The species composition of the mangrove forest along the Abatan River in Lincod, Maribojoc, Bohol, Philippines and the mangrove forest structure and its regeneration status between managed and unmanaged Nipa palm (*Nypa fruticans* Wurmb)

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Thesis submitted in fulfillment of the Degree of BSc Tropical Forestry and Nature Management at Van Hall Larenstein University of Applied Sciences, The Netherlands

Clients: PROCESS-Bohol, Inc. and ALIMANGO

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Dense Nipa vegetation with *Sonneratia alba* and *Avicennia marina* trees in the background
Sonneratia alba along the Abatan River
Seedling of *Avicennia officinalis* in between a Nipa palm

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Abstract

The species composition, diversity, population structure and natural regeneration status of mangroves in managed and unmanaged Nipa (*Nypa fruticans* Wurmb) were studied along the Abatan River in Lincod, Maribojoc, Philippines with the purpose of evaluating the effects of Nipa management on the mangrove forest health. This study was carried out as part of a project by PROCESS-Bohol, Inc. entitled, ''Re-assessment of Community-Managed Mangrove Forest Ecosystems in Maribojoc Bay". A total of 56 plots with an area of 100 m^2 were sampled and evaluated for trees and 112 subplots of 25 m^2 for Nipa palm and juveniles. A total of 295 individual mangrove trees, 167 saplings and 1,588 seedlings belonging to 21 tree species were recorded in the 105 ha mixed mangrove forest. A total of 29 true mangrove species and 18 mangrove associates were recorded in the villages of Lincod and Cabawan, of which the globally endangered *Camptostemon philippinense*. The overall mangrove forest in Lincod had a total density of 527 stems ha^{-1}; total basal area of 17.16 m^2 ha^{-1}**;** average DBH of 13.4 cm; average height of 11 m; and species diversity (H') of 1.93. Next to the dense and gregarious Nipa palm (15,000 palms ha^{-1}), the species composition was dominated by *Sonneratia alba* with a density of 180 stems ha^{-1} and an importance value (IV) of 103.23. Unmanaged Nipa was significally more dense (61,800 fronds ha^{-1}) compared to managed Nipa (45,500 fronds ha^{-1}). Although all mangrove trees formed together a reverse-J-shaped diameter distribution in both managed and unmanaged Nipa area, mangroves in managed Nipa were considered healthier with good condition and more adequate mangrove regeneration, while unmanaged Nipa had a higher structural development. Besides, the value of mangrove tree species diversity in managed Nipa was more diverse with Shannon-Wiener (H' = 2.203) as compared to unmanaged Nipa which had a lower value (H' = 1.693).

Keywords: Mangroves, Management, Nipa.

Contents

Abstract ... 3
Contents ... 4
Acknowledgements ... 6
1 **Introduction** ... 7
1.1 Introduction to mangroves ... 7
1.2 Nipa palm ... 8
1.3 Problem statement ... 8
1.4 Background ... 9
1.5 Aim and objectives ... 9
2 **Materials and methods** ... 10
2.1 Study site ... 10
2.1.1 Sampling site: Lincod, Maribojoc ... 12
2.2 Data collection ... 13
2.2.1 Nipa palm ... 13
2.2.2 Trees ... 14
2.2.3 Regeneration ... 15
2.2.4 Understory ... 16
2.2.5 Salinity and high tide levels ... 16
2.3 Data analyses ... 16
2.4 Field equipment ... 18
3 **Results and discussion** ... 19
3.1 Salinity and high tide levels ... 19
3.2 Nipa palm management ... 19
3.3 Species composition ... 21
3.3.1 Assessment of total number of mangroves and mangrove associates ... 21
3.3.2 Vegetation analysis ... 25
3.4.4 Species diversity ... 27
3.4 Forest structure between managed and unmanaged Nipa ... 28
3.4.1 Structural characteristics of mangrove tree species ... 28
3.4.2 Tree biomass and carbon storage ... 28
3.4.3 Condition ... 30

3.4.4 Diameter distributions 31
3.4.5 Regeneration 32
3.4.6 Understory development 36
4 Conclusions 37
5 Recommendations 38
Literature 39
Appendix 1 Plot data 43
Appendix 2 Nipa plots 45
Appendix 3 Mangrove tree species diversity in Lincod 49
Appendix 4 Mangrove tree species diversity between managed and unmanaged Nipa 50
Appendix 5 Mangrove sapling diversity between managed and unmanaged Nipa 51
Appendix 6 Mangrove seedling diversity between managed and unmanaged Nipa 52
Appendix 7 Structural characteristics of mangroves between managed and unmanaged Nipa 53
Appendix 8 Mangrove tree condition 55
Appendix 9 Regeneration status 56
Appendix 10 Mangrove species reported in this study 59

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1 Introduction

1.1 Introduction to mangroves

Mangroves are evergreen trees or large shrubs, including ferns and a palm, which normally grow in or adjacent to the intertidal zones in the tropics and subtropics and which have developed special adaptations in order to survive in this hypersaline environment such as aerial roots, salt excretion, and viviparous reproduction (Tomlinson, 1986; Spalding et al., 2010). Mangroves have little capacity for vegetative propagation and are thus dependent on seedlings for forest maintenance and distribution (Tomlinson, 1986). Mangrove forests provide a wide variety of ecosystem goods and services. Services include nutrient cycling, sediment trapping, carbon storage, erosion control, coastal protection from cyclones and tsunamis and habitat for numerous (economically important) organisms; whereas goods include edible products (e.g. fish and crustaceans), timber, fuel wood, charcoal, roofing materials, fodder, honey, pulp, tannin, and medicines. Despite the many services and benefits provided by mangroves, they have often been undervalued and mistakenly viewed as wastelands and unhealthy environments (FAO, 2007). In fact, mangroves are highly productive ecosystems and the relatively small number of mangrove species worldwide collectively provides a wealth of goods and services while comprising only 0.12% of the world's total land area (Ashraf and Habjoka, 2013).

According to the FAO (2007), the total area covered by mangroves throughout the world has declined from 18.8 million ha in 1980 to 15.2 million ha in 2005, with less than 7% being protected (Giri et al., 2010). The area covered by Philippine mangroves declined from an estimated 500,000 ha in 1918 (Brown and Fisher, 1918; as cited by Primavera, 2000) to 117,700 ha in 1995 (DENR, 1995), which possibly led to the local extinction of some rare species. The most rapid decrease in mangrove coverage occurred during the Shrimp Fever of the 1980s which encouraged mangrove conversion to aquaculture ponds, both legal and illegal (Yao, 2000). Overexploitation by coastal dwellers, conversion to agriculture, salt ponds, urban development and industry, harbor and channel construction and mining have also contributed to the degradation of mangrove forests (Primavera, 2000). Even replacement by monoculture Nipa palm (*Nypa fruticans*) plantations reduced the area of natural mangroves (Primavera et al., 2004). However, the mangrove area increased to 310,531 ha in 2010 (DENR, 2012) due to increased awareness and community-based rehabilitation, of which 10,622 ha are found in Bohol. The mangrove forest along the Abatan River has been estimated as the 3rd largest riverine mangrove forest (about 400 ha) in Bohol, after the Inabanga River and the rivers of the Candijay mangrove forest, by the analysis of aerial photographs.

There are 70 known true mangrove species in the world belonging to 17 families (Polidoro et al., 2010), of which 44 (63%) can be found in the Philippines including: 1 endangered (*Camptostemon philippinense*), 1 vulnerable (*Avicennia rumphiana*) and 3 near threatened (*Aegiceras floridum*, *Ceriops decandra* and *Sonneratia ovata*) (Spalding et al., 2010). Bohol has 32 identified true species of mangroves, making the province one of the most biologically diverse mangrove ecosystems in the country (Green et al., 2002). However, this number will nowadays be higher as in 2002 because some species that time were not considered as mangroves but as mangrove associates. True mangrove species are those species that grow in the mangrove habitat only, while those not restricted to this habitat are mangrove associates (Lugo and Snedekar, 1974; FAO, 2007).

1.2 Nipa palm

Nipa (*Nypa fruticans* Wurmb) is one of the most common, widely distributed, and useful palms in the mangrove forests of South and Southeast Asia along riverbanks and in the understory. It is the only palm considered a mangrove and is known to provide a major source of livelihood alternatives to many coastal communities (Primavera et al., 2004). Nipa differs from other palms because it has no vertical stem, but has horizontal creeping stems known as rhizomes, growing underground. It has fronds (leaves), which can extend up to 9 m long, and flower stalks that grow upwards from the surface (Giesen et al., 2007). Nipa is very fast growing and considered a 'foundation species' as it forms dense and often monospecific stands that control population and ecosystem dynamics, including fluxes of energy and nutrients, hydrology, food webs, and biodiversity (Ellison et al., 2005).

Along the Abatan River in Bohol, Nipa is utilized for various purposes: mature fronds are made into shingles for roof thatching and used for decorations like native baskets, hats and fans; young leaves are used for cigarette wrapping; young seeds are eaten raw or made into sweet meat; and Nipa sap is a source of vinegar, sugar and a local wine called 'tuba' (Green et al., 2002).

1.3 Problem statement

Although Nipa is an economically important mangrove species, the extensive and dense stand possibly threatens the mangrove vegetation by outcompeting and replacing other mangrove species (Figure 1.1). This aggressive succession could lower the overall biodiversity of the mangrove habitat. These however, are just hypotheses, as little scientific information is available concerning the effects of Nipa palm on other mangrove species and no extensive research on the Abatan mangrove forest has been done.

Figure 1.1. The Nipa palm (*Nypa fruticans*) often forms a dense monospecific stand.

1.4 Background

However, there was a biodiversity resource assessment of the Abatan Watershed by the Silliman University Marine Laboratory conducted from April 28 to May 2, 1997 in which the total amount of mangrove species found in Lincod, Maribojoc was listed (Lepiten et al., 1997). Despite the existence of this document, it is considered out of date and unreliable for there were mangroves considered as mangrove associates.

This study was therefore carried out for the Participatory Research, Organization of Communities and Education towards Struggle for Self-reliance (PROCESS)-Bohol, Inc. as part of their project entitled, ''Re-assessment of Community-Managed Mangrove Forest Ecosystems in Maribojoc Bay''. This study was conducted in the village of Lincod, part of the Maribojoc Bay and managed by the Abatan Lincod Mangrove Growers Organization (ALIMANGO).

1.5 Aim and objectives

This study aimed to identify and analyze the composition and diversity of mangrove tree species in the study site, and to determine the forest structure and current natural regeneration status of the mangrove tree species between managed and unmanaged Nipa. Knowledge of the exact species composition is a basic and important prerequisite, which can improve the understanding of the structure and present condition of the mangroves. This knowledge is essential for conservation and sustainable management of the mangroves along the Abatan River.

Therefore, the specific objectives of this study were: (1) to describe the species composition, forest structure and regeneration status (species, density, frequency, basal area, diversity, condition, biomass, height, diameter distributions, and the importance value) of mangroves in the village of Lincod, Maribojoc along the Abatan River in Bohol, Philippines; (2) to compare this structure and regeneration status between managed and unmanaged Nipa; and (3) to provide an up-to-date list of the total number of mangrove species and mangrove associates found in the villages of Cabawan and Lincod. These objectives address the following research question:

- ✓ *"Does the management of Nipa palm (Nypa fruticans) tilts the balance towards a healthier mangrove forest (with higher natural regeneration potential, species diversity, condition and level of structural development?''*

This study can be used as baseline data for future ecological studies as well as improving our scientific understanding of the mangrove forest dynamics and the role of Nipa.

2 Materials and methods

2.1 Study site

The study was conducted along the Abatan River estuary in the province of Bohol, Philippines (Figure 2.2), which covers about 400 hectares of mangroves. Two rivers and numerous creeks and channels run through the mangrove forest, namely the Abatan River, which drains into the Maribojoc Bay, and the Bato River, a tributary of the former.

The main vegetation consists of mangrove species and mangrove associates and the study site is part of one of the most diverse mangrove forests in the Philippines with a total of 25 identified mangrove species by PROCESS-Bohol PRA results and the Silliman University Marine Laboratory (Lepiten et al., 1997). This riverine mangrove forest is inundated twice a day (tidal range of approximately 1.5 meters), and has a high value for wildlife conservation and ecotourism.

Figure 2.1. The dog-faced water snake is common in Southeast Asia's mangroves.

Compared to their low vegetative diversity, mangroves have a much greater animal diversity with many species being restricted to the mangrove ecosystem. Animals from both the marine and terrestrial environments can be found in the mangroves. The vertebrate fauna includes a variety of birds, mudskippers, rats, fruit bats like the large flying fox (*Pteropus vampyrus*) which is an important mangrove pollinator and seed disperser, lizards like the mangrove skink (*Emoia atrocostata*) and water monitor (*Varanus salvator*), and snakes such as the dog-faced water snake (*Cerberus rynchops*) (Figure 2.1), the extremely venomous king cobra locally known as Banakon (*Ophiophagus hannah*), Samar cobra locally known as Ugahipon (*Naja samarensis*) and the Philippine whipsnake locally known as Hanlulukay (*Dryophiops philippina*) (personal observation and personal communication with Nipa cutters). A wide variety of invertebrates like ants, spiders, fiddler crabs (*Uca* spp.) and mud lobsters (*Thalassina anomala*) were seen and the study site is home to the very rare and endemic *Pteroptyx macdermotti* firefly, which uses several mangrove species as its display tree (Middeljans, 2013).

Despite its importance, the Abatan River has not been declared by the DENR as a protected area under the National Integrated Protected Areas System (NIPAS) Act of 1992. The climate of the study site is tropical, and classified by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) as Corona Type IV, which is characterized by rainfall more or less evenly distributed throughout the year. The mean annual temperature is 28 °C with a daily average minimum and a daily average maximum of 24 °C and 32 °C, respectively. The mean annual rainfall at the nearest weather station in Tagbilaran (5 km from the study site) ranges between 1,500 mm and 2,000 mm. Usually, the maximum rainfall occurs between June and December. The mean relative humidity is 83%. The soils of the Abatan River are clayey and classified as Hydrosol, Bolinao Clay and Calape Clay Loam.

