Community-based Mangrove Planting Handbook

A step-by-step guide to implementing a mangrove rehabilitation project for the coastal communities of Papua New Guinea

OFFICE OF CLIMATE CHANGE AND DEVELOPMENT

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Papua New Guinea Office of Climate Change and Development (OCCD)

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Front cover

General view of *Rhizophora* plantation at Idubada in Port Moresby

Propagule of *Bruguiera sexangula* attached to parent tree

Mangrove nursery at Motupore Island Research Centre

Youths planting mangroves at Pelipatu, Manus Island

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Minister's Message

Message from the Minister for Forests and Climate Change

Climate Change is here to stay. It has no boundaries and cuts across all sectors of the economy. It is important that Climate Change must be mainstreamed and implemented through the policies of other sectors, in particular, agriculture, transport, forestry, water resources, land-use and environment.

The issues and challenges of climate change and the strategies to address them clearly complements the national goals of poverty alleviation and sustainable development, as is articulated under pillar five of Vision 2050.

There is the political will as indicated by the creation of the Office of Climate Change and Development and its elevation to have its own Ministry. Papua New Guinea is a leader in the region on matters of climate change.

HON. JOHN PUNDARI, OBE, MP

We are in the process of developing a climate change policy. The policy will help to draft a climate change legislation which we expect to get through parliament later this year.

All stakeholders including government, private sector, development partners, non-government organizations and the civil society in general must work together to address this emerging issue of Climate Change. Climate change is a global issue but the strategies to foster resilience has to be driven by the local communities exposed to the climate change risks

Adaptation to the adverse effects of climate change is vital in order to reduce the impacts of climate change that are happening now and increase resilience to future impacts. Coastal flooding and sea surges among other climate related risks are prevalent in most coastal communities throughout PNG. The cost in terms of casualties and damage to assets resulting from sea level rise will continue to increase annually unless we initiate cost effective adaptation measures. It has been identified that mangrove planting and rehabilitation is the most effective and least cost method of coastal defense against rising sea level. Mangrove plants not only provide buffer and hence reduce or ameliorate the intensity or severity of coastal flooding, but also promote eco-tourism and serve as a breeding ground for marine bio-diversity.

Our overall adaptation strategy is to;

Firstly, identify, coordinate and monitor programs and projects that support the development of specific adaptation solutions that protect the country's assets and people against the risk of climate change,

Secondly, reduce-climate related risks in vulnerable communities through an integrated approach that addresses both short and long term impacts, hence making climate risk management a part of national development planning, and

Thirdly, lead and coordinate climate change adaptation initiatives by consulting and soliciting expert advice from all stakeholders including our development partners, central government line agencies, non-government organizations, private sector and the civil society at large.

Finally, I wish to acknowledge the contribution made by the Wildlife Conservation Society (WCS), the Executive Director and his staff from the Adaptation Division of the Office of Climate Change and Development and UNDP through the Adaptation Fund for assisting with the publication of this Community Based Mangrove Planting Handbook.

I hope this Handbook will become a useful tool for anyone and everyone who wish to take up mangrove planting as a first line of defense against coastal flooding and sea surges.

……..
HONORABLE PATRICK PRUAITCH, CMG, MP
Minister for Forest and Climate Change

Foreword

Executive Director of the Office of Climate Change and Development

Executive Director, Mr Varigini Badira

The Office of Climate Change and Development (OCCD) was established in 2010 and tasked with a very important developmental function – to deliver on Pillar 5 of Vision 2050. This and all other overarching policy documents support and provide for mainstreaming and committing resources to addressing issues of climate change as a whole of government approach. All stakeholders including government, private sector, development partners, non-government organizations and the civil society in general must work together to address this emerging issue of Climate Change.

OCCD is basically tasked with ensuring that Papua New Guinea follows a path of climate-compatible growth; that the country's economy develops while simultaneously mitigating greenhouse gas emissions and reducing vulnerability to climate change risks.

The objective is to ensure that our people build their capacities to be resilient to the risks and impacts of climate change through the implementation of appropriate adaptation measures to counter extreme weather and climatic events.

Progress has been made to integrate climate change adaptation and risk reduction both at the national policy level and the local level. What has emerged is that, while drawing on international expertise and support, most initiatives and support are targeted at local needs and problems and can be addressed from within – as is often quoted, "think globally but act locally".

Protecting ecosystems, improving farming methods, developing early warning systems, instituting building designs, water excesses and shortages and enhancing public awareness and education are adaptation/mitigation measures which can be done, and OCCD is committed to it and is happy to work with everyone.

This Mangrove Handbook can be used as a tool to advance the Millions of Mangrove Initiative that is aimed at helping rural communities with the necessary skills to take responsibilities for their actions to protect themselves from increased coastal flooding and sea surges. The Handbook is meant to be used in the field as it clearly shows a step-by- step guide beginning with planning, site analysis, identifying the right species, planting and ensuring its survival.

It is our hope that this practical handbook is used extensively and we encourage all stakeholders particularly our community leaders in coastal communities across PNG to take up mangrove planting as a least cost method of coastal defense.

Finally, I wish to acknowledge all contributions made towards the drafting and eventual publishing of this handbook and in particular the Wildlife Conservation Society (WCS).

I welcome and endorse this Mangrove Handbook as a demonstration of our commitment to helping vulnerable coastal communities throughout Papua New Guinea.

God bless Papua New Guinea.

……
VARIGINI BADIRA
Executive Director

Acknowledgements

This Community-based Mangrove Planting Handbook was developed as an activity under the Millions of Mangrove Initiative (MoM) of the OCCD. This is a result of the collaboration and coordination through the Mangrove sub-working group established under the climate change Adaptation Technical Working Group (ATGW). We would like to thank the mangrove sub-working group comprised of experienced representatives from the Mama Graun Conservation Trust Fund, WWF, WCS, TNC, UPNG, PNGFA, DEC, PNGCLMA, OPRA and OCCD for their valuable contributions and time.

The OCCD would like to acknowledge those who contributed (listed on separate page) significantly to starting up the pages of this handbook and motivated its production. Thank you to our reviewers, Arison Arihafa and Nathan Whitmore of WCS, David Mitchell of Conservation International, Tanya Zeriga-Alone and Roy Banka of LEAF. A special thank you to the WCS PNG Country Program for seconding Mazzella Maniwavie to the OCCD to finalise this handbook.

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Glossary of Terms and Abbreviations

Abiotic	Refers to the non-living components of the environment e.g. water and soil.
Abscission collar	The part joining the cap of a propagule to the hypocotyl, where the hypocotyl when ripe detaches from.
Afforestation	Planting trees where they did not originally occur, e.g. on mudflats.
Anaerobic	Lacking oxygen
Anthropogenic	Made by man.
Biodiversity	Biological diversity; the number and relative abundance of different species of plants, animals and micro-organisms, in an ecosystem.
Biomass	Total weight of animals and /or plants per unit area.
Brackish	Water that is a mixture of seawater and freshwater, as in river mouths.
CBO	Community - based Organisation
CI	Conservation International
Community	Any group of organisms or a population belonging to a number of different species that coexist in the same area and interact with each other and their environment.
CPG	Community Project Group.
CPM	Community Project Manager.
Conservation	The protection, maintenance, management, and restoration of the natural environment.
DEC	Department of Environment and Conservation
Deforestation	Clearing forest.
Detritus	Remains of dead and decomposing plants and animals.
Ecology	The scientific study of interactions between organisms and their physical and biotic environment
Ecosystem	A unit made up of the complex interactions of the biotic community of plants, animals and micro-organisms, including humans with the abiotic environment such as soil, water and temperature.
Ecosystem restoration	Act of bringing an ecosystem back into, as nearly as possible, to its original condition, renewing it or bringing it back into use.
Eh:	Redox potential, a quantitative measure of the reducing power of chemical elements in soil. Redox potential also provides a means of measuring the degree of available dissolved oxygen in soil.
Family	A group consisting of related genera of plants or animals that share similar characteristics. E.g. Rhizophoraceae.

Genus (plural: genera)	A group of species regarded as so closely related, sharing very similar features. In biological classification it is above the species level. E.g. Bruguiera.
Ground-truthing	Confirming maps obtained from satellite images by doing ground surveys.
Habitat	The environment occupied by individuals of a particular species.
Hardening	A nursery procedure in which seedlings are toughened to withstand conditions of the out planting area through gradual exposure to sunlight and controlled watering prior to out planting.
Hydrological	The depth, duration and frequency of tidal inundation, and of tidal flooding.
Hypocotyl	The portion of a seedling between the stem and root. In Rhizophora it is the main cylindrical part of the propagule.
In-kind contribution	Donate goods such as nursery materials (e.g. tools) or services such as labour and transport instead of money as contribution towards a project.
Intertidal zone	The intertidal generally refers to the area that is above water at low tide and under water at high tide.
Inundation	A condition in which water from any source temporarily or permanently covers a land surface.
Implementing entity	Organisations or groups responsible for carrying out required project actions, considered to be NGOs, CBOs and communities
Mangrove	Trees, shrubs, palms or ground ferns growing in the zone between high and low tide marks.
Mangrove buffers	Strands of mangroves that protect communities from storm surges and coastal erosion, either natural or artificially planted.
MoM	Millions of Mangroves initiative.
Mudflats	Open expanses of inter-tidal mud, usually at the entrance of an estuary, tidal creek or seaward edge of mangrove forest.
Non viviparous	Having seeds that start germinating after the seed detaches from the parent tree.
NFA	National Fisheries Authority.
NGO	Non-governmental organisation.
NRI	National Research Institute.
Nursery bed	A bed used to grow seedlings until they are ready to be planted in a permanent site.
OCCD	Office of Climate Change and Development
PNGOPRA	Papua New Guinea Oil Palm Research Association
Organic matter	That portion of the soil that is composed of the remains of plants, animals and micro-organisms that once lived and their waste products in the environment.
Outplant	To transplant a seedling from a nursery bed, greenhouse or other location to the area assigned for reforestation.

Pest	A destructive insect or other animal that attacks plants, crops, food or livestock.
pH	A measure of how acidic or basic water or soil is.
Phenology	The study of the timing of natural events, such as flowering in plants and breeding and migration in animals, in relation to climatic conditions.
PIP	Public Investment Program.
PNGCLMA	Papua New Guinea Centre for Locally Managed Areas
PNGFA	Papua New Guinea Forestry Authority
Porous	Having small pore spaces between soil particles through which liquid or air may readily pass.
ppt	parts per thousand is a measure of the concentration of dissolved substances in water.
Propagules	Any seed, fruit or other part of a plant which when dispersed is able to produce a new plant. Here we refer to the viviparous fruits or seeds of the Rhizophoraceae family.
Reforestation	Planting trees where they once grew but were cleared.
Root collar	The point on a tree where the roots join the main stem or trunk.
Salinity	Measurement of the amount or concentration in grams of dissolved salts in sea water, often expressed as parts per thousand (ppt).
Sedimentation	The process in which sediments carried in impure water are deposited at the bottom of a river, stream or ocean.
Seed	A reproductive unit of a plant consisting of an embryo, food store and protective coat and is able to produce a new plant. Here we also refer to the non-viviparous seeds of mangroves
Species	An individual belonging to a group of living organisms of one kind that are able to inter-breed. The basic unit of biological classification. E.g. Rhizophora stylosa.
Strand	A group of mangroves of the same type forming a distinct stand.
Substrate	The earthy material, such as mud, gravel, sand and organic matter on which a plant is attached and growing.
Succession	The progressive replacement of one dominant type of species or community by another in an ecosystem overtime leading to a stable climax community.
Tidal	A situation in which the water level periodically fluctuates due to the gravitational forces of the moon upon the rotating earth.

Thinning	Cutting down and removing some plants from a row in a nursery or forest area to allow more space for the others to grow healthily.
TNC	The Nature Conservancy
UPNG	University of Papua New Guinea.
WCS	Wildlife Conservation Society
WWF	World Wildlife Fund for Nature
Zonation	Arrangement or distribution in zones.
Zones	These are groupings of the same species of mangroves within a whole mangrove forest; a belt or area to which certain species are limited.

How to use this Hand book

This handbook gives a step-by-step guide on how to rehabilitate mangroves. This handbook is part of an initiative led by the National Government's Office of Climate Change and Development to address and reduce the impact of climate change on coastal communities. Although the driving motivation behind the handbook is to address coastal flooding, it has been designed to be applicable to planting mangroves for all purposes, including conservation, fisheries, eco-tourism or others.

The main activities of a mangrove planting project outlined in this handbook are split into 6 phases and the activities related to the six phases will be colour coded for easy reference as follows:

Rationale	= **Purple**
Planning and site analysis	= **Yellow**
Planting Activities	= **Green**
Ensuring survival	= **Blue**
Awareness and training	= **Red**
Funding	= **Orange**

Introduction

Mangroves are specialised groups of plants that have adapted to grow in the intertidal zone along tropical and subtropical shorelines and is a highly productive ecosystem providing habitats for multitudes of animals and unique plants. In PNG mangrove forests fringe large parts of the coast and form extensive stands at the mouths of large rivers including the Fly, Purari and the Sepik River. They also occur elsewhere in smaller stands and on sheltered sides of islands. PNG is only second to Indonesia in terms of species diversity with a record of 43 species and makes up 75% of the total mangrove cover in the Pacific region.

Coastal communities in Papua New Guinea depend on mangroves for forest products. Mangrove trees been harvested over generations for construction materials. Mangroves provide a habitat for fish, crabs, shells, birds and reptiles that sustain the diet of locals. More critical is the structurally designed rooting systems of mangroves which provide a shield against the effects of climate change.

With the intensifying negative effects of climate change mangroves will afford a natural defence against storm surges, coastal erosion and coastal flooding. Consequently, analysis by the Office of Climate Change and Development (OCCD) has highlighted community-based mangrove planting as a cost effective adaptation measure for coastal communities.

Many communities along the shores of the North Coast, South Coast and Island Regions of PNG have historically been afforded protection by mangroves. Unfortunately, over-exploitation and degradation of mangrove areas means communities are losing their protection against storm surges and coastal erosion.

Intervention is needed to stem and reverse this loss, but rehabilitation and planting efforts to date have been fragmented and most often failed. To be an effective adaption measure, the scale and success rate of mangrove planting projects in PNG need to be greatly increased, this document has been conceived to help do just that.

The design of the handbook is the outcome of extensive review of local and international mangrove literature, discussions of the OCCD's Sub-Technical Working Group on Mangroves, the first ever PNG mangrove workshop and review by local botanists and researchers, NGO workers and leaders and both local and international mangrove experts**.**

Rational for Planting Mangrove

1.1 DEFINING MANGROVE RESTORATION GOALS

The first step in any restoration or rehabilitation program is to define the goals or reasons why you want to plant mangroves in your community. This is the most important part of your proposed plan because the goals will guide you through the restoration process and help you identify the activities which must be included to provide the project with a clear framework for operation and implementation.

There are three (3) main goals for restoration:

- **Protection of coastal areas**. Planting mangroves to reduce shoreline erosion and to increase the protection of coastal communities against the bad effects of climate change such as coastal flooding, high winds and waves and tsunamis.

- **Restoration of a mangrove ecosystem for sustainable production and utilisation of natural resources**. The main aim of restoration here is to plant mangroves which will continue to support livelihoods without destroying the mangrove forest. This means sustainably harvesting mangrove products such as firewood, timber for building materials and other marine products such as crabs, fish and shells in a way that present and future generations can continue to benefit from the mangrove ecosystem. This also includes creating fish or crab ponds among existing mangrove forests or planted mangrove to increase income for coastal dwellers.

- **Conservation of existing undisturbed mangrove forests**. This is done to maintain the ecological processes such as providing breeding grounds for fisheries that support livelihoods, and preserving biodiversity (varieties of animals and plants) that provide us with food and clean air. If your goal to restore the mangrove ecosystem is conservation, then you can achieve this through creation of:

  - Protected sites: internationally recognised areas set aside for nature and biodiversity protection;
  - National parks: areas set aside usually in collaboration with or by the government for conservation and for human visitation and appreciation of nature;
  - Nature reserves: an area set aside for protection of certain animals, plants and physical features

- Wildlife sanctuaries: an area set aside exclusively for use by wild animals which are protected when they visit or live in that area.

Once you have identified your goal (s) for planting you can now start your community awareness and project Planning and site analysis.

2. Planting and Site Analysis

2.1 DEVELOP A BASIC PROJECT WORKPLAN

A workplan is a written project plan produced before project activities begin. It outlines what needs to be done, when, for how long and by whom. A good workplan will:

- Include all essential tasks, reducing the chance of forgetting or missing a step when activities start.
- Break long-term goals into several smaller steps
- Prioritise activities according to their importance and how easy they are to implement (easy and important tasks should be done first, unimportant and difficult tasks should be done last)
- Assign tasks to individuals or defined groups, to make sure no tasks are duplicated and establish clear accountability
- Clearly state how individual or defined group performances will be assessed and what the implications of poor performance will be
- Set expectations for project progress and establish a project schedule that can be tracked and monitored.
- Help to develop a budget and ensure adequate funding and other resources are available. (See Table A1 and A2 in Appendix 1 to develop your budget for income and expenses)

See Table B in the Appendices section for an example of a work plan.

Constantly revisit your workplan to keep track of progress and update activities that need to be brought forward, delayed or changed.

2.2 AND 2.3 IDENTIFY THE GENERAL PROJECT AREA AND SELECT THE SPECIFIC PROJECT SITE

Before any detailed project work begins, you need to identify a suitable area as your project site. Table 1 below lists a set of criteria to guide you in selecting an appropriate mangrove site.

