the previous President. Several parts of the country are still poor and need development, but as Sri Lanka no longer falls under the criterion of a low-income country have several donor agencies withdrawn their funding to the country. The NGOs work was perceived more restrained and reduced, but some topics could still receive funding within: livelihood development focused on post-conflict beneficiaries; rights-based development rather than need-based charity; and environmental protection. In addition, internationally available funds addressing Sustainable Development Goals (SDG), global environmental issues, and biodiversity loss are global concerns causing national response to focus on mangrove conservation, biodiversity, and livelihood promotion. PALM Foundation does not believe they would have been able to implement their project 10 years ago, had it not been for the increased global concerns on these issues.

- **Insufficient implementation on existing regulations for mangrove conservation.** There are many regulations in force on mangrove protection, but they are not being implemented thoroughly. Perceptions among some key informants expressed that environmentally destructive development is still happening. At the same time has the contemporary President, Maithripala Sirisena, created a set of rules under which all Governmental institutions must abide, regarding environmental conservation and environmental awareness. Consequently, the NGOs and Divisional officers perceive to gain more Governmental support on environmental conservation compared to before, but yet not implemented or prioritized by all sectors, as critiqued by academic informants from fields of mangrove ecology, management, and education.
- **The fishing pressure in Batticaloa District** is perceived to have increased and threatens to deplete the fish stock. Fishers at both sites were concerned as both increased fishing activities and illegal fishing methods had been observed. Net-fishing with small mesh size, night-time light fishing, goggle and motorboat fishing are considered illegal. Those who fish with illegal methods gain increased income at the expense of the long-term sustainability and future livelihood for wider fishing communities. Caused by insufficient job opportunities, people are pushed to fishing using any tools, and this issue was not addressed by the authorities, as perceived by an academic informant.
- **Environmental protection and remaining need for development.** While the projects' objectives focus on environmental conservation and restoration, the

environmentalists cannot omit the need for economic development in the study locations. Still today, shrimp farms were mentioned as a big threat to mangroves in Sri Lanka, but perhaps perceived as a necessary evil by developers to gain local economic income, but according to academic informants the authorities implements projects and punish the people if they are not abiding the new regulations, without properly listening to the problems villagers are facing. There has been a village protest that successfully stopped shrimp farming activities to initiate in their village. Local consulting of options for economic development, other than shrimp farms, would be more suitable.

4.7.1 Improvements suggested from all interviews

- In Nasivanthivu, local villagers proposed some leeway in the mangrove protection regulations so they could provide themselves with wood for proper fences to keep animals away from eating on their crops. Also, to allow mangrove wood for traditional purposes such as brush piling, making coffins, and medical purposes.
- Many women in Sathurukondan suggested removing some trees and clean up around the mangrove edges to make it safer for them. Also putting up lights would help keeping thieves and illegal activities away. In addition, women at both sites suggested planting trees that could support their livelihood with food or income. For example jackfruit, mango, coconut, or plants for cows to graze are more useful plants to them.
- Low interest loans could help local villagers' development, instead of high interest loans from private firms which creates monetary dependency to repay the banks. Fishers sell fishes for a small price, and low interest loans would be helpful.
- Many fishers wished for more mangrove replanting, protection, awareness, and education to increase the fish production. Further, were more emotional awareness and care for mangrove forests needed, opposed to only explaining ecological benefits. Targeting local villagers as well as Divisional, District, and Provincial level, Religious leaders, and Politicians would mutually boost effort and motives to protect mangorves. Mangrove values may be latent in the back of people's head, but when resources are decreasing, the value is increased. The implementation of protecting mangroves had taken place for some years now, but still implementation is going slow.
- Several respondents and key informants agreed that mangroves would regenerate naturally and do not need to be replanted. But as human cut, take land, or throw

rubbish in the forest, they need to replant them. Many recommended security guards among the mangroves to prevent any further illegal or disturbing activities.

- Academic research should be better captured in management design and technical and scientific assessments are needed to properly address the remaining identified issues. Further, detailed and specific research is needed to understand the impacts influencing the mangrove ecosystems and ecological prerequisites to provide the desired ecosystem services. Some examples mentioned by key informants: extent of sufficient water exchange and flood impact on ecosystem function; accumulation of toxins, solid wastes, and nutrition (negative or positive as natural filters); salinity and freshwater balance; necessary feedbacks reinforcing production of mangroves to maintain the wetland in Sathurukondan.
- Increasing the economic development gives access to alternatives away from using mangrove wood resources altogether and reduce cutting. The economic development may be increased with more education, skills training, and technical course enrollment. This is useful when there is a lack of unskilled work and when demand for labor is shifting. Key informants from CC&CRMD and academia believe funding should focus on providing villagers with these options.

4.7.2 Perceptions of ecotourism opportunities

Both study sites have large ecotourism potential which has been proposed and discussed in the respective Committees. Governmental officers, academic informants, and NGOs alike, highlight that any tourism operation should be under community-based ownership and management so that the revenues will benefit the villagers. Local organizations and FCS are often considered relevant for leading such projects as they know most about the lagoon resources and may ensure sustainable management. RDS and WRDS were also mentioned as well organized group. In addition, while Governmental supervision is necessary at the implementing stage, good planning is important to preserve cultural and TEK in non-destructive practices, as highlighted by an academic key informant. Then, tourists can experience the true local identity that preserves these values and cultures, instead of destructive haphazard development.

The villagers were in favor of such ecotourism management opportunities based on the household interviews and group discussions. Many respondents in Nasivanthivu realized the

possibility of sharing local mangrove knowledge, alternative incomes, and bringing further development to the island:

> *"If more people came and would hire a boat, I can get income and the other poor people can get some income. [...]By coming here, they can also ask a lot of questions about the mangroves and people like us from the villages can share our knowledge and information. This is really good"* (respondent 8, Nasivanthivu).

Also in Sathurukkundan were perceptions mostly optimistic that tourism would bring more development and more job opportunities. As long as the tourism would not destroy the environment, it would be supported. However, few were negative to tourism, because introducing such activities may eventually push fishers out from the mangrove water ponds to only cater for bird-watching activities. CEA and another local NGO proposed a tourism project in Sathurukondan. They proposed a boardwalk among the mangroves for easy access to bird watching, but it was however, turned down by protests from private stakeholder for unknown reasons, but the tourism pursuit continues within the Wetland Committee. The exact details of the opposition to that project could unfortunately not be obtained during the field work.

5.0 DISCUSSION

5.1 Mixed research methods

This mixed method approach was complementary, using different sources which could triangulate and enforce the validity of the derived information (Bryman 2012). While initially not intentionally aimed for triangulation, some common and complementary findings emerged from both the social and ecological inventories. For example, the ecological knowledge among household respondents gave light to what characteristic different species have and their persistence in the ecosystem. And the erosion threat as mentioned by households and key informants was visible also in the mangrove forest field-visits by tipped trees along the shorelines, which may not have been understood if only observed in field. In addition was encroachment or land claim also present and verified by both data collection methods, especially in Sathurukondan. Such encroachment or claims for land was not as highlighted through the interviews regarding Nasivanthivu but the field visits encountered burned flora along the mangrove shores adjacent to paddy fields. Encroachment may be a creeping component that threatens the mangrove forest extent eventually, since similar drivers to these expansion of lands exists at both locations (increasing population density and development demand). This process was identified as a result from the comparative case study approach.

5.2 Forest characteristics in the Mangrove Ecosystems

5.2.1 True and associate mangrove species and index calculations

The identified species are aligned with identified species in previous mangrove studies in Sri Lanka and Batticaloa District (Jayatissa et al. 2002; Mathiventhan 2007; Pinto 1986). The higher mangrove diversity and evenness indices in Nasivanthivu may result from the dominancy of *Excocaria agallocha* in Sathurukondan by a remarkable 81.6 %. Noteworthy in Sathurukondan, including the IVP values for the mangrove associates *Cerbera manghas, Clerodentron inerme,* and *Acrostichum aureum,* rendered the latter species second most common with 39.9 % and *E. agallocha* 44.6 %. Similar composition was prevalent in 2007, also in the case of *C. inerme* with 3.9 % and *Avicennia marina* 3.0 %, which were rare and very rare respectively in 2007 where mangrove associates still exceedes those of true mangrove species (Mathiventhan 2007).

In Nasivanthivu, the mangrove associate *C. inerme* is the most dominant species despite its lower encounter by numbers compared to the true mangrove *Lumnitzera racemosa*. Further, in presented order were *E. agallocha*, *Rhizophora apiculata,* and *A. marina* common in Nasivanthivu to a more even extent. Together with three additional species: *Brugueira. gymnorhiza*; *Ceriops tagal*; and *Heritiera litterolaris* indicates a higher biodiversity of true mangroves species in Nasivanthivu, despite the lower tree denisty. In addion, more presence of diverse life growth forms existed in Nasivanthivu, but was still dominated by trees due to the very common mangrove associate tree, *Hibiscus tiliaceus*. The presence of mangrove associates are dependent on the transects lengthts landward and the dominancy differences are influenced by the field sampling measurements which had to be adapted.

As a result of the measurement were basal area and the mean calculated for the population of plants affected. The basal area is a factor in the Important Value Index and Percentage (IVP) which gives greater dominance to ferns and shrubs which have a large ground cover compared to the diameter of tree stems at breast height. The species-specific measurements was aimed to describe the biodiversity composition and was a result of pilot sampling in the mangrove forests to save time, but still capture nature's complex structure.

5.2.2 Species diversity, composition, structure, and regeneration

Both study sites experienced complex stands and patches of different structure which, according to Alongi (2009) is common in mangrove ecosystems where local disturbances create mosaic patterns in forest stands structure and varied succession status after canopy gaps triggers regeneration. As mangroves ecology commonly resembles those of opportunistic species, they are commonly disturbed all along Sri Lanka (De Silva & De Silva 1998) but as mentioned by the respondent are mangroves regenerating and growing at both study locations, despite continued small-scale cutting.