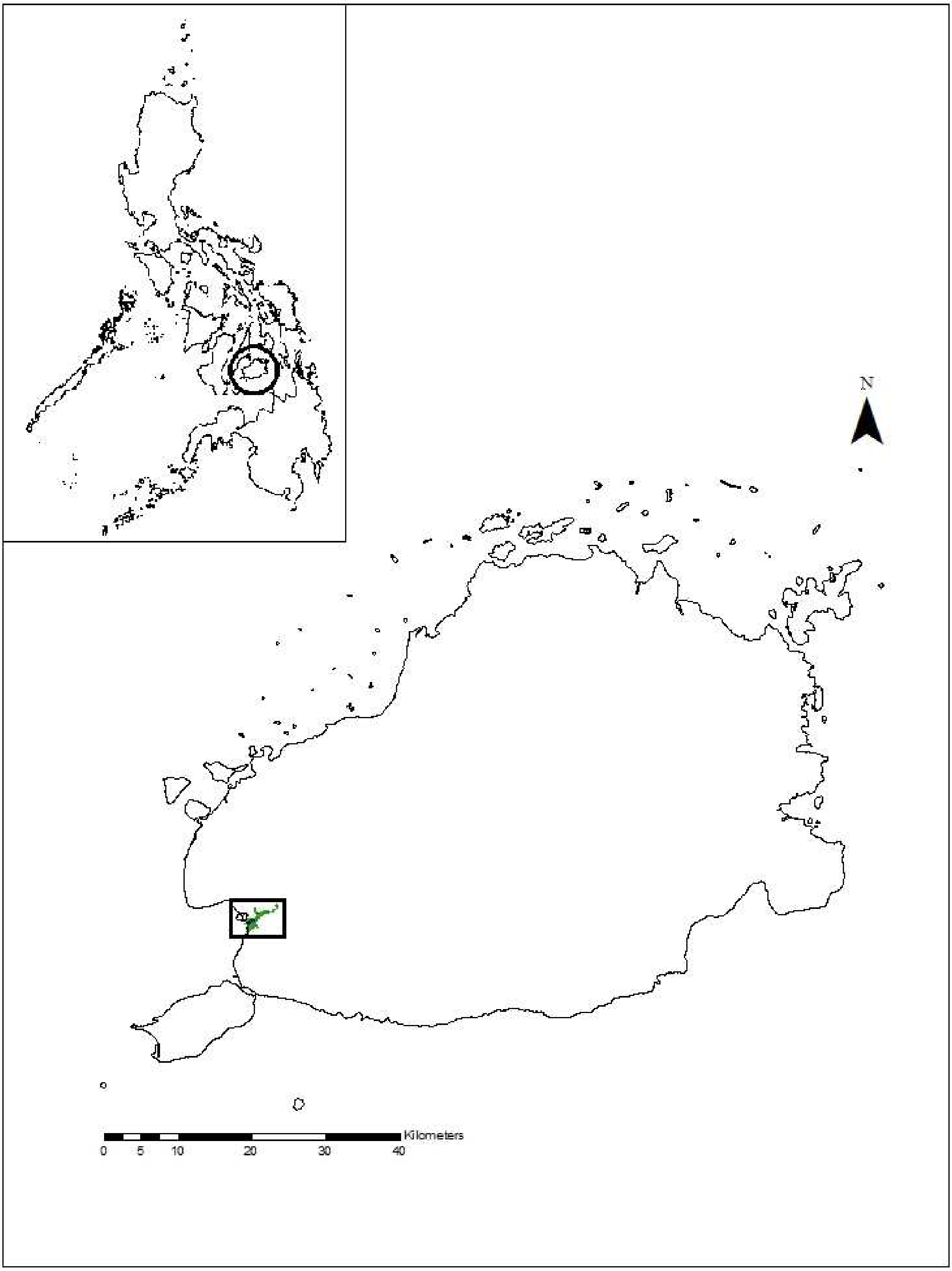

Figure 2.2. Location of the Abatan River study site in the province of Bohol, Philippines.

2.1.1 Sampling site: Lincod, Maribojoc

The mangrove community of Lincod in the municipality of Maribojoc was chosen as the sampling site based on the following criteria: 1) abundance of Nipa palms and other mangrove species; 2) accessibility; 3) management under a Community-Based Forest Management Agreement (CBFMA).

Lincod is the largest mangrove area along the Abatan River Estuary with 105 ha of riverine mangrove forest, located downstream and bordering the Maribojoc Bay at 9.71°N to 9.72°N latitude and 123.86°E to 123.87°E longitude (Figure 2.3). Among 105 ha of mangroves, *Nypa fruticans* is the dominant species found. Nipa naturally occurred in Lincod in low numbers and increased during the 1940's, when some locals started to plant the species. However, this 'natural' Nipa could be naturally distributed from De La Paz, where according to PROCESS-Bohol PRA Results (Lepiten et al., 1997), the first Nipa was planted in the 1870's with seedlings from the province of Samar. The mangrove forest is managed by the Abatan Lincod Mangrove Growers Organization (ALIMANGO) under CBFMA No. 42859-43573 which was adopted on July 7, 1998. This policy issued by the Department of Environment and Natural Resources (DENR) in 1995, serves as a 25-year tenure rights of a people's organization (PO) over its mangrove area renewable for another 25 years (DENR, 2003). With CBFMA, ALIMANGO members are tasked to properly protect and manage the area which is difficult to agree with the Non-ALIMANGO members, except for the claimants due to inheritance, as they don't participate in the protection of the whole 105 ha mangrove area (Victoria Gentelizo, personal communication).

Adjacent to the mangrove area is a 65 ha aquaculture pond established especially for milkfish (*Chanos chanos*) and shrimps (*Macrobrachium* spp.) which can no longer pose a threat since the mangrove area is under CBFMA.

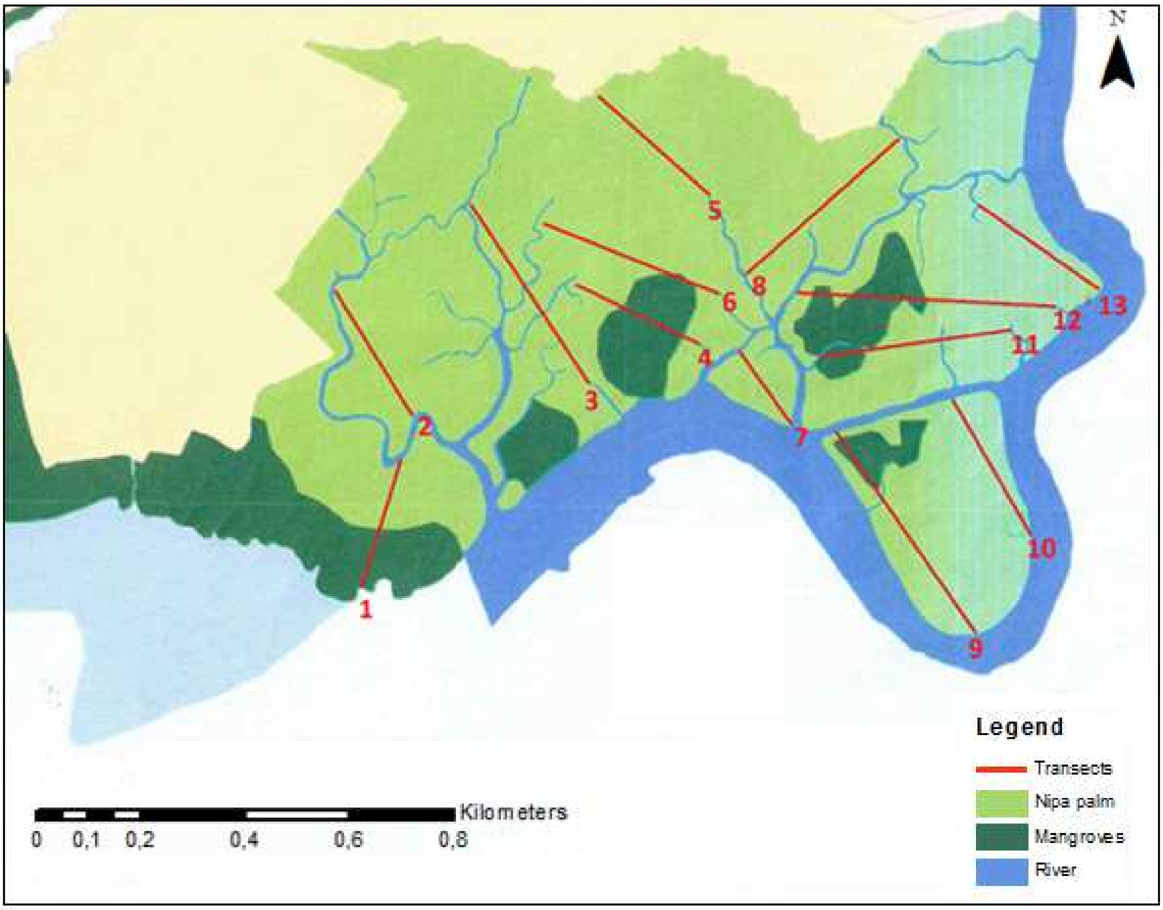

Figure 2.3. The 105 ha riverine mangrove forest and 13 transects in the sampling site of Lincod, Maribojoc.

2.2 Data collection

Fieldwork was carried out during low tides in the months of April and May, 2014. Thirteen transects ranging from 150 - 600 meters were laid out from the river going inland, in such a way that they represented as good as possible the mangrove forest of the different locations (Figure 2.2). Transect locations were predetermined using remotely sensed satellite imagery (e.g. Google Earth and Landsat) of the study site and a geographic information system (ArcGIS10).

56 plots (Appendix 1) of 10 x 10 m, were randomly established along the transects in managed and unmanaged Nipa with the use of a 10 m long rope and previously cut Nipa fronds (leaves), and their center points recorded with GPS. A total of 3700 m² (in 37 plots) and 1900 m² (in 19 plots) were sampled in managed and unmanaged Nipa respectively. Within each 100 m² ''Transect Line Plot (TLP)'', the following mangrove parameters were measured and recorded: total number of trees, total number of species, stem diameter at breast height (DBH in cm), the height (m) and health of the trees. Two subplots of 5 x 5 m (total of 112) were set out within each main plot to count the number of Nipa and regeneration (Figure 2.4).

Mangroves and mangrove associates were identified to the species level using the Handbook of Mangroves in the Philippines - Panay by Primavera et al. (2004); the Mangrove Guidebook for Southeast Asia by Giesen et al. (2007); and the Beach Forest Species and Mangrove Associates in the Philippines by Primavera and Sadaba (2012). Unidentified specimens were photographed and emailed to Dr. Jurgenne H. Primavera, Co-Chair of the IUCN Mangroves Specialist Group, Philippines, and to Wim Giesen, senior environmental specialist and senior consultant for Euroconsult Mott MacDonald, for identification.

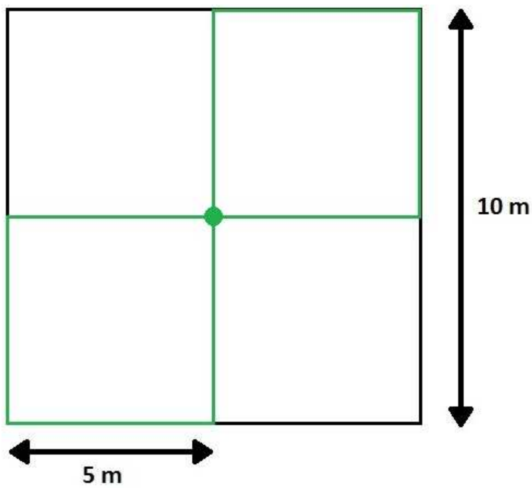

Figure 2.4. Shape and dimension of the TLP.

Nipa cutting activities and the present condition of the forest were observed within the sampling site. On-the-spot verbal, non-structured interviews were conducted with the Nipa cutters met during the fieldwork. The ALIMANGO was also interviewed using a questionnaire about Nipa management under CBFMA.

Measurements of Nipa palm, trees, saplings, seedlings, understory, and high tide levels and salinity which might directly influence the structural patterns present in the study site, were conducted as described below.

2.2.1 Nipa palm

The number of Nipa was counted in two 25 m² subplots as this mangrove has a stem that grows beneath the ground, making it impossible to measure the DBH. The average number of mature Nipa in these two subplots was taken and multiplied by four to give an estimation of the Nipa density per 100 m². Also, the number of fronds and leafstalks for about 20 individuals were counted and averaged, to help categorizing the plots into managed and unmanaged Nipa. Nipa management was characterized by its common characteristics (Table 2.1).

Table 2.1. Common characteristics of managed and unmanaged Nipa.

Managed Nipa	Unmanaged Nipa
- Tenure boundary of 4 Nipa fronds	- No tenure boundary or a rotten one
- Often light green leaves *	- Often dark green and dead brown leaves *
- Often 2-3 leaves *	- Often 4-5 leaves *
- < 40% of leafstalks are leaves *	- > 40% of leafstalks are leaves *
	

* These are general indications and not all Nipa has these characteristics.

2.2.2 Trees

The species name, height and diameter at breast height (DBH, diameter at 1.3 m) of all trees in each 100 m² TLP were measured and recorded and the trees were classified as healthy, unhealthy (sick) or dead using Duke et al. (2005) their classification system (Table 2.2). From these data basal area, stand density, and tree biomass were calculated.

Table 2.2. Classification and characteristics of mangrove tree condition, based on the method of Duke et al., 2005.

Classification	Characteristics
Healthy	Leaves green, no visible signs of sickness
Sick	Yellow, wilting leaves. Low foliage cover
Dead	Tree dead

Trees include all woody stems with a DBH of ≥5 cm. If swelling, forks or prop roots occurred which did not allow a measurement being taken at 1.3 m, the following rules dictated in English et al. (1997) were used (Figure 2.5). The DBH of *Rhizophora* species were measured 30 cm above the highest stilt-roots. The total height of the first two trees in each plot was measured using a Suunto™ clinometer. The other trees were estimated visually.

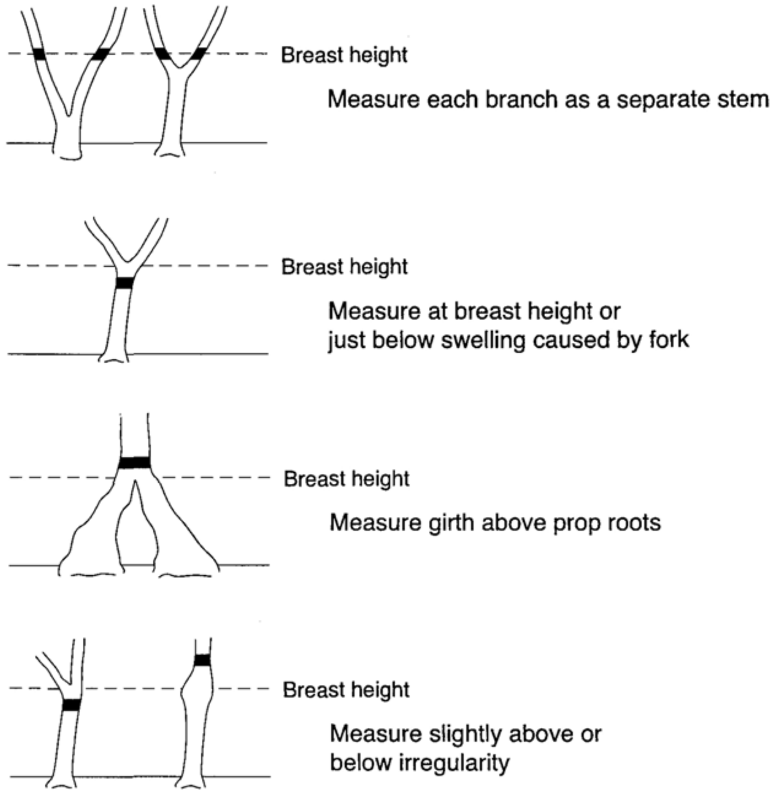

Figure 2.5. Measuring DBH of unusual or different tree growth forms (English et. al., 1997).

2.2.3 Regeneration

Seedlings and saplings were counted species wise and for numbers in two 25 m² subplots. Saplings were defined as woody stems between 1 - 4 m high and with a DBH smaller than 5 cm, and seedlings as mangrove tree species below 1 m. *Rhizophora*- and *Avicennia* seedlings (except for *A. rumphiana*) were recorded as *Rhizophora* spp. and *Avicennia* spp. as it was often not possible to identify them to the species level.

The natural regeneration status of tree species in managed and unmanaged Nipa was classified as frequent regeneration, infrequent regeneration, no regeneration and new regeneration or not abundant according to the following criteria:

1. Frequent regeneration: a higher proportion of individuals in lower diameter classes as compared to higher diameter classes.
2. Infrequent regeneration: a higher proportion of individuals in higher diameter classes as compared to lower diameter classes.
3. No regeneration: seedlings and saplings were absent indicating that these species are not regenerating and may be replaced by some other tree species in the future.
4. New regeneration or not abundant: juveniles were present but mature adults were absent.

Assessing regeneration is important (e.g. of woody species, potentially being outcompeted in some instances by *Nypa fruticans*).

2.2.4 Understory

All aboveground biomass of shrubs, herbs and non-vascular plants other than seedlings, saplings and trees were identified to the species level.

2.2.5 Salinity and high tide levels

Pore-water salinity was measured with a refractometer. Within each TLP, one water sample was collected inside Nipa stalks if possible and the salinity measured. The refractometer was cleaned between the plots to prevent cross contamination of the samples.

The average high tide levels were recorded by measuring the height of the visible marks on the stems of Nipa palms (Figure 2.6).