Table 1: Site selection criteria

1st stage – the general project area	
Natural suitability (general, can be one or several of these)	Degraded area – The site is a former mangrove area that is degraded Gap – The site is a gap within non-degraded stands Mudflat - The site is on a mudflat with barrier islands River – The site is on an open area along a brackish river
Social-economic suitability	Adaptation value – It is reasonably expected that people and property of the community will be better protected against coastal flooding after mangroves have been rehabilitated
2nd stage – the specific project site	
Natural suitability (specific)	Natural growth – There are signs of secondary growth or sparse vegetation (few mangrove species growing) Correct zonation – The site is not submerged by more than 1.5 m of salt water (this prevents or minimizes barnacle infestation). Align species to be planted with the zonation pattern of natural stands in a nearby forest. Sheltered area - There is limited or no exposure to strong waves, currents and winds Even tides - The tide is such that there is an even period of inundation and dry. This is a rule of thumb and varies across species Tidal flat * – The site is a tidal flat (these areas are best for expansion of mangrove stands.) Lack of sea grass – The site is not a sea grass bed Few pests – Avoid areas that are highly infested with pests such as crabs and barnacles Area of accretion – mangrove seedlings will grow in areas of soil build up, not in areas that are being eroded.
Social-economic suitability:	Conflict of interest – Rehabilitation will not conflict with existing or future land-use and/or development needs Community buy-in – A clear majority of the community and its leaders support mangrove planting in the proposed area Landowner agreement – No individual community members have a claim to the mangrove area and oppose rehabilitation.

* Planting on tidal flats can be successful, but chances of failure are greater when on areas where mangroves don't normally grow.

2.4 CONDUCT A DETAILED EVALUATION OF THE SITE

Site evaluation is one of the most critical components of a mangrove rehabilitation project. A successful project can only be planned and carried out if the characteristics and conditions of the site are well understood.

The seedlings survival guidelines and actions outlined in this section are adapted from Maniwavie (2012) and from the Mangrove Action Plan's "5-steps to Ecological Restoration of Mangroves" guide. By the end of this section it may even be apparent that you can restore your mangrove site without planting any mangroves!

Before proceeding to the actions below you must first of all consider the possible survival of seedlings that are going to be planted in your site. This will involve observing certain environmental factors to determine whether your seedlings to be planted will have a high or low chance of surviving.

- Recent scientific investigations (Interpretation of seedling survival models) has shown that
  - The single most important factor for high mangrove survival is to plant in sites which are not exposed to winds and waves.
  - Mangroves survive best in areas protected from these harsh environments.
  - Mangroves survive better in places which have high organic matter which generally means in areas close to forested places, next to land with good soils and streams, or where dead leaves accumulate.
  - Mangroves do best in places with a mixture of mud and gravel sediments and do not do well in very sandy sediments.
  - Knowing this information will help you decide to plant or avoid replanting in problematic sites thus minimising wasted time, labour and project funding.

Contact an NGO, CBO or UPNG and the National Fisheries Authority (NFA) for assistance if there is uncertainty about identifying environmental factors.

2.4.1 FRUITING SEASONS

Understand the biology and ecology of the mangrove species at the site, in particular the patterns of reproduction (when the seeds/fruits are produced), their flowering or fruiting seasons, where the propagules are distributed and successful seedling establishment within the intertidal zone.

Contact an NGO, CBO or the LAE PNG National Herbarium for assistance if there is uncertainty about the identity of the mangroves near your site.

- Identify which species would naturally occur at your site

  - Ask knowledgeable locals about the species that previously grew on the site. Showing pictures of species can make recollection and identification easier and more accurate. Conduct a basic survey of the species occurring on or near the site to generate your own information in support and compare with the local knowledge.

  - Identify seeds that wash up onto the site

- Understand the pattern of reproduction of suitable mangroves. It is important for planning purposes to know when seeds will be available for collection. This is when you need phenological information, and you can get this information from herbarium species collection or use of a mangrove species photographic guide

- Make a copy of Table C of the Appendices section

  - Use local knowledge, together with the help of a local NGO/CBO if needed, and fill in the template so that it looks like the example in Table 2 below.

Table 2: Reproduction

Species	Type of Seed	Months available	Indicator of Maturity	Size at Maturity
Avicennia marina	Propagule	J F M A M J J A S O N D	Yellow fruit skin	Weight of seed >30g

- Understand the dispersal pattern of suitable mangroves. The seeds of the various mangrove species near your site will travel different ways and different distances depending on the tidal currents, and so some may not reach your site. You may also find that seeds from mangroves far away *do* make it to your site, and could be suitable for planting.

  - Make a copy of Table C of the Appendices section

  - Use local knowledge, together with the help of a local NGO/CBO or local Forest officers if needed, and fill in the template so that it looks like Table 3 below.

Table 3: Dispersal

Species	Months available	Distance from site to seed source			*Presence/ absence of seeds at site	
Avicennia marina	J F M S M J J A S O N D	0-1km	1-5km	5km+	Yes	No

* Includes seeds/propagules (rooted, alive or dead) in the rehabilitation area

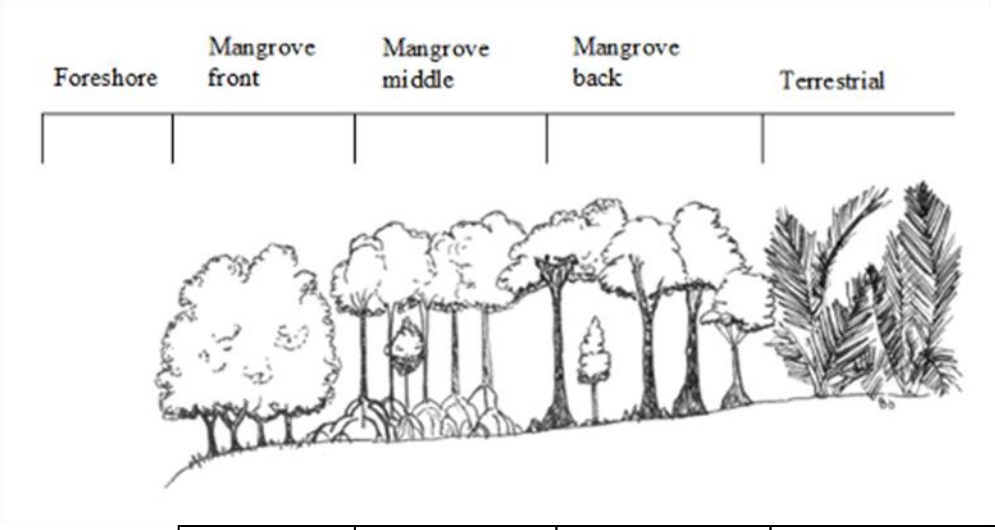
- Understand zonation pattern of suitable mangroves. Zonation refers to the distribution of mangrove species across the intertidal zone due to variations in species tolerance to

environmental factors such as salinity. Zonation patterns are characterised by a sequence of plant communities that usually results in bands of vegetation that occur parallel to the shoreline.

– Identify the zonation of nearby, healthy mangroves. This is most useful if these nearby areas resemble the conditions at your site and is most likely that your mangroves were removed only within the last few years.

  □ Observe the zonation of mangroves at nearby stands, going from the foreshore to the terrestrial margin, noting down where different species grow.

  □ Sketch a basic diagram of the zonation pattern, using Figure 1 as an example. The sketch should reflect reality, so use a tape measure to measure how wide the different species zones are and note them down.



A. marina *Sonneratia* *R. stylosa* *R.apiculata*	*R.apiculata* *R.mucronata* *B.gymnorrhiza*	*A. alba* *A. officinalis* *B.sexangula* *Xylocarpus*	*Mangrove associates*
Mud, sandy, sandy loam, gravelly sand, rocky or coral rubble	Mud, sandy loam, muck	Mud, sandy loam, sandy	Terrestrial soil

Figure 1: A basic illustration of mangrove zonation (modified from Whitten et al., 1987)

– Now, identify the zonation pattern of your mangrove planting site and their distributions; compare this to the substrate pattern of the mangrove area used for your zonation chart.

– If your mangroves were removed many years ago or the site conditions have obviously changed, a new and different zonation pattern will likely be required and more attention must be paid to site conditions and matching the right species to the conditions. This can mean bringing in species that do not normally grow in the area.

- Understand the substrate of your site. The different species of mangroves prefer different types of substrates and knowledge of the substrate type at your site will help determine which species you need.
  - At the same place where you observed the zonation pattern, now observe the substrate types.
  - Mark the substrate pattern on your zonation chart and note how they match up to the zones and species.
  - Now, identify the substrate types on your mangrove planting site and their distribution; compare this to the substrate pattern of the mangrove area used for your zonation chart.

Table 4: How different substrate characteristics influence species

Substrate type	Description	Typical species
Mud*	A mixture of silt and clay with organic matter. Can be as shallow as 2 cm or deeper than a meter. Avoid mud that smells very strongly of rotten egg or is so soft you sink up to your knees into it.	*Bruguiera cylindrica* *Bruguiera gymnorrhiza* *Ceriops tagal* *Rhizophora apiculata* *Rhizophora mucronata* *Rhizophora stylosa*
Gravelly sand	A mixture of gravel (pieces of rocks and stones) and sand.	*Avicennia marina* *Osbornia octodonta* *Sonneratia alba* *Rhizophora stylosa* *Xylocarpus rumphiana*
Rocky or coral rubble	These substrates are generally quite hard, but with thin layers of sediments.	*Avicennia marina* *Pemphis acidula,* *Rhizophora apiculata* *Rhizophora stylosa* *Sonneratia alba*
Sandy	Sandy substrates normally consist of very small grains of rock, shell and coral with little or no organic matter. Like mud, sand may be as shallow as 2-3 centimetres or as deep as several meters.	*Osbornia octodonta* *Rhizophora apiculata* *Rhizophora stylosa* *Sonneratia alba*
Sandy loam	A mixture of clay, silt, sand and organic matter.	*Avicennia marina* *Rhizophora apiculata* *Rhizophora stylosa* *Sonneratia alba* *Sonneratia caseolaris*

Muck	Similar to mud except that it contains more organic matter than mud. It also tends to be deeper, starting at more than 10 cm thick up to a few meters. Like mud, muck may have the same foul, rotten egg smell; if so, planting should not be attempted.	*Bruguiera gymnorrhiza* *Ceriops australis* *Ceriops decandra* *Ceriops tagal* *Rhizophora mucronata*

*If mud smells very strongly like rotten egg, it means that the mud has high sulphur content and is very acidic.

2.4.2 Hydrological

This is the single most important factor in establishing a successful mangrove restoration project. You must understand the normal hydrological patterns that control the distribution, establishment and growth of mangroves in your area.

- Understand how deep your site is submerged by the tides.
  - Go to the nearby mangrove site that you used to sketch the zonation diagram and monitor the tides. Observe the limits of the high tides and low tides during a full moon or new moon, these are the “spring tide” water marks
  - Observe the limits of the high tides and low tides during a half moon, these are the “neap tide” water marks
  - Average sea level is between the neap tide high and low water marks
  - Add the different tide water marks to your zonation sketch, such as in Figure 2 below.

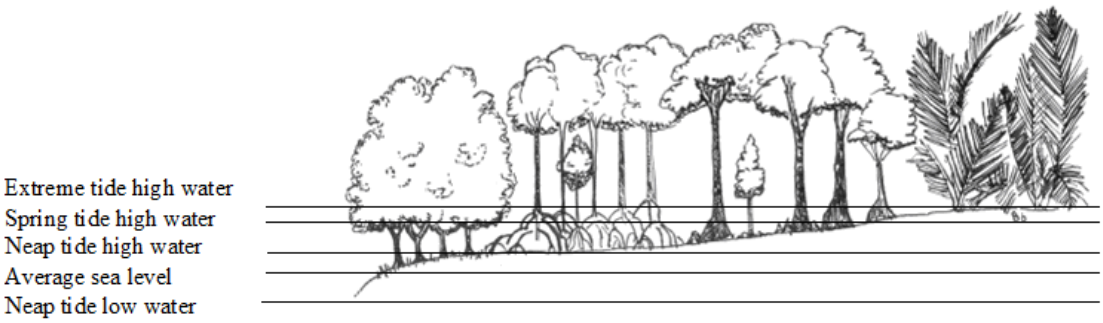


Figure 2: Zonation and tidal patterns (modified from Whitten et al., 1997)

In general, mangroves should be planted above the average sea level to avoid being inundated too often and below the extreme high water level to avoid competition from terrestrial plants

- Understand the duration and frequency of the tides affecting your site

  - Monitor the duration of the tides and record how many hours each zone of mangroves is inundated by the water and how long they are dry.

  - Monitor how often the tide reaches a certain level each month and fill in a tidal inundation matrix similar to Table 5.

  - For example, if on your site all high tides reach at least 0-2.4m, then the flooding frequency of tides between 0-2.4m is 56-62 (i.e. 2 high tides per day x 31 days per month = 62 times per month)

  - Add the inundation frequency and duration information onto your zonation diagram and you should now have a detailed chart that gives a good idea of what a healthy, natural mangrove strand should look like on your site.

  - Your zonation chart should look something like Figure 3. This will be an important reference tool for future activities.

Table 5: Tidal inundation classes (Watson, 1928)

Class	Type of tides it is flooded by	Height above average low tide level	Flooding frequency (times per month)
1	All high tides	0-2.4 m	56-62
2	Medium high tides	1-3.4 m	45-59
3	Normal high tides	3.4-4 m	20-45
4	Spring tides	4-4.6 m	2-20
5	Extreme tides i.e. King	4.6 + m	2

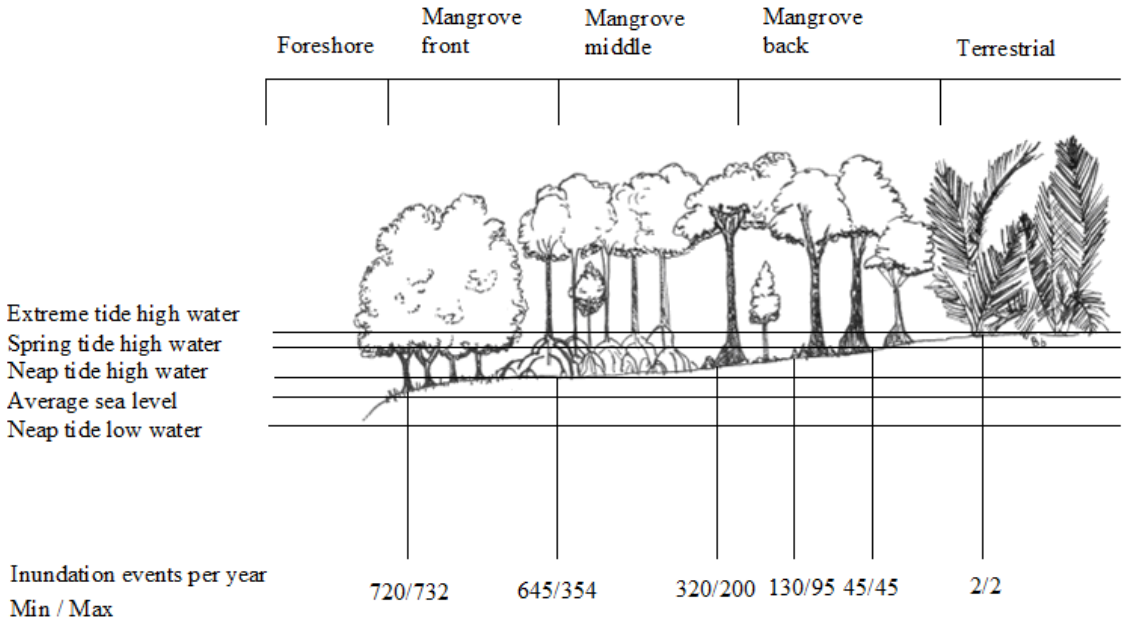


Figure 3: A complete diagram representing the zonation in mangrove forests along the inundation levels (modified from Whitten et al., 1987).

2.4.3 Disturbances

- If your project site used to be well covered by mangroves but is now barren or degraded, it is important to understand what led to the degradation and what is preventing natural recovery. Disturbances can be classified according to whether they are natural or man-made and whether they are hydrological or non-hydrological in nature.

- Identify the causes of degradation of your mangrove site. Look at Table 6, for a list of the most common stresses responsible for mangrove losses, and note which of these are relevant to your site and other nearby mangrove areas.

- Determine when the different stresses began or happened and when the mangroves began to degrade. As a general rule, the closer together the start of the stress and the start of the degradation, the more likely it is that one caused the other.

Do you need a fence around the site?

A fence may be necessary if livestock like pigs often enter the site. However, if you want to keep out people or screen out debris, awareness and support from the community together with regular patrols of the plantation are much more effective.

Table 6: Typical stresses to a mangrove site

	Hydrological stress	Non-hydrological stress
Natural	■ River mouth blocked by sandbank preventing water flow ■ Drought leading to lack of fresh water or ground water ■ Floods leading to too much salt or fresh water ■ Ongoing storm surge (or cyclone) event	■ Insect infestation defoliating trees ■ Fungal infection ■ Barnacle infestation killing seedlings ■ Crabs and snails damaging seedlings and trees
Man-made	■ Soil is hypersaline and too acidic usually after intensive shrimp farming) ■ Drains, ditches or dykes that divert fresh water away from mangroves (e.g. aquaculture ponds) ■ Roads cutting through mangroves without culvert and drainage preventing water flow	■ Domestic animals damaging seedlings e.g. pigs foraging ■ Boats being dragged or paddled over seedlings ■ Plastic and other rubbish smothering seedlings ■ Pollution from sewerage, oil from industrial waste ■ Excessive sedimentation due to upland activities e.g. deforestation ■ Over-consumption of seeds for food ■ Over-harvesting of wood, usually for food and firewood

2.4.4 Removal of stresses and restoration of natural condition

Once you understand what is negatively affecting the mangroves on your site, take actions to restore appropriate hydrology for maximum natural growth and change community habits to reduce man-made destruction.