Sathurukondan

In Sathurukondan landward mangrove patch were a pattern of smaller and seemingly younger trees (juveniles) and mixed vegetation more prominent along the forest edges and the A15 highway. Regenerating and dead stumps, and mixed species (associates and true mangroves) are growing back on spaces from the past clearance of army forces along the road (Mathiventhan 2007). Due to increased human access there was also much mixed vegetation (life-forms) and species (associates) prominent along the margins towards the villages and

along the paths inside the mangrove forest. The forest characters gradually turned into thicker and fewer trees deeper into the large mangrove patch which resonates with a mature mangrove stand by Alongi (2008). The canopy cover was dense with *Derris scandens* and *E. agallocha* similar to simple mangrove stands with one main canopy dominant and absent understory vegetation (Smith 2002), but in light gaps, the presence of seedlings and saplings were increased in the understory, as well as regenerating stumps and cuts in than compared under closed canopy patches. This aligns with findings from other research where light gaps promote natural regeneration and opportunity for other species to colonize which increase productivity and diversity and hence ecological resilience (Amir & Duke 2009; Duke 2001; Smith 2002). Such light gaps could result from lightning strikes, small cuttings, or local fires.

Alongi's (2009) argument that local canopy covered species are more likely to recolonize available space than colonizing propagules dispersed with distance shed light to positive feedback of regeneration of dominant species, such as *E. agallocha* in Sathurukondan with highest amount of saplings. This competitive exclusion by canopy dominants has a big role in regulating recruitment in gaps and subsequent forest succession characterized in disturbed mangrove forest (Alongi 2009). *E. agallocha* was mentioned to be a tolerant species to coppicing which could explain its dominancy in Sathurukondan, in contrast to large mangrove clearances usually promoting dispersals of propagule seed species, such as *R. apiculata* (Walters et al. 2008).

Mathiventhan (2007) argued that the wide mangrove clearance by SLAF created opportunity for *A. aureum* to colonize, which has been suggested a result from removal of true mangrove species (De Silva & De Silva 1998). In a previous study was *A. aureum* found to inhibit regeneration and dispersion of *R. apiculata* propagules and was therefore considered a pest among true mangrove species (Srivastava et al. 1987 cited in Dahdouh-Guebas et al. 2005b). The prevailed dominance of the *E. agallocha* and *A. aureum* in Sathurukondan could indicate out-competition of other true mangroves such as *R. apiculata*. This is also aligned with previous intact mangroves elsewhere in Batticaloa Lagoon where thicker and higher trees had been replaced with lower secondary and scrubby mangroves such as *A. aureum, C. inerme,* and *E. agallocha* after a disturbance (GreenTech 2010).

Among true mangrove species, there were more dead stumps and cuts of *L. racemosa* than *A. marina,* but the latter had substantially more regenerating stumps and cuts. In addition, *A. marina* had more seedlings than *L. racemosa,* and the former was more frequent on the

lagoon side of the A15 highway whereas *L. racemosa* more prominent on the landward side. According to Duke (2001) *A. marina* is also proven to be tolerant to coppicing, especially in comparison to *Rhizophora* species, which concurs with *A. marina's* tolerance in Sathurukondan. Further, *Rhizophora* are ecologically more vulnerable to disturbances and changed environmental conditions (Duke 2001). Few older respondents mentioned that *R. apiculata* historically been more abundant along the lagoon fringes but that cyclone and army clearance has amplified erosion and caused its decline from the lagoon shorelines. Duke (2001) also mentions that in absence of stabilizing trees at the waters' fringes can erosion also threaten upstream mangrove stands. Tilted *E. agallocha* were found along the lagoon fringes from the field observations, which could be the effect of such extensive erosion.

Regarding underlying hydrological conditions to sustain a sound mangrove ecosystem and provision of ES have many studies concluded that sound hydrological fluxes is a vital component for mangrove restoration and replanting processes (see Dahdouh-Guebas et al. 2000; Dahdouh-Guebas et al. 2005a; Kathiresan 2008; Lewis 2005; Triwilaida & Intari 1990; Walters et al. 2008). The average tidal amplitude in Batticaloa Lagoon is at maximum 40 cm (NECCDEP 2010a) and unfortunately for Sathurukondan, the road culverts were believed to prevent sufficient water exchange to the large landward mangrove patch (District Coordinator at the CC&CRMD. Personal communication, 15th October 2016) detracting from the soil moisture, which influences the microbial activity and subsequently the forest production (Quan et al. 2016). On the contrary, in the rainy season the mangroves are inundated with freshwater for a prolonged period of time, which could contribute to maintain soil moisture, but also cause mangrove degradation as studied in Indonesia (Kathiresan 2008; Triwilaida & Intari 1990) and Batticaloa Lagoon previously by choking or felling the mangroves (Mathiventhan & Jayasingam 2014). Degrading effects on mangroves caused by changes in hydrology conditions is perhaps most noticeable to cause altered distribution and species composition (Dahdouh-Guebas et al. 2005a). Such changes are caused by dam, road, and other infrastructure developments in Sri Lanka.

E. agallocha is also tolerant to reduced hydrological fluxes, in addition to being less preferred for firewood by households (Dahdouh-Guebas et al. 2000; Mathiventhan 2007; Ransara et al. 2012) which could further explain its persistence and dominance in the landward mangrove patch. Perhaps are the environmental conditions for true mangrove species such as *R. apiculata* to colonize deteriorating. *E. agallocha* and *A. aureum* are still common today as 10

years ago (Mathiventhan 2007) one can also suspect the area is experiencing cryptic ecological degradation. As identified by Dahdouh-Guebas et al. (2005a), cryptic ecological degradation means that even though total mangrove forest cover may increase viewed from afar, on local level it may become invaded with mangrove associated plants or species with less desirable functions to the ecosystem. Another factor that supports the ecological degradation is fisher's mangrove knowledge in Sathurukondan where *E. agallocha* was not perceived to promote fish production in the same manner as *R. apiculata, A. marina, L. racemosa* and *S. caseolaris.* The physical appearances of the root systems (prep root and phnemaphores) were believed to be the functional component connected to increased fish production and hindering erosion. Endemic cichlids in Asia (*Etroplus suratensis* and *E. maculatus*) further prove this functionality and preference of mangrove vegetation for nesting over non-mangroves and non-vegetated sites in Batticaloa Lagoon (Ahamed & Dharmaretnam 2016).

Based on these findings, the landward mangrove forest in Sathurukondan may be in a process of becoming a mangrove associate-dominated forest. Mukherjee et al. (2014) argues mangrove forests can still be highly functional despite low plant biodiversity and evenness given as long there are key-stone species important for maintaining the specific ES. However, as the mangroves have historically provided fish habitat, erosion and storm protection, the current species composition may gradually detract from the mangrove ecosystem resilience by deteriorating conditions for functional mangroves species that provide those ES, despite increase in mangrove forest area cover. Dahdouh-Guebas et al. (2005b) found that mature mangrove stands dominated with *R. apiculata* and no cryptic ecological degradation, experienced low impact from the tsunami and hence is desirable for building resilience from natural hazards. Natural hazards may not be eliminated but their disastrous effects can be reduced by protecting healthy mangrove ecosystems. This argues for protecting and restoring healthy and mature coastal mangroves which also may render coastal communities to recover more quickly and re-establish their livelihoods (Ashlin 2012) and hence building SES resilience.

However, in light of a wetland forest with mixed species of true and associated mangroves it can build resilience by continuing to favor conditions for tolerant species such as *E. agallocha* and *A. aureum*. As habitat for migrating birds, the mixture of mangrove and associates may be positive due to the increasing amount of trees and nesting places. In this light, the mangroves

in Sathurukondan may need spatially separated management regimes depending on their environmental conditions as the current hydrological conditions differ in the patches opposite of the road. The management regime would have to specify objectives and desired ES to answer with proper measures to sustain the provision of those ES. Similarly to a mangrove forest in Kenya which experienced increased cover and *C. tagal* at the expense of *R. mucronata* it was suggested to clarify whether the increased mangrove cover was enough or if it would be necessary to remove *C. tagal* to make way for the more economically viable *R. mucronata* (Dahdouh-Guebas & Koedam 2002).

Nasivanthivu

Due to absence of past studies, respondents' narratives of the recent past were the foundation for the mangroves history in Nasivanthivu. A similar trend of increasing mangrove cover has happened in Nasivanthivu, but with contrastingly higher densities of saplings and percentage of juveniles of all species. Also here, *E. agallocha* and *A. marina* have proportionally more regenerating stumps than *L. racemosa,* which gives insight to the regeneration capacity of those species also in this location. The frequent presence of cuts on *L. racemosa* could be a result of its availability for harvesters, but all mangrove species showed evidence of cuts and the local harvesting may not be too selective to cause a change in species composition (De Silva & De Silva 1998). In addition, Nasivanthivu has higher biodiversity and evenness index value of true mangrove species.

The forest stand structure was mixed with no clear pattern except most *R. apiculata* on the lagoon fringes with closed canopies and dense understory with few *B. gymnorhiza* and *C. tagal* emerging. *A. marina* together with mangrove associates, such as *C. inerme, H. tiliaceus,* and *P. pusilla,* were dominant along the forest margins. Zonation could partly explain this gradient of species (Kathiresan 2008; Smith 2002) despite limited tidal amplitudes. Major zonation patterns take considerable time to be established, and they are not common in Sri Lanka due to human interference (De Silva & De Silva 1998). The mixture of mangrove species and associates together within the forest landward margins could be partly explained by, but not exclusively to, human disturbances, such as cutting and clearances. *A ilicifolius* is, similar to *A. aureum* a pioneering species among mangroves which colonize cleared spaces from removal of selective true mangrove species (De Silva & De Silva 1998), which could indicate such disturbances. However, propagule predation can further contribute substantially to the forest composition as many grapsid crabs were present in the ecosystem. In mangrove

ecosystem in Sri Lanka's southwestern coasts have crabs predation on *A. officinalis* propagules limited its distribution and hence impacted mangrove stands. This was a result from changes in micro-habitat that favored an increased the crab population (Dahdouh-Guebas et al. 2011). Further could sound soil conditions as a result of sediment accretion and tidal fluctuation cause local conditions that make habitat for a varied amount of mangrove species. The geomorphology of the location could also be more similar to a riverine mangrove patch with conditions for more luxuriant growth and low salinity (De Silva & De Silva 1998). The exact reason for species distribution, higher biodiversity, and evenness index values in Nasivanthivu than in Sathurukondan, is not proven based on these findings. But it could suggest to partly consisting of a combination of human disturbance, propagule-predation, and sufficient tidal-fluctuation causing habitats for a variety of mangroves species to compete for space without one dominating species.