Figure 2.6. Visible high tide marks on Nipa.

2.3 Data analyses

All recoded data was stored in a Microsoft Access database and analyzed quantitatively by using Microsoft Excel. Vegetation analysis was done using the formula of density, relative density, dominance or basal area, relative dominance, frequency, relative frequency and the Importance Value Index (IVI). The ecological importance of each species in relation to the total forest community was calculated by summing its relative density, relative dominance and relative frequency (Curtis and Macintosh, 1951). It provides a better index than density alone regarding the importance or function of a species in its habitat.

Vegetation analysis was decided to limit on true mangrove trees and shrubs only. *Nypa fruticans*, *Acrostichum aureum*, *A. speciosum*, *Acanthus ebracteatus*, *A. ilicifolius*, and *A. volubilis* were excluded as they are palm, ground ferns and shrubby herbs and therefore did not allow the same scientific approach as used in the study of the vegetation ecology of woody plants (e.g. they have no stem to measure). However, Nipa density of mature and juvenile palms was determined for the comparison between managed and unmanaged Nipa. Mangrove tree species diversity, tree biomass and regeneration status were compared between managed and unmanaged Nipa. Species diversity was calculated using Shannon-Wiener Diversity Index (H'). A one-way analysis of variance (ANOVA) was used to test for statistically significant differences in salinity, Nipa density, tree density and juvenile density between managed and unmanaged Nipa. Results were considered significant if $P < 0.05$. A two sample Kolmogorov-Smirnov test (KS-test) by Smirnov (1939) was used to determine if the tree diameter distributions between managed and unmanaged Nipa differed significantly. Results were considered significant if the computed maximum difference (D-value) was higher than the critical D-value**.**

For the important quantitative analysis such as density, dominance, and frequency of tree species the following equations were used:

Density

Density of each species (n/ha^{-1}) = number of individuals * 10,000 m^2/area of plot in m^2.

Species richness (relative density)

The relative density describes the percentage of individuals belonging to a species.
Relative density = density of each species (n/ha)/total density of all species (n/ha) * 100%.

Basal area

Basal area in m^2 for an individual tree = 0.00007854 * stem DBH (cm).
Total basal area of all species (m^2/ha^{-1}) = sum of all species basal area / (10,000 m^2/area of plot in m^2).

Species abundance (relative dominance)

Relative dominance = total basal area (m^2/ha^{-1}) of a species / basal area (m^2/ha^{-1}) of all species * 100%.

Frequency

Number of plots in which a species occurs/total number of plots * 100%.

Species distribution (relative frequency)

The relative frequency is the percentage of plots in which a particular species is found.
Relative frequency = frequency of one species/ total frequency of all species in different plots * 100%.

Importance value of a species

The importance value of a species was determined as per Curtis and Macintosh (1951): Importance value index (IVI) = relative density + relative dominance + relative frequency.

Species diversity

Species diversity between managed and unmanaged Nipa was determined by using Shannon-Wiener Diversity Index (H') as:

$$\text{Diversity } H' = -\sum_{=n}^{s} P_i \ln p_i$$

Where: s = the number of species, Pi = the proportion of the total number of individuals consisting of the i th species, and ln = log base n

Tree biomass and carbon storage

Above-ground tree biomass (AGB) and below-ground tree biomass (BGB) were estimated using allometric equations developed by Komiyama et al. (2005):
AGB = 0.247 * p * (DBH^2) ^ 1.23
BGB or root weight = 0.196 * p 0.899 * (DBH^2) ^ 1.11

Where: AGB = above-ground biomass (kg), BGB = below-ground biomass (kg), ρ = species-specific wood density (g/cm^3) (available from: http://db.worldagroforestry.org/wd), and DBH = tree diameter at breast height (cm). AGB and BGB for each mangrove species was summed to get the total biomass in managed and unmanaged Nipa (expressed in t/ha^{-1}). Biomass was converted to the equivalent of carbon by multiplying the biomass with 0.45 as per Twilley et al. (1992).

Diameter distributions
Obtained DBH per species were grouped into 5 cm diameter classes to form class boundaries of 5 – 9 cm, 10 – 14 cm, 15 – 19 cm, etc.

2.4 Field equipment

The following equipment was used during the field work:

Equipment	Use
Garmin™ GPSMAP 60C	Navigate to the plot and record plot centers
Silva™ Compass	Plot layout and maintain exact bearing when walking a transect
Suunto™ PM-5/1520 Clinometer	Measure tree height
H_2 Ocean™ Salinity Refractometer	Measure salinity
10 m long rope	Plot layout
Meter stick	Measure inundation and for seedling/sapling identification
Diameter tape	Measure tree diameters at breast height (1.3 m)
Pink flagging tape	Mark plot corners and center
Detailed maps of the study area	Navigate to the predetermined transect locations
Field forms, clipboard, pencils and ball pen	Record data (geographic coordinates, salinity, high tide levels, species, number, height, DBH, health, saplings, seedlings, Nipa number, and remarks
Sony™ DSC-HX50 camera	Photograph the area and individual mangrove species
Dry-Bag	Protection of equipment and field forms during rains and crossing tidal creeks

3 Results and discussion

3.1 Salinity and high tide levels

Salinity and high tide levels are two of the more important factors that control growth and distribution of mangrove species (Lugo and Snedekar, 1974; Giesen et al., 2007). Salinity in the mangrove environment varies from seawater (around 35 parts per thousand (‰)) in the lowest intertidal area to upstream rivers (less than 1 ‰) (Hutchings and Saenger, 1987). Therefore, measurements of high tide levels and salinity were done to conclude on mangrove zonation in the sampling site (Appendix 1 and Table 3.1). These can be used for a future comparative study of Lincod with another area.

The low intertidal area of Lincod is inundated twice a day with about twelve hours between the first and last high tide level. The average high tide levels observed in the plots ranged from 45 to 100 cm (n = 48); average 68 cm, median 68 cm, mode 60 cm.

The pore-water salinity ranged from 18 to 32 ‰ (n = 43); average 26‰, median 27‰, mode 28‰. The low salinity records measured were probably influenced by flooding tidal water, river discharge and abundant rainfall. Although there were great changes in salinity levels, there was no significant difference in salinity between managed and unmanaged Nipa when they were pooled and compared (ANOVA, $F = 0.065$, df = 1, $P = 0.8$).

Table 3.1. Pore-water salinity and high tide levels of the mangrove forest plots in Lincod.

	Salinity (‰)	**High tide level (cm)**
Min	18	45
Max	32	100
Average	26	68
Median	27	68
Mode	28	60

3.2 Nipa palm management

The Nipa palm in Lincod is usually harvested twice a year (every six months) during low tides. The two outside fronds are cut about 0.6 - 1.0 m from the ground level using a bolo machete, while the other two to three fronds in the middle of the palms are left, depending on the size of the smallest frond. When this is still very small, a total of three fronds are left to ensure recovery of the Nipa palm. However, Nipa is sometimes utilized once a year when it grows slow or thrice a year when the leaves easily get mature (Victoria Gentelizo, personal communication).

Of the 56 plots, 37 (66%) were established in managed Nipa, while 19 (34%) were established in unmanaged Nipa (Appendix 2). Unmanaged Nipa showed a range of 1,800 to 25,600 palms ha^{-1} and had an average density ± SD of 14,800 ± 7,700 palms ha^{-1}, while managed Nipa showed a range of 4,200 to 24,200 palms ha^{-1} and had an average density of 15,100 ± 4,700 palms ha^{-1}. The average density of the total Nipa in Lincod was 15,000 ± 5,800 palms ha^{-1}. This is more than the recorded 1,025 to 6,400 palms per hectare (average of 3,267 palms ha^{-1}) in Malaysia by Rozainah and Aslezaeim (2010) and by Cadiao and Espiritu (2012) who recorded an average of 770 palms ha^{-1} at the seaward zone of

Occidental Mindoro, Philippines. There was no significant difference in density between managed and unmanaged Nipa (ANOVA, F = 0.043, df = 1, P = 0.84).

Although managed and unmanaged Nipa showed more or less the same average density, unmanaged Nipa was considered more dense. This was due to the number of alive spear leaves and the height of these leaves. Managed Nipa contained an average of 3.02 ± 0.43 leaves per individual while unmanaged Nipa contained an average of 4.14 ± 0.43 leaves per individual palm. This gave an average of 45,500 leaves per ha for managed Nipa and 61,800 leaves per ha for unmanaged Nipa. A significant difference was seen in Nipa leaf density (ANOVA, F = 6.136, df = 1, P = 0.02). Also average height of unmanaged Nipa was about 6.3 meters (n = 17) and of managed Nipa about 4.6 meters (n = 36). As well as the higher leaf density as the taller leaves made it more difficult for light to penetrate to the forest floor.

Nipa regenerates quickly in comparison to woody mangrove species. A total of 260 juveniles were seen in the assessed 112 subplots showing a density of 929 juveniles per hectare. The number of juveniles was higher in managed Nipa ($1173/ha^{-1}$) compared to unmanaged Nipa ($453/ha^{-1}$). This is lower than the number of mature palms per hectare. However, Nipa does not need seeds for reproduction as it has an underground horizontal stem, known as rhizome, from where new individuals appear resulting in the extensive and dense Nipa stands (Figure 3.1).

Figure 3.1. Vegetative reproduction by rhizomes is known to be a habit of *Nypa fruticans*.

Of the managed Nipa, 9 plots (24%) were considered as very dense (>180 palms per 100 m^2), 23 (62%) as moderately dense (100 - 180 palms per 100 m^2) and 5 (14%) as open (<100 palms per 100 m^2). Of the unmanaged Nipa, 9 plots (47%) were considered very dense, 3 plots (16%) as moderately dense and 7 plots (37%) as open (Figure 3.2). The high number of open Nipa left unmanaged is because this often grow under the mangroves (mainly *Sonneratia alba*) and is therefore often of bad quality. Owners however need to maintain their areas by removing deceased or unexpanded leaves, making it easier for other Nipa cutters to go to their areas (Victoria Gentelizo, personal communication). Managed Nipa is often kept moderately dense with 1 m spacing in between, making it easy to access while providing enough palms for utilization.

Nipa was categorized into managed and unmanaged as with fewer categories, data and conclusion were stronger.

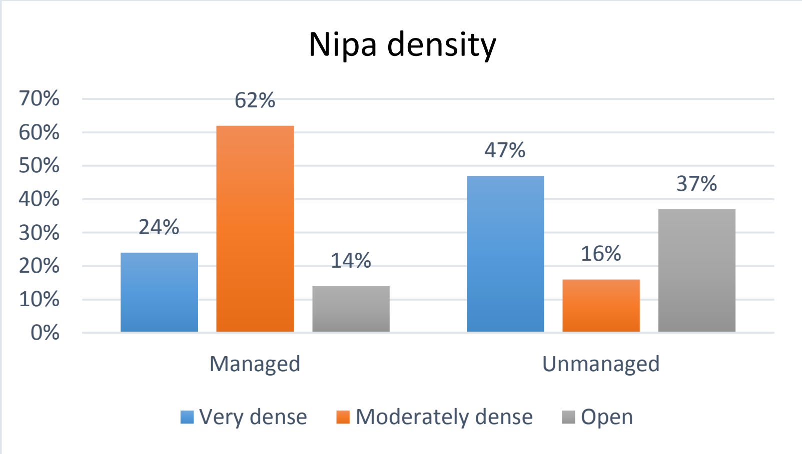

Figure 3.2. Density classes between managed and unmanaged Nipa.

3.3 Species composition

3.3.1 Assessment of total number of mangroves and mangrove associates

A total of 29 'true' mangrove species from fourteen families were identified in the adjacent villages of Lincod and Cabawan, Maribojoc (Table 3.2). Appendix 10 provides photographs to illustrate the 29 Philippine mangrove species reported in this study.

The common true mangrove species were: *Aegiceras corniculatum, Avicennia marina, A. officinalis, A. rumphiana, Ceriops zippeliana, Excoecaria Agallocha, Nypa fruticans, Rhizophora apiculata, R. stylosa, Sonneratia alba* and *Xylocarpus granatum.* Six mangrove species appeared to be rather rare: *Bruguiera sexangula* (three individuals), *Camptostemon philippinense* (two individuals), *Ceriops tagal* (two individuals), *Cynometra iripa* (one individual), *Lumnitzera racemosa* (two individuals) and *Scyphiphora hydrophylacea* (one individual).

Comparing the data gathered in this study with the total number of mangroves cited by Polidoro et al. (2010) throughout the world, means that almost 41% of the total mangrove species known to occur in the world are present in the riverine Abatan mangrove forest. Also, using the data cited by Spalding et al. (2010), who stated that there are about 44 mangrove species known to occur throughout the Philippines, 66% of these are found in Abatan.

Of the 29 true mangrove species identified, 26 were found in the sampling site of Lincod. These are mostly downstream and intermediate estuarine species, which are inundated during all high tides. The adjacent village of Cabawan contained 22 species of which four were not seen in the former. These species (*Acanthus ebracteatus*, *Bruguiera sexangula*, *Cynometra iripa* and *Dolichandrone spathacea*) are the back mangroves, found in intermediate to upstream estuarine zones, which are only inundated by the highest tides, and are therefore unlikely to occur in Lincod.

Thirteen mangrove species were previously recorded in Lincod by the Silliman University Marine Laboratory (Lepiten et al., 1997). However, this is an incomplete species list as the present study identified 26 species in the sampling site. Also two species (*Barringtonia asiatica* and *Derris trifoliata*), although mangrove associates were considered as mangroves, making the number of identified 'true' mangrove species by the Silliman University: eleven. *Ceriops decandra* and *Sonneratia caseolaris* were recorded in 1997. However, during this study it was confirmed that the *C. decandra* should be *C. zippeliana* and the *S. caseolaris* should be *S. alba*. The village of Cabawan was not assessed by the Silliman University.

The 29 Philippine mangrove species identified in this study makes the Abatan River one of the most diverse mangrove sites in the Philippines. Other mangrove sites with a high species diversity are the mangrove areas of Aurora with 30 species (Rotaquio Jr. et al., 2007), Bugtong Bato-Naisud basin along the Ibajay River, Aklan Province with 28 true mangrove species (Primavera, 2010), Jawili, Tangalan River, Aklan Province with 25 species (Primavera, 2010), Pagbilao Bay in Quezon Province with 25 species (Janssen and Padilla, 1999), Olango Island with 23 species (Magsalay et al., 1989) and the Makato River in Aklan Province with 22 species (Primavera, 2010).

Table 3.2. List of identified true mangrove species in the villages of Lincod and Cabawan (Sources: The Plant List, 2010[1]; Spalding et al., 2010[2]; Giesen et al., 2007[3]; Melana et al., 2000[4]). Red List Categories[5] refer to Polidoro et al. (2010); LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered.