- Focus on the man-made stresses at this stage of your project, there is little you can do to alter most natural hazards.
- Prioritise solutions that can be made in one go, rather than those that take time. For instance, modifying constructions such as putting a drain under a road can be quick and have immediate impact, while behavioural changes, like getting people to reduce consumption of the mangroves normally take more effort and time to implement.
- Use Table 7 as reference of possible solutions to man-made stresses, but note that this does *not* contain all possible stresses or solutions. Use your knowledge of your community and environment to identify other stresses and come up with other effective solutions

Table 7: Man-made stresses and solutions

Stress	Solution
Domestic animals damaging seedlings e.g. pigs foraging	Put up a fence to stop animals roaming the mangrove area. Encourage community members to take their animals to other areas for feeding. Get communities to build pig fences and keep them in.
Over-consumption of propagules for food	Create and implement community laws to institute closure periods and/or harvesting limits and restrict access to certain sites or create a mangrove management plan. Provide alternative crops. Do more educational awareness.
Over-harvesting of wood, usually for fuel and construction	Create and implement community laws to restrict harvest size. Provide alternatives e.g. terrestrial wood trees. Alternate fuel wood species with the same burning capacity as mangrove species.
Plastic and other rubbish smothering seedlings	Determine source of rubbish, if local or distant. If local implement a waste management system for your community and encourage neighbouring communities to join.
Boats being dragged or paddled over seedlings	Set aside and encourage community members to use one main passage.
Fishermen casting nests and lines across mangrove seedlings	Encourage fishermen to avoid casting their nets and lines into mangrove areas and to be careful when untangling nets and lines caught up accidentally, rather than just pulling.
People trampling seedlings when gathering wood or hunting for food amongst the mangroves	Encourage community members to be more careful of seedlings because they are necessary for the long-term health of the mangroves.
Drains, ditches or dykes that divert fresh water away from mangroves	Redesign diversions so that enough fresh water reaches the mangrove areas.
Roads cutting through mangroves without culvert and drainage preventing water flow	Place culverts underneath road at key drainage areas. Engage with construction companies and various stakeholders involved in road design and construction, so that they build structures that will not affect the health of mangroves.
Children are careless and tend to damage seedlings especially during planting	Educate children not to destroy seedlings and get them involved in actual planting.

Natural restoration

Mangroves will grow without help if the conditions are right. So, before going any further, ask yourself whether the changes you have so far made under Section 3-4 are enough to fully rehabilitate your mangrove site without actually planting anything.

Only if you think that natural recovery will be too slow or not enough should you try planting. Allowing nature to do the work can be more effective and require much less effort! However, there are reasons to plant even if nature could do the job. The table below shows the advantages and disadvantages of natural restoration.

ADVANTAGES AND DISADVANTAGES OF NATURAL RESTORATION OF MANGROVES

Advantages	Disadvantages
Cheaper	Absence of mature trees means supply of seeds may be low
Much less effort	Excessive wave action could prevent establishment of seedlings
Little need for equipment	Pests may destroy seedlings before establishment
Less substrate disturbance	No control over spacing but important when preparing site for coastal defence
Saplings establish more rapidly	Limited community involvement prevents development of a sense of responsibility towards the mangroves
The right species will automatically grow in the right tidal zone	No control of the species which establishes

Now that you have completed steps 2.1-2.4, you should have a better understanding of what needs to be done on your site for the rehabilitation to succeed. Take the time to update your workplan; here are some things you should consider:

- Did the work you completed so far follow the workplan?
  - What made the workplan useful? What worked? What didn't work?
  - What can you do to better follow the workplan?
- Are there new activities that should be added or unnecessary activities that can be taken off the workplan?
- Are the expected times given for activities reasonable? Do the activities need more or less time?
- Is the sequence of events correct or do priorities need to be changed?

3. Planting Activities

3.1 CONSTRUCTING A NURSERY

The need for nurseries depends on the species you want to grow and the conditions of your site. Mangroves with large propagules such as Rhizophora can be successfully planted directly into the substrate without having to spend time in a nursery. Direct planting is considerably cheaper and easier than having a nursery phase and planting from pots/bags.

However, international research and case studies have shown that an initial growth phase in a nursery tends to improve the chances of seedling establishment and survival, especially where the substrate is unstable or the seeds are small. That said, nurseries face their own challenges, as shown in Table 8.

Table 8: Problem resulting from poor nursery selection

Problems	Likely reason
High mortality due to under-watering. There is no balance between the amount of fresh water and salt water.	No nearby fresh water/salt water source
High mortality due to flooding.	Nursery area exposed to high rainfall run-off or placed in wrong tidal range
High mortality due to low level of care	Nursery is too far from village
Loss of plants from theft	Nursery is too far from village
High mortality due to lack of proper substrate for potting.	Nursery is too remote from a proper source of appropriate potting substrate.
High mortality due to overcrowded plants.	Nursery is too small for the number of plants being grown.
High mortality due to long transport distance to planting area.	Site is not centrally located.
High mortality due to pests like crabs.	Nursery site placed at intertidal area that is infested with crabs.

Care should be taken to follow the steps outlined below so that your nursery is as successful as possible and the seedlings that you transfer to your site are healthy and prepared for the harsh natural conditions at the restoration site.

3.1.1 Nursery site selection

Critical to success of your nursery is its water supply, its location and accessibility, the drainage and the size of its area. These are described in detail below.

- **Water supply:** Locate your nursery where it can get some salt and some fresh water. You can set it up near the sea where it will be periodically inundated by tides or a river, but make sure that it is not vulnerable to strong flooding.

- **Location and accessibility:** Put the nursery where it is easiest to get water, materials and mangroves in and out.

  - Consider the distance from the planting site to the houses of those working at the nursery; the closer the nursery is to houses the more likely it is that daily activities will take place. However, make sure that you monitor the site closely, as the closer the nursery is to households the more it is exposed to disturbances from children and animals.

  - If possible, the nursery site should be an existing open area to avoid the cutting of trees.

  - A good idea is to have some trees in the nursery to shade some areas of the nursery and leaves and twigs from removed vegetation can be used to start the compost beds.

- **Good drainage:** Select a site that drains well and is relatively flat and shallow. Though mangroves are subject to flooding, proper drainage is essential because plants will die if always in water.

- **Size of area**: Use the standard dimensions below to guide you when calculating the area needed for your nursery.

  - Create sections to use as nursery beds or to hold seedlings in polypots or polybags, or alternatively use bamboo or dead banana stem.

  - A standard nursery bed is 10 m long and 1 m wide. The number of beds you need depends on how many seedling you want to plant. For example,

    - If you want to plant *Rhizophora stylosa* and your polypots are 20 cm in diameter, you can get 5 polypots to a meter (Figure 4).

    - So in a 10 m x 1 m space, you can fit at least 50 x 5 polypots, which means 250 seedlings.

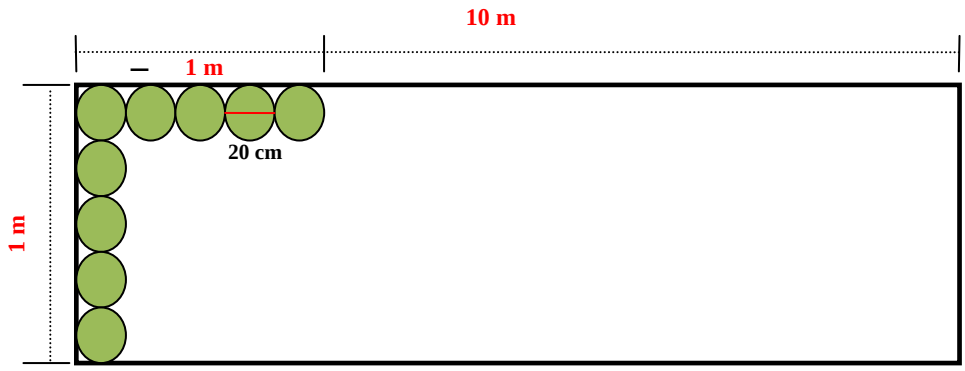


Figure 4: A standard nursery bed

- If you want to plant 1 hectare at a density of 1 seedling per square meter, you need 10,000 seedlings. This would mean you need 10,000 / 250 nursery bed, which are 40.
- nursery beds are usually 1 m apart
- Have an additional area of roughly 100m^2 for potting area, equipment storage, germination and hardening beds, and a loading zone for boats and/or vehicles.
- Taking all these details together: 40 x 10 m^2 for nursery beds + 40 x 10 m^2 for gaps between beds + 100m^2 as a general working area adds up to 900m^2. This is beginning to be a large area, so if there were not enough land, you could
    - reduce the gaps between the beds,
    - reduce the size of the working area,
    - reduce the area needed to be planted
    - or reduce the area need to be planted. Use smaller polybags (this will likely impact
- or reduce the area need to be planted. Use smaller polybags (this will likely impact the growth of your seedlings though).

Before deciding on the area required for your site, you need to know how many seedlings you need to produce and which species they will be.

See sections 3.2.1 and 3.2.2 on how to select the right species and calculate how many you need.

3.1.2 Designing and building nursery

After selecting a nursery site it is time to think about the design. There are several steps in this process:

- **Identifying workers**: The Community project group (CPG) must decide who will be responsible for all the phases of the project. Up to ten people may be needed to design and build the nursery.

- Determine the boundary

  - Sketch a map showing the boundary of the nursery area and basic information about the shape of the area and the approximate lengths of each of its sides. Remember how many seeds you will need and the area required for your nursery.

  - Planning is easier if you lay out the nursery as a square or rectangle.

- **Develop your nursery plan**: Carefully consider what goes where. Think about how to get seeds in and seedlings out (by foot, boat or truck), where will the seedbeds or nursery beds be, where will the water go in and out?

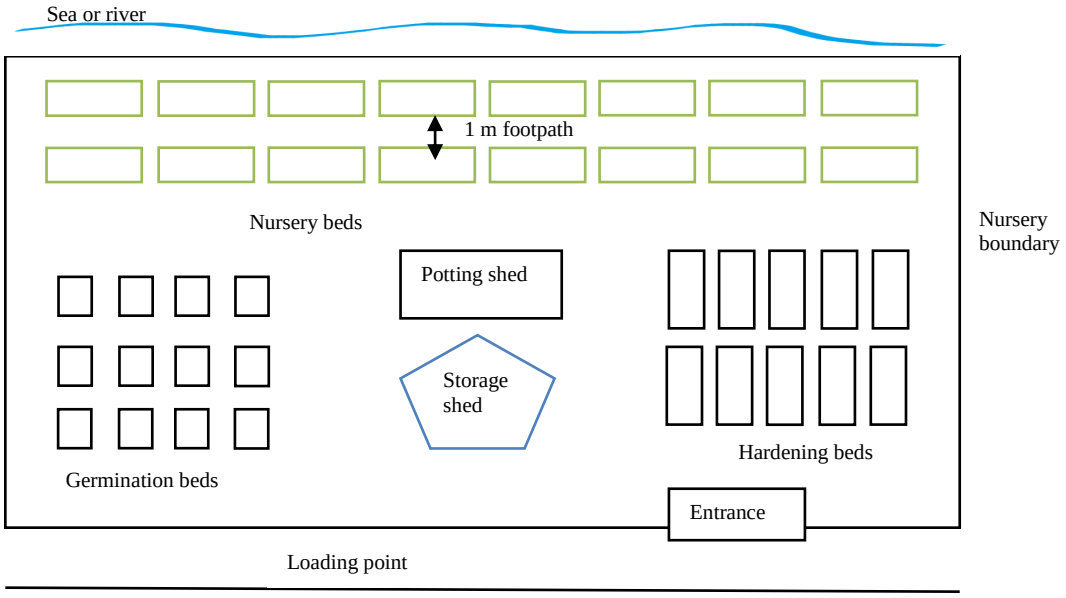


Figure 5: Typical layout of the main components of a nursery

- **Build the nursery**

  - This will probably require the whole CPG or more, but not everyone has to do the actual construction. Other important activities include:

  - Buying or obtaining the necessary materials

- Transporting materials or workers to the site

- Buying or borrowing tools (shovels, hammers etc.) needed to build and operate the nursery
- Preparing lunch for those working on the nursery

- The site should be levelled by digging the high levels and putting the substrate in the low spots. Excess substrate can be stockpiled at the potting substrate area.

- Once clearing and levelling have been completed, the nursery should be laid out using the prepared map. Mark out the various parts of the nursery and begin construction

- **Seed germination beds**

  - These are 10m x 1m beds raised slightly (5cm to 10cm) above the level of the surrounding area, higher than nursery beds. Use these beds to germinate small non-viviparous seeds before transplanting to polybags.

  - For back mangrove species such as *Xylocarpus spp., Bruguiera cylindrica, Heritiera litoral*is raise the beds at least 30 to 50 cm above the level of surrounding area and locate at the row parallel to the land.

    - Raise the area either by bringing in substrate to each bed or by digging out the substrate from a 40-centimetre wide area immediately next to the beds.

  - Keep the substrate from spreading by lining each bed with timber strips/wood, rocks or bamboo curb. Concrete blocks can be used but are expensive.

  - When planting species with small seeds, sow them in seedbeds and not directly into pots or polybags. Wait for these seeds to germinate and when they are about 5 cm tall, carefully move them into polybags or pots. Make sure you take and keep the soil around the roots when you transplant them. Use a thin stick to dig holes in the polybags before transplanting the seedlings.

- **Potting sheds.** Potting sheds can be made out of Nipa or coconut leaves. Typically larger than 3 x 4 meters in area (and may be twice that), they are built with three walls; and instead of a door, a fourth wall is kept open.

- **Potting substrate**

  - Collect substrate from the future planting area or a similar area to be sure that it is suitable for the mangroves.

  - To minimise the potential negative impact on the site, only remove as much soil as you need.

- **Hardening beds.** The hardening beds will be used to harden off your seedlings before planting in your site. The hardening bed is constructed with the same design as the nursery beds. Roofing over the hardening beds can be made from nipa leaves and supported by 1.5 m poles.

- **Bagging and storage sheds.** Construct this like the potting shed but with a door to be closed and locked when storing nursery tools.

3.2 GATHERING SEEDS

Review all the information you have put together in steps 2.2-4.4; it is now time to work out what species you need, how many seeds you need and when you can collect them.

3.2.1 Decide which seeds you need.

This is one of the most important steps in your project and there are several ways to go about it.

- **The basic approach**. Refer to the mangrove information sheet provided in Table D in the Appendices and use the information you collected in steps 2.2-2.4 to identify appropriate species for each zone on your site.

  - If multiple species are suitable for each zone, choose the species that best meets the goals of your project by asking yourself questions such as:

    - Which species is the easiest to collect?

    - When do I want to collect seeds? When do I want to plant the seeds?

    - Which species do I prefer for their resources benefit? e.g. food, medicine, wood etc

- **The scientific approach**. While the decision of where to plant mangroves and what species to focus on can be made using information within this handbook, engaging a professional scientist from an NGO, University or Government department such as OCCD can give you a higher quality of information on which to base your decisions.

  - A scientist may also want to know additional information about the area, such as the local climate and other environmental factors, to more precisely evaluate appropriate species. Contact your local NGO and LLG's that have links for assistance in measuring these environmental factors.

  - Combine the additional information with the information collected in steps 2.2-2.4 and go through the mangrove information sheet provided in Table G in the Appendix section to identify appropriate species for each zone on your site.

  - If multiple species are suitable for each zone, choose the species that best meets the goals of your project by asking yourself questions such as

- Which species is the easiest to collect?
- When do I want to collect seeds? When do I want to plant the seedlings?
- Which species do I prefer for their resources benefits, e.g. food, medicine, timber etc

3.2.2 Determining how many seeds are needed

- **Sketch a site map**: Sketch a map of the project site, such as in Figure 6 below. It does not have to be exact, but should be clear enough to provide users with guidance on the location of human and animal paths, and intended planting blocks as well as seedling density.

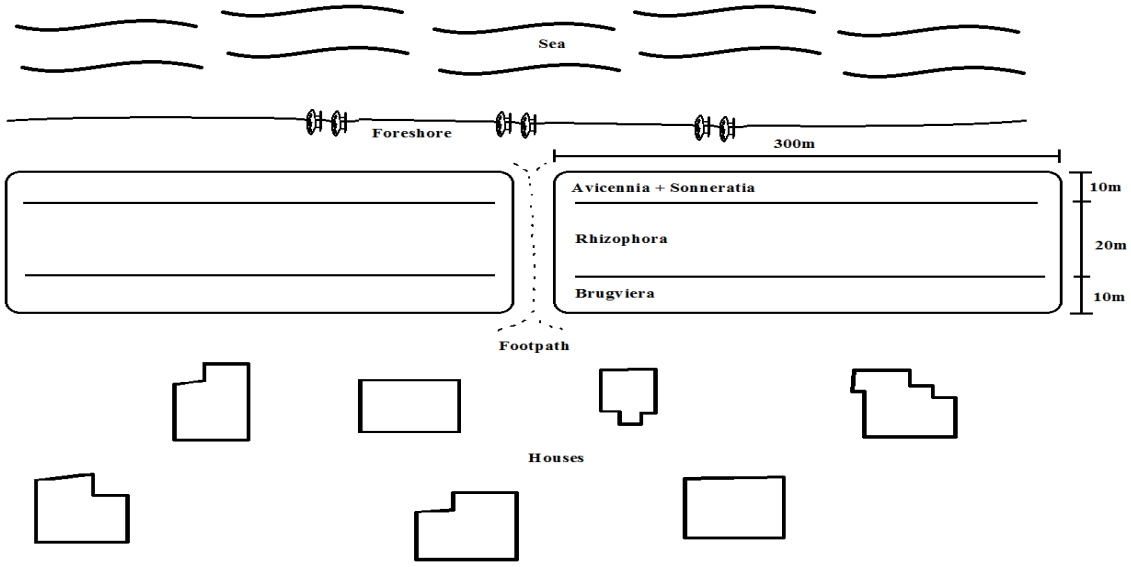


Figure 6: An example of project site sketch map.