Nasivanthivu has a higher abundance of true mangrove species that contributes to provision of fish habitat (*R. apiculata, A. marina,* and *L. racemosa*), based on fisher's TEK. According to Biggs et al. (2012. p 425), functional redundancy and response diversity are important for provision of ES as *"capacity of functionally similar elements to partially or fully substitute for each other"* and is building resilience. One difference between the sites is possibly the influence of tidal exchange in the mangrove ecosystem in Nasivanthivu which have been expressed as the one most important component for successful mangrove regeneration in many studies, as discussed in the section above (5.2.2 *Sathurukondan*). This tidal exchange could allow favorable conditions for the mangrove ecosystem, which could improve the species diversity and even composition (Kathiresan 2008), for a healthy ecosystem that provides beneficial ES that builds SES resilience.

However, hydrological processes also had major negative impact due to the creeping threat from soil erosion following the tsunami, and in recent decades heavy floods have wiped away mangroves and planted saplings. Erosion is a threat that detracts from SES resilience as mangrove saplings are prevented from settling and generating, and undermining sediment accretion is lost. Erosion and may be caused by human developments and lagoon deepening interventions in the adjacent lagoon. The extent to which existing mangroves and replanted saplings can withstand and protect the shorelines is uncertain, but solving the erosion only in Nasivanthivu may cause issues elsewhere along the wave trajectory.

In accordance with observations by Duke (2001), the shoreline erosion may be in a process of eroding landward mangrove species too if the protective fringing mangroves is absent. The satellite imagery showed evidence of changes in mangroves cover, and where stands have eroded and where mangroves have resettled (Figure 6). In the field, there were tilted trees of other species (*H. litterolaris* and *E. agallocha*), but we cannot say whether the eroded mangrove patches previously hosted *R. apiculata* and the erosion is amplified by its absence. Neither can we conclude whether there is a net gain or loss of mangrove extent, but the imagery does show a dynamic disturbances and regeneration processes occurring in Nasivanthivu, where some intact areas allow mangrove stands to mature.

In conclusion had many respondents from both locations mentioned that mangroves have regenerating and grown bigger in recent years. As a result from this, some fishers had noticed an increase in the amount of caught fish within the lagoons. These statements were common at the same time as acknowledging that some cutting still persist within the forest, but then seemingly without deteriorating mangrove forest cover or fish stock. This could showcase mangroves high productivity and provision of ES despite small scale disturbances, as discussed on light gap creation that increase productivity and biodiversity.

5.3 Shift in mangrove perception, uses, and dependency

The villagers knowledge on mangrove characteristics and benefits often came from a combination of sources from previous generations and own observation, in addition to the programs from the Government. The awareness shared from the Government agencies seemed to have affected some respondents understanding of mangroves and legitimizing its protection. The manner in which respondents had been given this information, face-to-face, through notice-boards, or between villagers and neightbors, also seemed to contribute in their understanding of mangorve to some degree. In Sathurukondan, in the absence of the details from face-to-face encounters, most respondents had the impression that mangroves benefited the birds only and that being the reasons for protecting mangroves, based on information on the boards surrouding the mangroves. In additino, a large extent of the awareness programes seems to have gone through the existing institutions on local level in Sathurukondan.

In contrast, respondents in Nasivanthivu were more positive to protecting the mangrove for the sake of the village prosperity as a fishing village, despite seemingly less immediate alternatives to reduce mangrove dependency. The installation of the replanting program and

MCEC in Nasivanthivu invited villagers to participate in mangrove replanting activities which could have strengthening the social coherence and village identity. Similar has close relationships among stilt-fishers in southern Sri Lanka encouraged trust building and shared any acquired knowledge to all community members (Deepananda et al. 2016). Therefore, villager attachment to Nasivanthivu could have increased their acceptance to support protection management, but also by the fact that they cannot easily relocate or migrate and therefore must act to sustain their livelihood in Nasivanthivu (Galappaththi & Berkes 2014; Ostrom 1990). This idea of social cohesion, connecting villagers to a common cause may build SES resilience in Nasivanthivu as contributing to facilitated governance by mutual understanding, building trust and widen participation (Biggs et al. 2012; Lebel et al. 2006). This could also be one example where some are willing to give up short-term livelihood needs for the prosperity of long-term livelihood security and SES resilience (Orchard et al. 2016). However, this cohesion and care for the mangrove would need to be nourished in order to be long-lived and viable alternatives should be available to refrain going back to destructive activities.

Awareness programs and replanting schemes at both locations may generally have contributed to a changed perception among many villagers from exploitation into protection, as a result from deepened understanding of positive mangroves benefits and services. Participants in awareness programs showed generally high care for the mangroves and how mangroves provide services for the household livelihood. Further, these programs were successful to share the information using the existing local network between villagers and Government to reach out within these organizations and institutions, especially from FCS and among respondents in Nasivanthivu. Such membership connections and participation in programs could therefore contribute to build mangrove concern and resilience. Further, such institution could provide beneficial networks to create access to assets for individuals and facilitate re-organization under situations of a natural hazard for example.

Further could the replanting and awareness raising contribute to building SES resilience by sharing and spreading knowledge on mangroves among several stakeholders to increase the ecological knowledge in social memory and refrain from destructive practices towards the mangroves. In this light, may non-members from any CBOs risk marginalization if not included in such local institution or programs (Adger 2000), especially if dealing with benefit distributions or permit allowances. As these institutional connections are important to consider, it is equally important to point out that there were nuanced perceptions among the

respondents where some respondents valued and cared for mangroves without getting any such awareness or knowledge from government or organizations' projects, and some kept using mangroves for their livelihood as they had less alternative assets to replace mangroves. Under the purview of strict conservation and protection regime, those respondents would be more exposed of risk to financial penalties or jail if caught. As emerged from interviews, the benefit distributions from NGOs and governments agencies to cope with restricted resource access have not targeted those most vulnerable. Careful consideration of beneficiaries could prevent structural marginalization by targeting people who are excluded from CBOs, or those poorest and elderly, as identified as most vulnerable in mangrove dependent communities in southern Sri Lanka (Satyanarayana et al. 2013).

5.3.1 Mangrove ES and management outcome desirability

Sustainable management would be facilitated through understanding, motivation, and legitimizing of management objectives and desired outcomes among resource stakeholders (Evans 2012; Walker et al. 2002). This is especially important in CBMs where initial desirability of ES and management outcomes are not agreed upon among the resource stakeholders. Strict resource conservation may not be a priority for local stakeholders who traditionally used the same resources and would then be a scale mismatch to put local users responsible for the protection (Hein et al. 2006). Households' desired ES from mangroves may primarily be wood for fencing and firewood, and many women in Sathurukondan even expressed mainly undesired ES from mangroves, and they were not initially fond of conserving mangroves. Fishers primarily declared mangroves as fish habitat the most desired ES together with Governmental Officers which additionally mentioned the protective and regulating ES of mangroves as desirable and to be the focus for the mangrove conservation.

These different desired ES among different stakeholders may be conflicting, but efforts from PALM Foundation was to bring resource users and resource rulers together to discuss and agree on management efforts that maintain provision of the desired ES from the SES, as its desirability is normative depending on the stakeholders asked. Raising awareness, giving training (encourage learning and experimentation), and connecting local organizations to higher governmental agencies (participation, transparent communication, polycentric governance) are some important measures to inform stakeholders at different scales of challenges and perceptions of mangroves that could create social acceptance and some degree of management legitimization.

Further, in Negombo estuary, on Sri Lankas west coast, is brush pile fishery one common traditional fishing practice which requires mangrove wood and brushes for construction. The fishers are using traditional knowledge and practices with optimal utilization of mangrove resources to ensure sustained construction material for brush piles year round, while maintaining mangrove cover and marine habitat, despite reduced mangrove species diversity (Amarasinghe et al. 2002). Therefore could different desired ES be properly maintained by sounds efforts and practices where traditional and local ecological knowledge are useful incorporated in management agreements. Building social capital and mutual trust would prevent scale mismatches and work out conflicting desired ES, and build SES resilience (Biggs et al. 2012; Walker et al. 2002).

5.3.2 Institutional opportunities through Fisheries Co-Operative Societies

Fishers are often percieved as the most vulnerable group, but also a resourceful group to include in baseline surveys, program implementation, and disaster response programs due to their knowledge of local fishing resources and practices (Deepananda et al. 2016; Allison & Ellis 2001). Fishers membership in FCS and their collaborative management connection to DOFAR are unique in that they offer experimentation and TEK exchange between local level to higher political level (Deepananda et al. 2016). Together, DOFAR and the FCS could provide valuable sources that create adaptive capacity through SES memory and knowledge, and identify future sustainable trajectories and opportunities. The FCS were also important nodes in the recovery and reconstruction process in the tsunami aftermath, but it was criticized to excluded non-member fishers, such as part-time fishers, to obtain aid and support (Risvoll 2006). Also in recent times was this the main restriction for membership, in addition to the payment for membership, which is minimum 50 rupees per month, which some still argue is too high, but it increasess dependeing on fishing grounds, tools, and method used by the fisher. Therefore this formal institution is not accessible for many fishers which is a continued flaw in reaching out and targeting the most vulnerable fisher folks. It may risk exclusion of part-time fishers involvement in local environmental management briefings, baseline surveys, and disaster or relief programs.

Contrastingly, Allison and Ellis (2001) found that artisanal fisheries' diverse livelihood and substitution into other professions is an adaptive strategy. Geographical mobility and substitution a crucial strategy to prevent livelihood failure when faced with decreased fish production and is a realistic alternative when acceptable income cannot be achieved from one

income source alone (Allison & Ellis 2001). The findings suggest that part-time fishers in Sathurukondan successfully shifted between fishing and other occupations as a seasonal strategy with the diversification available in their vicinity. Including part-time fishers as FCS member could diversify and provide resourceful knowledge and practices as the level of expertise also among part-time fishers varies considerably (Deepananda et al. 2016). In the face of a disaster can it further promote access to disaster responses (Risvoll 2006) and capacity to self-organization or generally act as an node-institution which connect to wider network within DOFAR, and could fosters learning and experimentation where knowledge is gained and shared, from top-down to bottom-up, as a rule of thumb for adaptive governance (Olsson et al. 2006).