Family[1]	Scientific name[2]	Local name[3,4]	Red list Category[5]	Lincod	Cabawan	Total
Acanthaceae	*Acanthus ebracteatus*	Diluario	LC	•	•	•
	Acanthus ilicifolius	Tingloy	LC			
	Acanthus volubilis		LC	•		•
	Avicennia alba	Bungalon puti	LC			
	*Avicennia marina**	Bungalon	LC	•		•
	*Avicennia officinalis**	Api-api	LC	•	•	•
	Avicennia rumphiana	Piapi	VU	•	•	•
Arecaceae	*Nypa fruticans**	Nipa	LC	•	•	•
Bignoniaceae	*Dolichandrone spathacea**	Tuwi	LC		•	•
Combretaceae	*Lumnitzera littorea**	Tabau	LC	•		•
	Lumnitzera racemosa	Kulasi	LC	•		•
	Lumnitzera x rosea					
Ebenaceae	*Diospyros vera*	Batulinao	LC			
Euphorbiaceae	*Excoecaria agallocha**	Alipata/Buta-buta	LC	•	•	•
Leguminosae	*Cynometra iripa*		LC		•	•
Lythraceae	*Pemphis acidula*	Bantigi	LC			
	Sonneratia alba	Pagatpat	LC	•	•	•
	*Sonneratia caseolaris**	Pedada	LC			
	Sonneratia ovata	Pagatpat baye	NT			
	Sonneratia x gulngai					
Malvaceae	*Brownlowia tersa*	Maragomon	NT			
	Camptostemon philippinense	Gapas-gapas	EN	•		•
	Heritiera littoralis	Dungon late	LC	•	•	•
Meliaceae	*Xylocarpus granatum**	Tabigi	LC	•	•	•
	Xylocarpus moluccensis	Piagau	LC	•	•	•
Myrsinaceae	*Aegiceras corniculatum*	Saging-saging	LC	•	•	•
	Aegiceras floridum	Saging-saging	NT			
Myrtaceae	*Osbornia octodonta*	Taualis	LC	•	•	•
Pteridaceae	*Acrostichum aureum*	Lagolo	LC	•	•	•
	Acrostichum speciosum	Paku laot	LC	•	•	•
Rhizophoraceae	*Bruguiera cylindrica*	Pototan lalaki	LC			

	Bruguiera exaristata		LC			
	Bruguiera gymnorrhiza	Busain	LC	●	●	●
	Bruguiera parviflora	Langarai	LC	●	●	●
	Bruguiera sexangula	Pototan	LC		●	●
	*Ceriops decandra**	Lapis-lapis/Malatangal	NT			
	Ceriops tagal	Tangal/Tungog	LC	●		●
	Ceriops zippeliana		LC	●	●	●
	Kandelia obovata	Bakauan baler	LC			
	*Rhizophora apiculata**	Bakauan lalaki	LC	●	●	●
	*Rhizophora mucronata**	Bakauan babae	LC	●	●	●
	Rhizophora stylosa	Bakauan bato	LC	●	●	●
	Rhizophora x lamarckii					
Rubiaceae	*Scyphiphora hydrophylacea*	Nilad/Sagasa	LC	●		●
		Total number of mangrove species		26	22	**29**

* Recorded in Lincod by the Silliman University Marine Laboratory (Lepiten et al., 1997).

Ten mangrove associates were seen in Lincod, while in Cabawan thirteen species were found (Table 3.3). The climbers *Derris trifoliata* and *Finlaysonia obovata* were the most common mangrove associates in the area. *Morinda citrifolia* and *Terminalia catappa* are considered beach forest species according to Primavera and Sabada (2012).

Table 3.3. List of mangrove associates in the villages of Lincod and Cabawan (Based on The Plant List, 2010[1]; Giesen et al., 2007[2]; Primavera and Sadaba., 2012[3]).

Family[1]	**Scientific name[1]**	**Local name[2,3]**	**Growth form[2]**	**Lincod**	**Cabawan**	**Total**
Apocynaceae	*Dischidia platyphylla*	Kwarta-kwarta	Epiphyte		●	●
Apocynaceae	*Finlaysonia obovata*		Climber	●	●	●
Aspleniaceae	*Asplenium nidus*		Fern	●	●	●
Blechnaceae	*Stenochlaena palustris*		Fern		●	●
Combretaceae	*Terminalia catappa*	Talisay	Tree	●	●	●
Compositae	*Pluchea indica*		Shrub		●	●
Convolvulaceae	*Ipomoea pes-caprae*	Palang-palang	Ground-dwelling herb	●		●
Flagellariaceae	*Flagellaria indica*	Huak	Climber		●	●
Leguminosae	*Derris trifoliata*	Butong	Climber	●	●	●
Leguminosae	*Pongamia pinnata*	Bani	Tree	●		●
Leguminosae	*Sophora tomentosa*	Tambalisa	Tree	●		●
Malvaceae	*Hibiscus tilliaceus*	Malabago	Tree		●	●
Moraceae	*Ficus* spp.		Tree		●	●
Phyllanthaceae	*Breynia vitis-idaea*	Sungut-olang	Shrub	●		●
Polypodiaceae	*Drynaria quercifolia*		Fern	●	●	●
Rubiaceae	*Hydnophytum formicarum*		Epiphyte		●	●
Rubiaceae	*Morinda citrifolia*	Nino/Bangkoro	Tree		●	●
Rubiaceae	*Nauclea orientalis*	Bangkal	Tree	●		●
		Total number of mangrove associates		10	13	**18**

3.3.1.1 Threatened and notable species

Camptostemon philippinense (S. Vidal) Becc. (1889)

The *Camptostemon philippinense*, locally known as 'Gapas-gapas' is very rare and has a limited and patchy distribution in Indonesia and the Philippines (Duke et al., 2010c). It is the rarest species in the Philippines and classified by the IUCN Red List as 'Endangered' (the only Philippine mangrove classified under this category). It is endangered under Criterion C, which means it has a small population size estimated to be less than 1,200 mature individuals globally, with continued decline (Polidoro et al., 2010). There are very few individuals, even in areas where it is found. In the Philippines, it is estimated that there are less than 1,000 mature individuals and in the Indonesian part of the range it has been estimated that there are less than 200 mature individuals (Duke et al., 2010c). This species is found in the low intertidal region along tidal creeks (Primavera et al., 2004). It is highly threatened by removal of mangrove areas for fish and shrimp aquaculture ponds in the Philippines, and coastal development throughout its range (Duke et al., 2010c). Also along the Abatan River this species is very rare as only two individuals were seen in the sampling site of Lincod (Figure 3.3).

Figure 3.3. The *Camptostemon philippinense* is the most endangered Philippine mangrove species.

Avicennia rumphiana Hallier F. (1918)

Locally known as 'Piapi', is endemic to Southeast Asia (Giesen et al., 2007), but uncommon in the Philippines and considered as 'Vulnerable' by Duke et al. (2010b) on the IUCN Red List of Threatened Species. It is listed as Vulnerable under Criterion A as the mangrove habitat within this species range has declined with 30% between 1980 and 2005 (Polidoro et al., 2010). This species is found in the downstream estuarine zone in the high intertidal region (Robertson and Alongi, 1992). According to Tomlinson (1986) it has a high tolerance of hyper saline conditions. It is the largest *Avicennia* species, sometimes growing to 30 m in height with a girth of 3 m, and can be distinguished from its more common relatives by its leaves (Giesen et al., 2007). Although uncommon in the Philippines, *A. rumphiana* is common in the Abatan mangrove forest.

Lumnitzera racemosa Willd. (1803)

A pioneer species of small trees up to 9 m high that usually occurs in the in the upstream zone in the mid to high intertidal region, but may also colonize disturbed sites (Giesen et al., 2007; Tomlinson, 1986). However, along the Abatan River, two individuals were observed next to a *Scyphiphora hydrophylacea* in the seaward zone. *L. racemosa* is intolerant of shade and able to withstand a maximum pore-water salinity of 78‰ (Robertson and Alongi, 1992). The timber is hard and durable (Giesen et al., 2007) and the species was therefore used for house posts and fencing (live and dead branches) in the Philippines (Ellison et al., 2010b). This could be the possible reason for the low number of individuals along the river.

Scyphiphora hydrophylacea C.F.Gaertn. (1806)

This species is a small tree up to 3 m high, but rarely exceeding 2 m (Giesen et al., 2007). Although it is relatively widespread, it is generally uncommon and appears in small numbers in most areas of its range (Ellison et al., 2010c). This species is found on banks of tidal creeks and rivers, tolerating a high salinity (Primavera et al., 2004). One *S. hydrophylacea* was seen growing together with the two *Lumnitzera racemosa*, making this species very rare along the Abatan River.

Ceriops zippeliana Blume. (1850)

This species is widespread and common and was formerly recognized as *C. decandra* in the majority of its range (Sheue et al., 2009). This is also the case along the Abatan River where this species is labelled as *C. decandra* (Figure 3.4). The *C. zippeliana* can be distinguished from its relatives by the color of its propagules which are red compared to *C. decandra* and *C. tagal* which are yellow. Also the propagules of *C. zippeliana* point upwards and in all directions and are not all hanging downwards as in *C. tagal*. The *C. zippeliana* is found in the mid to high intertidal zone in intermediate regions of estuaries. This species generally grows to 3 m or more, and is considered to be a slow-growing species (Primavera et al., 2004).

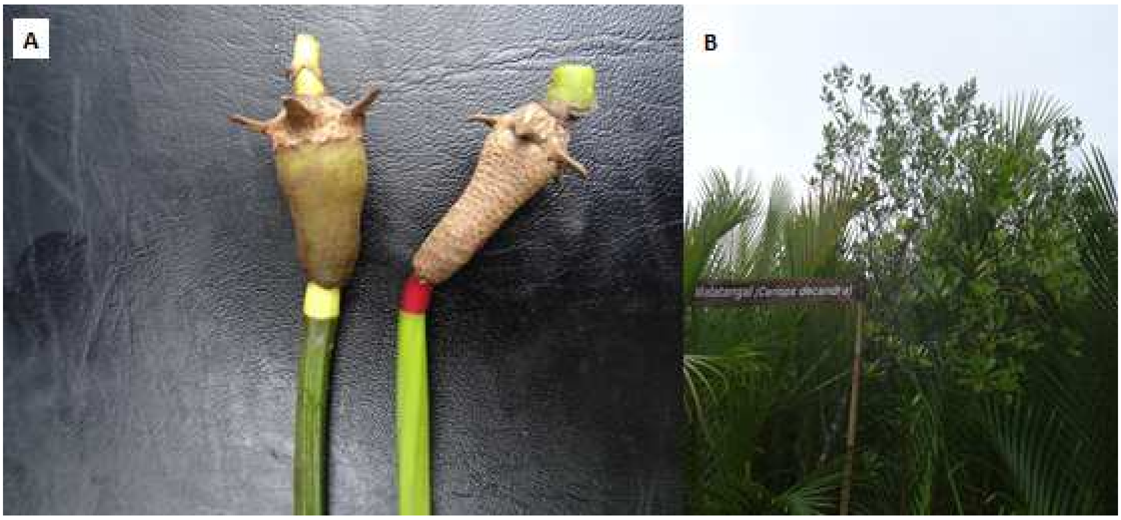

Figure 3.4. A) Propagule of *Ceriops tagal* (left) and *C. zippeliana* (right). B) *C. zippeliana* is incorrectly named *C. decandra* along the Abatan River.

3.3.2 Vegetation analysis

A total of 295 individual mangrove trees were recorded in Lincod within 5600 m², belonging to 16 species. Table 3.4 shows the results of the vegetation analysis based on the actual observation and data gathered. The total density of all woody mangrove species was 527 ± 44 stems ha^{-1}, which is considered to be relatively low, comparing to other riverine mangrove forests e.g. Ranong, Thailand, an average density of 812 trees ha^{-1} has been reported (Aksornkoae, 1993) and in the mangrove forest along the Ibajay River, Aklan Province, Philippines an average density of 967 trees ha^{-1} was reported in 2002 (Primavera et al., 2007).

Comparing species, *Sonneratia alba* was the most abundant with 180 stems per hectare, representing more than 34% of the total stand density, followed by *Aegiceras corniculatum* with 63 stems per hectare (12%) and *Avicennia officinalis* with 57 stems per hectare (11%). These are typical seaward species and therefore abundant in the sampling site. *Bruguiera parviflora* and the endangered *Camptostemon philippinense* were least dense with only two stems per ha. A total basal area (dominance) of 17.16 m^2 ha^{-1} was recorded. Basal area varied from 7.55 m^2 ha^{-1} for *S. alba* to only 0.02 m^2 ha^{-1} for *B. parviflora*. The *Sonneratia alba* also had the highest species distribution being recorded in 39% of the plots, followed by *Avicennia marina* (frequency of 16%). The mangroves in the area had an average height of 11 m; and an average DBH of 13.4 cm. *Avicennia rumphiana* was the biggest mangrove observed with an average height and average DBH of 15.9 m ± 4.3 and 22.7 cm ± 11.5 (range of 8 - 46 cm) respectively, while *A. corniculatum* (4.4 m ± 1.3; 5.6 cm ± 1.0) and *Ceriops zippeliana* (5.5 m ± 0.6; 5.3 cm ± 0.5) were the smallest.

Figure 3.5. The *Sonneratia alba* had the highest importance value.

Of the 16 mangrove tree species subjected for analysis, *S. alba* (Figure 3.5) turned out to have the highest relative density of 34.24%, relative dominance of 43.99%, relative frequency of 25%, and therefore got the highest importance value (IVI) of 103.23. This is followed by *A. officinalis* having a relative density of 10.85%, relative dominance of 10.29%, relative frequency of 7.95% and with an IVI of 29.09. The species of *A. rumphiana* ranked third with a relative density of 5.08%, relative dominance of 13.96%, relative frequency of 7.95% and with an IVI of 27.00. The abundant *A. corniculatum* ranked only sixth in terms of importance value because it has a very small relative basal area. On the other hand, *Bruguiera parviflora, Camptostemon philippinense* and *Osbornia octodonta* were the three mangrove species which had the lowest relative density, lowest relative dominance, lowest relative frequency and revealed also as the species having the lowest importance values respectively. The species with a high importance value are pioneer species while the ones with a low importance value are shade-tolerant succession species. This data confirms that *S. alba* is the principal mangrove species in the sampling site.

Table 3.4. Vegetation analysis of the mangrove tree species ranked by their importance value.

Species	Number of individuals (n)	Plots of occurrence (n)	Frequency (%)	Stem density (n/ha)	Basal area (m²/ha)	Average height (m)	Average DBH (cm)	Relative density (%)	Relative dominance (%)	Relative frequency (%)	IVI	Rank
Sonneratia alba	101	22	39	180	7,55	13,4	15,9	34,24	43,99	25,00	103,23	**1**
Avicennia officinalis	32	7	13	57	1,77	11,4	14,4	10,85	10,29	7,95	29,09	**2**
Avicennia rumphiana	15	7	13	27	2,40	15,9	22,7	5,08	13,96	7,95	27,00	**3**
Rhizophora apiculata	18	8	14	32	1,12	10,2	14,6	6,10	6,50	9,09	21,70	**4**
Rhizophora stylosa	23	8	14	41	0,79	10,8	10,8	7,80	4,63	9,09	21,52	**5**
Aegiceras corniculatum	35	7	13	63	0,28	4,4	5,6	11,86	1,63	7,95	21,45	**6**
Avicennia marina	19	9	16	34	0,64	11,0	10,7	6,44	3,73	10,23	20,40	**7**
Lumnitzera littorea	18	4	7	32	1,43	11,3	16,8	6,10	8,34	4,55	18,99	**8**
Xylocarpus moluccensis	4	4	7	7	0,54	13,3	19,3	1,36	3,14	4,55	9,04	**9**
Excoecaria agallocha	13	2	4	23	0,37	7,7	9,6	4,41	2,15	2,27	8,83	**10**
Ceriops zippeliana	4	3	5	7	0,03	5,5	15,3	1,36	0,16	3,41	4,93	**11**
Rhizophora mucronata	6	2	4	11	0,06	8,0	6,5	2,03	0,38	2,27	4,68	**12**
Xylocarpus granatum	2	2	4	4	0,05	14,0	10,0	0,68	0,29	2,27	3,25	**13**
Osbornia octodonta	3	1	2	5	0,07	7,3	9,7	1,02	0,42	1,14	2,58	**14**
Camptostemon philippinense	1	1	2	2	0,05	11,0	14,0	0,34	0,29	1,14	1,76	**15**
Bruguiera parviflora	1	1	2	2	0,02	13,0	8,0	0,34	0,09	1,14	1,57	**16**
Total of all species	**295**		**157**	**527**	**17,16**	**11,0**	**13,4**	**100**	**100**	**100**	**300**	

IVI is the important value index calculated as: IVI = RD + RDo + RF, where relative density (RD), relative dominance (RDo), and relative frequency (RF) can add up to a maximum value of 300 (per Curtis and Macintosh, 1951).