- **Choose a planting pattern:** There are several planting patterns that can be used to plant mangroves, each with its own particular benefits, but most mangrove planting efforts distribute the mangroves evenly across the site, here described as strip planting. The three common ones described here are strip planting, inverted-V and the cluster pattern.

- **Strip planting:**
  - The traditional way of planting mangroves, can be used for all site types
  - Plant seedlings in rows, equally spaced from each other
    - If the site is protected from waves and wind, plant using normal spacing

- If the site faces medium to high winds or waves, decrease spacing between seedlings

- However, this can create an unnatural look, varying the spacing between seedling will create a more natural look.

  - If seedlings were planted close together and are doing well after 2 years, you may need to transplant some seedlings and increase the space between trees

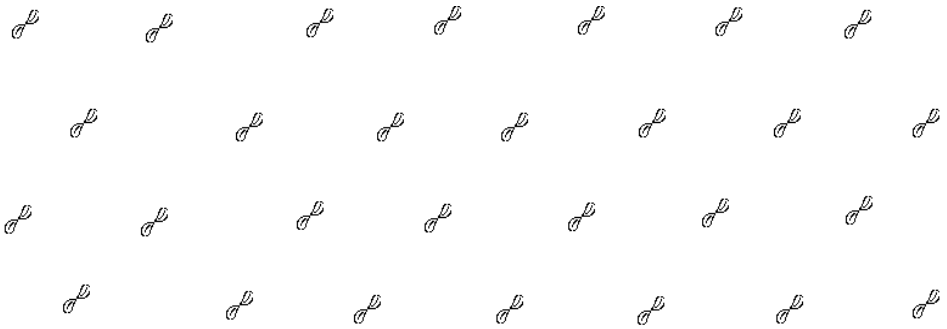


Figure 7: An example of strip planting viewed from above

Table 9: Factors that influence planting (assuming strip planting pattern)

Factor	Influence on spacing	Example: Avicennia marina
Sheltered site	Normal spacing	1 m x 1 m
Strong winds	Reduce normal spacing by half	0.5 m x 0.5 m
Strong current and/or waves	Reduce normal spacing by half	0.5 m x 0.5 m
Low nutrient substrates	Use double normal spacing	2 m x 2 m

- **Inverted V planting:**

  - Good for sites facing moderate wave or wind action

  - Space seedlings at between 25 - 50 cm apart in V-shaped groups, about 11 seedlings per group. Plant so that the point of the V faces the sea to deflect wave impact.

- Space each V between 1-1.5m from each other

- If all seedlings in the V are growing well after 2 years, take some out and transplant them to where there are gaps.

Figure 8: An example of inverted-V planting viewed from above

- **Cluster planting:**

  - Good for site facing strong wave or wind action

  - Space seedlings at between 25-50 cm apart in small clusters, about 10 seedlings per cluster

  - Space each cluster between 1-1.5 m away from the next one

  - If all seedlings in the cluster are growing well after 2 years, take some out and transplant them where there are gaps.

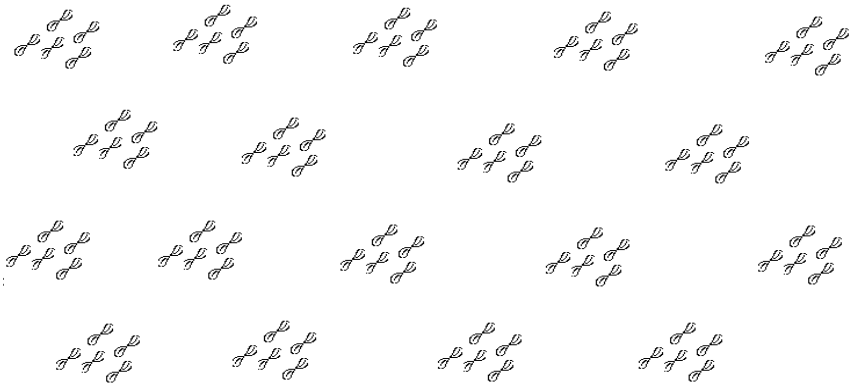


Figure 9: An example of cluster planting viewed from above

- **Calculate how many seedlings you will need** (Steps A to H below assume a strip planting pattern, but a similar process should be followed for other planting patterns too)

A. Using the information in Table D, go through Table9 above thinking about what level of wind and waves your seedlings will face and what the purpose of your planting is. Modify the normal planting spacing of your species accordingly.

B. Calculate how much area each seedling will require at that spacing. For example, if spaced at 25 cm apart, each seedling will take up 0.25 m x 0.25 m = 0.0625 m^2, or if spaced 2 m apart, they take up 2 m x 2 m = 4 m^2 in area.

C. Determine the proportions of your zones and then calculate the area of each zone; this will be easiest if your zones are rectangular, e.g. if your total site is 1000 m^2 and half is going to be for *Rhizophora mucronata,* then proportion will be 50% and the area for that zone will be 50% x 1000 m^2 = 500 m^2.

D. Divide the area of each zone by the area needed for each species to get the number of seedlings required per zone. For example, if species being planted requires 2 m^2 per seedling and the zone for that species is 800 m^2, you will need 800 / 2 = 400 seedlings to fill the area.

E. Estimate how many seedlings will survive the nursery phase (e.g. 80% will survive). See Table 10 for more details.

F. Now divide the seedlings needed for planting by the expected survival rate e.g. if you need to plant 100 seedlings and the survival rate is expected to be 80%, then 100 / 0.8 = 125 seedlings need to be raised, i.e. 25 more than you need to plant.

Table 10: How to calculate the number of seeds you need to collect and grow in the nursery in year. 1. The second calculation in b) is d1one when two species are planted in one zone, so you need to divide the amount in a) by 2

Zone	Species	Spacing needed (m^2)	Area (m^2)	Seedlings needed year 1	Expected nursery survival rate	Seedlings needed for nursery, year 1
Zone 1	Ao	1 x 1 = 1	300 x 10 = 3,000	a) 3,000/1 = 3,000 b) 3,000/2 = 1,500*	80%	1,500 / 0.8 = 1,875
Zone 1	Sa	2.5 x 2.5 = 6.25	300 x 10 = 3,000	a) 3,000/6.25 = 480 b) 480/2 = 240*	80%	240 / 0.8 = 300
Zone 2	Ra	2 x 2 = 4	300 x 20 = 6,000	6,000/4 = 1,500	80%	1,500 / 0.8 = 1,875
Zone 3	Be	0.8 x 0.8 = 0.64	300 x 10 = 3,000	3,000/0.64 = 4,700	80%	4,700 / 0.8 = 5,875

G. Estimate how many seedlings are expected to fail after planting at the site every year. After you have planted your seedlings in year 1, you should collect and grow enough seeds to replace the expected failures. For example, if you planted 1000 seedlings and you think 90% will survive, you need to replace the 10% that will die. So, in year 2 you need to plant 1000 x 10% = 100 seedlings. And remember, if you expect some failures in the nursery, you will need to grow even more (See Table 11 for more details).

Table 11: How to calculate the number of seeds needed to replace failed seedlings in the first 2 years of the project

Zone	Species	Year 1 seedlings planted	Expected loss rate	Replacement seedlings needed year 2	Seeds needed for nursery year 2 (given you know expected nursery survival)
Zone 1	Ao	1,875	50%	1,875 x 0.5 = 940	940 / 0.8 = 1,175
Zone 1	Sa	300	50%	300 x 0.5 = 150	150 / 0.8 = 190
Zone 2	Ra	1,875	40%	1,875 x 0.4 = 750	750 / 0.8 = 940
Zone 3	Be	5,875	30%	5,875 x 0.3 = 1,760	1,760 / 0.8 = 2,200

H. Repeat the replacement planting process until over 80% of seedlings planted are alive and growing. For example, if you plant 100 in year one and 50 die (50%), plant 50 replacements in year 2. If 25 (50%) die through year 2, plant 25 replacements in year 3 and 13 die (~50%). Your project will then have a three year success rate of 88% (50 + 25 + 13 = 88 surviving seedlings from 100).

If an individual zone will be planted with more than one species, divide the seedlings needed by the number of species. See calculations for Zone 1 in Tables 10 and 11 above for an example.

3.2.3 Collecting and Transporting Seeds and Propagules

Now that you know how many seeds you need to plant on a yearly basis, you need to collect the seeds.

- **Timing of collection.** Most species only produce seeds for a few months a year while others produce year-round so collecting propagules and seeds at the right time is critical.

  - In your own area observe year round the times of the fruiting season for the major mangrove species and use the template in Table C to mark out those seasons. Timing will vary from region to region.

  - When fruiting season begins, start looking out for seedlings washing up on shore. After 1-2 weeks since the first seed, you can be sure that fruiting season has really begun and you can start heading out to collect.

- You will likely need to make several trips over the course of a few weeks to get enough propagules for your site as you are relying on nature to bring the seeds to your area.

- **Prepare your collection team**. Decide whether you will use a small or large group of volunteers. A large group might collect more seeds faster, but they can be more difficult to organise and may not be necessary.

  - Decide the on the number of people needed for collecting based on the availability of quality seedlings in the collection area. If quality seedlings are abundant, even one person could easily collect a few hundred seeds in half a day – e.g. if they were to collect 4 propagules a minute for 4 hours, they would have 900 seedlings! (4 x 60 x 4 = 900)

  - Raise awareness that you need help and are looking for volunteers.

  - Give the volunteers some training on what to look for and what to do. Use pictures of (or demonstrate with real examples) the trees and seeds you want to collect and teach people how to collect healthy, ripe seeds without damaging the trees or mangrove floor.

  - The volunteers should take some large bags to put the collected seeds in. They should not need any other equipment as they should only take seeds on the ground.

- **Collect the seeds**

  - Collect seeds and propagules from the shore or under mature healthy trees, not from trees. Though collecting from trees is easier, it is likely that you will collect seeds that are not yet mature and you may also damage the trees.

  - If you do however, choose to harvest propagules from wild trees, look for the following characteristics:

    - Collect propagules/seeds from healthy matured trees, i.e. trees >5 years old.

    - The mostly harvested are propagules from *Rhizophora* species which when ripe have a distinct yellow/reddish collar (1-1.5cm wide) that forms between the **hypocoty**l and the cap. Propagules are easily released from the cap when harvested from tree.

    - For other species transition in seed/propagule colour distinguishes their ripeness and maturity (see Table E in the Appendices).

  - When collecting from the shore, make sure you only select healthy, good quality seeds and propagules. Look for the following characteristics:

    - They are free from physical damage, e.g. from crabs or have missing parts caused by wave action.

- Free from insect damage, i.e. no borer holes.

- They are large seeds/propagules of any given species and fully matured. They are fresh, without developed roots.

- Selecting seeds and propagules with all of these characteristics increases successful germination.

To be sure of the qualities to look for in a seed or propagule, get help from an expert from FRI, NGO or mangrove specialist.

- **Use of wildlings:** If there are not enough seeds or propagules in your area it is possible to use wildlings (young saplings between 0.5-1m tall) as planting material. Wildlings are collected either by "balling" with a spade or by "coring" with a corer.

  – Balling:

  - For a 10 cm tall wildling, the diameter of the excavation should be approximately 10 cm; for a 20 cm wildling, 20 cm and so on.

  - Insert the blade of the spade into the substrate at the appropriate distance from the wildling, lift up the chunk of substrate containing the wildling and gently wrap mud around the root ball.

  - Wrap the "ball" in plastic or some other material (e.g. banana leaf) so that the soil is kept intact and the roots are not exposed during transportation.

  – Coring:

  Your corer can be constructed from hollow steel pipes (usually 10 cm in diameter). The corer should have a length of about 30 cm and have two handles. Corer should have a serrated edge at bottom to allow penetration into the soil.

  - Slide the corer over the seedling and push the corer into the ground in a spiral motion.

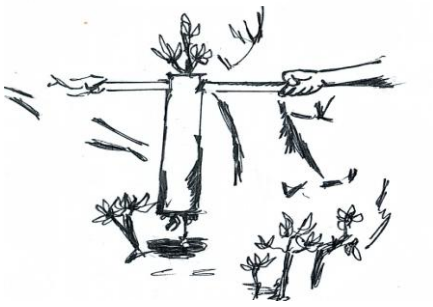
  - Lift the corer out and carefully shake it to release the plug of soil carrying the wildling.

  - Wrap the "plug" in plastic or some other material (e.g. banana leaf) so that the roots are not exposed during transportation.

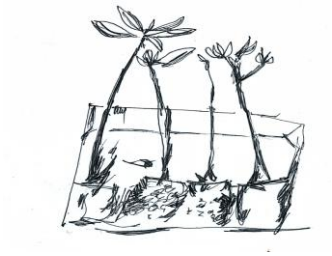
  - Place the seedlings in wooden trays to keep them intact when transporting for planting.

Step 1

Step 2



Step 3



Step 4

Figure 10: Harvesting wildings using a corer

- Whether balling or coring, the seedlings should be potted at the nursery or planted on site as soon as possible and not more than a day after collection.

- In uprooting/collecting wildlings, extra care must be taken not to damage the root system.

■ Sorting and transporting seeds and propagules.

- Propagules can be packed in bundles of 50 or 100. Make bundles from palm or banana leaves to keep the propagules moist.

- Small seeds should be transported in rice or copra bags with a moist cloth placed on top of each bag. Be sure to keep the cloth moist throughout the trip and do not expose the materials to direct sunlight, as this will cause damage. Open baskets made from palms are also suitable.

- Wildlings should be transported on trays (see Figure 10) or in large flat-bottom containers such as a plastic crates. Keep each root ball wrapped and do not pack wildings too tightly otherwise you could damage their roots. Keep the wildlings moist and protect them from the sun with banana or palm leaves to prevent them from drying out.

- If transporting by boat, protect the seedlings with a canvas or some coconut fronds. Do the same if you are transporting the material by truck. Avoid placing the propagules or seeds in direct sunlight.

3.3 OPERATING AND MANAGING A NURSERY

3.3.1 Storage

- Between collection and propagation, the seeds and propagules must be prepared for planting or storage.
- Allow small seeds to air-dry somewhat prior to storing, i.e. you can spread them on banana leaves or copra bags under tree shade to remove excess moisture. Aim for a dry seed coat.
- Place the air-dried seeds in plastic bags, seal the bags and store them at room temperature. Some seeds do not like drying or cool temperatures and too much shade so these must be experimented.
- Propagules may be kept under shade for as long as 2 weeks without adversely affecting their viability, but avoid placing them on the ground or any moist surface to prevent root development. Open baskets are best for storage.
- Do not store too many seeds in one big basket as heat may be generated and kill the seeds.

Protect your seeds from drying out or getting burned by the sun or they will die.

3.3.2 Propagation

The following activities are needed to germinate seeds and propagules and produce seedlings:

- Preparation of potting substrate**:** The growth of seedlings in the nursery significantly depends on the quality of the potting substrate. Fast root development is enhanced when the potting substrate is porous, i.e. substrate allows water to drain out.
  - If possible, use sandy-loam substrate (mixture of sand and mud) that is high in organic matter, a 50:50 ratio of substrate and organic matter is best as potting mix.
  - For germination seedbeds mix equal amounts of coarse sand with black forest soil and sieved organic matter.
  - Prepare potting substrate in advance to avoid unnecessary delays which can result in high seedling mortality, especially for wildlings. It is a good idea to prepare potting substrate of several cubic meters and have it on hand at all times.

Figure 11: A typical potting shed for keeping substrate moist

- **Germination techniques**: Here are some short descriptions on how to germinate some of the major groups before transplantation to the field.

  - *Rhizophora*, *Ceriops* and *Bruguiera* groups.

    - Certain species (propagules ≥15 cm long) can be successfully sown directly into the substrate of sites that are well protected from winds and waves.

    - On sites that are exposed to winds and waves, it is best to raise the propagules in polybags or bamboo in a nursery before transplanting to degraded sites.

    - The illustration below gives you an idea of how propagules can be germinated in polybag for cultivation in a nursery.

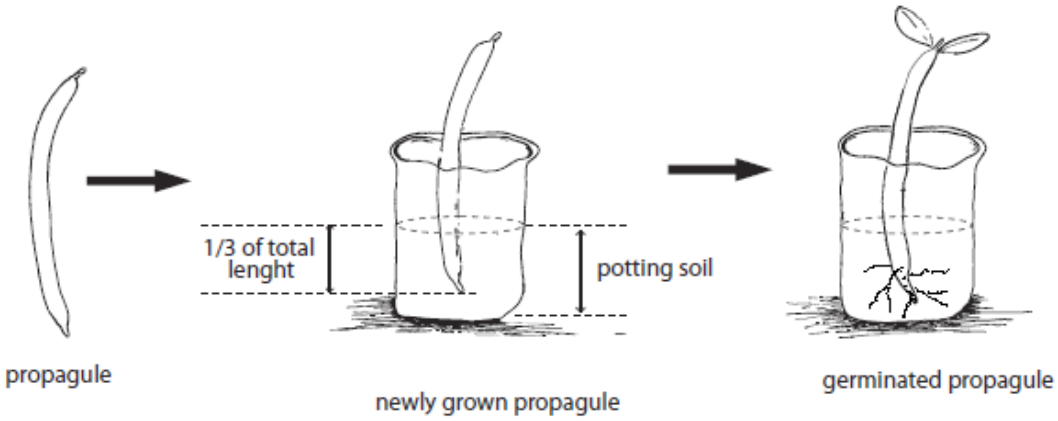


Figure 52: Cultivating propagules in a nursery

  - *Sonneratia* group.

    - Sow these boomerang-shaped seeds in a seedbox/seedbed with sandy substrate.

- Bury ½ the seed with the curved portion up.
- *Sonneratia* has a big potential for reforestation due to its wide range of habitat in the front zones and high salinity in back zones.