5.3.3 Livelihood strategies and capacity to reduce mangrove dependency

The findings suggest how households' livelihood strategies cope with access changes depended on their capacity to use and access replacements for mangrove resources, or support given to do access replacements. Households' mangrove uses and dependency increased as war and tsunami pushed people into using the assets available in their surroundings, but mangrove use decreased in response to enforced mangrove protection regulations which restricted that livelihood asset. Poor people tend to have limited financial assets and high dependency to a single natural resource (DFID 1999) and studies on livelihood revival after the 2004 tsunami found that reduced natural resource dependency among fishing households and coastal communities built household resilience if accompanied with livelihood diversification between several assets (Orchard et al. 2016; Pomeroy et al. 2006).

The mangrove replacements made among the respondents differed in qualities and durability depending on the households' assets and access to such replacements. In Nasivanthivu, several villagers simply replaced mangrove wood with other species and still use time and efforts to collect that wood for basic needs, which may not be a viable alternative that contribute to the households well-being (DFID 1999). On the opposite, it could take more time to collect the alternative wood whch may be located further away than the mangrove resources. Concrete pillars, gas stoves, and kerosene lamps would be a more viable solution that are longer-lived and reduce dependency on wood resources all toghether, while potentially preventing degradation in adjacent terrestrial forest as a result of the limited access to the adjacent mangrove forest. Sathurukondan households' had to a wider extent transitioned from using wood all together but it was mainly the households themselves that

had to obtain these alternatives which would require financial assets to invest in such long lasting replacement. This would put hardship on those households without enough financial resources or other assets to invest from. A similarly transition had occurred in southern Sri Lanka where rich households bought firewood or gas stoves, whereas poor households would be the collectors of wood for sale or own use (Satyanarayana et al. 2013). Interestingly, the same study found that traditions and preference among some households were reasons for continued mangrove wood use, despite their income level. This indicated that traditional mangrove uses are not transitioned solemnly by economic development but a more profound habituatal change too, which could give some meaning to the variety of perceptions to why some still cut mangroves also in Batticaloa District.

Access and clusters for alternative assets for livelihood diversification

Sathurukondan household respondents had more sources of incomes and higher financial assets compared to Nasivanthivu. The latter also had majority of income from professions which are highly dependent and influenced by the natural environment and its seasonality which makes them vulnerable to unpredictable climatic and weather variation (Ellis 1998). In addition, Sathurukondan had more enrollments in higher education level. Further were increased mobility and flexibility to generate income between seasons a positive strategy for part-time fishers to match the variability of fish stock (Allison & Ellis 2001). In this context, Sathurukondan households have capabilities to livelihood diversification and access to better replacements to cope with mangrove access changes. This *substitution capacity* within a diversified livelihood builds resilience as it indicates successful adaptation and strategies (Ellis 2000 cited in Risvoll 2006).

These differences between available and accessible assets between the locations could be explained by the access to urban areas and varied opportunities clustered there. Sathurukondan lies 5 km away from Batticaloa town, the district capital, with more infrastructure, housing-, job-, and educational opportunities. The higher economic opportuinties in Sri Lankan cities are associated with lower poverty levels than in rural areas (Kesavarajah 2011) and similar observations were made in a study on a social-ecological mangrove system in Zanzibar (Othman 2005) where urban vicinity reduced the mangrove dependency of inhabitants, and urban mangroves grew in the absence of any destruction. Further, Mathiventhan (2007) considered that ambitions of Sathurukondan families to educate their children to get good jobs with stable incomes, could explain the higher number of

villagers enrolled in schools. This ambition remains among the current respondents, which sheds light as to how location gives access to building capacity within human, social, and financial assets which increase livelihood security (DFID 1999) and build mangrove resilience (Othman 2005).

In the case of Nasivanthivu, access to urban areas is not as direct as in Sathurukondan. Access to Valaichchenai by road is not very frequent with public transportation, and the shortest distance would be crossing the Lagoon which would require a boat. However, Nasivanthivu households experience a strong social cohesion among the villagers that is a powerful social asset that contribute to build SES resilience, as discussed earlier (5.3). In terms of livelihood diversification, Orchard et al. (2016) found that mangrove dependent communities in Vietnam could diversify between low cost activities within crab, shrimp, fish, and other shoreline animal harvesting to build resilient livelihoods in pace with mangrove ecosystem change through time. However, PCZRSMP's Monitoring and Evaluation Assistant (personal communication. 25th October 2016) recognized a continued need for skilled training and more alternative livelihood options that increases flexibility into income generating activities throughout the seasons. This was highlighted in order to sustain viable mangrove conservation and support villagers to refrain from using mangrove resources.

Brick-house donation in Nasivanthivu significantly reduced the wood demand for cottages, but recently cracks and leaks had appeared in those same houses, and access to long-term replacements are still necessary due to continued use for wood for fuel and fencing. However, Orchard et al. (2016) found that mangrove dependent communities did not use and respond homogeneously to ecosystem change and hence: "*identifying the characteristics of those households most dependent on mangrove system provisioning goods [mangrove resources] and vulnerable to change is crucial in order to provide targeted livelihood support to those who need it most*" (Orchard et al. 2016. p 878). Including the wider community surrounding the mangroves for equal benefit distribution is further crucial for a successful common property management (Ostrom 1990).

PCZRSMP project objective was to restore coastal ecosystems and ensure sustainable coastal ecosystem restoration and management by reducing human impact on coastal ecosystems (IFAD&GEF 2016). Promote coastal households development by minimizing mangrove dependency and livelihood diversification and security were therefore targeted efforts by the project. One such PCZRSMP project consideration was to reduce the fishing pressure by

reducing fishers from fishing altogether, but so far were only the local Committees and NRM protection regime implemented. There were no clear plans for wider skill development or alternatives.

Ecotourism considerations

Ecotourism had contributed to sustainable conservation and development and generated village revenues in Panama and Vakarei from the PCZRSMP outcomes through mangrove conservation management. Panama mangrove conservation through bird watching had increased income for the communities, and boat-safaris in the mangrove area had been implemented in Vakarei. Similar plans were believed to bring diversified incomes to Sathurukondan and Nasivanthivu too, but the plans were yet at a natal stage in the management process. Most respondents were positive to nature friendly tourism activities in both locations which is crucial for viable socio-economic development through tourism (Ross and Wall 1999). According to Buultjens et al. (2016), post-conflict tourism development in northeastern parts of Sri Lanka have lacked diverse inclusion of stakeholders, fair distribution of benefits, and local consultation. Sathurukondan and Nasivanthivu had respondents respectively who felt left out from current benefits from development programs previously which indicate a risk for such marginalization. Local participation in ecotourism planning and decision-making could create a platform where positive or negative attitudes are met and discussed to prevent injustices and conflicts through clear policies, regulations and leadership (Datta et al. 2012; Ross & Wall 1999). According to Adger (2000) should tourism not replace other livelihood assets but rather be a complementary activity that contributes to livelihood diversification. Small-scale tourism enterprises and informal sector are more efficient to diversify the economy and enhance resilience by promoting equity and access to assets (natural, social, and financial) than large tourism operators (Adger 2000). CBO and governmental agencies links are also an efficient approach to reach out to local level stakeholders but with risk for excluding non-members from the benefits and revenues. These considerations are important for future progress in ecotourism management design and implementation.

5.4 Mangrove management structure, design, and implementation process

The PCZRSMP project implementation process aims to coordinate between national and local government agencies, international and local NGOs, and villagers (IFAD&GEF 2016). Insufficient coordination, monitoring, and law enforcement in the past had contributed to

degrade mangrove forests resources (Risvoll 2006; Mathiventhan 2007), whereas the scout-networks and arrests of mangrove cutters today have seemingly contributed to ecological regeneration. The PCZRSMP ambitious project has potential for enhancing the SES resilience through sound governance and co-management at both study sites. The components of community-government co-management arrangements via the CCC and local Committees promotes resilience through: polycentric governance structure, maintaining diversity and connectivity, fostering understanding of SES as complex adaptive systems, learning and experimentation, institutional diversity through participation across scales but also laterally between sectors (Biggs et al. 2012). The latter may specifically be a result from involvement of PALM Foundation which has contributed to horizontal connections between local villagers and Governmental agencies, and lateral between sectors on Department level in Batticaloa District.

So far has the project created inputs into solid knowledge bases along the east coasts, that are claimed to be connected with previous networks on socio-economic development and natural resource conservation strategies under the purview of NECCDEP and SAM-site programs (NECCDEP 2010a; NECCDEP 2010b; IFAD&GEF 2016). Best practices learned from past experiences have been institutionalized within the National Coastal Zone and Coastal Resource Management Plan (NCZ&CRMP) (IFAD&GEF 2016) that would transfer this participatory approach to island wide implementation henceforth (CC&CRMD 2016). Environmental awareness is also highlighted to be raised among school children, governmental officers, local villagers, and other stakeholders in civil society.

Further, efforts to mobilize, empower, and connect local villagers through the Committees to Divisional and Sectoral institutions contributes to broadening participation, connectivity of sharing knowledge, responsibility and benefits. This also allows villagers' struggles, TEK, and practices to be recognized among decision-makers. In co-management arrangement is institutional diversity further connecting various stakeholders at different scales which previously been separated in the CNRM. Previous lack of implementing participation (Mathiventhan 2007) is carefully addressed in recent management approach to prevent information gaps among local, government, NGO, and international donor agencies in addition of being transparent.

These institutional structures are crucial as they create incentives to sustainable resources uses that link the social and ecological resilience (Adger 2000) and not only focusing on strict

conservation. Sustainable practices derived in CBM elsewhere in Sri Lanka also has potential for resilient co-management systems within reservoir fishing (Amarasinghe & De Silva 1999), brush pile fishery (Amarasinghe et al. 2002), small-scale shrimp farming (Galappaththi & Berkes 2014), and stilt fishers (Deepananda et al. 2016). The co-management arrangements may encourage small scale trial-and-error ecosystem experiments (revolts and recovery) by local people with ecological and social memory but prevent large scale collapse as a component of resilience that is a prerequisite for building adaptive capacity for transformation in the future (Berkes & Seixas 2005; Olsson et al. 2006; Tengö & Hammer 2003).

5.4.1 Local participation and inclusion in management

Mangrove conservation in Sri Lanka has usually put a total ban on mangrove resource base that alienates coastal people to some degree from their traditional uses (Amarasinghe et al. 2002). However, conserving mangroves does not have to exclude rational utilization or sustainable use of mangroves from management efforts as they are productive trees to withstand small disturbances, as discussed previously (5.2.2 *Sathurukondan*). However, in light of past decentralization and promotion of co-management and local participation (CC&CRMD 2016), should not some degree of local sustainable practices of mangrove resources then be evident in recent plans and implementations? Key informants mentioned some negative views of insufficient management implementation and continued discards of environmental issues and true local concerns within the approach and design.