3.4.4 Species diversity

The overall species diversity of mangroves in Lincod had a high Shannon-Wiener Diversity value of H' 1.93 (Appendix 3). Total mangrove species richness was higher in managed Nipa as compared to unmanaged Nipa as a total of 17 true mangrove tree species were found in managed Nipa compared to only 12 species in unmanaged Nipa. The mean values of the Shannon-Wiener Diversity Index (H') for mangrove trees, saplings and seedlings were also higher in managed Nipa than in unmanaged Nipa (Table 3.8 and Appendix 4, 5, 6). Shannon Diversity Index for trees in managed Nipa was 2.20 compared to 1.69 in unmanaged Nipa; Shannon Diversity Index for saplings was 1.76 in managed Nipa compared to 1.45 in unmanaged Nipa; and Shannon Diversity Index for seedlings was 1.23 in managed Nipa compared to 0.27 in unmanaged Nipa. These values show that managed Nipa was more diverse in mangrove tree species compared to unmanaged Nipa.

Table 3.8. Shannon-Wiener Diversity Index (H') for trees, saplings and seedlings in managed and unmanaged Nipa.

		Managed Nipa	Unmanaged Nipa
H'	Seedlings	1,234	0,270
	Saplings	1,764	1,454
	Trees	2,203	1,693

3.4 Forest structure between managed and unmanaged Nipa

3.4.1 Structural characteristics of mangrove tree species

A study of the forest structure requires structural parameters, such as density, basal area and biomass (Saenger, 2002; Dahdouh-Guebas and Koedam, 2006). Appendix 7 illustrates the basal area, density, average height and average DBH of mangrove tree species between managed and unmanaged Nipa. A total of 451 ± 36 and 674 ± 86 stems ha^{-1} were recorded within managed and unmanaged Nipa respectively. There was no significant difference in mangrove tree species density between managed and unmanaged Nipa (ANOVA, F = 2.282, df = 1, P = 0.14).

Six mangrove species - *Aegiceras corniculatum, Avicennia rumphiana, Osbornia octodonta, Rhizophora apiculata, R. stylosa* and *Sonneratia alba* were considered more dense in unmanaged Nipa, while *Avicennia officinalis*, *Ceriops zippeliana*, *Excoecaria agallocha*, *Lumnitzera littorea* and *Xylocarpus moluccensis* were more dense in managed Nipa. The other species showed more or less the same density or had insufficient data. There was definitely a difference in species composition between managed and unmanaged Nipa. *S. alba*, *A. officinalis* and *L. littorea* showed the highest density in managed Nipa while unmanaged Nipa was dominated by *S. alba*, *A. corniculatum* and *R. stylosa*. Based upon basal area, *S. alba* and *A. officinalis* co-dominated managed Nipa and *S. alba* and *A. rumphiana* co-dominated unmanaged Nipa. However, both had *S. alba* as the most abundant species. *A. officinalis* was not found in unmanaged Nipa. This could mean that *Nypa fruticans* outcompetes *A. officinalis* and so *A. officinalis* only thrives when competition from *N. fruticans* is low. Total basal area was also higher in unmanaged Nipa (22.53 ± 3.73 m^2 ha^{-1}) compared to 14.45 ± 1.4 m^2 ha^{-1} in managed Nipa. Average tree species height and DBH did not vary much between managed (11.1 m ± 4.7; 13.6 cm ± 6.9) and unmanaged Nipa (10.9 m ± 5.8; 13.1 cm ± 8.4). *Xylocarpus moluccensis* attained the highest DBH (19.3 cm ± 16.3) in managed Nipa area followed by *Avicennia rumphiana* (19 cm ± 8.4) and *Lumnitzera littorea* (16.3 cm ± 7.4). *X. moluccensis* was not recorded in unmanaged Nipa where *A. rumphiana* was the biggest (26.9 cm ± 13.8), followed by *S. alba* (16.2 cm ± 7.8) and *Rhizophora apiculata* (16.1 cm ± 6). *A. rumphiana* was tallest in both managed and unmanaged Nipa, while *A. corniculatum* was the smallest. Perhaps one possible explanation for the lower average tree height and DBH in unmanaged Nipa was because of the high density of *A. corniculatum*, which tends to be a small tree or shrub, typically 2 - 3 m tall (Primavera et al., 2004). This caused the average height and DBH of the mangrove species in unmanaged Nipa to drop considerably.

3.4.2 Tree biomass and carbon storage

Mangroves are among the most carbon-rich habitats on the planet, potentially storing four times as much carbon as other tropical forests, including rainforests (Donato et al., 2011). Carbon is stored both in standing biomass, as well as in below-ground root biomass and soils. The average biomass of a mangrove forest in the Philippines is estimated to be around 401.8 t ha^{-1} with roughly 176.8 t ha^{-1} carbon being stored (Lasco and Pulhin, 2000).

Managed Nipa in Lincod had an estimated above-ground tree biomass of 81.97 t ha^{-1} and an estimated below-ground tree biomass of 27.39 t ha^{-1}, giving a total mangrove tree biomass of 109.36 t ha^{-1} (Table 3.5.). *Sonneratia alba* had the highest standing biomass, followed by *Avicennia officinalis* and *Lumnitzera littorea* with 28.42 t ha^{-1}, 12.87 t ha^{-1} and 12.29 t ha^{-1}, respectively. Estimated above-ground tree biomass in unmanaged Nipa was 142.21 t ha^{-1} and estimated below-ground tree biomass was 45.5 t ha^{-1} (Table 3.6.). The combined AGB and BGB in unmanaged Nipa was 187.71 t ha^{-1}. Estimated above-ground biomass in unmanaged Nipa ranged from 0,21 t ha^{-1} for *Rhizophora mucronata* to 69,36 t ha^{-1} for *S. alba*.

Mangrove tree carbon biomass was lower in managed Nipa (49.21 t ha^{-1}) compared to unmanaged Nipa (84.47 t ha^{-1}) using the 0.45 conversion factor between biomass and carbon stock (Twilley et al., 1992). These carbon stocks are relatively low compared to the average carbon biomass in the country. These findings further confirm the low structural development of the mangrove forest. However, biomass of seedlings, saplings, non-woody plants (e.g. *Nypa fruticans*) and soils was not measured. The mixed mangrove forest was classified as secondary forest when comparing the above-ground biomass with a summation of studies of other mangrove areas in Southeast Asia as listed by Rabiatul Khairunnisa and Mohd Hasmadi (2012).

The allometric equations developed by Komiyama et al. (2005) were the only ones used to determine the tree biomass. These equations are based on wood density, which according to Komiyama et al. (2008) may be a more important factor in the determination of biomass than site or species. Allometric equations are preferred as they are non-destructive.

Table 3.5. Species-specific wood density, tree biomass and tree carbon storage in managed Nipa (Source: World Agroforestry Centre, n.d.[1]).

Managed Nipa				
Species	**Wood density[1] (g/cm³)**	**AGB (t ha^{-1})**	**BGB (t ha^{-1})**	**CB (t ha^{-1})**
Aegiceras corniculatum	0,5967	0,21	0,10	0,14
Avicennia marina	0,7316	3,08	1,14	1,90
Avicennia officinalis	0,6500	12,87	4,65	7,88
Avicennia rumphiana	0,7316	8,72	2,72	5,15
Bruguiera parviflora	0,8427	0,11	0,05	0,07
Camptostemon philippinense	0,4867	0,25	0,10	0,16
Ceriops zippeliana	0,7250	0,13	0,06	0,09
Excoecaria agallocha	0,4288	1,65	0,65	1,04
Lumnitzera littorea	0,7270	12,29	3,94	7,30
Rhizophora apiculata	0,8814	3,14	1,09	1,90
Rhizophora mucronata	0,8483	0,29	0,13	0,19
Rhizophora stylosa	0,9400	4,29	1,42	2,57
Sonneratia alba	0,6443	28,42	9,48	17,05
Xylocarpus granatum	0,6721	0,11	0,05	0,07
Xylocarpus moluccensis	0,6535	6,42	1,80	3,70
Total	**-**	**81,97**	**27,39**	**49,21**

AGB is above-ground biomass; BGB is below-ground biomass; CB is carbon biomass.

Table 3.6. Species-specific wood density, tree biomass and tree carbon storage in unmanaged Nipa (Source: World Agroforestry Centre, n.d.[1]).

Unmanaged Nipa				
Species	**Wood density[1] (g/cm^3)**	**AGB ($t\ ha^{-1}$)**	**BGB ($t\ ha^{-1}$)**	**CB ($t\ ha^{-1}$)**
Aegiceras corniculatum	0,5967	1,78	0,87	1,19
Avicennia marina	0,7316	3,52	1,31	2,17
Avicennia rumphiana	0,7316	38,04	10,58	21,88
Lumnitzera littorea	0,7270	3,48	1,07	2,05
Osbornia octodonta	0,9475	1,19	0,47	0,75
Rhizophora apiculata	0,8814	17,00	5,63	10,18
Rhizophora mucronata	0,8483	0,21	0,09	0,13
Rhizophora stylosa	0,9400	7,27	2,79	4,53
Sonneratia alba	0,6443	69,36	22,53	41,35
Xylocarpus granatum	0,6721	0,37	0,15	0,23
Total	**-**	**142,21**	**45,50**	**84,47**

AGB is above-ground biomass; BGB is below-ground biomass; CB is carbon biomass.

3.4.3 Condition

Of the 451 stems ha^{-1} recorded in managed Nipa, 405 or 90% were classified as healthy, while unmanaged Nipa had only 72% healthy trees of the 674 stems ha^{-1} (Table 3.7). This was because unmanaged Nipa had much more unhealthy trees than managed Nipa had (21% against 2%). The high number of sick and dead trees could be due to the earthquake that struck the island October 15, 2013 as many trees (especially *Sonneratia alba*) along the river were also seen dead compared to before the earthquake (personal observation). However, a more likely explanation is mangrove competition for light and/or nutrients as most recorded sick trees were of *Aegiceras corniculatum* (89 stems ha^{-1} or 63%) (Appendix 8), a small understory tree species mainly observed in unmanaged open Nipa (58 stems ha^{-1} or 65%), mostly under a dense canopy layer of *S. alba*. Although this species is tolerant of a wide range of light conditions, it probably still needs more light than it is getting. A high number of unhealthy *A. corniculatum* was also observed in a study by Duke et al. (2005).

The most dead trees were of *S. alba*. In managed Nipa, 20% of the *S. alba* trees were dead compared to 12% in unmanaged Nipa. This was not only attributable to natural succession but also to cutting as this species was used for housing construction in the past (Primavera et al., 2004), before Lincod was entitled as a CBFMA area, further strengthened in 2011 by Executive Order No. 23 declaring a "moratorium on the cutting and harvesting of timber in natural and residual forests nationwide."

Table 3.7. Total mangrove tree condition between managed and unmanaged Nipa ([1] condition based on Duke et al., 2005).

	Managed Nipa		**Unmanaged Nipa**	
Condition[1]	Stems/ha	% of stems	Stems/ha	% of stems
Healthy	405	90	484	72
Sick	11	2	142	21
Dead	35	8	47	7
Total	451		674	

3.4.4 Diameter distributions

Mangrove tree species showed a “positive” diameter distribution of all species taken together in managed Nipa as well as in unmanaged Nipa (Figure 3.6 and 3.7). The observed reverse-J-shaped diameter distributions show an uneven-aged mixed species mangrove forest that is self-sustaining. The two diameter distributions differed significally between managed and unmanaged Nipa (KS-test, Dmax = 0,12, Dcrit = 0,01).

An exponential trendline was added to the graphs because of its ability to represent natural forest stands; a negative exponential trendline resembles an ideal natural forest. The negative exponential trendline showed a lack of small trees of 5 to 14 cm DBH, and 5 to 19 and 30 to 34 cm DBH than expected in managed and unmanaged Nipa respectively. Also, of the 284 stems ha^{-1} within diameter class 5 - 9 in unmanaged Nipa, as many as 147 stems belonged to *Aegiceras corniculatum*. This species is considered a shade-tolerant shrub or small tree, typically 2-3 m high but may reach 5 m (Primavera et al., 2004) and is therefore not to be found in the higher diameter classes. Diameter distributions of mangrove tree species are shown in chapter 3.4.6.

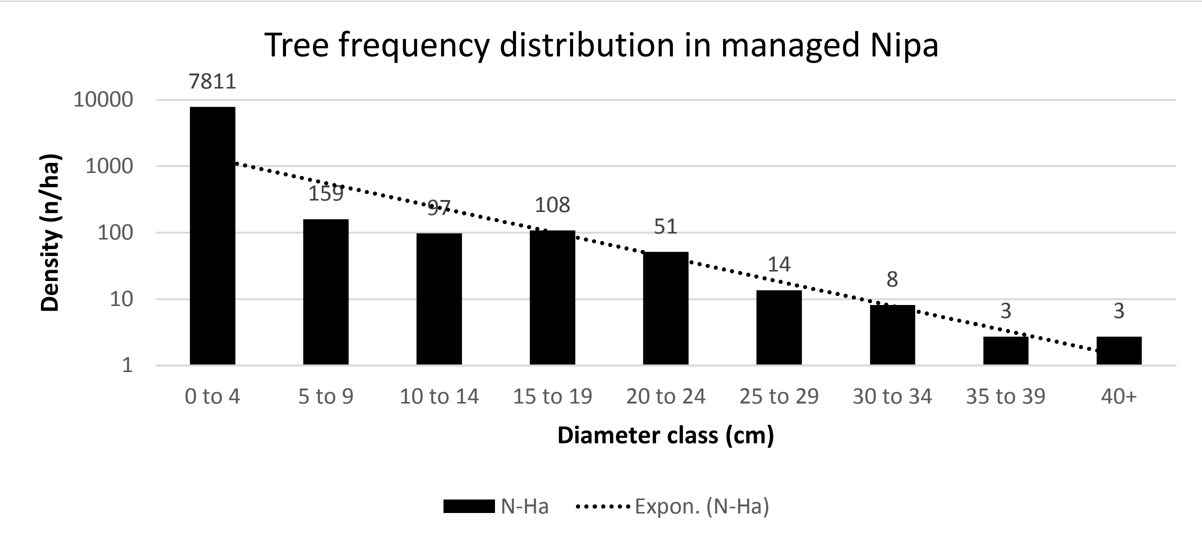

Figure 3.6. Diameter distributions of mangrove tree species in managed Nipa.

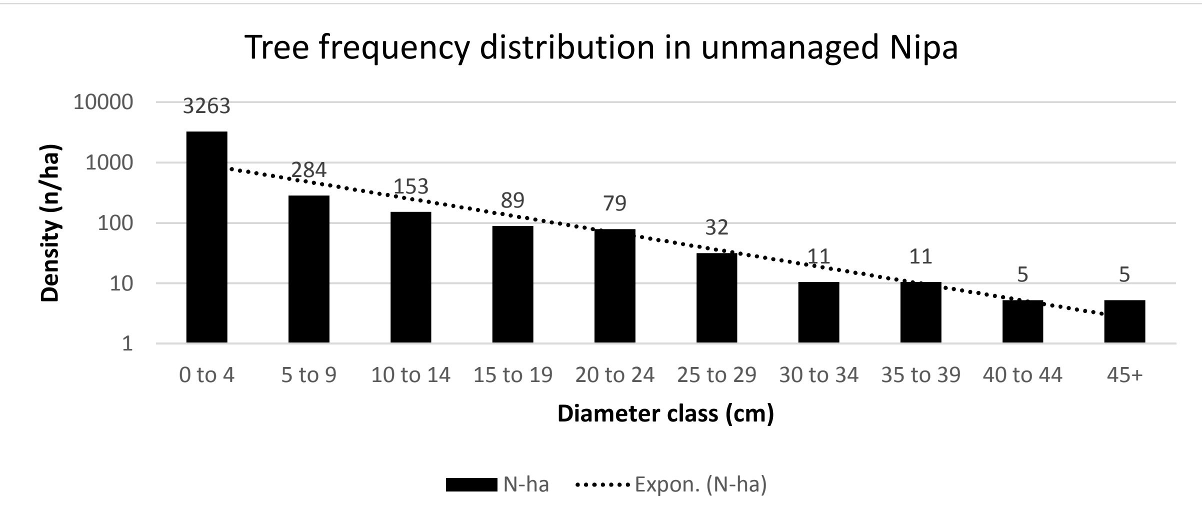

Figure 3.7. Diameter distributions of mangrove tree species in unmanaged Nipa.