- The illustration below demonstrates how species with small to medium sized seeds can be germinated first directly in seedbed and then transferred to polybags when they reach 5-10 cm tall and have 2 leaves.

- For early and uniform germination, soak the fruit in fresh water for 7 days and then sow the seeds.

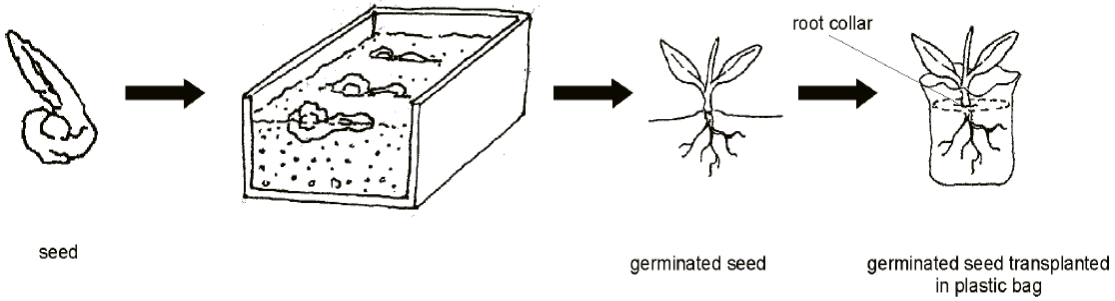


Figure 6: Cultivating *Sonneratia* seed

– *Avicennia* group.

- The easiest species to germinate; sow either in seed beds or directly in bags.

- Sow seeds in an upright position half buried with the emerging leaf or the cracked portion of the seed at ground level

- Once the seedlings develop a pair of leaves they can be handpicked for potting.

- Cover the seeds with a thin layer of substrate and water daily with brackish or salty water.

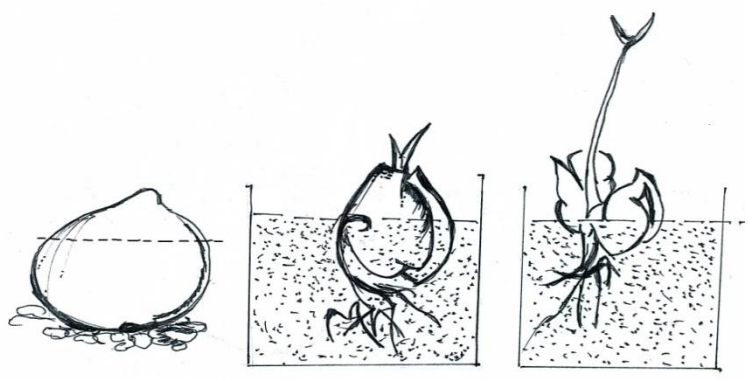


Figure 14: Cultivating *Avicennia* seed.

– *Xylocarpus* group.

□ Germinate the big angular seeds in seed beds or directly in pots.

□ Sow the seeds halfway with the embryo eye just at the substrate surface.

□ Water daily with brackish water.

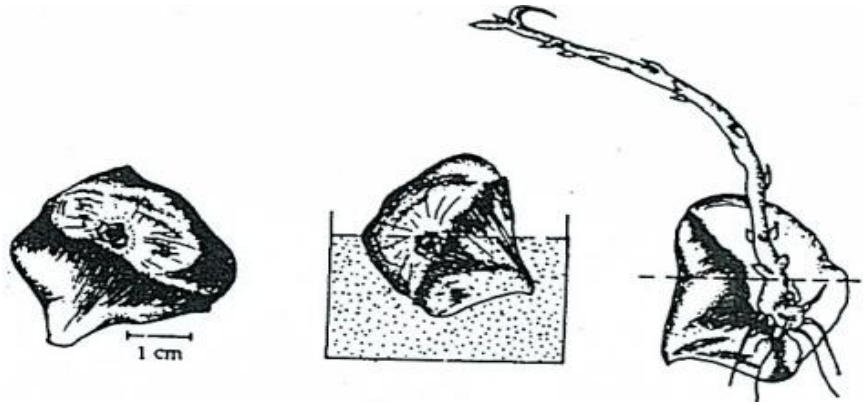


Figure 15: Cultivating *Xylocarpus* seed

■ **Potting**: Directly plant propagules and transfer small seedlings from seed box/bed to the polybag before planting in the field. Table 15 shows the different sizes of plastic bags for the different species.

– Seedlings

□ Carefully dig small seedlings out of seedbeds and move them using a flattened stake or spoon to minimize root damage

□ Plant the seedlings in the bag with the root collar level with the surface of the substrate in the bag.

□ Propagules - place propagules about 1/3 of their length deep in an appropriately sized bags.

□ Wildlings - place wildlings directly into polybags and take extra care not to damage the root system.

Table 22: Examples of appropriate polybag sizes

Species	Bag size (*l* x *w* cm)
Avicennia officinalis	10 x 15
Bruguiera cylindrical	10 x 15
Ceriops tagal	15 x 25
Rhizophora mucronata	20 x 30
Rhizophora stylosa	15 x 25

3.3.3 Nursery management

- Useful tools to have at your nursery include a hammer, saw, bush knife, hoe, shovel, small shovel, rake, watering cans or boxes, wheel barrow, pick mattock and spading fork.

- Organize shifts to operate and manage the nursery on a daily basis. Due to the importance of nursery operations, it is best if CPG members assume responsibility for managing the nursery. Typically it takes 4 to 6 months to grow out seedlings to the point where they can be transplanted.

- The CPG needs to decide the nursery management team and work schedule. It is usually easiest for the management team to consist of several people working part-time to share the work.

- Daily activities

  - **Watering**: If nursery is an upland one i.e. at back mangrove or not within intertidal zone, seedlings must be watered twice a day at the early stage with equal amounts of fresh and salt water. Later, watering can be done once a day towards the out planting season (4 to 6 months old) to acclimatize seedlings. This activity is very important and must be done religiously or the seedlings will get dry and die.

    - Water seeds and seedlings daily because even one missed day can negatively affect the growth rate and survival of the plants.

    - But do not water if there has been a lot of rain.

    - Use fresh water or brackish water before placing seedlings in hardening beds.

    - Water plants as early as possible every morning.

  - **Monitoring and maintenance:** Keeping track of what is happening to your trees and early intervention when there are issues is vital to the success of your rehabilitation project.

□ Shading:

- Shade the newly potted seedlings from intense sunlight. Shading material usually consists of coconut leaves, nipa palms or grass for temporary nurseries while permanent mass production nurseries you can use greenhouse shade cloth before the hardening process.

□ Weeding:

- Weed the nursery at least once a week to keep the seedlings free from competition. Weeding is especially necessary when the nursery is an upland (terrestrial) one.

- Remove any plants that are not mangroves and put them in a compost pile.

□ Protection from pests, diseases and stray animals:

- Conduct daily inspections for insect pests; any insects on the plants should be manually removed. See Table 13 for common insects and diseases that may harm the seedlings and the corresponding control measures. In areas with stray animals, fence the nursery with local materials such as bamboo pole

- See Table 13 for common insects and diseases that may harm the seedlings and the corresponding control measures. In areas with stray animals, fence the nursery with local materials such as bamboo pole.

Table 33 :Pests and disease control measures (Sinohin et al. 1996)

Pest / Disease	Damage	Control measures
Tussock moth	Larvae or hairy caterpillar feeds on leaves of young seedlings	Manual removal of larvae
Seed borer	Bores propagules and breeds on seedling / hypocotyl	Remove propagules with evidence of insects or holes Air-drying of propagules to reduce moisture content before germinating
Plant lice	Sucks nutrients of *Rhizophora*	Spraying with chemicals at company's specification or use chili spray*
Scale insect	Sucks nutrients causing curling of leaves	Spraying with chemical at company's specification or use chili spray
Slug caterpillar	Defoliation (loosing leaves)	Manual removal of larvae
Bagworm	Defoliation	Manual removal of bagworm
Leaf spot	Brown spots interfere with photosynthesis; defoliation if severe	Removal of infected leaves and burning
Rhizophora mosaic	Defoliation; interferes with photosynthesis	Removal of infected seedlings and burning
Stray animals	Trample or eat seedlings or their leaves	Fence the nursery with local materials such as bamboo poles

*chili spray is made from ground sun-dried chili mixed with water and kept overnight with some soap as a fixer so that it stays on the leaf.

- **Hardening off**: The hardening process must take place at least 4 weeks before outplanting. Hardening involves exposing plants to increasing amounts of sunlight until seedlings are fully exposed to sunlight. Likewise the amount of watering is reduced. Reduce shade by removing each layer of coconut leave or nipa palm. Table 14 shows a typical hardening treatment.

Table 14: A typical hardening process

Number of weeks				
Treatment	1	2	3	4
Reduce shading	Remove 1st layer (25%)	Remove 2nd layer (50%)	Remove 3rd layer (75%)	No more shading
Reduce watering frequency	Once a day	Once every 2 days	Once every 3 days	No more watering

- Grading, Sorting, Packaging and Transport of Seedlings.
  - After 6 months, select the seedlings that are 50 cm or more in height.
  - Sort those that meet this minimum requirement according to height before packaging and transport to the planting area ready for planting.
  - Seedlings that had grown less than 50 cm should spend more time in the nursery.
- Post Nursery Operations
  - When all the seedlings have been transplanted, make any repairs needed and clear out any remaining infected or dead seeds or seedlings before the next planting cycle.

3.4 PREPARATION FOR PLANTING

The plantation sites often need some preparation prior to planting. The Community Project Group (CPG) should walk over the entire area and determine what needs to be done.

3.4.1 Site preparation

- Clear the site of unwanted vegetation, debris, plastics, pieces of metal, tree branches and stumps. Keep in mind the potential for rubbish such as plastic coming in with tides, and seasonal accumulations of broken seaweed and seagrass.
  - When removing unwanted vegetation, make sure that unwanted vegetation (e.g. mangrove fern) does not grow back by taking it out by the root, do not just cut them.
  - Put up any fencing or barriers that were considered necessary during your site assessment in order to prevent damage to seeds, propagules and seedlings from the threat of pests, debris, livestock and humans.
  - If needed, construct a simple fence or stone barrier.

- The following tools and materials are very useful for preparing the site:
  - Bush knives, spades, rakes, mattock and corers,
  - Barrier materials such as rocks; fencing poles such as bamboo; and fencing ropes and wires.
- Make sure that the area to be planted is clearly marked, including the various planting zones for each species.
- Finally, make sure to estimate how long it will take for the incoming tide to cover the site. This will allow you to work out the amount of labour you will need to complete planting, but most importantly minimize the loss of seedlings due to drying out.

3.4.2 Volunteer recruitment and training

Select and train your volunteers in advance.

- Decide whether you will use a few planters over a few days or whether you will use a large group to plant everything in one day. Generally, the fewer people that do that planting the better the planting and the higher the success.
- Hold an instruction event that includes an on-site demonstration to educate the planters on the proper techniques as contained in the sections below.
- Make sure all volunteers attend, even if the group is large, because if they do not know what they are doing your seedlings will die and your effort would be wasted.

3.5 PLANTING

Mangroves can either be planted directly into the ground on a site or spend time in a nursery before being transplanted. Though this document covers spending time in a nursery before site planting, direct planting can be successful in the right conditions (see section 3.5.2).

3.5.1 Planting times

Seasonal

- Plant your mangroves at the same time that the species would naturally begin to grow naturally. If the species grow year round, it is best to plant in the wet season, especially for species that occur at the mangrove back.

- Do not plant during periods of high wind and/or high tides e.g. cyclone season if in Milne Bay Province.

- If major flooding occurs close to the time you want to plant, wait a few days after the flooding before starting to plant.

Daily

- Begin planting during low tide in the front zones of the plantation and move toward the mid and back zones as the tide comes in.

Do not sow propagules deeper than the recommended depth, this will stop the seeds from breathing and they will die. Generally propagules are sown one-third of their length in firm substrate and one-half of the length in soft substrate.

3.5.2 Direct planting with propagules or seeds

Mangroves such as *Rhizophora*, *Xylocarpus* and *Heritiera littoralis* can be planted directly into the substrate in very sheltered sites. If done correctly, this method is cheap and easier than using a nursery but often fails due to incorrect practices.

- One of the most common reasons for failure using direct planting is that the propagules are pushed too deep into the substrate so that the seed cannot “breathe” and slowly dies.

- Depending on the species, propagules must be pushed ⅓ or ½ of their length into the substrate.

- When planting in the ground, place the lower wider half of the propagule into the substrate.

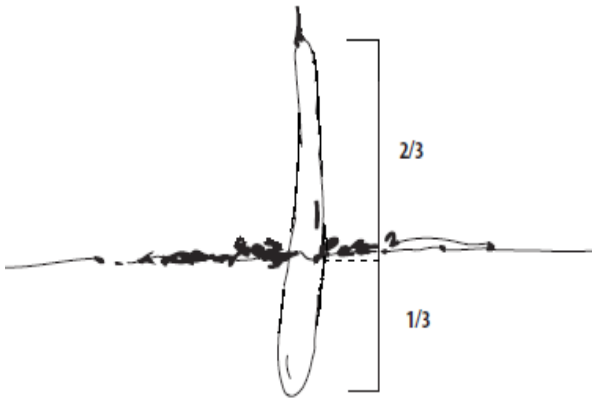


Figure 16:Correct planting depth for direct planting of propagules

- If the substrate is hard, holes the size of the propagules should be made before inserting the propagules.

- After planting, press firmly around the propagules.

3.5.3 Planting from pots/bags

This planting strategy involves considerably more cost and effort than direct planting.

- Take the seedlings to the site one day before planting and leave them in the tidal area you want them planted. Position the seedlings upright next to a support e.g. trees.
  - The soaking of the plants by the tides will loosen the soil from the polybags/pots, making it easier to remove the plants and allowing the polypots/bags to be reused.
  - DO NOT leave your seedlings the planting site if it is subject to strong tides and winds. Your seedlings may get swept away and/ or damaged. Rather soak the plants with water from a watering can or manually dip them in the sea before storing them at a higher elevation.

- Things to watch out for when planting
  - **Hole Size:** Prepare holes for planting that are 1.5 times wider and 1.5 times deeper than the root ball of the seedling (see Figure 17)
  - **Removing the polybag/pot:** Having soaked the bag in fresh or sea water beforehand, carefully remove the polybag or pot without damaging it and without disturbing the seedling or its soil. Bags and pots can be re-used while seedlings grow better if their soil remains relatively undisturbed.

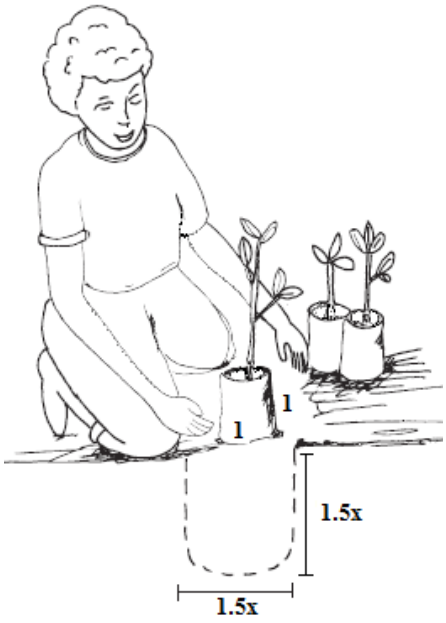


Figure 17: Correct hole diameter and depth when transplanting from polypots and polybags

– **Correct depth and avoiding "J"-Roots:** The correct depth for a seedling is when the root collar is in line with the soil and the roots do not touch the sides of the hole (see Figure 18). A tree can die if it is planted too shallow or too deep.

  □ If the roots of the seedling are tangled up or wrapped tightly around the root ball, gently untangle them so that they hang downwards.

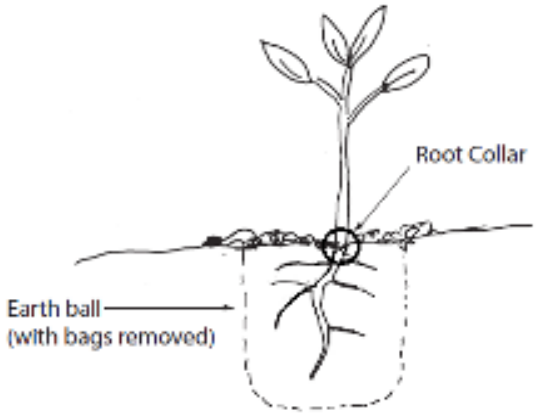


Figure 18: Correct planting depth

□ Lower the seedling into the hole until the root collar is in line with the top of the hole, but do not allow the roots of the seedling to touch the hole's sides or bottom. When roots curl upward against the hole (like the letter "J") it can stunt growth or even kill the plant. You may need two people per seedling to do this.

□ Finally, have one person fill the hole in with substrate while the other continues to hold the seedling at the same height.

Figure 19: Compacting the substrate around a newly planted seedling

- **Loose Substrate:** Do not trample on the substrate surface after planting a seedling. Lightly fill the substrate into the hole until it is completely filled with loose substrate and *gently* compact with your hands.

- **Spacing:** Mangroves do not naturally grow in straight lines, so don't worry about being too exact about spacing when planting your seedlings. Spacing can be 1-1.5 m.

- **Pruning:** If before planting you notice that some roots are damaged, remove them to avoid possible *Phytophthora* invasion (a disease that destroys the plant roots).

4. ENSURING SURVIVAL

4.1 MONITORING AND EVALUATION

The purpose of monitoring is to examine the project implementation (Planting Activities) in the field. Monitoring and tending of mangrove plantations is critical as they provide useful information that will help you improve your project in the future. Many lessons can be learnt based on the growth performance of planted seedlings. These include site selection, choice of species and causes of mortality.

Information collected from restoration monitoring can be used to determine whether project goals are being met and if corrections are necessary in the middle course of the project.