The PCZRSMP project objectives were set up on ecosystem restoration with conservation objectives, and based on key informants from FD and CC&CRMD it would be without allowing sustainable use that would disturb the mangrove ecosystem. Further, many key informants highlighted that any developer or project implementer must go through GS with their proposals which in turn consult Divisional Secretaries and villagers for support before any activity can be implemented (Kruse 2007). Regarding some respondents suggestions to allow some continued use on mangrove wood, it would seem like their support for the project objectives were not considered, nor alternative ways for management, but perhaps the participatory were rather an approach to include local input on issues and challenges on the set management objectives.

However, perhaps it was too soon to recognize any of the participatory outcomes regarding the plans made within respective Committee at the study locations. Or, it could perhaps indicate internal flaws in the management implementation process and approach as past

critique on claims of participatory and CBM of coastal natural resources have been debatable. Hierarchical authorities that lack will to alter the status quo could prevent local participants' ideas to be considered, as found in SAM sites in southern Sri Lanka (Landstrom 2006). Also, the government's dominant role in tourism developments could indicate a hesitation of devolvement of power to local authority in post-conflict areas (Buultjens et al. 2016), further suggest an insufficient absorption of participatory and local inclusion and practices. The sustainable management efficiency is not assessed or identifiable through this study. It is however interesting to reflect and evaluate what is being said compared to what is realized in practice on management efforts and implementation policies and plans.

All local authorities should promote civil society participation and partnerships under mandate by section 4.5 of the government's Extraordinary Gazette number 1632/26 issued on 19 December 2009, but implementing community involvement has not been systematic despite allocating budgets targeted for such partnership (Commonwealth Local Government Forum n.d.). In light of these findings, there is a risk of continued top-down implementation approach regarding setting the objectives and management goals and the PCZRSMP's potential to build SES resilience would still need to be acknowledged and realized in terms of considering true local concerns and desirability. Further, the political trust among some household respondents were doubtful, and this mutual trust and accountability between local actors and government would need to be built in order to facilitate information sharing and support for transparent and legitimate NRM (Lebel et al. 2006). The increased space for environmental governance after the civil war may not result in suitable or desired outcomes without wider legitimacy and support among stakeholders to make substantial change (Walker et al. 2002).

5.4.2 Sustainable mechanisms: long-term motivation and responsibility

The project was in its final phase at the time of the data collection, but the discussed sustainable mechanism had yet to be implemented and legalized in the agreements, which threaten the project's long-term sustainability. In light with Landstrom (2006) finding, had previous SAM process in Hikkaduwa halted due to government officials' unwillingness and lack of organizations to continue the management planning process for long-term. One potential weakness in Sathurukondan, according to Project Monitoring and Evaluation Assistant (Personal communication. 25th October 2016) was the voluntary participation of the chairpersons of government officials in the GS or Divisional Secretariat, in the suggested co-

management arrangement with the Wetland Committee, CCC. If the participation of the chairperson is not declared as mandatory, could it risk same fate for unwillingness to support the co-management in the long-term.

Landstrom (2006) further found that the institutional collaboration in early SAM processes had local establishment difficulties of: "*weak community-based organizations that were unable to take on the responsibility that was considered required for participation in the management process"* (Landstrom 2006. p 19). Public departments had indicated they would absorb continuing funding to the Committees but it would still require advocating and lobbying on behalf of the communities for long-term commitment (IFAD&GEF 2016). This highlights that continued support could be necessary in this case to enable CBOs to take on responsibility of NRM and where mutual participation stimulate mutual motivation across administrative scales and groups. Monitoring is time and energy consuming, and without a self-sufficient mechanism to boost motivation and progress, it may detract the SES resilience and project discontinuation by disconnecting local people and the Committee with wider institutions.

However, CBM of small scale shrimp farms in northwestern Sri Lanka are self-organized in local shrimp associations with their own set of regulations and management (Galappaththi & Berkes 2014). The elected officials in these associations take decisions on behalf of the memberships in the associations, based through collective agreement. Government aquaculture extension officers are working closely with the associations to make sure they comply with national level regulations, but they are mainly monitoring and not involved in the decision-making. The community associations are connected in zonal and national organization (Sri Lanka Aquaculture Development Association) to manage diseases and develop effective shrimp aquaculture system. In this light, the government officer as chairperson is perhaps not a prerequisite for the progress of the Wetland Committee in Sathurukondan, but could support a connection to a wider network for further development in sustainable mangrove and community management.

The project implementation progress had gotten further in Nasivanthivu where LMC and DMC had signed the management plans over the lagoon resources and clearly demarcated geographical area. Perhaps due to facilitating efforts of the PALM Foundation. PALM Foundation's transparent approach required participation at multiple levels for decision-making where one noteworthy component is the awareness need at cross-sectoral level

(laterally), by consulting 23 stakeholders representing governmental departments responsible for lagoon resources. As previous issues have inefficiently and insufficiently been addressed within each department individually could this approach contribute to build SES resilience on many principles such as: broadening participation, combining different types of knowledge for learning and good cross-scale communication, foster an understanding of SES as complex adaptive systems that need cross-sectoral solutions (Biggs et al. 2012; Colding et al. 2003).

Scaling up potential drivers for ambitions project as PCZRSMP, may external forces, such as United Nations' Sustainable Development Goals (SDG), have created a global pressure on environmental issues, which contributed available funding to target project objectives regarding biodiversity conservation and poverty reduction in Sri Lanka. Global pressures as such external drivers could indirect influence the number of local projects and contribute to more beneficiaries. Such forces could build SES resilience by feeding resources into more projects but prolonged funding could detract resilience by making SES dependent on such external funding without having building up an internal capacity to self-organize. In light of the PCZRSMP project, the resilience could deteriorate as the project is near to an end and further funding is uncertain due to the country's increased income per capita in Sri Lanka (Department of External Resources 2014). The Divisional, District, and GS administration cooperates with plans and projects for development, but the Divisional Secretariat monitors all the planning to prevent overlapping projects and areas (Kruse 2007). This could prevent future project implementation at the study sites as they already are targeted replication sites (IFAD&GEF 2016), which risk improvements and other needs from being targeted in the Sathurukondan and Nasivanthivu.

5.5 Project efforts and outcome mismatches

5.5.1 Solid waste dumping mitigation: local adaptation of lessons learned

The dumped solid waste was identified at both locations from field observations, whereas it being mentioned as an issue through interviews only regarding Sathurukondan. Surprisingly no respondents or key informant mentioned the waste accumulated in Nasivanthivu, and it is unclear whether solid wastes are not considered a threat or simply overlooked in the management. One suggestion could be tidal exchange that contributes to flush the sediments and prevent toxins and salinity from accumulating, and from causing wider concern among the respondents.

Through the PCZRSMP project were rubbish bins and training given to villagers in Sathurukondan to prevent further solid waste dumping in the mangroves there. The issue narrated by the respondents however indicates that the rubbish comes in truckloads probably from restaurants and people outside the village. The issue of dumping rubbish in the mangroves is therefore not completely solved by the measures taken to address the issues. This effort was replicated strategy from the waste management in Vakarei which improved the quality of ecosystems along the channels there together with community awareness programs IFAD&GEF 2016). In addition to bad smell and ugliness, the toxicity from such remnants are accumulating may cause groundwater pollution and degrade and create unfavorable conditions for mangroves or any plants to continue to grow. However, a study SES resilience in Zanzibar (Othman 2005) revealed that non-toxic waste may actually benefit mangroves production as nutrient additives which is positive together with mangrove ecosystems filter suspended particles, toxins and nutrients from wastewater through bioremediation (Herteman et al. 2012; Khan et al. 2012). This positive effect was mentioned in Nasivanthivu which is helpful to purify villagers well-water as adjacent factories in pollute the lagoon.

In Sathurukondan, assuming the flood cause more damage than what possibly is compensated for improved soil conditions through flushing, the pollution is accumulated in the mangrove soils. The impact from toxic pollution and chemicals are not known in the area and are negatively influencing the mangrove ecology on uncertain grounds, which is recommended to study further on precautionary grounds. The solid waste disposal is therefore assumed a potential threat that is reducing the resilience in Sathurukondan SES as chemicals in the soils causes concerns of affecting the mangrove reproduction and biology. The similar process may be present in Nasivanthivu but to a smaller extent as the water fluxes could contribute to a higher threshold within the ecosystem domain and hence not as an alarming threat to the SES resilience.

5.5.2 Encroachments: land management plans and property rights

Encroachments are a threat with historical roots that reduces the chances for mangrove regeneration and loss of functional components of the ecosystem (Mathiventhan 2007) in addition to prohibiting mangroves landward migration availability in the face of sea level rise (Alongi 2008). Private people, businesses, and Governmental agencies alike caused past land use changes on mangrove areas is Sathurukondan where land rights disputes and

encroachment impacts are more visible in nature. When Governmental efforts demarcated the mangrove area for conservation was the old leases not considered (Jayasingam 2015) and such processes have delayed protected land legalization in northwestern lagoons in Sri Lanka (Perera & Kotagama 2012), as well as causing delays in the gazetting process of the Wetland Committee in Sathurukondan. Some respondents' ambitions were to enlarge their businesses next to the road and several hoped for more infrastructural development in the future to shine light on unintentional land claims and perhaps unawareness of land user rights. Land entitlements with legal land ownership are still restricted to implement any activities or cut vegetation without permission from GS and CEA, in their own land.

These creeping threats to the mangrove forest were not as visible through interviews in Nasivanthivu but it experience similar drivers to increased encroachments resulting from villagers resettling after civil war and village development demands and needs. Mangrove stretches between the shoes and paddy fields had been burned which could indicate encroachment efforts to remove mangroves for expansion of paddy field. This idea was suggested on basis of NGO informants' statements where this has happened in the past, and instances where toxic chemical have been used with intention to degrade the mangrove trees and claim the land once the trees are gone (personal communication. 7th November 2016) Further, as a result from continued increase in population, urbanization, and large scale tourism in Batticaloa District are coastal vegetation under threat for such land grabs and land use conversions (Buultjens et al. 2016; Sri Lankan Department of Census and Statistics 2012). If land disputes are not settled and land rights properly explained at an early stage could they threat further mangrove conversion at both locations in the future (Adger 2000; Olsson et al. 2006).