3.4.5 Regeneration

The number of mangrove juveniles was higher in managed Nipa (7,810/ha^{-1}) than in unmanaged Nipa (3,263/ha^{-1}) (Figure 3.9 and Table 3.9). Mangrove juvenile densities were highly variable**.** However, based on the total number of juveniles, there was no significant difference (ANOVA, F = 0.256, df = 1, P = 0.61) in regeneration density between managed and unmanaged Nipa plots (Appendix 9).

Normally a minimum of 2,500 seedlings per ha are required to qualify natural regeneration as being sufficient (Srivastava at al., 1984). Managed Nipa had a very high likelihood of good natural regeneration for true mangrove species; a very high number of seedlings (7,086/ha^{-1}) compared to saplings (724/ha^{-1}) and adults (451/ha^{-1}). Unmanaged Nipa had a lower number of mangrove seedlings (2,916/ha^{-1}), and the number of saplings was less than the number of adults (347/ha^{-1} and 674/ha^{-1} respectively) and therefore had a lower likelihood of good natural regeneration.

The higher regeneration in managed Nipa could be explained by the fact that this was moderately disturbed (Nipa harvesting) compared to unmanaged Nipa. Hence in managed Nipa, there is less competition for light and space between the mangrove individuals and species, which provides a good regeneration potential. In unmanaged Nipa there is more competition for light between juveniles and adult trees as most individuals were pioneer species, which results in an increase in the mortality rate among juveniles. Some of the pioneer species their propagules drop into the mud immediately around the parent trees while others disperse by tidal action for an extended period until they strand in a "suitable" area (Tomlinson, 1986). This suitable area could be the managed Nipa which receives more light in the understory layer as compared to unmanaged Nipa which may be the one reason of good regeneration status.

Another reason for high juvenile mortality could be due to predation on propagules and recently rooted seedlings (especially on *Avicennia* and *Rhizophora* spp.) primary by grapsid crabs (Grapsidae), but also by insects, snails and rats (Murphy, 1990; Farnsworth and Ellison, 1997; Dahdouh-Guebas et al., 2011) The presence of crabs results in fewer mangrove seedlings and saplings, but does not affect trees (Primavera et al., 2009). Grapsid crabs (Figure 3.8) are considered significant seed predators of mangroves and can be a threat to the successful regeneration or restoration of mangroves (Smith et al., 1989; Dahdouh-Guebas et al., 1997). Grapsid crabs have selective preferences for propagules they eat. A global survey by Farnsworth and Ellison (1997) reported an overall propagule attack rate of 23% with species specific rates varying from 50% for *Avicennia marina* to 34% for *Rhizophora mucronata*, 28% for *Bruguiera gymnorrhiza*, 25% for *Ceriops tagal* and *R. apiculata*, and 18% for *R. stylosa*. A study by Smith et al. (1989) showed that grapsid crabs were able to exclude *A.marina* from the mid-intertidal area of a mangrove forest by consuming 100% of its propagules, but when they were excluded from this area, *A. marina* was able to establish and grow in this same mid-intertidal area. Although pre-dispersal

Figure 3.8. A purple climber crab (*Metopograpsus* spp.) of the Grapsidae family, feeding on a *Rhizophora apiculata* propagule.

predation contributes to seedling mortality, Farnsworth and Ellison (1997) concluded that mangrove seedling density remains to be explained by factors other than pre-dispersal predation.

Table 3.9. Regeneration status of mangrove tree species between managed and unmanaged Nipa.

	Managed Nipa		Unmanaged Nipa	
Life phase	Individuals (n)	Density (n/ha)	Individuals (n)	Density (n/ha)
Seedling	1311	7086	277	2916
Sapling	134	724	33	347
Tree	167	451	128	674
Total	1612		438	

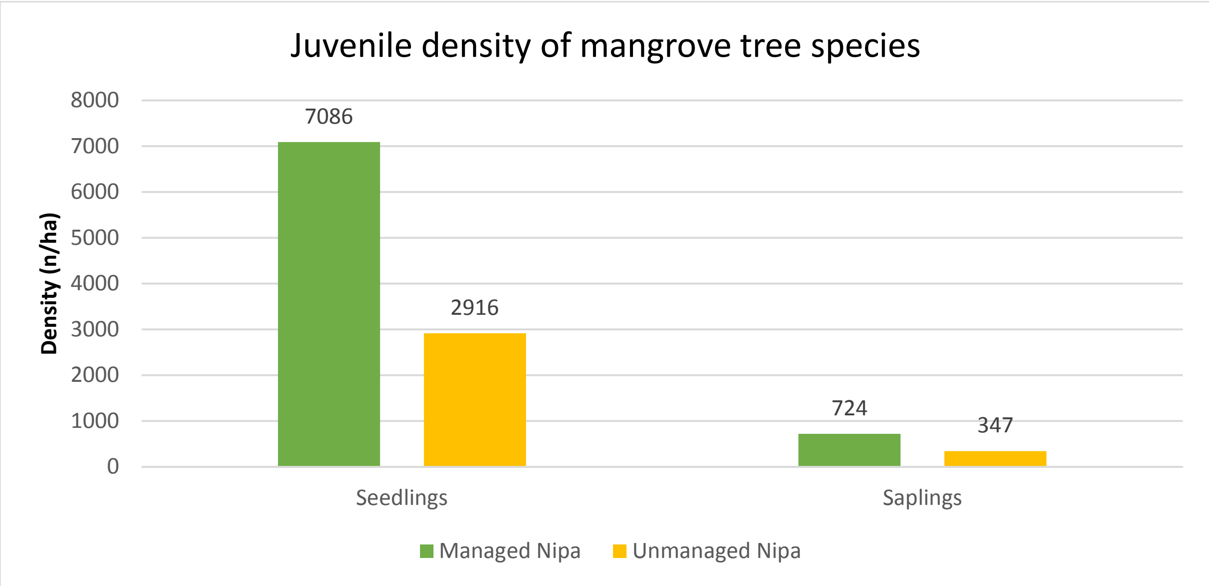

Figure 3.9. Comparison of seedling and sapling density between managed and unmanaged Nipa.

Mangrove species densities in three different life forms (tree, sapling and seedling), between managed and unmanaged Nipa are shown in Appendix 9. Of the 21 mangrove tree species found in Lincod, a total of 16 species regenerated in managed Nipa compared to 10 species in unmanaged Nipa. Comparison of regenerating mangrove species in managed Nipa showed that *Aegiceras corniculatum* was the most abundant (4,854 juveniles ha^{-1}) followed by *Ceriops zippeliana* and *Sonneratia alba* (757 and 411 juveniles per hectare respectively). The least abundant species was *Bruguiera gymnorrhiza* (5 juveniles' ha^{-1}). *A. corniculatum* and *C. zippeliana* were also the most abundant regenerating species in unmanaged Nipa (2,874 and 74 juveniles per hectare respectively), followed by the *Rhizophora* species (total of 168 juveniles ha^{-1} or 56 juveniles ha^{-1} per species).

On average, twelve parent trees are required per ha to serve as seed sources for regeneration (FAO, 1994). The mangrove species - *Aegiceras corniculatum, Avicennia marina, Ceriops zippeliana, Excoecaria agallocha, Rhizophora apiculata, Rhizophora stylosa, Sonneratia alba* and *Xylocarpus moluccensis* were good regenerating species in managed Nipa with reverse-J-shaped diameter distributions (Appendix 9). These species are expected to remain dominant in the near future. *Avicennia officinalis, A. Rumphiana* and *Lumnitzera littorea* were in infrequent regeneration phase. *Camptostemon philippinense* was found a not regenerating species with individuals only present in the adult form. Availability of seeds and competition among species for space and light may be the reason of no regeneration. *Bruguiera gymnorrhiza, B. Parviflora, Osbornia octodonta, Rhizophora mucronata,* and *Xylocarpus granatum* were not abundant.

In unmanaged Nipa only *Aegiceras corniculatum, Avicennia marina* and *Rhizophora stylosa* were found in frequent regeneration status. Three species - *A. rumphiana, R. apiculata* and *Sonneratia alba* had infrequent regeneration. Apparently, two mangrove species: *Lumnitzera littorea* and *Osbornia octodonta* have not reproduced and of four species - *A. officinalis, Ceriops zippeliana, R. mucronata*, *Xylocarpus granatum,* juveniles were present but mature adults were absent.

However, the sample size of 56 plots was not sufficient to conclude on the regeneration status per species as a high number of species were classified as not abundant - no mature individuals of these species were recorded in the plots while mature individuals were observed in managed and unmanaged Nipa. Also *Ceriops tagal, Heritiera littoralis, Lumnitzera racemosa* and *Scyphiphora hydrophylacea* were not recorded in the plots, but observed in Lincod in small numbers. Thus it was impossible to determine regeneration status for these species.

Diameter distributions of the six woody mangrove species with the highest importance value are shown in Figure 3.10. The stem numbers correspond to those shown in Appendix 9.

Sonneratia alba approximated a reverse-J-shaped distribution, meaning that the species is self-sustaining in managed Nipa, representing a healthy regenerating population. This is a fast-growing pioneer species, intolerant of shade with a low seed viability (Kathiresan et al., 2010). The bell shaped distribution that was found in unmanaged Nipa indicates that the population of *S. alba* is unstable and under threat due to lack of recruitment through regeneration.

Aegiceras corniculatum juveniles were not only found in managed Nipa, but also under closed canopy in the dense unmanaged Nipa due to its shade tolerance. This species is characterized by its small propagules, easy dispersion by water flows, and high reproduction ability, and, could therefore occur in high numbers.

Avicennia officinalis was abundant in managed Nipa, but trees and seedlings were not recorded in unmanaged Nipa. This species easily disperses and is fast growing/fast producing (Duke et al., 2010a). The high number of regeneration in managed Nipa could be due to the fact that *A. officinalis* is known to produce a carpet of seedlings under a parent tree as this is a suitable habitat.

Avicennia rumphiana had a low juvenile density in managed as well as in unmanaged Nipa. Although this species is known to be fast growing and one of the first to colonize new areas, it probably has a low reproduction ability along the Abatan River.

More *Rhizophora apiculata* and *R. stylosa* trees were recorded in unmanaged Nipa than in managed Nipa. These species remain as a seedling waiting for one of the nearby overhanging trees to die which would provide more light. Underneath a dense canopy, there is not enough light for a seedling to develop and grow, so the seedlings are using their own energy reserves, and waiting their time while growing very slow. Eventually they run out of energy, and if there is no light gap, they die.

Although the diameter frequency distributions formed a reverse-J shape, seedlings or saplings were often absent. However, mangrove establishment and recruitment appears to be sporadic and highly irregular in space (Saenger, 2002). Species vary greatly in how their regeneration appears. In general, the differences in regeneration between one species and another depends on different factors such as soil type, salinity, availability of seeds and competition for space, light and water.

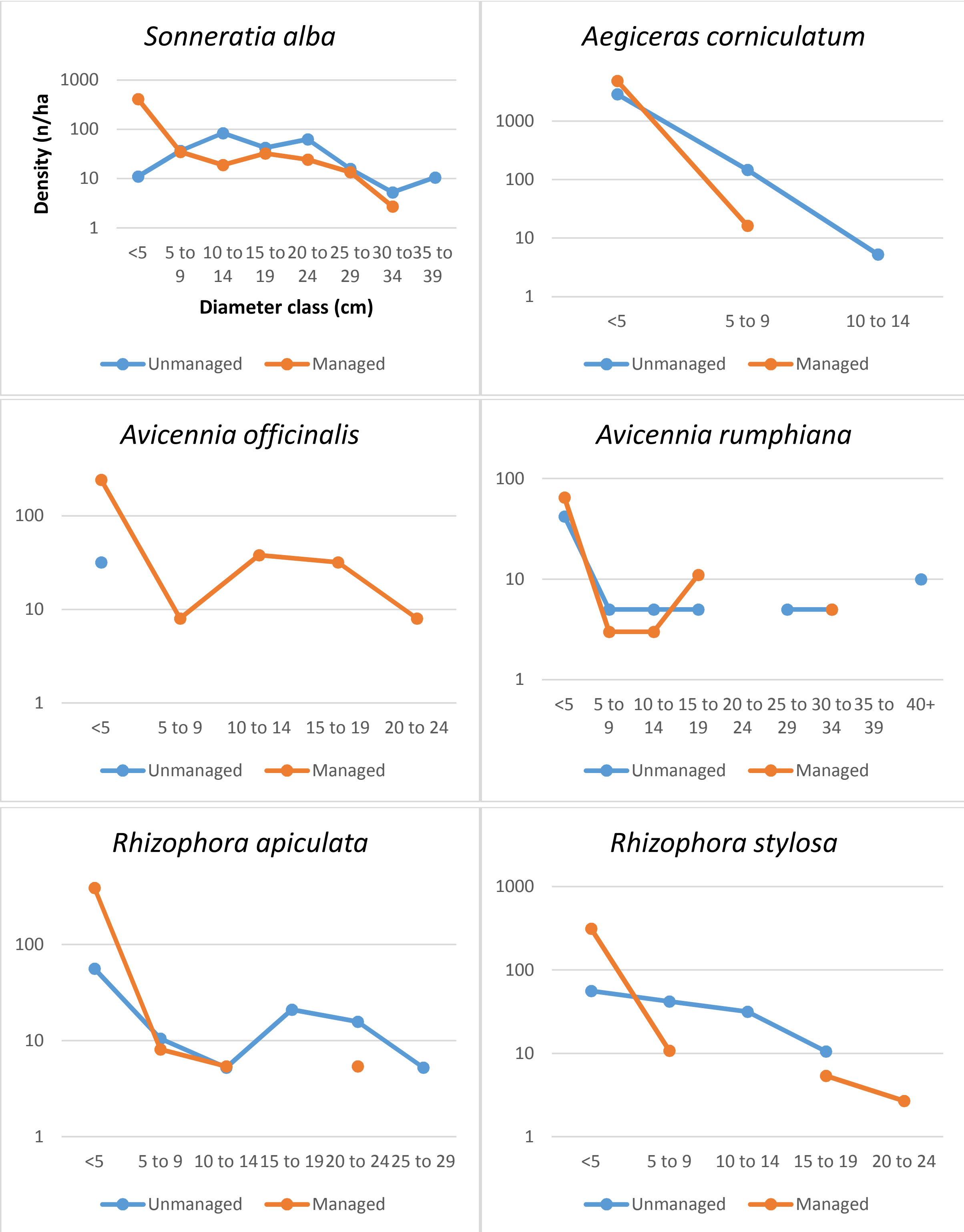

Figure 3.10. Diameter distributions of the six woody mangrove species with the highest importance value.

3.4.6 Understory development

Compared to other forest types, mangrove forests generally lack understory (Janzen, 1985; Snedaker and Lahmann, 1988). Shrubs, grasses, lianas, and other herbaceous plant species do not usually occur under the closed canopy in mangrove forests. This was also observed in Lincod. However, understory was seen in the managed Nipa areas which were highly disturbed, allowing more light to reach the forest floor. Of the mangrove understory species, the mangrove fern *Acrostichum aureum* was in addition to the dominant Nipa palm, which is also considered as an understory species, the most widely distributed, being recorded in two plots (frequency of 4%). This is a fast growing species, known to easily colonize disturbed areas in saline soils (Ellison et al., 2010a) and could therefore become a major barrier for natural mangrove rehabilitation, as observed elsewhere (Dahdouh-Guebas et al., 2005; Medina et al., 1990).