The first two years after planting are the most intense, requiring regular monitoring of growing seedlings and maintenance work. Generally, from the third year onward, the level of care required becomes less, but may involve thinning the trees if they were planted densely and for the purpose of timber production.

4.1.1 Training of community project group members on Monitoring and Evaluation

- Get an expert to train selected members of your community project group on how to conduct effective monitoring and evaluation.

- Techniques learnt must support improvement of future activities of the project and replication of the Monitoring and Evaluation process

- The monitoring techniques used in the field should be in a simplified form and standardized to allow easy and more detailed and accurate measures of progress towards meeting goals/outputs established prior to restoration. See Template 1 Forms for monitoring and evaluation in appendices to guide you in collecting data.

  - For rehabilitation activities, initial or baseline monitoring and evaluation must contain information on number of seedlings planted, their species, planting techniques, site condition, pest threats etc. See Template 1 forms on Rehabilitation.
  - Regular monitoring and evaluation after planting must include data on plant survival rate (see Monitoring and Evaluation Results), threats, replenishment planting etc…

  - The selected members of your CPG form the technical team of the project and must fully understand and know how to interpret data collected in the field particularly plant survival before commencing any monitoring activities on their own.

- Data collection and storage:
  - Field data collected must be entered into spreadsheets if you have access to a computer so analyses can be done orderly and easily especially working out the survival rate.
  - All field data (electronic and/or paper), data analyses, measuring and monitoring forms/reports must be stored in a dedicated and safe place, preferably offsite and must be accessible by all project members.
- Experts should continue to be involved in the project as advisors and to monitor aspects of the project which require specialized expertise

Table 15: Monitoring phase activities (modified from Field, 1998b)

	Activities	Comments
	Monitor mangrove species that develop	Compare success of seedlings according to species and zones they were planted in within rehabilitation site
	Monitor seedling growth at time intervals	Measure density (number of seedlings per m^2), percentage cover and species composition of both planted mangroves and those that develop naturally (ask an expert) Measure average height and the number of leaves of selected seedlings, and when they start reproducing (ask an expert)
	Monitor survival rate of plants	Count the number of seedlings growing and surviving and workout survival rate per year (see Appendices).
	Record level of failure of saplings	Provide a scientific explanation for failure (this may require help from an outside expert)
	Record level of rubbish accumulation	Note source of rubbish and steps taken to minimize the problem
	Adjust spacing of mangrove seedlings and saplings to an optimum level	Frequency of thinning (if for timber production), replanting or natural regeneration should be noted.
	Estimate cost of restoration project	The estimation of costs should include all the undertakings including the preparation, propagule collection, nursery establishment, field transplantation etc
	Monitor impact of any harvesting project	This should be part of any long-term record for restoration
	Monitor characteristics of the rehabilitated mangrove ecosystem.	This involves detailed measurement of animals; plants and physical environment of the new mangrove ecosystem and comparison with similar undisturbed mangrove ecosystems (ask an expert).

	This is usually done in the 3rd to 5th years when the plantation is matured and animals/plants have inhabited the rehabilitated area.

4.2 MAINTENANCE

Active maintenance during the early years of the rehabilitation is important to the health and success of your mangroves.

4.2.1 Maintenance activities in the first two years

- Visit the plantation daily immediately after planting to be certain that things are all right and to perform the daily chores listed below. For example, if a large amount of green algae log floats into the area, those who regularly visit will be able to remove it before it can do too much damage.

- Once seedlings become established you can reduce visits to the plantation to few times a week.

- Develop a routine to inspect both the entire plantation and specific patches.

  - Imagine the site divided into blocks and make it your business to look closely at a few plants in each block because it is impossible to look at each and every plant.

  - It is easier to walk around and inspect seedlings across the whole plantation at low tide.

  - Check for:

    - Encrusting organisms like barnacles and oysters

    - Insects and moth larvae eating leaves

    - Dead or dying plants
    - Plants entangled in algae, seaweed or seagrass and plastics.

- Removing encrusting barnacles and oysters.

  - Remove shells by hand before the propagules are totally covered. Do *not* scrape the propagules with a bush knife since that will result in plant damage and eventual death.

  - Once the shell is carefully t off, simply throw it in the water because it will not be able to reattach itself to the mangroves.

- Removing grazing animals or insects.
  - Pluck them from the leaves, trunks and branches of the seedlings and place them in a bag.
  - Remove the bag from shore for disposal; do *not* simply throw them in the water because they can reach another tree.

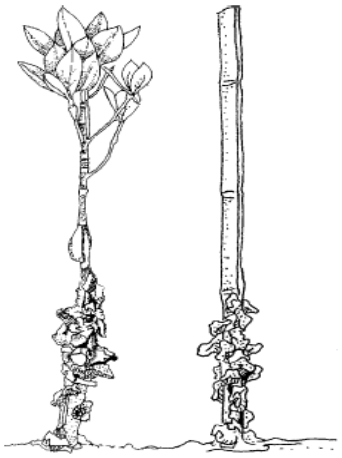


Figure 20: Encrusting barnacles on a mangrove sapling

- Removing dead or dying trees.
  - Quickly remove dead or dying trees from the area.
  - If seedlings are dying in large numbers, it may be necessary to replace them with seedlings from the nursery or other stocks.
  - If seedlings are dying in large numbers, it is important to determine why. Contact an expert to inspect some sample seedlings or visit the area to evaluate the site.
- Install or repair any necessary fences or barriers.
- If you find extensive problems and it will take more than a few hours to fix the damage, involve more members of the Community project group or community.
- Remove debris such as plastics, pieces of metal, tree branches from site. Keep in mind the potential for debris such as plastics coming in with tides, and seasonal accumulations of broken seaweed and seagrass.

Without caring for the area daily, a lot of problems can develop. The more problems a plantation has the less effective it will be as a coastal defence and the less benefit it will provide to the community and the coastal ecosystem.

4.2.2 Maintenance activities in subsequent years

- Thinning - if you planted your mangroves more densely than normal or they have simply all survived and grown very well, it may be necessary to thin them out to allow proper growth, especially if you intended for the plantation to produce quality timber.

  - If the trees are below a meter high it is possible to uproot and move the trees further apart. Do this in a similar way to collecting wildlings.

  - If the trees are over a meter high, they may be too large to move so always thin before they get too tall.

- Pruning - another maintenance activity that takes place after the initial year or two of intensive maintenance. It is the cutting of unnecessary branches and stems and is done to enhance height and trunk diameter growth rate. This is advised for timber production plantations.

  - Do not cut more than 30% of the living branches over a 1-2 year period. Over-pruning will harm plant growth.
  - For bigger branches, make a cut underneath the branch 10 centimeters from the trunk. Then make a cut on the top of the branch close to the trunk to avoid bark splitting i.e. you will be cutting diagonally.

Both thinning and pruning at the 5-year point and beyond results in plenty of sustainable fuel and construction wood.

4.3 REPORTING

Well run projects always have a monitoring, evaluation and reporting system to keep track of progress. Evaluation can be defined for your purposes as an assessment of the progress of a project over a period of a year.

These reports will be valuable for community members that want to know the details of the project they are supporting and if you have received money from any donors. They will want to know how effectively their money has been used. The data records and notes taken during frequent monitoring activities of the nurseries and sites will form the basis for the evaluation.

There are two key reports that you should produce a progress report and a financial report.

- **Progress report** – this is a basic summary of what activities have been achieved, what is yet to be achieved and the problems encountered. The progress report should be written yearly and should have a:
  - Monitoring section: this involves an analysis of the status of the nursery and/or planted mangroves. Points to consider include:
    - How many seedlings survived the nursery phase?
    - If many seedlings died, what was the cause of mortality?
    - How can problem be addressed?
    - What stresses are your planting seedling facing? And how can you deal with this stresses to increase chances of survival?
  - Evaluation section: this part of the report requires more information about the project operations. Go through the activities on your workplan, think of what might be useful for an outsider to know in relation to those items. For example, some points could cover:
    - How the community responded to the project
    - What the biggest issues were and what was done about them
    - What the overall attitude of community is towards the project.

- **Financial report**: use the budget you produced with your workplan as your starting point and use your records of income and expenditure (such as bank statements or receipts).
  - Do a summary of actual expenditure and how it compares with budgeted expenditure
  - Overview of income: how much money came into the project and where did it come from?
    - Donations
    - Government funding (e.g. Community budget allocations) or
    - Other
  - Overview of expenditure: how much money was spent on the project and what was it spent on?
    - Materials and equipment,
    - Training costs,
    - Activity related costs (e.g. giving food to volunteers on planting days),
    - Fundraising costs,
    - Wages or wage equivalents from in-kind labour time by volunteers or
    - Other
  - Inventory summary: what equipment and tools did you start with, what did you buy, replace or lose during the year? What do you have now?

If you are unsure of how to do report, ask a community member that may have done some before or local CBO or NGO.

4.4 PROTECTED AREAS

Papua New Guinea has 57 protected areas under three different environmental legislations (DEC). The total number of protected areas comprises of National Parks and Wildlife Management Areas. These protected areas represent almost 3 percent of PNG's territory.

Creating a protected area that includes your mangrove can be an effective way to ensure your project is managed sustainably long-after intensive project activities have ended. The management of these areas varies from co-management arrangements between local landowners and government to those consisting solely of local landowners such as in Wildlife Management Areas (WMA).

There are strong benefits to engage in conservation. The most obvious benefit is that protected area communities still have access to vital natural resources, such as fish and wood, which may be seriously depleted or degraded in the neighbouring communities. There is thus great socioeconomic value in maintaining, managing and protecting local ecosystems.

If you are interested in creating a protected area, contact the relevant NGOs or your LLG or councillor who will link you with appropriate people listed in Table F in the Appendices for help.

5. AWARENESS AND TRAINING

5.1 AWARENESS

Before beginning any project activities, it is important to get as much of your community in support of your project as possible and aim to involve them in all aspects of your project.

This will assist in mobilizing labour for the often tiring work and encourage a sense of responsibility that will improve the chances of long-term survival of your mangroves.

5.1.1 Running your first awareness

Organise a community gathering or use an existing forum like a church open session to run your first awareness. Ask the OCCD, DEC and NGOs for awareness material such as posters, brochures and presentations to help explain:

- What climate change is and what its effects on PNG has been and will be if we do not do anything about it
- What role mangroves play in climate change adaptation? If the community knows the roles mangroves play, then they will appreciate that what we are doing is important
- What the benefits of mangroves are
- What your proposed mangrove project is
- How the community can get involved and help make your project a success

Repeat awareness activities from time to time to maintain support and involvement of the community.

5.1.2 Meet with community members who will impact your project

- Identify and meet with community members who can influence your project the most. For example:
  - community leaders that have influence over how the community uses natural resources and land
  - LLG council members and presidents

- project champions i.e. people who will take ownership of the project because they believe in looking after the environment
- community members that are main drivers of mangrove degradation
- families living near your site or bordering healthy mangrove areas
- fishers who catch fish in the mangroves or take their boats through them

- Try as much as possible to get these influential groups involved in your project, in both planning and implementation. Understanding their needs and using their knowledge will be critical to the success of your project.

5.1.3 Select a community project manager and a community management group

- Have community leadership select a candidate as community project manager (CPM) and form a community project group (CPG). See table 16 for characteristics and roles of CPM and CPG.

Table 16: Characteristics and roles of CPM and CPG positions

Characteristics of good candidates for CPM and CPG positions	
CPM	■ Respected member of community with project management skills ■ Ability to work with all community members and influencers ■ Has demonstrated skills at planning and managing community activities or other projects ■ Talent for teaching and passing on knowledge
CPG	The group should have as a minimum, ■ A Chairperson, ■ A Treasurer and ■ A Community Project Manager (CPM) Should be made of members of the community with: ■ A background of committed involvement in community initiatives ■ The respect of the whole community ■ History of participation in organizing or carrying-out community activities ■ The Treasurer should be highly trustworthy and have a history of managing the finances of a group ■ Include a representative of any outside support that will be assisting with the project, such as an NGO
Role of the CPM and CPG	
CPM	■ Manage the day-to-day activities of the project ■ Be the lead point of contact for all project activities ■ Be the main signatory on all reports

CPG	■ Develop basic guidelines, policies and rules to improve group decision making and deal with conflicts (Borrow from good existing rules where available) ■ Develop the project plans and lead the implementation of activities ■ Create and sustain awareness and support amongst community ■ Manage project funds ■ Write and submit reports ■ Organise any special interest groups or cooperatives to market alternative livelihoods

Get assistance from your ward member, Local Level Government or a Community Based Organisation (CBO) and use their existing procedures as much as possible. Otherwise, section 2.1 provides a good guide.

5.1.4 Conducting regular follow-up awareness

It is important to continue to doing regular follow-up awareness activities throughout your project. You need to keep your community interested and involved. Put up a notice board to keep track of progress in a central place and update it often

- Use forums like church open sessions or women's groups to make announcements and call for assistance

- Involve the community in all aspects of the project and have them drive the project. This will encourage a sense of responsibility for the mangrove community and help with the sometimes labour-intensive word

5.2 TRAINING

It is important that your CPM has the required skills and knowledge to lead the project. The CPM will also need to pass on his skills to the rest of the CPG as well as temporary volunteers.

- The CPM should have good skills in the 5 categories below. If he/she does not have them at the start of the project, select another candidate that does or arrange for and receive training. Contact an NGO or the OCCD for advice on where to receive training.

  - Mangrove rehabilitation and management,
  - Project management,
  - Financial management,

- Alternative livelihoods, and
- Reporting

- To further improve the abilities of the project team, look out for and attend any mangrove training workshops organized by the government or NGOs. If there are none organized, speak to your local CBO or NGO about how one could be arranged.

6. FUNDING

6.1 PROJECT COSTING

Before you can ask for funding, you need to have an estimate of how much your project is going to cost. When you go to people asking for a large amount of funding, they will almost always want to see a budget of your project that shows how much money you need and what you plan to spend it on.

6.1.1 Develop your budget.

Prepare your budget at the same time as you develop your basic workplan (see section 2.1).

- Estimating costs
  - Go through each action of the workplan and if the action will require money to carry-out, estimate how much money it will cost.
  - Costs to think about are building materials, equipment, wages, incentives (such as food for labour), transportation and other costs e.g. fundraising costs of an event to raise money for the project)

Avoid paying incentives as much as possible. Incentives can end up being very expensive and if you use them once, people may expect and demand compensation every time.

- Estimating income
  - Think about how you will fund your project. Can you do it without money from in-kind contributions and use of available resources? Will you get money from the community? Will you get government funding? Can you find a company to sponsor it? How else could you get money?
  - Identify sources of funding (see next section 5.2) and how much they have available. If you are fundraising, estimate how much you think people are willing to give and multiply that by how many people you think will give (but be careful of *over*estimating)

6.1.2 Refining your budget

- Again, do this at the same time you refine your workplan (see section 1.5); this will make it easier to identify changes.

- Once you have identified the necessary changes, incorporate them into your budget.

6.2 IDENTIFYING SOURCES OF FUNDING

This section aims to provide the skills and knowledge for mangrove rehabilitation projects that are both successful and low-cost. However, additional financial support may be necessary under certain circumstances, so here is some advice on how to secure that extra funding.

The table below gives some of the different funding sources that may be available to communities and some of the advantages and disadvantages of each source. For more details on potential sources of funding, see Table G in the Appendices section.

Table 17: Advantages and disadvantages of various different funding source

	Advantages	Disadvantages
National government	Several agencies focussed on disaster risk reduction, climate change and the environment	Not usually provided direct to communities
	Special development funding (PIPs) that can be used for many purposes	Normally focussed on capacity building and coordination of local agencies
		Can take over a year to access funds
Provincial and district government	Provide direct financial support	Few or no funds focussed on disaster risk reduction, climate change or environment
	Many development funds available	Funds often quite small
LLG	Provincial funding is supposed to follow plans based directly on those of Wards and LLGs	Allocation process often unclear and not transparent
	Funding can be used on implementation activities rather than just capacity or planning	Allocation at funds often at the discretion of the Governor or Open Member rather than according to development plans
		Can take over a year to access funds
Development agency	Many agencies with access to large funds	Do not normally provide financial support to communities or projects

	Many agencies with a mandate to support either disaster risk reduction, climate change and environmental cause	Do not normally support communities on an ad hoc basis Can be very selective in who they support
NGO	Most are directly supporting disaster risk reduction, climate change and environmental issues Normally clear and transparent allocation process Typically respond quickly so the easiest way to access mangrove replanting initiatives is to form a long-term relationship with an NGO	Do not normally provide financial support to communities or projects Do not usually provide ad hoc support as they follow annual or multi-year workplans closely
Private sector organisations	Many companies are looking to support disaster risk reduction, climate change and environmental related projects Can move very quickly if they are interested in a cause	Unclear how many private organisations they could provide funds for Unclear how much funding is available
Community raised Funds	Communities will note importance of the initiative and respond quickly by donating funds.	Community members may not be interested and not contribute funds to the support the initiative.

6.3 APPLYING FOR AND SECURING FUNDS

6.3.1 Requirements for securing funding from sources

Applying for funds can be challenging, but there are 5 things that almost any source funds would want you to provide before they give you money. If you have each of the following ready, the process of getting funds from most sources should be much smoother and easier:

- **Project summary** of provides an overview of the purpose, goals and activities of the project, it notes key people, dates and locations (think what, where, when, why, who and how)
- Overall project workplan and budget (see sections 2.1 and 2.5)
- **Highlight** the budget items that need funding and how much they will cost all together (have clear motivations for why these specific actions should be supported)
- **Community's contribution to project**, what is the community's financial or in-kind contribution to the project?

- **Financial management summary** of how you plan to manage the funds (e.g. bank account, trust fund, signatories).