Encroachment and land claims influence SES by detracting from resilience as it threatens to degrade the mangrove ecosystem by land conversion and land use changes that cannot be changed back, such as abandoned shrimp farms where natural mangrove regeneration is absent (Mathiventhan 2007). In this response, the PCZRSMP aims to establish ownership right to the mangrove areas to local Committees through gazetting in combination with wider awareness in the education sector and villages. But awareness has yet to inform about importance of property rights among the mangrove area and gazetting the Committees give them power to prosecute any violators of their management plan. Gazetting the mangrove area to the local management plan, as declared by the local Committees, could have the

potential to clearly demarcate the conservation areas and prevent unintentional encroachment and land grabs from private households, companies and Governmental agencies alike. At the same time, it could threaten to marginalize fishers from using brush piling and the related TEK, but further villagers fishing grounds in the mangrove ponds, sources for medical plants, or fruits for sale or consumption. The management plan would declare what the demarcated area would be used for and whether some sustainable use of mangrove resources for local uses would be allowed. As suggested by Amarasinghe et al. (2002), sustainable practices by local users could be maintained through rational utilization of mangrove resources without denudation of mangrove forests.

5.5.3 Matching desired ES in management efforts

The common objectives of replanting mangroves for bird and fish habitat may have varied success depending on the measures taken and where. In Sathurukondan, the lagoon side mangroves experienced more tidal fluctuations with living macro-fauna and erosion which could have inhibited regeneration of *R. apiculata.* Replanting them may not have brought about any noticeable increase in presence at the study location (Mathiventhan 2007). The fishers there highlighted that post-care of replanted mangrove saplings was absent which has contributed to sapling survival in replanting schemes previously in Sri Lanka (Kodikara et al. 2017). Suitable replantation locality must also be considered in replanting schemes and in relation to meeting management objectives (Walters et al. 2008). The replanting objective in Sathurukondan was to increase biodiversity among the mangroves as habitat for birds and fishes. A more suitable effort, but perhaps costly, could be improving hydrology and naturally favorable conditions to boost natural regeneration of *R. apiculata, S. caseolaris,* or *A. marina* to increase the fish production based on the functionality of those species. However, replanting mangrove associates were more successful within the landward mangrove patch in Sathurukondan and could meet the objective of increasing the species biodiversity, however, its contribution to support the fish production would be uncertain.

Regarding the mixed objectives and outcomes in Sathurukondan, Datta et al. (2012) suggests that if it is not possible to achieve both ecologic or socio-economic sustainability together, focusing on one aspect should depend on location, historical function, and user preferences of the mangrove stands. Decision on the user preference and sustainability direction should derive from consulting local villagers and decisions should be recognized to have a feedback effect (slow or fast variable) on the ecosystem (increased biodiversity, increased fish

production or increased coastal protection) and "*enable consequences of earlies decisions to influence the next set of decisions which make adaptation possible*" (Berkes et al. 1998. p 19). The feedback may further influence the ecosystems resilience towards a desired domain of attraction, or undesired domain of attraction which could be an unintentional result (Berkes et al. 2003; Folke et al. 2004). The dominancy of mangrove associates as non-functional species for fish production or coastal protection in Sathurukondan could be an undesired resilient domain of attraction which is possibly sustained through restricted hydrology feedback. However, as with objective of a bird sanctuary, the tree species may not matter and hence the current status of a desirable resilient status. This brings to light how to make effective management efforts that match primary objectives and make fruitful outcomes and not to feed undesired resilient domains which may be costly and hard to change back from.

Mangrove replanting efforts in Nasivanthivu were considered successful as replanted saplings continued to grow bigger and in relation to objectives of conserving and increasing mangrove cover for fish production and shoreline protection. The efforts were further successful in causing concerns among the villagers for post-care in replanted saplings and a regenerating mangrove forest. The sale of mangrove saplings did not contribute much to the livelihoods but it was the contribution to the village was reason enough for collecting and replanting for most respondents. However, the continuing erosion was not evidently abated from the replanting efforts, which had been amplified by mangrove removal on the opposite shoreline and lagoon deepening. Replanting schemes can build SES resilience if it occurs at suitable locations where regeneration needs a boost and with applied post-care to ensure success rate in sapling survival. However, sound hydrology conditions can have a stronger positive influence on the ecosystem and if investments are limited should efforts at both locations focus on setting the hydrology conditions for long-term regrowth. Further, the erosion threats on the lagoon fringing mangroves is detracting resilience by undermining sediment accumulation which prohibits regrowth mangrove settlement and must be addressed across wider Division Secretaries in order to find holistic solution for the erosion or its causes.

5.6 SES's placement in Adaptive Cycle and processes on different scales

The adaptive cycle can generate knowledge on what cause change in resilience in the ecosystem processes and functions and thresholds in all phases of the adaptive cycle (Colding et al. 2003) and such knowledge is important for future transformation and adaptive capacity (Olsson et al. 2006).

The SES in Sathurukondan has previously been in Ω phase from direct disturbances from shrimp farming (Galappaththi & Berkes 2014), cyclone, civil war (Mathiventhan 2007), human uses, and tsunami, erosion, and floods. Human uses have been influenced by indirect forces caused by the same events where α and r phases have initiated as a result of human migration, abandoning shrimp farm practices, and institutional rules restrictions from using mangroves. Sathurukondan mangrove ecosystem today experienced regenerating patches with higher biodiversity with mangroves and associates indicating r phase with high resilience contributing to maintaining it a mixed vegetated area (Holling 1986).

E. agallocha and *A. aureum* are dominant, opportunist species which colonizes disturbed areas and regenerate rapidly which contribute to recolonize gaps as a process of remember process (Gunderson & Holling 2002) from the ecological memory (Berkes et al. 1998) which is building resilience by enhancing the ecosystems connectivity (Biggs et al. 2012). This process could be resilient in an undesired manner as similar species with undesired ES were dominant since a decade ago. Less accessible patches are dominated by mature trees of few species, indicating a late stage of the r phase transitioning into early K phase in the adaptive cycle (Holling 1986). Depending on the desirability in the management objectives and efforts could the ecosystem perhaps become more suitable for true mangroves if the dominant feedback promoting this phase are considered, for example by improving the water exchange to the landward mangrove patch.

The mangrove forest as a whole is heterogeneous but arguing for a holistic illustration of the phase I would suggest the end of the r phase or at early K phase in the adaptive cycle. The reduced local harvesting from human use (small scale Ω) seems to have transitioned the forest into a regenerating growing forest cover (phase r and K phase) where continuous smaller scale Ω phase is not causing a *revolt* affecting the wider ecosystem into a changed domain of attraction. However, there are feedbacks on a larger scale that slowly change hydrology, as a slow variable, that is pushing a large patch of the ecosystem closer towards a threshold where conditions won't be favoring true mangroves species anymore, and creep-erosion risking the extent of lagoon ward mangroves.

Nasivanthivu mangrove forests have previously been disturbed into a Ω phase by war, tsunami, cyclone, flood, erosion, and local cutting with similar as in Sathurukondan. The subsequent α and r phases were triggered by institutional regulations that intervened in the social dimensions to restrict access to mangroves rather than social migration. Today the

mangrove forest is also heterogeneous with a mosaic of successional stages but the evenness and high juvenile and sapling density from all species suggests an α or r phase with high diversity, regeneration, and resilience. Existing species are regenerating and reproduce themselves in disturbed or open areas from dispersed seed among mature forest stands in a process of remember (Gunderson & Holling 2002). The connectivity from the mature stands and the regrowth that has occurred could also indicate a K phase. There were also minor areas of destruction (Ω phase) within the forest and the ecological memory and connectivity to recolonize those areas in a remember process remains to see, but respondents past perception of regrowth and resettling from erosion suggest a positive reproduction. So, Nasivanthivu mangrove forests are experiencing a mosaic of all phases without causing degrading revolt to impact the forest functions of providing ES, as of yet, but continued erosion and resettlement may shift the mangroves spatial distribution within the lagoon.

The mangrove ecosystem as a whole could be r phase but with smaller scale cycles pushing the system towards both spectrums of growth and degradation. The mangroves are regenerating and growing with all true mangrove species but within a spatial dynamic where trees are removed and resettled inside the lagoon. This study could not determine whether there is a net loss or gain in the mangrove cover but it has identified some processes that influence the SES and under what conditions they may detract or build resilience.

5.6.1 The social dimension in the adaptive cycle

The social features of the SES and its' management may also be placed in adaptive cycle based on characteristics from Carpenter (2016, April 13) on triggers and types of processes happening in respective phase. Sathurukondan SES management development from the PCZRSMP project have been implemented and initiated, but has yet to sign the management plan and gazetting the area, suggesting an early r phase. The end of the project and its supervision may cause the management regime to institutionalize and mature into a K phase, but considering the threats discussed earlier, there is risk of a collapse Ω without the efficiency of the sustainable mechanisms (see section 5.4.2). The progress in Nasivanthivu is similar but farther with rapid progress and learning from villagers, members, and government officials with a position in the late r phase. The background of local committees' connection to local NGO, exposure trips, and the CCC meetings (however yet infrequent) increase the connectivity to wider governance structure which also could suggest an early K phase but the

lifespan of the project in Nasivanthivu is very short, and would be matured in time after the projects supervision to get efficient and gain incremental progress.

The opportunities from generating income from ecotourism was still only at natal scale in Nasivanthivu, as a natal idea in α phase which could be adapted from efficiently looking at progress from the project in Vakarei and learning from there. Contrastingly in Sathurukondan, had efforts to implement a bird park in Sathurukondan failed due to objection from land owners where the initial idea went straight through Ω phase of that plan. The ecotourism idea pursuits in but the concept must be shaped in the reorganization connected with support from departments and local villagers to solve land conflicts in order to sustain fair and beneficial development based on ecotourism.

Looking at the panarchy and wider institutional network for managing the SES are the local Committees defined the lowest adaptive cycle for the social dimension, unless the household or individual decisions are in a higher village authority position. The Committees can contribute with knowledge on the local SES, revolt, and could get support and advice, remember, from larger scale administration which is connected to several nodes of local committees in the wider District and Province (Gunderson & Holling 2002). The Provincial management of environmental coastal ecosystems is built up from past experiences, programs, and governance set up (NECCDEP and SAM) that shaped the contemporary coastal natural resources governance since early 2004 (Asian Development Bank 2012). The PCZRSMP project with this participatory and co-management for the SES are contributing to the connectivity of the SESs' social K phase.