Also *A. speciosum* (Figure 3.11) and the shrubby herb *Acanthus volubilis* were seen. Common mangrove associated understory was composed of climbers like *Finlaysonia obovata* (recorded in 8 plots) and *Derris trifoliata* (recorded in 3 plots). The lack of herbaceous understory is probably related to the frequent tidal flooding and high salinity levels.

Figure 3.11. *Acrostichum speciosum* is a major barrier for natural mangrove recovery.

4 Conclusions

Based on the study, it is concluded that the Abatan River supports a rich diversity of mangroves representing 29 true mangrove species belonging to fourteen families. Six mangrove species (*Bruguiera sexangula, Camptostemon philippinense, Ceriops tagal, Cynometra iripa*, *Lumnitzera racemosa* and *Scyphiphora hydrophylacea*, of which the second is a globally endangered species) were found to be rare; their distribution is restricted to one or a few trees only. At present, all these species are at serious risk as no systematic attempt has been made to conserve them, nor to educate the local people about their significance and current situation. This data shows that the mangrove species composition is relatively high and therefore needs proper protection, conservation and management.

The mangrove forest in Lincod contained 26 mangrove species, dominated by two genera, *Avicennia* and *Rhizophora*. Twenty-one mangrove tree species were found, providing a high species diversity (H' 1.93), which justifies its essentiality for mangrove management and protection. An additional five non-woody species were documented. Mangrove diversity is probably boosted by the large freshwater discharge and sediments carried by the Abatan River along with tidal flushing from the Maribojoc Bay. The high average pore-water salinity makes it possible for mangroves to grow with eliminating most vascular plant species that are not adapted for growth in a saline habitat.

The overall mangrove structure was dominated by the distribution of two important species, namely *Sonneratia alba* and *Nypa fruticans*. *N. fruticans* and *Aegiceras corniculatum* occupy the understory showing a high density of individuals, while *S. alba* absolutely dominates (IVI of 103.23) and plays a crucial role in species composition of the sampling site. This was followed by *Avicennia officinalis* (IVI = 29.09) and *A. rumphiana* (IVI = 27). The least important species were *Bruguiera parviflora* (IVI = 1.57) and the globally endangered *Camptostemon philippinense* (IVI = 1.76). The species with a high importance value are pioneer species and are tolerant of a wide salinity range, while shade-tolerant climax species like *Bruguiera parviflora, Excoecaria agallocha, Rhizophora mucronata* and *Xylocarpus granatum* were less important. Understory other than Nipa and mangrove juveniles was almost not observed, which is good as it safeguards the characteristics of the low intertidal area of Lincod. Only in two plots the mangrove fern *Acrostichum aureum* was recorded. The presence of this species is an indication that the area is regularly disturbed. The total density, basal area and biomass of all woody mangroves is considered to be relatively low, compared to other riverine mangrove forests, which indicates that the mixed mangrove forest in Lincod is a secondary forest being of low structural development.

Population structure and regeneration status of mangrove tree species in terms of densities of seedlings, saplings and adults varied greatly between managed and unmanaged Nipa. Seventeen species were found in managed Nipa compared to twelve in unmanaged Nipa. *Sonneratia alba* and *Avicennia officinalis* showed the highest density in managed Nipa while unmanaged Nipa was dominated by *S. alba*, *Aegiceras corniculatum* and *Rhizophora stylosa*. Unmanaged Nipa had a higher tree density (674 compared to 451 stems ha^{-1} in managed Nipa) and basal area (22.53 compared to 14.45 m^2 ha^{-1} in managed Nipa), while managed Nipa a higher natural regeneration potential. Besides, the value of mangrove species diversity in managed Nipa was more diverse with Shannon-Wiener (H' = 2.203) as compared to unmanaged Nipa which had a lower value with Shannon-Wiener (H' = 1.693). This result indicates that moderate disturbances as Nipa management increases species diversity. Although managed Nipa had a higher species diversity, the biomass of mangrove trees was lower (109.36 compared to 187.71 t ha^{-1}). Normally, the higher the basal area, the greater the biomass and level of development of a mangrove community. The overall mangrove stand is considered in good health because of the active protection by ALIMANGO against illegal logging and fishpond conversion. In managed as well as in unmanaged Nipa a reverse-J-shaped diameter distribution was observed. However, in unmanaged Nipa, the shade-tolerant *A. corniculatum* predominated the lower diameter classes and of the total 674 stems ha^{-1}, only 72% were classified as healthy, compared to 90% in managed Nipa (n = 451 stems ha^{-1}). The high number of unhealthy trees is due to competition for light and/or nutrients with other trees as most were found under a dense canopy. These results show that Nipa has little to no effect on mature tree condition, but that large canopy trees have effect on lower Nipa quality which is the reason of why it is often left unmanaged. However, the significantly more dense unmanaged Nipa makes it more difficult for mangrove juveniles to establish with only three species in frequent regeneration status compared to eight in managed Nipa.

5 Recommendations

It is important to link science to management in order to have effective and efficient and sustainable mangrove management. Therefore, this study can be used as baseline data for future ecological studies as well as improving our scientific understanding of the mangrove forest dynamics and the role of Nipa. It is recommended that the Abatan River should be designated as a protected area under the National Integrated Protected Areas System (NIPAS) Act of 1992 as it has a high species diversity (H' 1.93) and as it is home to the globally endangered *Camptostemon philippinense* and the very rare and endemic *Pteroptyx macdermotti* firefly. Being a protected area is essential to conserve these species and protection of the mangrove forest also contributes to the conservation of many other species of wildlife that use the habitat as refuge. Urgent protection is needed for the remaining *Camptostemon philippinense* individuals as well as research to improve the low survivorship and to determine minimum viable population size**.** However, conservation of the mangroves would be necessary but is not enough. The dense unmanaged Nipa should be subjected to management for maximum structural development and to ensure that it will not displace woody mangrove species. Gaps should be created in the unmanaged Nipa to stimulate natural regeneration of pioneer mangrove species such as *Avicennia* spp. and *Sonneratia alba*. The small number of saplings and 'young' mangrove trees should be liberated by selectively eliminating competitive Nipa until they are tall enough to overtop the palms, so that they will be able to replace the older generations.

More data is required over a longer time period to compare mangrove regeneration status per species between managed and unmanaged Nipa, and to conclude on competition of Nipa with other mangroves. Further studies should consider other important factors such as substrate, tidal currents and propagule availability, dispersion, and predation. It is therefore important to note that long-term community-based field monitoring should be carried out at regular intervals to monitor species composition and structural changes of the Abatan mangrove forest.

Mass occurrence of the shade-tolerant *Acrostichum* spp. should be removed as these species form a threat to the growth and regeneration of mangrove trees and thereby decreases biodiversity.

Literature

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Appendix 1 Plot data

Line_no	Plot_no	Latitude*	Longitude*	Average high tide level (cm)	Average salinity (‰)
1	1	9,71741	123,86045		
1	2	9,71781	123,86090		
1	3	9,71861	123,86148		
2	4	9,71959	123,86154	60	32
2	5	9,71992	123,86084	70	28
2	6	9,72070	123,86057	55	22
2	7	9,72113	123,86039	45	31
3	8	9,71969	123,86473	75	29
3	9	9,72075	123,86374	80	
3	10	9,72142	123,86317		30
3	11	9,72210	123,86311	50	
3	12	9,72306	123,86266	70	31
4	13	9,72077	123,86636	60	
4	14	9,72082	123,86610	70	22
4	15	9,72138	123,86560		
4	16	9,72152	123,86535	55	26
4	17	9,72181	123,86493	55	27
4	18	9,72249	123,86375		
4	19	9,72334	123,86406		
5	20	9,72404	123,86653	55	20
5	21	9,72445	123,86609	50	28
5	22	9,72492	123,86532	50	22
6	23	9,72076	123,86701	95	
6	24	9,72100	123,86666	70	29
6	25	9,72148	123,86626	80	22
6	26	9,72172	123,86607	85	29
7	27	9,72044	123,86750	70	28
7	28	9,72023	123,86761	90	27
7	29	9,71997	123,86800	75	28
8	30	9,72206	123,86779	65	27
8	31	9,72300	123,86844	75	25
8	32	9,72417	123,86929	45	24
9	33	9,71673	123,87106		
9	34	9,71741	123,87057	95	26
9	35	9,71793	123,87056	100	
9	36	9,71841	123,86970	75	26
9	37	9,71922	123,86945	60	21
10	38	9,71780	123,87184	60	28
10	39	9,71835	123,87178	75	25
10	40	9,71937	123,87110	60	26
10	41	9,71965	123,87097	50	27
11	42	9,72102	123,87175	75	

11	43	9,72094	123,87122	65	22
11	44	9,72064	123,87049	75	30
11	45	9,72068	123,86998	60	26
11	46	9,72085	123,86919	60	29
12	47	9,72134	123,87257	60	20
12	48	9,72132	123,87174	50	23
12	49			60	27
12	50	9,72130	123,86898	95	24
12	51	9,72133	123,86807	75	18
13	52	9,72174	123,87311	75	28
13	53	9,72192	123,87262	80	28
13	54	9,72263	123,87228	65	28
13	55	9,72304	123,87207	60	28
13	56	9,72335	123,87146	70	29
			Average	68	26
			Standard Deviation	14	3
			Median	68	27
			Mode	60	28

* Latitude and longitude coordinates are in decimal degrees.

Appendix 2 Nipa plots

Managed Nipa

Line_no	Plot_no	Density class	Density (n/ha) x100	Leafstalks (n)	Leaves (n)	Leaves (%)	Leaf density (n/ha) x100	Average height (m)
1	1	moderately dense	132	8,3	2,65	32%	350	5,5
2	4	moderately dense	172	11,96	3,15	26%	542	4,5
2	5	open	42	8,94	3,31	37%	139	4
2	6	open	82	9,91	3,57	36%	293	4
2	7	moderately dense	132	12,24	2,71	22%	358	4,5
3	9	moderately dense	110	8,39	2,74	33%	301	5
3	10	moderately dense	178	9,97	2,58	26%	459	5,5
3	12	moderately dense	156	10,56	2,41	23%	376	5
4	13	very dense	188	12,31	3,46	28%	650	3,5
4	19	very dense	218	10,33	3,52	34%	767	4
5	20	very dense	210	9,12	3,47	38%	729	3,5
5	21	moderately dense	130	8,2	2,16	26%	281	4,5
5	22	very dense	242	12,42	3,33	27%	806	3
6	23	moderately dense	116	8,59	3,23	38%	375	5,5
6	25	open	46	11,64	3,79	33%	174	4,5
6	26	open	76	9	3	33%	228	3,5
7	27	moderately dense	142	9,25	3,26	35%	463	4,5
7	29	moderately dense	160	8,55	3,03	35%	485	4
8	31	moderately dense	176	9,24	2,76	30%	486	4,5
8	32	moderately dense	148	10,9	2,79	26%	413	6,5
9	33	moderately dense	140	8	2,33	29%	326	
9	36	open	92	9,86	3,38	34%	311	5,5
9	37	moderately dense	122	11,06	2,83	26%	345	4
10	38	moderately dense	162	9,58	3,67	38%	595	7

10	39	moderately dense	132	9,46	2,92	31%	385	
10	40	moderately dense	162	10,29	3,29	32%	533	4,5
10	41	very dense	220	9,69	3,23	33%	711	4,5
11	42	very dense	200	9,79	3,18	32%	636	5
11	45	moderately dense	134	10,32	3,46	34%	464	4,5
11	46	moderately dense	110	10,04	2,91	29%	320	4
12	47	very dense	192	9,03	2,27	25%	436	4
12	50	moderately dense	162	8,29	2,97	36%	481	4
12	51	moderately dense	160	10,54	3,57	34%	571	4,5
13	52	very dense	208	9,94	2,66	27%	553	6,5
13	54	moderately dense	168	12,43	2,43	20%	408	6
13	55	very dense	200	10,67	3,08	29%	616	4,5
13	56	moderately dense	176	10,41	2,59	25%	456	4
		Average	**151**	**9,98**	**3,02**	**31%**	**455**	**4,6**
		Standard Deviation	**47**	**1,26**	**0,43**	**5%**	**161**	**0,9**
		Median	**160**	**9,91**	**3,03**	**32%**	**456**	**4,5**

Unmanaged Nipa

Line_no	Plot_no	Density class	Density (n/ha) x100	Leafstalks (n)	Leaves (n)	Leaves (%)	Leaf density (n/ha) x100	Average height (m)
1	2	open	76	7,33	4,76	65%	362	8
1	3	open	82	11,42	4,11	36%	337	4
3	8	very dense	212	8,4	4,13	49%	876	6,5
3	11	moderately dense	136	12,92	5,25	41%	714	6,5
4	14	open	60	8,62	3,77	44%	226	5,5
4	15	open	18	8,89	4,44	50%	80	4,5
4	16	very dense	192	8,43	3,93	47%	755	6
4	17	very dense	216	9,33	4,17	45%	901	7
4	18	very dense	232	7,93	4,5	57%	1044	8

6	24	moderately dense	128	7,37	3,93	53%	503	7,5
7	28	open	34	7,94	3,65	46%	124	7
8	30	very dense	208	8,24	4,62	56%	961	5,5
9	34	moderately dense	160	6	3,78	63%	605	4,5
9	35	open	86	7,62	3,69	48%	317	
11	43	open	62	8,19	3,5	43%	217	7,5
11	44	very dense	224	8,11	4,17	51%	934	7
12	48	very dense	256	8,36	4,36	52%	1116	7,5
12	49	very dense	234	11,19	3,92	35%	917	4
13	53	very dense	192	9,34	3,97	43%	762	5
		Average	**148**	**8,72**	**4,14**	**49%**	**618**	**6,2**
		Standard Deviation	**77**	**1,61**	**0,43**	**8%**	**336**	**1,4**
		Median	**160**	**8,36**	**4,11**	**48%**	**714**	**6,5**

Results of One-Way ANOVA for palm density between managed and unmanaged Nipa

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Managed Nipa	37	5596	151,2432	2210,967
Unmanaged Nipa	19	2808	147,7895	5955,064

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	149,7456	1	149,7456	0,043292	0,83596	4,019541
Within Groups	186786	54	3458,999			
Total	186935,7	55				

Results of One-Way ANOVA for leaf density between managed and unmanaged Nipa

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Managed Nipa	37	16821,56	454,6368	26030,6873
Unmanaged Nipa	19	11750,74	618,46	112657,7937

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	336913,4	1	336913,4	6,136142702	0,016406	4,019541
Within Groups	2964945	54	54906,39			
Total	3301858	55				

Appendix 3 Mangrove tree species diversity in Lincod

Shannon-Wiener Diversity Index in Lincod				
Species	**Density (n/ha)**	**Relative density (Pi)**	**ln(Pi)**	**Pi*ln(Pi)**
Aegiceras corniculatum	63	0,118644068	-2,131627295	-0,252904933
Avicennia marina	34	0,06440678	-2,742536377	-0,176637936
Avicennia officinalis	57	0,108474576	-2,221239454	-0,240948009
Avicennia rumphiana	27	0,050847458	-2,978925155	-0,151470771
Bruguiera parviflora	2	0,003389831	-5,686975356	-0,019277883
Camptostemon philippinense	2	0,003389831	-5,686975356	-0,019277883
Ceriops zippeliana	7	0,013559322	-4,300680995	-0,058314319
Excoecaria agallocha	23	0,044067797	-3,122025999	-0,137580807
Lumnitzera littorea	32	0,061016949	-2,796603598	-0,17064022
Osbornia octodonta	5	0,010169492	-4,588363068	-0,046661319
Rhizophora apiculata	32	0,061016949	-2,796603598	-0,17064022
Rhizophora mucronata	11	0,020338983	-3,895215887	-0,07922473
Rhizophora stylosa	41	0,077966102	-2,55148114	-0,198929038
Sonneratia alba	180	0,342372881	-1,071854839	-0,36697403
Xylocarpus granatum	4	0,006779661	-4,993828176	-0,033856462
Xylocarpus moluccensis	7	0,013559322	-4,300680995	-0,058314319
Total of all species	**527**			
		Shannon-Wiener Diversity Index (H')		**1,928747943**