6.3.2 Targeting appropriate funding sources

Once you have a clear idea of what your funding needs are you can target appropriate sources e.g. the District Support Grant. Below are some things to look for when targeting sources of funds:

- **Alignment** - are the goals of your project in line with the goals of the fund?
  - If the fund is supposed to support disaster risk reduction, climate adaptation or environment activities, the application process should be straight forward.
  - If the fund is supposed to support something like agriculture, it is unlikely your project will get support unless generating food from the mangroves is a key goal of your project.
- **Geographic coverage** – does the fund support projects in your province/district/LLG/ward?
  - If a fund is limited by mandate to a particular area that doesn't include your community, it is unlikely to be able to support your project
  - Some funds are not limited to areas but still prefer to support only projects in areas that they are already active in and have established relationships
- **Conditions and limitations** - what kind of conditions does the fund apply to its support?
  - Are there performance requirements – if so, what are they?
  - Are there specific things the fund does *not* support (e.g. livelihood activities)
- **Size** - how much funding do they have available? What is the maximum amount of funding they provide? It is normally easier to get funding from many small funds rather than a few large ones, but they can be harder to manage
- **Time horizon** - how many months/years support do they provide? Try and secure funding that will be provided over several years to increase the long-term sustainability of your project
- **Track record** - has the fund already supported similar projects to yours? (past support often means the fund will be more likely to fund similar projects)
- **Turnaround** - how quickly does the fund move from applications to providing support? (This information is not always known but could save you months of waiting)

6.4 FINANCIAL MONITORING AND REPORTING

See section 4.3 on evaluation and reporting.

REFERENCES

Bovell, O. 2011. *Guyana Mangrove Nursery Manual*. Guyana Mangrove Restoration Project, 23 pp.

Brown, B. 2004. *Do Your Own Mangrove Action Project: An Action-Research Problem-Solving Method.* Mangrove Action Project, Yogyakata, Indonesia.

Chan, H.T. and Baba, S. 2009. *Manual on Guidelines for Rehabilitation of Coastal Forests damaged by Natural Hazards in the Asia-Pacific Region.* International Society for Mangrove Ecosystems (ISME) and International Tropical Timber Organization (ITTO), 66 pp.

Duke, N.C. 2006. *Australia's Mangroves: The Authoritative Guide to Australia's Mangrove Plants*. University of Queensland, Brisbane, 200 pp.

Feller, I. C. and Sitnik, M. 1996. *Mangrove ecology: a manual for a field course*. Smithsonian Institution, Washington, DC, 21 pp.

Field, C. D. 1996. *Restoration of mangrove ecosystems*. International Society for Mangrove Ecosystems, Okinawa, Japan.

Gattenlöhner,U., Lampert, S. and Wunderlich, K. 2007. *Mangrove Rehabilitation Guidebook*. Global Nature Fund, Radolfzell, Germany, 68 pp.

Giesen, W., Wulffraat, S., Zieren, M. and Scholten, L. 2007. *Mangrove Guidebook for Southeast Asia*. FAO Regional Office for Asia and the Pacific.

Gilman, E., Van Lavieren, H., Ellison, J., Jungblut, V., Wilson, L., Areki, F., Brighouse, G., Bungitak.J., Dus, E., Henry, M., Sauni, I.Jr., Kilman, M., Matthews, E., Teariki-Ruatu, N., Tukia, S. and Yuknavage, K. 2006. Pacific Island Mangroves in a Changing Climate and Rising Sea. UNEP Regional Seas Reports and Studies No. 179. United Nations Environment Programme, Regional Seas Programme, Nairobi, KENYA.

Guidelines for community-based rehabilitation of mangroves. DENR Recommends Vol.5. Ecosystems Research and Development Bureau (ERDB), Philippines, 10 pp.

Hiraishi, T. and Harada, K. 2003. Greenbelt tsunami prevention in South-Pacific region. *Report of the Port and Airport Research Institute*, *42*(2), 1-23.

Kairo, J. G. 2008. *Conservation and management of mangrove forests in Kenya*. Mangrove Reforestation Program Kenya Marine and Fisheries Research Institute. Mombasa, Kenya.

Kitamura, S., Anwar, C., Chaniago, A. and Baba, S. 1997. *Handbook of Mangroves in Indonesia –Bali and Lombok*. International Society for Mangrove Ecosystems (ISME). Tokyo, Japan.

Lewis III, R., Streever, B. and Theriot, R. F. 2000. *Restoration of mangrove habitat* . Engineer Research and Development Center, Vicksburg MS Environmental Lab.

Longman, K. A. 2003. *Raising seedlings of tropical trees* (Vol. 2). Commonwealth Secretariat, London, United Kingdom, 156 pp.

Lovelock, C.C. 1993. *Field Guide to the Mangroves of Queensland*. Australian Institute of Marine Science (AIMS).

Mangrove Action Project. 2006*. 5-Steps to Successful Ecological Restoration of Mangroves.*

Maniwavie, M. 2013. Survival Rates and Factors Controlling the Survivorship of Mangrove Seedlings at Selected Replanted Sites in Central Province, Papua New Guinea. *Biology Department.* Port Moresby, University of Papua New Guinea.

Maniwavie, T. 2009. *An Introductory Manual on the Biology and Restoration of Mangrove Ecosystems.* Motupore Island Research Centre Educational and Outreach Programme, 71 pp.

Maniwavie, T. 2007. *A Pictorial guide to the Mangroves of Papua New Guinea*, 39 pp.

Marquardt, J. and. Trevena, M. 2009. *Protecting Mangroves: Benefits for People and the Environment, Reforestation Efforts and Experience from San Agustin*. An Education Kit. Center for Education, Research and Volunteerism (CERV) in the Philippines and Meaningful Volunteer, Philippines, 84 pp.

McLeod, E. and Salm, R.V. 2006. *Managing Mangroves for Resilience to Climate Change*. IUCN, Gland, Switzerland, 64 pp.

Melana, D.M., Atchue, J., Yao, C.E., Edwards, R., Melana, E.E., and Gonzales, H.I. 2000. *Mangrove Management Handbook*. Department of Environment and Natural Resources, Manila, Philippines through the Coastal Resource Management Project, Cebu City, Philippines, 96 pp.

Percival, M. and Womersley, J.S. 1975. *Floristics and Ecology of the Mangrove Vegetation of Papua New Guinea*. Botany Bull No.8. Department of Forests Papua New Guinea, 96 pp.

Primavera, J. H.and Esteban, J. M. A. 2008. A review of mangrove rehabilitation in the Philippines: successes, failures and future prospects. *Wetlands Ecology and Management*, *16*(5), 345-358.

Ramasubramanian, T. and Ravishankar, R. 2004. *Manual on Mangrove Nursery Raising Techniques*. M.S. Swaminathan Research Foundation, Chennai, India, 48 pp.

Rasool, F. and Saifullah, S. M. 2005. A new technique for growing the grey mangrove *Avicennia marina* (Forssk.) Vierh., in the field. *Pakistan Journal of Botany*, *37*, 969-972.

Raga, M.N. 2006. Water use survey report, Barakau village, Central Province, Papua New Guinea. *SPREP,* Apia, Samoa.

Salmo, S., Torio, D. and Esteban, J. M. 2007. Evaluation of rehabilitation strategies and management schemes for the improvement of mangrove management programs in Lingayen Gulf. *Science Diliman*, 19(1).

Sheaves, M. 2009. *Preliminary Evaluation of Mullins Harbour Coastal Wetland Complex: Habitat Inventory, Condition and Threats*. A report to Conservation International, Port Moresby.

Spalding, M., Kainuma, M. and Collins, L. 2010. *World Atlas of Mangroves*. Earthscan.

Stewart, M. and Fairfull, S. 2008. *Mangroves*. In Industries, NDOP (Ed.). Sydney, NSW Government.

Suryadiputra, I. N.N. and Telly, K. 2007. *Demonstration of Community-based Mangrove Reforestation in Aquaculture Landscapes to Promote Ecological Productivity, Sustainability and Environmental Security in Aceh, Indonesia.* Wetlands International - Indonesia Programme, Bogor.

Technical Guidelines for the Establishment of a Coastal Greenbelt. 2007. The World Conservation Union (IUCN). Sri Lanka Country Office.

The Environmental Justice Foundation. *Mangroves: Nature's Defence Against Tsunamis - A Report on the Impact of Mangrove Loss and Shrimp farm development on coastal defences.* Environmental Justice Foundation, London, UK.

The Guyana Restoration Project. 2010. *Mangrove forest guide*. National Agricultural Research Institute, Mon Repos East Coast Demerara.

The Guyana Restoration Project. 2010. *Mangroves: understanding the basics*. National Agricultural Research Institute, Mon Repos East Coast Demerara.

Thoi H.V. and Thinh, P.T. 2010. *Mangrove Nursery Manual*. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH and Management of Natural Resources in the Coastal Zone of Soc Trang Province, Vietnam.

Whitten, A.J., Damanik, S.J., Anwar, J. and Hisyam, N. 1987. The Ecology of Sumatra. Gadjah Mada University Press, Indonesia.

Wibisono, I.T.C. and Ita Sualia. 2008. *Final Report: An Assessment of Lessons Learnt fromthe "Green Coast Project" in Nanggroe Aceh Darussalam (NAD) Province and Nias Island, Indonesia, Period 2005-2008*. Wetlands International - Indonesia Programme, Bogor.

Useful websites

✓ **www.glomis.com**

Global Mangrove database & Information Systems. A database providing information on the characteristics of single mangrove species and the mangrove ecosystem. It also includes scientific literature relating to mangroves, institutions and scientists working on all aspects of mangroves, as well as regional projects and programmes related to mangroves.

✓ **www.lewisenv.com**

Lewis Environmental Services. Provides expert consultation on restoration of wetlands and various relevant publications on ecological mangrove restoration available online.

✓ **www.mangroveactionproject.org**

Mangrove Action Project. A website providing information on bottom-up approaches to mangrove conservation and restoration issues and related coastal ecosystems. It also provides access to specific case studies, publications and annual reports.

✓ **www.mangroverestoration.com**

Mangrove Restoration website. A source for information on Ecological Mangrove Restoration and provides links to related websites on mangroves as well as downloadable PDF files to view.

✓ **www.mangrove.or.jp**

The International Society for Mangrove Ecosystems. A source for information on mangrove ecosystem conservation, rational management and sustainable utilization. Includes publications available online.

✓ **www.mangrove.org**

mangrove.org is a website dedicated to the development of a methodology that would provide the optimum conditions for successful mangrove afforestation and reforestation. You can access information on how to apply this methodology and related case studies as well as related videos.

✓ **www.wetlands.org**

Wetlands International. Provides information on the conservation and restoration of wetlands and the sustainable use of its resources.

APPENDIX 1

TABLE A1: BASIC BUDGET TEMPLATE- INCOME

Category	Description (e.g. Church fundraiser)	Budget amount	Actual amount	Difference
Income				
Community fundraising				
Sub-total				
Government funding				
Sub-total				
Donor funding				
Sub-total				
Other				
Sub-total				
Total				

* Note: For each category item, there should be supporting information and calculations that show how you arrived at the numbers in the basic budget

TABLE A2: BASIC BUDGET TEMPLATE – EXPENCES

Category	Description (e.g. Church fundraiser)	Budget amount	Actual amount	Difference
Expenses				
Community fundraising				
Sub-total				
Government funding				
Sub-total				
Donor funding				
Sub-total				
Other				
Sub-total				
Total				

TABLE B: TEMPLATE FOR A BASIC PROJECT WORKPLAN

Objective	Activities	Sub - Activities	Owner	Related parties	J	F	M	A	M	J	J	A	S	O	N	D
Awareness and training	Create awareness amongst the community and get their support for the project	Community gathering	Joseph E	Community members												
		Meet important members	Joseph E	Community members												
		Select CPG and CPM	Joseph E, community	Community leaders												
		Follow-up awareness	CPM, CPG members													
	Attend skills training courses and workshops	Technical training course	CPG member	NGO X, Academic Y												
		Reporting training workshop	CPG member	NGO Z												
Progress reviews																
Team availability																
Joseph E					√	√	√	**x**	√	**x**	√	√	√	√	√	√

Things to remember when developing a workplan

Work planning is an approach to breaking down complex tasks into manageable pieces and processes. It also gives relevance to day-to-day activities by ensuring that they contribute toward critical, longer-term goals as effectively and efficiently as possible and by required deadlines.

- There are 3 golden rules for developing a great workplan. For each group and each individual:

  1. Set aspirational and specific targets, ideally 5-7 key objectives per year. You should avoid setting targets that are too unrealistic, don't set targets that are too easy either, as this can create complacency.

  2. Work backwards from each target to identify and define critical milestones, often 3-5 milestones per target. Milestones are key achievements that are needed to meet a target.

  3. Identify and define activities that need to be done in order to reach each milestone, usually 1-2 per week for each milestone

- With the golden rules in mind, there are 12 steps to follow to develop an effective workplan.

  1. **Define high level objectives / targets**: what are the major needs of your project? (e.g. creating awareness in the community)

  2. **Work backwards to break each objective into a set of actions and activities** : You may need to break complex activities down even further, into clearly defined sets of tasks and activities

  3. **Set measurable goals for each activity** : e.g. "Collect 5,000 seeds" is measurable, "Collect seeds" is not measureable

  4. **Agree on prioritized order for activities**: prioritise activities based on their expected impact on the project and on how easy they are to implement. High priority activities have significant impact and/or are easy to implement.

  5. **Create a graphic schedule of the workplan** : e.g. a spreadsheet such as Table D above

  6. **Set milestones** : identify and define key achievements needed to reach your targets and set deadlines for all targets

  7. **Set deadlines**: set deadlines for all targets, milestones and activities. This focuses your efforts and stops the project taking too long.

  8. **Assign owners for each activity**: to ensure accountability, it is important to assign responsible people or "owners" to each activity. If an activity is not progressing according to plan, it is clear who to talk with to find out why.

9. **List related individuals, agencies, as needed** : in addition to owners, it is good to list individuals or organisations who will be necessary or helpful in completing activities

10. **Schedule progress meetings**: it is important to have regular meetings to assess project progress, see how progress compares with the workplan, and update the workplan where necessary.

11. **Check team availability**: find out when team members will not be available to work; note this on the workplan and evaluate the effects on the project activities, especially where absent members are responsible.

12. **Have the CPM and CPG sign off the workplan** after its initial completion and after every round major update.

TABLE C: TEMPLATE FOR REPRODUCTION AND DISPERSAL

Species	Type of seed	Months available						Indicator of maturity	Size at maturity	Distance from site to seed source			Presence / absence of seeds at site	
Avicennia marina	Propagule	J	F	M	A	M	J	Yellow fruit skin	Weight of seed > 30g	0-1 km	1-5 km	5km +	Yes	No
		J	A	S	O	N	D							
		J	F	M	A	M	J			0-1 km	1-5 km	5km +	Yes	No
		J	A	S	O	N	D							
		J	F	M	A	M	J			0-1 km	1-5 km	5km +	Yes	No
		J	A	S	O	N	D							
		J	F	M	A	M	J			0-1 km	1-5 km	5km +	Yes	No
		J	A	S	O	N	D							
		J	F	M	A	M	J			0-1 km	1-5 km	5km +	Yes	No
		J	A	S	O	N	D							
		J	F	M	A	M	J			0-1 km	1-5 km	5km +	Yes	No
		J	A	S	O	N	D							
		J	F	M	A	M	J			0-1 km	1-5 km	5km +	Yes	No
		J	A	S	O	N	D							
		J	F	M	A	M	J			0-1 km	1-5 km	5km +	Yes	No
		J	A	S	O	N	D							

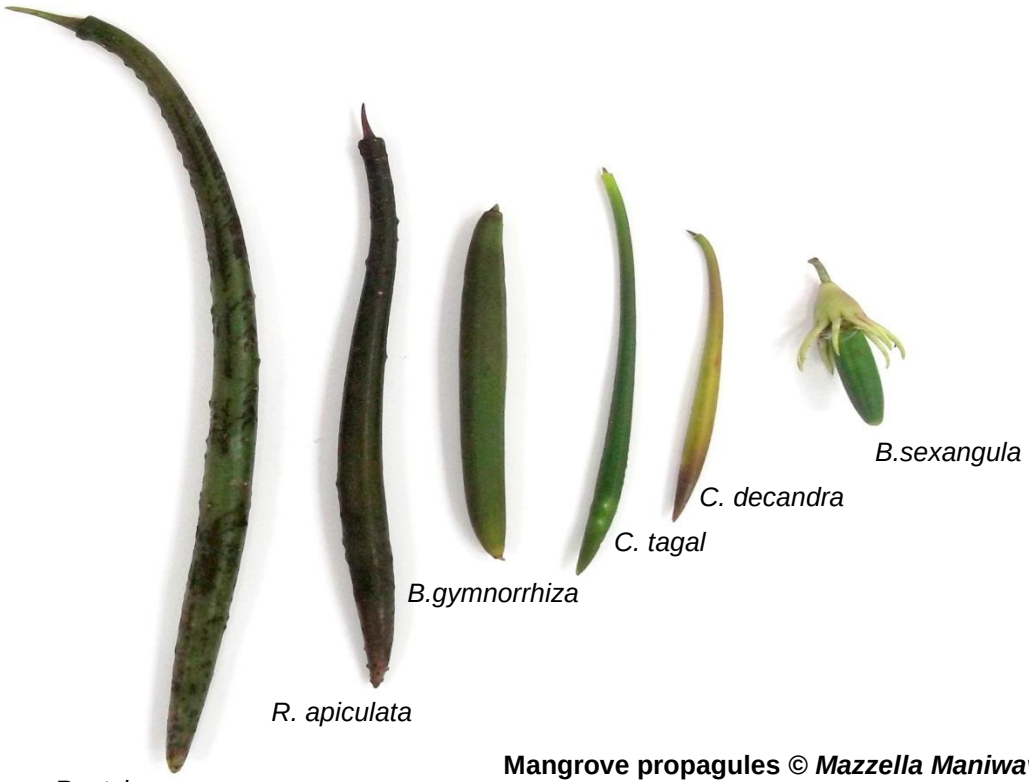
TABLE D: PLANTING ZONES OF DIFFERENT MANGROVE SPECIES