The civil war cut off CNRM governance (Ω phase) in large areas of Eastern and Northern Province in Sri Lanka which was worsened (trapped in Ω and α phase) due to the tsunami. However, the tsunami and subsequent external funding had been factors that, to some degree, initiated a participatory CNRM through α and r phase to reconnect and even shape the national CZMP in its contemporary form (IFAD&GEF 2016). The larger scale social dimension is placed in K phase together with the common goal of sustainable development to restoring coastal ecosystems and livelihood diversification through the PCZRSMP project. The ambitions to shape and contribute with their lesson learnt to the larger administration with input to the CZMP and governance efforts on national scale where such revolts from small scale build resilience by sharing the local knowledge with communities elsewhere through connecting the governance structures.

5.7 Future management recommendation that could enhance SES resilience

For achieving long-term sustainability, a resilience-centered approach to CNRM is suitable for maintaining desirable outcomes, which are legitimized from stakeholder participation early in the management design (Walker et al. 2002). Governing resilience and active adaptive governance is required to sustain desired ecosystem states (Folke et al. 2004). The step forward is to achieve adaptive governance by transitioning through opportunities and uncertainties based on the resilience-centered approach (Olsson et al. 2006). Derived from the above discussion are the following suggestions regarding future management consideration:

- Desirability of ES with suitable measures to maintain them would increase efficiency and not waste assets invested in the management budgets. Again, wider participation is crucial when declaring desired ES, formatting the objectives, and management outcomes. Sector-wide participation and awareness must reach out to stakeholders between departments, in addition to cross-scale, to seek out solutions that are not causing degradation or conflicts in other dimensions. It is difficult to abide all interests but wider participation can also identify suitable compensations that may be necessary (Datta et al. 2012; Hein et al. 2006). Compensating should be realistic viable options based on economic returns of the reduced resource access (Othman 2005) and equally distributed (Datta et al. 2012). Through local level participation could vulnerable groups be identified and support given to ensure livelihood improvement to those who are in most need, it could also build trust and justify decisions on CNRM. It is crucial that local issues and conflicts are resolved if they are to be motivated to take on responsibility for long-term sustainable CNRM through CBM (Biggs et al. 2012).
- Local legitimization and trust that is grounded for CBM of natural resources combined with gazetting and penalizing can be efficient in reducing ecological degradation from waste dumping, encroachment, and unplanned development. However, it may be better to address encroachment by allocating space for housing for increased population and the underlying causes behind encroachments (Perera & Kotagama 2012). Unsolved land conflicts and unclear property rights regulations may cause continued encroachments despite justification for CNRM and awareness of the importance of the mangrove ecosystem.
- Mandatory and frequent meetings within the Committee plans would promote sustainable management progress after the project cessation and boost motivation. The

institutional cooperation and support could be necessary as the end of the PCZRSMP is near and such support and advice into the local level management nodes can promote reorganization in case of a disturbance (Biggs et al. 2012) motivation and mutually update actors on concurrent issues. In addition, practicing good governance through mandatory management plan may, in time, hopefully elevate management standards in future. Further, connecting these institutions to MFF or Seacology initiatives would be a suitable option for this transitional period and allocating training and funding for diversifying livelihood options, especially in Nasivanthivu.

- Increased understanding of feedbacks and slow variables (for example: tidal exchange; sediment accretion and erosion, due to geomorphology; soil chemistry composition; encroachment) are important to identify thresholds for long-term sustainable management over the SES and reduce risk of catastrophic regime shifts (Olsson et al. 2006; Scheffer et al. 2001). Acknowledging them could eventually allow small scale experiments and cut of dominant feedback to undesirable resilient states or prevent large scale shifts due to build up stresses that changes the conditions and provision of ES (Carpenter et al. 2001; Holling 1973; Scheffer et al. 2001). Maintaining slow variables, such as regulatory ES, may be used as a proxy to manage for uncertainty and future change and what thresholds a SES experience (Biggs et al. 2012). Hydrology for example is influenced by catchment area landward and coastal area seaward (often occurring cross sectors and scales of administration) and would be best managed in collaboration between Divisions, Districts, and Provinces to solve hydrology issues. The conditions at both Sathurukondan and Nasivanthivu must not only fall into the hands on the local Committees, but the tidal fluctuation would be best address through further cross-sectoral and cross-divisional cooperation to create a sustainable and resilient SES. The lagoon-wide-approach within the PCZRSMP framework in Nasivanthivu and Valaichchenai lagoon are seemingly in a large enough scale of two bordering Divisional Secretariat units, to address complex issues within the lagoons.

6.0 CONCLUSION

The findings from this study show how the natural and social settings and processes differ in their contribution to SES between the two villages of Sathurukondan and Nasivanthivu. The underlying environmental conditions are important for a healthy mangrove ecosystem and necessary for maintaining provisions of ES. Adequate tidal fluctuation promotes suitable conditions for high diversity of true mangrove species and their natural regeneration that could contribute to building SES in terms of providing habitat for marine life, protection from natural hazards, and sustain traditional fishing practices like brush piling, with rational mangrove utilization.

Some further identified processes that builds SES resilience: presence of functional species that provide desirable ES; disturbance tolerant species that maintain area vegetated; sound tidal exchange that outcompete associate species and prevent toxins from accumulating; mangrove awareness and replanting programs; access to urban cluster and opportunities to increase substitution capacity for flexible livelihood diversification; social cohesion for natural resources responsibility; inclusion in wider institutional network for contribution to development and participation in experimentation. On the other hand are the processes detracting SES resilience: insufficient or exacerbated tidal exchange; prolonged inundation from monsoon floods; accumulating wastes and potential toxins; land rights disputes and encroachment; weak motivation and responsibility towards local Committee and wider management for long-term; social exclusion from local institutions and benefit distributions; continued need for development and sound alternatives for replacing mangrove resources.

The larger environmental governance network in Batticaloa District, which emerged since the tsunami and war cessation, has a large potential to build SES resilience through sharing lesson learnt among local nodes, such as the study locations. Its structure invites wider and diversified participation across scales and sectors, for a diversified understanding, knowledge, and information sharing in top-down and bottom-up approaches. However as the PCZRSMP project had big ambitions and objectives with potential to build SES resilience, its realization was not recognized nor properly assessed in this study. Based on critique on past initiatives and efforts in CBNRM in Sri Lankas CZ, have devolution of power, participatory approach, and issues with long-term commitments been flawed. Future studies on the internal relations and power distribution within the management structure could perhaps give more insight to

what causes such flaws and whether those same issues is present in Batticaloa Districts' environmental management administration.

Stronger connection to wider institutional governance networks would build SES resilience if desirable ES is agreed or compensated for with participating stakeholders. Connections with Seacology, MFF, and Mangrove Action Project together with local association and governmental agencies may further shape future management and decision-making trajectories that prevent marginalization, target the most vulnerable individuals, and promote traditional and sustainable practices in mangrove ecosystem management.

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APPENDIX 1 Data sheet for ecosystem inventory

PLANTS in transects

Site: Transect no: Date and time:

Plot no	Species name	Habitat (tree/shrub/fern/herb/grass/ liana)	Height (m)	DBH (cm)	Counts (stems/ numbers)	Status	Special features (DBH-height)

APPENDIX 2 Ecological Indices and calculation for descriptive statistics in the ecosystem inventory

Average diameter $= \sum DBH/N$

[$\sum$ DBH – summation of diameters at breast height, N – total number of trees]

Average height $= \sum Ht/N$

[$\sum$ Ht – summation of heights, N – total number of trees]

Density $= Total\ number\ of individual\ /\ Area$

Frequency $= Total\ number\ of\ hits\ of\ individual/\ total\ number\ of\ sample * 100$ %

Basal area (cm^2) $= (DBH)^2 / 4\pi$

[DBH – diameter at breast height, π – 3.14]

Importance Value Percentage $= (Relative\ density) + (Relative frequency) + (Relative\ dominancy)\ /\ 300$ %

Relative dominance

$= (Total\ number\ of\ a\ species/\ Total\ number\ of\ all\ species) * 100$ %

Relative frequency

$= (Total\ frequency\ of\ a\ species\ /\ Total\ frequency\ of\ all\ species) * 100$ %

Relative density

$= (Total\ basal\ area\ of\ a\ species\ /\ Total\ basal\ area\ of\ all\ species) * 100$ %

Species richness (Margalef diversity index) $= (S - 1) - (ln\ N)$

[S – total number of species, N – total number of all individuals]

Species diversity (Shannon-Wiener index) $= -\ \sum P_i\ ln\ (P_i)$

[P_i – proportion of number of a species i and total number of individuals of all species]

Species evenness (Pielou index) $= H\ /\ ln\ (S)$

[H – Shannon – Wiener index, S – total number of species]

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APPENDIX 3 Semi-structured household interview guide

Interview number: Date and Place:
Interpreter:

Demographic data

1. Approximate age?

2. How many people live in household?

3. Highest level of education that you to have completed?

   No Education ( ), O-level ( ), A-level ( ), University ( ), Grade: (old school system)

4. For how long have you lived in this area?

Livelihood data

5. What is your main source of income? (if there are more than one, ask them to prioritize them in order of importance)

6. Do your source/-s of income change with time? (Seasonal, monthly, daily) Or other reasons?

7. Average income per month? (LKR)

Resource dependency data

8. Do you use mangrove resources for any purposes? (Use table on the next page)

9. How did you learn this knowledge about the mangrove uses and species?

10. Does the mangrove ecosystem provide any non-material benefits or services that you find important? (Cultural or esthetical value)

11. Have you observed any changes in the mangrove forest in relation to: (Use table on the next page)
    - Existing types of animals?
    - Total area covered with mangroves?
    - Species types?
    - Access, restriction or availability of resources and reason behind them?
    - Patterns of human use and user groups associated with mangrove ecosystem.

12. Did you have to replace mangrove resources when mangrove access or availability was less? What was the reason behind?