Appendix 4 Mangrove tree species diversity between managed and unmanaged Nipa

Shannon-Wiener Diversity Index for managed Nipa				
Species	**Density (n/ha)**	**Relative density (Pi)**	**ln(Pi)**	**Pi*ln(Pi)**
Aegiceras corniculatum	16	0,035912215	-3,326677802	-0,119468367
Avicennia marina	32	0,071824429	-2,633530622	-0,189151834
Avicennia officinalis	87	0,191753491	-1,65154463	-0,316689449
Avicennia rumphiana	22	0,047882953	-3,03899573	-0,145516089
Bruguiera parviflora	3	0,005985369	-5,118437271	-0,030635736
Camptostemon philippinense	3	0,005985369	-5,118437271	-0,030635736
Ceriops zippeliana	11	0,023941476	-3,73214291	-0,089353011
Excoecaria agallocha	35	0,077809798	-2,553487914	-0,198686379
Lumnitzera littorea	46	0,101751275	-2,285223927	-0,232524447
Rhizophora apiculata	19	0,041897584	-3,172527122	-0,132921221
Rhizophora mucronata	14	0,029926845	-3,508999359	-0,105013282
Rhizophora stylosa	19	0,041897584	-3,172527122	-0,132921221
Sonneratia alba	132	0,293504766	-1,225861401	-0,359796164
Xylocarpus granatum	3	0,005985369	-5,118437271	-0,030635736
Xylocarpus moluccensis	11	0,023941476	-3,73214291	-0,089353011
Total of all species	**451**			
			Shannon-Wiener Diversity Index (H')	**2,203301684**

Shannon-Wiener Diversity Index for unmanaged Nipa				
Species	**Density (n/ha)**	**Relative density (Pi)**	**ln(Pi)**	**Pi*ln(Pi)**
Aegiceras corniculatum	153	0,226510316	-1,484964789	-0,336359844
Avicennia marina	37	0,05462372	-2,907287063	-0,158806834
Avicennia rumphiana	37	0,05462372	-2,907287063	-0,158806834
Lumnitzera littorea	5	0,007867003	-4,845078087	-0,038116244
Osbornia octodonta	16	0,023452575	-3,752774968	-0,088012238
Rhizophora apiculata	58	0,085943298	-2,454067523	-0,210910657
Rhizophora mucronata	5	0,007867003	-4,845078087	-0,038116244
Rhizophora stylosa	84	0,124981446	-2,079589987	-0,259910163
Sonneratia alba	274	0,406263916	-0,900752292	-0,365943153
Xylocarpus granatum	5	0,007867003	-4,845078087	-0,038116244
Total of all species	**674**			
			Shannon-Wiener Diversity Index (H')	**1,693098456**

Appendix 5 Mangrove sapling diversity between managed and unmanaged Nipa

Shannon-Wiener Diversity Index for managed Nipa				
Species	**Density (n/ha)**	**Relative density (Pi)**	**ln(Pi)**	**Pi*ln(Pi)**
Aegiceras corniculatum	286	0,395573997	-0,927417411	-0,366862213
Avicennia rumphiana	11	0,015214385	-4,185513949	-0,063680019
Bruguiera parviflora	5	0,006915629	-4,97397131	-0,034398142
Ceriops zippeliana	178	0,246196404	-1,401625672	-0,3450752
Excoecaria agallocha	32	0,044260028	-3,117673319	-0,137988307
Lumnitzera littorea	16	0,022130014	-3,8108205	-0,08433351
Osbornia octodonta	5	0,006915629	-4,97397131	-0,034398142
Rhizophora apiculata	103	0,142461964	-1,948680234	-0,277612813
Rhizophora mucronata	27	0,037344398	-3,287572356	-0,122772412
Sonneratia alba	22	0,030428769	-3,492366769	-0,106268422
Xylocarpus granatum	22	0,030428769	-3,492366769	-0,106268422
Xylocarpus moluccensis	16	0,022130014	-3,8108205	-0,08433351
Total	**723**			
		Shannon-Wiener Diversity Index (H')		**1,763991111**

Shannon-Wiener Diversity Index for unmanaged Nipa				
Species	**Density (n/ha)**	**Relative density (Pi)**	**ln(Pi)**	**Pi*ln(Pi)**
Aegiceras corniculatum	147	0,422413793	-0,861769893	-0,364023489
Avicennia marina	53	0,152298851	-1,881910566	-0,286612816
Avicennia officinalis	32	0,091954023	-2,386466577	-0,219445202
Avicennia rumphiana	42	0,120689655	-2,114532861	-0,255202242
Ceriops zippeliana	74	0,212643678	-1,548137387	-0,329201628
Total	**348**			
		Shannon-Wiener Diversity Index (H')		**1,454485378**

Appendix 6 Mangrove seedling diversity between managed and unmanaged Nipa

Shannon-Wiener Diversity Index for managed Nipa

Species	Density (n/ha)	Relative density (Pi)	ln(Pi)	Pi*ln(Pi)
Aegiceras corniculatum	4568	0,644742414	-0,438904401	-0,282980283
Avicennia spp.	486	0,068595625	-2,679526528	-0,183803796
Avicennia rumphiana	54	0,007621736	-4,876751106	-0,03716931
Bruguiera gymnorrhiza	5	0,000705716	-7,25629724	-0,005120887
Bruguiera parviflora	54	0,007621736	-4,876751106	-0,03716931
Ceriops zippeliana	578	0,081580805	-2,506161283	-0,204454654
Lumnitzera littorea	11	0,001552576	-6,467839879	-0,010041812
Osbornia octodonta	11	0,001552576	-6,467839879	-0,010041812
Rhizophora spp.	859	0,121242061	-2,10996623	-0,255816654
Sonneratia alba	389	0,054904728	-2,902155809	-0,159342076
Xylocarpus granatum	5	0,000705716	-7,25629724	-0,005120887
Xylocarpus moluccensis	65	0,009174312	-4,691347882	-0,043039889
Total	**7085**			
		Shannon-Wiener Diversity Index (H')		**1,234101369**

Shannon-Wiener Diversity Index for unmanaged Nipa

Species	Density (n/ha)	Relative density (Pi)	ln(Pi)	Pi*ln(Pi)
Aegiceras corniculatum	2726	0,93484225	-0,067377481	-0,062987316
Rhizophora spp.	168	0,057613169	-2,854004114	-0,164428221
Sonneratia alba	11	0,003772291	-5,58007282	-0,021049657
Xylocarpus granatum	11	0,003772291	-5,58007282	-0,021049657
Total	**2916**			
		Shannon-Wiener Diversity Index (H')		**0,269515**

Appendix 7 Structural characteristics of mangroves between managed and unmanaged Nipa

	Managed Nipa				Unmanaged Nipa			
Species	Basal area (m^2/ha)	Density (n/ha)	Average height (m)	Average DBH (cm)	Basal area (m^2/ha)	Density (n/ha)	Average height (m)	Average DBH (cm)
Aegiceras corniculatum	0,08	16	5,2 ± 0,8	5,8 ± 0,8	0,67	153	4,2 ± 1,3	5,5 ± 1
Avicennia marina	0,61	32	11,2 ± 4,7	10,6 ± 4,9	0,70	37	10,7 ± 3,5	10,9 ± 4,6
Avicennia officinalis	2,67	86	11,4 ± 2,6	14,4 ± 3,6				
Avicennia rumphiana	1,28	22	14 ± 8,2	19 ± 8,4	4,57	37	17,9 ± 2,8	26,9 ± 13,8
Bruguiera parviflora	0,02	3	13	8				
Camptostemon philippinense	0,07	3	11	14				
Ceriops zippeliana	0,04	11	5,5 ± 0,6	5,3 ± 0,5				
Excoecaria agallocha	0,56	35	7,7 ± 1,4	9,6 ± 4,8				
Lumnitzera littorea	1,91	46	11,4 ± 1,7	16,3 ± 7,4	0,50	5	10	26
Osbornia octodonta					0,21	16	7,3 ± 0,6	9,7 ± 2,1
Rhizophora apiculata	0,48	19	10,6 ± 3,2	12,3 ± 5,7	2,36	58	10 ± 2,6	16,1 ± 6
Rhizophora mucronata	0,07	14	7,8 ± 1,9	6,2 ± 0,8	0,05	5	9	8
Rhizophora stylosa	0,57	19	8,3 ± 2	13 ± 7,2	1,24	84	11,9 ± 2,9	9,8 ± 3
Sonneratia alba	5,20	132	12,9 ± 6,5	15,6 ± 7	12,13	274	13,8 ± 5,9	16,2 ± 7,8
Xylocarpus granatum	0,03	3	12	9	0,09	5	16	11
Xylocarpus moluccensis	0,86	11	13,3 ± 4,7	19,3 ± 16,3				
Total of all species	**14,45**	**451**	**11,1**	**13,6**	**22,53**	**674**	**10,9**	**13,1**
Standard Deviation	**1,40**	**36**	**4,7**	**6,9**	**3,74**	**86**	**5,8**	**8,4**

* Indicates the dominant species while + indicates the co-dominant species. (average ± standard deviation).

Results of One-Way ANOVA for mangrove tree species density between managed and unmanaged Nipa

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Managed Nipa	15	451,3514	30,09009	1265,644
Unmanaged Nipa	10	673,6842	67,36842	7367,19

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8338,044	1	8338,044	2,282391	0,144468	4,279344
Within Groups	84023,73	23	3653,205			
Total	92361,77	24				

Appendix 8 Mangrove tree condition

Species condition in managed Nipa				
Species	**Healthy (n/ha)**	**Sick (n/ha)**	**Dead (n/ha)**	**Total (n/ha)**
Aegiceras corniculatum	11	5		**16**
Avicennia marina	32			**32**
Avicennia officinalis	84		3	**86**
Avicennia rumphiana	22			**22**
Bruguiera parviflora	3			**3**
Camptostemon philippinense	3			**3**
Ceriops zippeliana	11			**11**
Excoecaria agallocha	35			**35**
Lumnitzera littorea	43		3	**46**
Rhizophora apiculata	14	3	3	**19**
Rhizophora mucronata	14			**14**
Rhizophora stylosa	16	3		**19**
Sonneratia alba	105		27	**132**
Xylocarpus granatum	3			**3**
Xylocarpus moluccensis	11			**11**
Total of all species	**405**	**11**	**35**	**451**

Species condition in unmanaged Nipa				
Species	**Healthy (n/ha)**	**Sick (n/ha)**	**Dead (n/ha)**	**Total (n/ha)**
Aegiceras corniculatum	53	89	11	**153**
Avicennia marina	37			**37**
Avicennia rumphiana	37			**37**
Lumnitzera littorea		5		**5**
Osbornia octodonta	16			**16**
Rhizophora apiculata	58			**58**
Rhizophora mucronata	5			**5**
Rhizophora stylosa	63	16	5	**84**
Sonneratia alba	211	32	32	**274**
Xylocarpus granatum	5			**5**
Total of all species	**484**	**142**	**47**	**674**

Appendix 9 Regeneration status

Managed Nipa											
Species	**Seedlings**	**Saplings**	**5 to 9**	**10 to 14**	**15 to 19**	**20 to 24**	**25 to 29**	**30 to 34**	**35 to 39**	**40+**	**Status**
Aegiceras corniculatum	4568	286	16								Frequent
*Avicennia marina**	243		16	8	8						Frequent
*Avicennia officinalis**	243		8	38	32	8					Infrequent
Avicennia rumphiana	54	11	3	3	11			5			Infrequent
Bruguiera gymnorrhiza	5										Not abundant
Bruguiera parviflora	54	5	3								Not abundant
Camptostemon philippinense				3							No regeneration
Ceriops zippeliana	578	178	11								Frequent
Excoecaria agallocha		32	24	5	3	3					Frequent
Lumnitzera littorea	11	16	5	14	14	8			3		Infrequent
Osbornia octodonta	11	5									Not abundant
*Rhizophora apiculata**	286	103	8	5		5					Frequent
*Rhizophora mucronata**	286		14								Not abundant
*Rhizophora stylosa**	286	27	11		5	3					Frequent
Sonneratia alba	389	22	35	19	32	24	14	3			Frequent
Xylocarpus granatum	5	22	3								Not abundant
Xylocarpus moluccensis	65	16	3	3	3					3	Frequent
Total density (n/ha)	**7086**	**724**	**159**	**97**	**108**	**51**	**14**	**8**	**3**	**3**	

* Number of seedlings was divided between the total genus density as it was often not possible to identify them to the species level.

Unmanaged Nipa											
Species	**Seedlings**	**Saplings**	**5 to 9**	**10 to 14**	**15 to 19**	**20 to 24**	**25 to 29**	**30 to 34**	**35 to 39**	**40+**	**Status**
Aegiceras corniculatum	2726	147	147	5							Frequent
*Avicennia marina**		53	16	11	11						Frequent
*Avicennia officinalis**		32									Not abundant
Avicennia rumphiana		42	5	5	5		5	5		10	Infrequent
Bruguiera gymnorrhiza											
Bruguiera parviflora											
Camptostemon philippinense											
Ceriops zippeliana		74									Not abundant
Excoecaria agallocha											
Lumnitzera littorea							5				No regeneration
Osbornia octodonta			11	5							No regeneration
*Rhizophora apiculata**	56		11	5	21	16	5				Infrequent
*Rhizophora mucronata**	56		5								Not abundant
*Rhizophora stylosa**	56		42	32	11						Frequent
Sonneratia alba	11		37	84	42	63	16	5	11		Infrequent
Xylocarpus granatum	11			5							Not abundant
Xylocarpus moluccensis											
Total density (n/ha)	**2916**	**347**	**274**	**153**	**89**	**79**	**31**	**11**	**11**	**10**	

* Number of seedlings was divided between the total genus density as it was often not possible to identify them to the species level.

Results of One-Way ANOVA for mangrove regeneration density between managed and unmanaged Nipa

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Managed Nipa	37	7805,405	210,9569	77742,86
Unmanaged Nipa	19	3231,579	170,0831	90295,64

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	20972,84	1	20972,84	0,255994	0,6149	4,019541
Within Groups	4424064	54	81927,12			
Total	4445037	55				

Appendix 10 Mangrove species reported in this study

(1) Diluario (*Acanthus ebracteatus*)

(2) *Acanthus volubilis*

(3) Lagolo (*Acrostichum aureum*)

(4) Paku laot (*Acrostichum speciosum*)

(5) Saging-saging (*Aegiceras corniculatum*)

(6) Bungalon (*Avicennia marina*)

(7) Api-api (*Avicennia officinalis*)

(8) Piapi (*Avicennia rumphiana*)


(9) Busain (*Bruguiera gymnorrhiza*)


(10) Langarai (*Bruguiera parviflora*)


(11) Pototan *(Bruguiera sexangula)*

(12) Gapas-gapas (*Camptostemon philippinense*)

(13) Tangal (*Ceriops tagal*)

(14) *Ceriops zippeliana*

(15) *Cynometra iripa*

(16) Tuwi (*Dolichandrone spathacea*)

(17) Alipata (*Excoecaria agallocha*)


(18) Dungan late (*Heritiera littoralis*)


(19) Tabau (*Lumnitzera littorea*)


(20) Kulasi (*Lumnitzera racemosa*)

(21) Nipa (*Nypa fruticans*)

(22) Taualis (*Osbornia octodonta*)

(23) Bakauan lalaki (*Rhizophora apiculata*)

(24) Bakauan babae (*Rhizophora mucronata*)

(25) Bakauan bato (*Rhizophora stylosa*)

(26) Nilad (*Scyphiphora hydrophylacea*)

(27) Pagatpat (*Sonneratia alba*)

(28) Tabigi (*Xylocarpus granatum*)

(29) Piagau (*Xylocarpus moluccensis*)