Name of species	ID Code	Noticeable characteristics	Sites and zones that is best for growth
Aegialitis annulata	Aa	Club mangrove	Sea front gravely substrate
Aegiceras corniculatum	Ac	Chilli fruit	Muddy/silt/clay and loam- tidal creeks
Avicenna alba	Aa	Pronounced beak fruit	Mangrove back/ silty clay
Avicenna lanata	Al	Beak hairy fruit	Muddy/silt/clay /loam- tidal creeks /back
Avicenna marina	Am	White mangrove	Any zone and sites Tolerant to high salt
Avicenna officinalis	Ao	Hairy seeds	Muddy/silt/clay at back of mangroves
Bruguiera gymnorrhiza	Bg	Red flowers	Muddy/silt/clay – with & back of *R stylosa*
Bruguiera cylindrical	Bc	Reflexed in fruit	Muddy/silt/clay/loam- back/along tidal creeks
Bruguiera exaristata	Be	Yellowish flower	Mangrove back, near salt marches
Bruguiera parviflora	Bp	Yellowish flower, erect in fruit	Middle of mangrove
Bruguiera sexangula	Bs	Yellowish flower	Along tidal creeks , muddy silt & clay
Ceriops australis	Ca	Smooth surface fruit	Mangrove back/tidal creeks-muddy/silt/clay
Ceriops decandra	Cd	upright fruit	Mangrove back/tidal creeks-muddy/silt/clay
Ceriops tagal	Ct	Ridged fruit	Mangrove back/tidal creeks-muddy/silt/clay
Excoecaria agallocha	Ea	White sap	Sandy/rocky/clay soils – back
Heritiera littoralis	Hl	leaf underside silvery	Mangrove back, hard clay – back
Lumnitzera racemosa	Lr	Succulent leaves, white petals	Mangrove back - sandy clays – back
Lumnitzera littoralis	Ll	Succulent leaves, red petals	Mangrove back - sandy clays – back
Nypa fruticans	Nf	Wild sago	Plenty of freshwater – entrance/creeks/rivers
Osbornia octodonta	Oo	Smelly leaf	Sandy/gravely/rocky both sea front/back
Pemphis acidula	Pa	Tiny capsule fruit	Only on rocky shores with high salinity
Rhizophora apiculata	Ra	Question mark shaped fruit	Muddy silt & clay at the back of *R. stylosa*
Rhizophora mucronata	Rm	Leaves and fruits larger than Ra and Rs	Muddy silt/clay along tidal creeks & Bays
Rhizophora stylosa	Rs	Well developed stilt roots	Rocky/clay/silt/sandy/gravely/sea front
Scyphiphora hydrophyllacea	Sh	Gear fruit	Loam, less mud and silt, inner river banks
Sonneratia alba	Sa	Star fruit, calyx reflexed	Mud mixed with gravel, best at river mouths
Sonneratia caseolaris	Sc	Start fruit red flowers	Muddy, areas of high rainfall year round
Xylocarpus granatum	Xg	Cannonball mangrove/brown fruit	Muddy silt & clay along tidal creeks
Xylocarpus moluccensis	Xa	Green guava fruit	Muddy silt & clay along tidal creeks
Xylocarpus rumphii	Xr	Small guava fruit	Rocky sandy shores with wave exposure

TABLE E: SEED COLLECTION INDICATORS OF RIPE SEEDS OR PROPAGULES FOR VARIOUS MANGROVE SPECIES (ADAPTED FROM FIELD, 1996)

Mangrove species	**Seeds (s) or Propagules (p)**	**Condition for collection**
Aegiceras corniculatum	p	Fruits become lightly pinkish to brown
Avicennia spp.	s	Seeds coat changes from green to light yellow. Seed coat becomes wrinkly
Bruguiera spp.	p	No abscission collar. The hypocotyl changes colour from green to brown
Ceriops spp.	p	Yellow abscission collar. The hypocotyl sometimes changes from green to red brown
Heritiera littorea	s	Mature fruit is dark brown
Nypa fruticans	s	Seeds change from light brown to dark brown
Rhizophora apiculata	p	Reddish abscission collar
Rhizophora mucronata	p	Yellow abscission collar
Rhizophora stylosa	p	Yellow abscission collar
Sonneratia spp.	s	Fruit changes colour from pale green to dark green with maturation
Xylocarpus granatum	s	Fruit changes colour from light green to dark
Xylocarpus moluccensis	s	Yellow to brown fruit. Floats in water

TEMPLATE 1: EXAMPLES OF PROPAGULES AND SEEDS



Mangrove propagules © *Mazzella Maniwavie*

A. marina- matured seeds

S. alba- matured fruit containing seeds

X. granatum- matured seeds

H. littorea- seeds

Mangrove seeds © *Thomas Maniwavie*

TABLE F: SOURCES OF EXPERTISE

Organisation type	Organization name	Focus of organization	Expertise	Office location(s)	Contact
National government	Office of Climate Change and Development	Climate Change	Awareness, Funding,	Port Moresby	+675 325 7528
National government	Department of Environment and Conservation	Conservation	Awareness, Funding, Protected Areas,	Port Moresby	+675 325 0180
National government	PNG Forest Authority	Forest management	Awareness, Training, Technical support,	Port Moresby	+675 327 7800
National government	PNG Forest Research Institute	Forest research	Training, Technical support	Lae	+675 472 4188
	National Herbarium		Technical support		+675 472 4188
	National Tree Seed Centre		Technical support		+675 472 4188
NGO	PNG Centre for Locally Managed Areas (CLMA)	Sustainability	Planning, Protected areas	Port Moresby	+675 346 2147
NGO	Mama Graun Trust Fund	Conservation	Funding, Protected areas,	Port Moresby	+675 325 6041
NGO	The Nature Conservancy (TNC)	Conservation	Awareness, Training, Planning, Technical support, Protected areas	**Port Moresby**, Manus,	+675 323 0699

NGO	Wildlife Conservation Society (WCS)	Conservation	Awareness, Training, Planning, Technical support, Protected areas	**Goroka,** Kavieng, Manus, Port Moresby	+675 532 3494
NGO	World Wide Fund for Nature (WWF)	Conservation	Awareness, Training, Planning, Technical support, Protected areas	Port Moresby, **Madang**, Manus,	+675 320 0149
Academic	University of Technology (Unitech)	Research	Technical support	Lae	+675 473 4686
Academic	University of Papua New Guinea (UPNG)	Research	Technical support	Port Moresby	+675 3267387

Notes:

1 .This list is not exhaustive; speak to the organisations listed above and knowledgeable people in your community to identify additional government, NGO and academic organisations and people that could assist your project.

2 .For organisations that have several locations around the country, the main office location is highlighted bold in column 5

TABLE G: SOURCES OF FUNDING

Fund type	Fund name Purpose of fund	Purpose of fund	Controlling organisation	Funding available (Kina)	Contact
National government	Various	Climate Change Adaptation	Office of Climate Change and Development	> 1,000,000	+675 325 7528
National government	Various	Conservation	Department of Environment and Conservation	> 1,000,000	+675 301 4500
National government	Various	Forestry	PNG Forest Authority	> 1,000,000	+675 327 7800
Provincial government	Primary Production Function Grants	Agricultural extension services for cash crops, food crops and livestock esp. drought resistant crops	Department of Agriculture and Livestock (DAL)	100,000 – 1,000,000	Call your provincial government
Provincial government	Other Service Delivery Function Grant	Disaster and environmental management	Disaster and Environment Management Unit (DEMU)	< 100,000	Call your provincial government
Provincial government	Health Function Grant	Water supply	Office of the Governor	< 100,000	Call your provincial government
Provincial government	Provincial Support Grants (Non-discretionary)	Various	Office of the Governor (via Provincial Financial Office)	100,000 – 1,000,000	Call your provincial government
Provincial government	Provincial Support Grants (Discretionary)	Various	Governor's trust fund	100,000 – 1,000,000	Call your provincial government

Provincial government	District Support Grants (Non-discretionary)	Various	Open Member (via Provincial Financial Office)	100,000 – 1,000,000	Call your provincial government
Provincial government	District Support Grants (Discretionary)	Various	Open Member's trust fund	100,000 – 1,000,000	Call your provincial government
Provincial government	Provincial Special Intervention Program	Various	Office of the Governor	> 1,000,000	Call your provincial government
Provincial government	District Services Improvement Program	Various	JDP & BPC	< 100,000	Call your provincial government
Provincial government	National Agricultural Development Program	Agricultural development	DAL	> 1,000, 000	Call your provincial government
Provincial government	Climate Change PIP	Climate change research, planning and adaptation	NDPM / DEU	< 100,000	Call your provincial government
Provincial government	Internal revenue	Various	Provincial Financial Office	> 1,000,000	Call your provincial government
Provincial government	LLG Internal revenue	Various		< 100,000	Call your provincial government
Provincial government	LLG Determination grants	Various		< 100,000	Call your provincial government

NGO	Global Environment Facility Small Grant Program (GEF SGP)	Conservation, Climate Change and Sustainable development	United Nations Development Program (UNDP)	unknown	+675 321 2877
NGO	Mama Graun Conservation Trust Fund	Conservation and Climate Change	Mama Graun Conservation Trust Fund	unknown	+675 325 6041
Corporate	BSP Go Green	Conservation, Climate Change and Sustainable development	Bank South Pacific (BSP)	unknown	+675 320 1212 or 70301212
Corporate	PNG Sustainable Development Program (SDP)	Various	PNG Sustainable Development Program Ltd	> 1,000,000	+675 325 5673 or 325 5674

TEMPLATE 2: FORMS FOR REGULAR MONITORING AND EVALUATION

REHABILITATION					
Conducted by	**:**				
Date	**:**				
Implementer	**:**				
Location	**:**				
Area	**:**				
Lay out of rehabilitation site:		(Pls attach)			
Condition and Status of planting site					
Substrate type	:				
Flooding level	:	Mn: …..cm	Max: ….cm	(*For mangrove planting site*)	
Previous land use (if any)	:				

The details for Planting

Activities				
<u>Planting</u>	Number of seedling	Date of planting	Planting technique	Comments
Planting stage 1				
Planting stage 2				
Planting stage 3				
<u>Replenishment planting</u>				
Replenishment planting stage 1				
Replenishment planting stage 2				
Replenishment planting stage 3				

* provide information in detail based on species

Spacing line (m)

MONITORING AND EVALUATION RESULTS

1. Survival rate of plants (%)

Count result:

No	Species	N Total	N Survived	N Dead	% SR	Comments
1						
2						
3						
4						
5						
6						
7						

Note: N Total = Total number of seedlings planted at start of project

N Survived = Number of seedlings surviving/alive at time of sampling

N Dead = Number of seedlings surviving/alive at time of sampling

% SR = Survival rate in percentage

- **How to calculate survival rate (SR):**

  %SR = N Survived/ N Total x 100%

I.e. number of seedlings surviving divided by total number of seedlings initially planted and multiplied by 100%.

2. Seedling growth

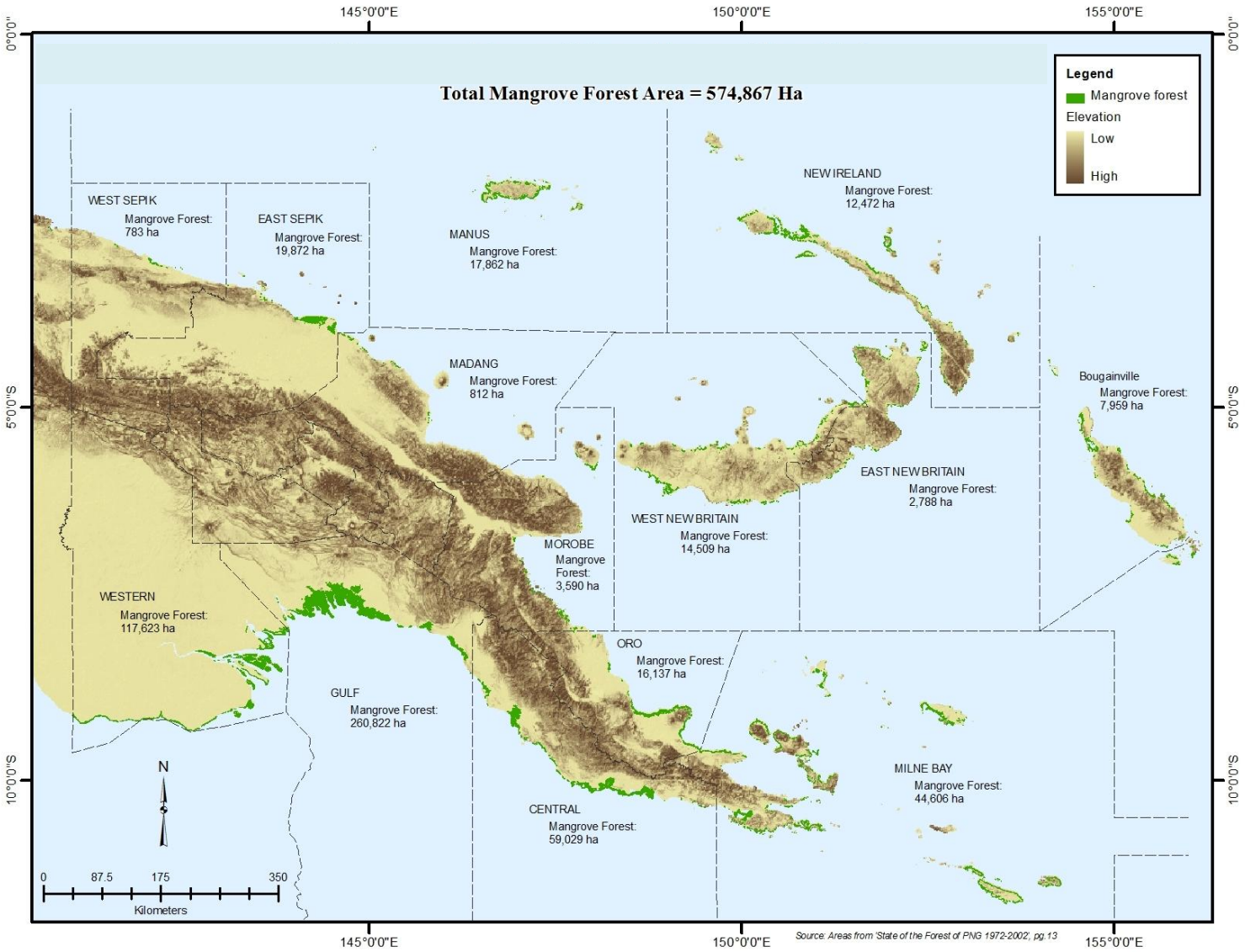
No	Species	Height (average)	Number of leaves
1			
2			
3			
4			
5			
6			
7			

3. Pest and Disease

Causing factor	Part of plant attacked	% of population attacked	Comments
a. Pest			
1			
2			
3			
4			
b. Disease			
1			
2			
3			
4			

APPENDIX 2

MANGROVE DISTRIBUTION IN PAPUA NEW GUINEA



MANGROVE SPECIES DISTRIBUTION IN MARITIME PROVINCES

Species	Provinces														
	ARB	**CNT**	**ENB**	**ES**	**GLF**	**MAD**	**MNS**	**MBE**	**MB**	**NCD**	**NI**	**ORO**	**WTN**	**WNB**	**WS**
Acrostichum aureum (fern)*		•			•	•	•		•		•		•		
Aegialitis annulata		•			•					•			•		
Aegiceras corniculatum	•	•	•		•	•	•	•	•	•	•	•	•	•	
Avicenna alba		•			•	•	•	•	•	•		•	•		
Avicenna lanata		•			•	•	•								
Avicenna marina		•			•	•	•	•	•	•	•	•	•		•
Avicenna officinalis		•			•				•				•		
Bruguiera cylindrical		•			•		•						•		
Bruguiera exaristata		•					•						•		
Bruguiera gymnorrhiza	•	•			•	•	•	•	•	•	•	•	•	•	•
Bruguiera hainesii		•						•							
Bruguiera parviflora	•	•			•	•	•	•	•		•		•		
Bruguiera sexangula		•		•	•	•	•	•			•	•	•	•	•
Ceriops australis		•													
Ceriops decandra		•			•					•			•		
Ceriops tagal		•			•	•	•		•	•			•		
Excoecaria agallocha		•			•	•	•		•		•		•		

Heritiera littoralis		•			•	•	•		•		•		•		
Lumnitzera racemosa		•					•			•			•		
Lumnitzera littorea								•	•		•				
Nypa fruticans (palm)		•		•	•	•	•		•		•		•		•
Osbornia octodonta		•					•			•			•		
Pemphis acidula		•				•	•								
Rhizophora apiculata	•	•		•	•	•	•	•	•	•	•	•	•	•	•
Rhizophora lamarckii (hybrid)Δ*		•					•						•		
Rhizophora mucronata		•			•	•	•		•	•	•	•	•		
Rhizophora stylosa		•		•	•	•	•	•	•	•	•		•		
Scyphiphora hydrophyllacea		•			•	•	•						•		
Sonneratia alba		•			•	•	•		•	•	•		•		
Sonneratia caseolaris				•			•	•	•				•		
Sonneratia ovata		•													
Xylocarpus granatum		•			•	•	•	•	•		•				
Xylocarpus moluccensis		•			•		•		•	•	•		•		
Xylocarpus rumphii		•													

– * Mangrove not used in mangrove planting Δ hybrid species, does not bear fruits

– **Note.** This species list was compiled from field observations and survey reports from a variety of sources and is

– incomplete for some provinces.