13. What are you using instead of mangroves?

Mangrove management perception

14. Who are responsible for managing the mangroves in this area?

15. Has anyone given you information about mangroves? Who were the ones giving information and what did they say?

16. Are You or have You ever been a member of any local group or association?

17. Have there been any conflicts related to the mangroves in this area?

18. Do your household benefit from this management?

19. Do you experience any challenges or difficulties in your everyday life because of the management regime?

21. What are your suggestions for improving the mangrove management to make it beneficial for you?

22. Additional comments or questions?

Use for question nr 8.Mangrove species specific usages

Name of species	For what purpose?	Who harvests it?	When is it harvested? How often?	Where in the forest is it harvested?	How do you know when/where to harvest it? (TEK)	Change in harvesting or resource quality/abundance over time?

*Use for question nr **11**. Mangrove forest changes*

Have You observed any changes in the mangrove forests in relation to:	Existing types of animals (life) and mangrove trees?	*Yes / No* *Less / More*
	Total area covered with mangroves? Species types?	*Yes / No* *Less / More*
	Access, restriction, or availability of resources and reason behind them?	*Yes / No* *Less / More*
	Patterns of human use and user groups associated with mangroves ecosystem?	*Yes / No* *Less / More*

APPENDIX 4 Interviewed and Consulted Key Informants

Assistant Divisional Officer. Forest Department. Personal communication. 19th October 2016

District Field Coordinator. Coastal Conservation and Coastal Resource Management Department. Personal communication, 25th Octobers 2016

Monitoring and Evaluation Assistant. PCZRSMP. Personal Communication. 25th October 2016

Professor of Botany. Eastern University of Sri Lanka. Personal communication. 3rd November 2016

Zonal Environmental Commissioner. Science Education Department. Personal Communication 8th November 2016

Mangrove Ecology Expert. Prev. Biodiversity Secretariat. Ministry of Environment and Natural Resources. Personal Communication. 21st November 2016

Grama Nildahari Nasivanthivu. Personal communication. 1st November 2016.

Range Forest Officer Valaichchenai. Personal communication. 1st November 2016

Consulted, informal talks rather than interview (very busy schedule – not all questions were possible to ask)

Government Agent / District Secretary. Batticaloa District. Personal communication 7th November 2016

Assistant Director. Department of Fisheries and Aquatic Resources. Personal Communication. 19th October 2016

Fisheries inspector Manmunai North. Personal communication. 21th October 2016.

Fisheries inspector Manmunai Pattu. Personal communication. 21th October 2016

Fisheris Inspector Valaichchennai (indirect Nasivanthivu). Personal communication. 31st October 2016

Extenstion Range Forest Officer. Personal communication. 31st October 2016

Grama Nildahari, local leader Sathurukkundan. Personal communication. 7th November 2016

Divisional Environmental Officer and Geography Special. Central Environmental Authority, Batticaloa District. Personal communication. 9th November 2016

NGOs

Executives Director and other project coordinators and members of PALM Foundation. Personal communication. 7th November 2016

District Program Communicator. Personal Communication. 27th October 2016

Project Manager. Sevalanka foundation. Personal Communication. 27th October 2016

Project Coordinator. Sevalanka foundation. Personal Communication. 27th October 2016

SOND –Local NGO (Telephone communication 26th October 2016)

Fishers Group Discussion

Sathurukkundan and Kokuvil Fisheries Co-operative Society members. Personal communication. 21st October 2016.

Nasivanthivu Fisheries Co-operative Society members and Disaster Management Committee. Personal communication. 1st November 2016.

APPENDIX 5 Key informant interview guide

Interview number: Place and Date: Interpreter (if present):

1 Name, Title, and job-description?

Mangrove Perception

2 What characteristics, benefits and services make this environment important for the:
- communities well-being?
- ecology of this area?

3 To Your best efforts, please state the cyclical or seasonal processes important for the mangrove ecosystem?

4 Do you believe this mangrove forest is capable of recovering / regenerating from future disturbances? Why or why not?

5 What are the existing and future threats to the mangrove ecosystem?

6 What are the existing and future opportunities to the mangrove ecosystem?

Mangrove management

7 To the best of your knowledge, could you describe <u>who are responsible</u> <u>and who are involved in managing</u> the mangroves in this area?

8 How has the mangrove management changed historically in this area? Reason for changes? -Do you see these changes as positive or negative? Why?

9 From where is the knowledge-base on mangroves derived? (Local community, Academics, External knowledge sources)

10 How would you evaluate the current management regime?

Power distribution

11 What influence policy making regarding mangrove management?

12 Are decisions briefed with communities before acted implemented?

13 What conflicts have arisen over mangrove decisions? How are conflicts resolved?

Multilayered governance network

14 What governmental bodies are there represented or connected within the current management regime?

15 Are results from academic research adapted in the institutions responsible for managing the mangrove forests?

16 In your experience, do any outside influences (international NGO, international conservation attitudes) affect mangrove forest/natural resource management in Batticaloa?

APPENDIX 6 Focus group discussion interview guide

Group discussion number: Place and Date: Interpreter:

1. How many households live in this community?

2. What are the different occupations of households in this community?

Mangrove Knowledge and Dependency

3. What are the general uses of mangrove resources in this community? What species and for what purpose?

4. How is the community benefitting from the mangrove ecosystem? Cultural and Esthetical values?

5. Where did You learn the knowledge You have on mangrove forest resources and benefits?

6. Have you observed any changes in the mangrove forest in relation to: (Table on next page)Existing types of animals? Total area covered with mangroves? Access, restriction or availability of resources and reason behind them? Patterns of human use and user groups associated with mangrove ecosystem?

7. What specific events have affected the community and the mangroves in this area? And how did the community respond to this impact?

8. What are the existing and potential future threats to the mangrove forest / community?

9 What are the existing and potential future opportunities to the mangrove forest / community?

Resource Management

10 What are the existing terms and rules for using mangrove resources? Are they well known and clearly communicated?

11 Is the local community involved in the management?

12 Do the households in this community benefit from the current mangrove management?

13 Would you have any suggestions for changing the mangrove management in any way? How?

14 How has the management objectives changed through history? Reason for the changes?

Use for question nr 6. Mangrove forest changes

Have You observed any changes in the mangrove forests in relation to:	Existing types of animals (life) and mangrove trees?	*Yes / No* *Less / More*
	Total area covered with mangroves?	*Yes / No* *Less / More*
	Type and quality of the services and products from the mangrove forests?	*Yes / No* *Less / More*
	Access, restriction, or availability of resources and reason behind them?	*Yes / No* *Less / More*
	Patterns of human use and user groups associated with mangroves ecosystem?	*Yes / No* *Less / More*

APPENDIX 7 Full species list of encountered species and calculations of dominance (IVP)

Table 1 presents the encountered true mangrove species and their Importance Value Percentage relative to the mangrove specie. The values in parentheses includes additional three mangrove associate species, at the bottom of the list, for comparison with previous study in Sathurukkundan. The abbreviations symbolizes the habitat for each species. T - Tree, S – Shrub, F – Fern.

Species	Family	Sathurukkundan	Nasivanthivu
Avicennia marina, S, T	Avicenniaceae	5.8% (3.0)	17.3 % (9.8)
Bruguiera gymnorhiza, T	Rhizophoraceae		2.6 % (2.3)
Ceriops tagal, T	Rhizophoraceae		1.5 % (1.3)
Excoecaria agallocha, T, S	Euphorbiaceae	81.6 % (44.6)	25.0 % (17.7)
Heretiera litterolaris, T	Sterculiaceae		1.0 % (0.8)
Lumnitzera racemosa, S, T	Combretaceae	7.0 % (4.3)	32.6 % (19.7)
Rhizophora apiculata, T	Rhizophoraceae	2.9 % (1.8)	18.8 % (11.0)
Sonneratia caseolaris, T	Sonneratiaceae	3.0 % (1.7)	1.2 % (1.1)
(Cerbera manghas, T)	Apocyanaceae	(0.8)	
(Acrostichum aureum, F)	Polipodiaceae	(39.9)	
(Clerodentron inerrme, S)	Capparidaceae	(3.9)	(36.3 %)
Number of species		5 (8)	8 (9)

Table 7 Encountered mangrove associates and coastal plants encountered during field inventory. Abbreviations symbolize the growth forms for each species. T - Tree, S – Shrub, F – Fern, G – Grass, H – Herb, C - Climber. Red text indicates unspecified species identification. Species are recorded by number of individuals except from species with * that are recorded in *hits* (frequency).

Species	Family	Sathurukkundan – Kokuvil	Nasivanthivu
Acanthus ilicifolius, S *	Acanthaceae	8	15
Acrostichum aureum, F	Pteridaceae	509	
Borassus flabellifer, T	Arecaceae	19	12
Calamus rotang,, F *	Arecaceae	11	
Calotropips gigantean, S	Apocynaceae	19	2
Cassia roxburghii, T	Fabaceae		10

Cerbera manghas, T	Apocynaceae	47	
Clerodentron inerrme, S	Lamiaceae	43	151
Cocos nucifera, T	Arecaceae	5	6
*Derris scandens, L **	Fabaceae	89	23
*Derris trifoliate, L **	Fabaceae	4	
Dolichandrone spathacea, T	Bignoniaceae	2	
Flueggea leucopyru, S, T	Phyllanthaceae	42	58
Hibiscus tiliaceus, T	Malvaceae	32	416
Ipomoea macrantha,G	Convolvulaceae	25	
Limonia acidissima, T	Rutaceae	1	
Morhinda tinctorina, T	Rubiaceae	13	10
Musa, T	Musaceae	4	
Nauclea orientalis, T	Rubiaceae	33	
Pandanus, T, S	Pandanaceae	10	
*Panicum maximum, G **	Poaceae		6
Phoenix pusilla, T	Arecaceae	27	102
*Sesuvium portulacastrum, G **	Aizoaceae	2	6
Tephrosia purpurae, S	Fabaceae		10
Terminalia arjunga, T	Combretaceae	12	
Tespesia popullnea, T	Malvaceae	2	20
*Typha angustifolia, G **	Typhaceae	27	4
Unidentified creeper (code 45)		10	
Unidentified fern *(Diplazium esculeuntum; striatatum*; *Osmundastrum cinnamomeum) F **	Athyriaceae / Osmundaceae	14	
Unidentified tree (*Salvadora persica; Callophyllum inophyllum) T*	Salvadoraceae / Calophyllaceae		204
Unidentified tree (code 60)			10
Unidentified tree (code 63)			31
Total no of species		**26**	**19**

Norges miljø- og biovitenskapelig universitet
Noregs miljø- og biovitskapelege universitet
Norwegian University of Life Sciences

Postboks 5003
NO-1432 Ås
Norway