# Five Steps To...

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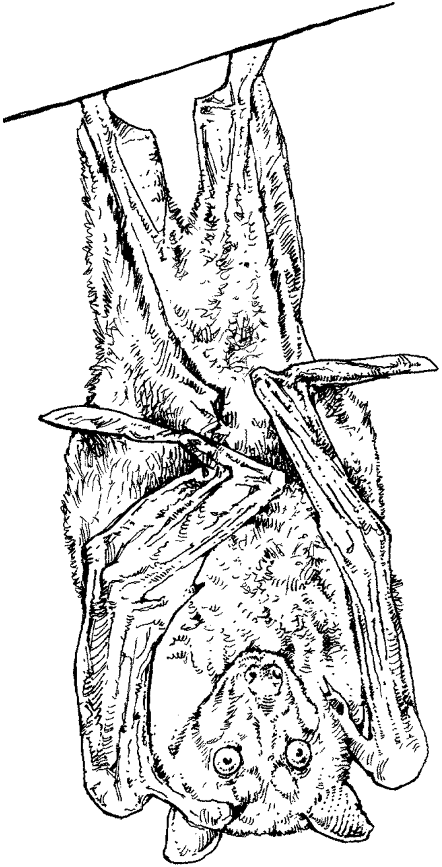
MANGROVE
MAP
ACTION PROJECT

# ...Successful Ecological Restoration of Mangroves



this manual was put together mostly in the wee hours of night by friends of the mangrove

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published by
Mangrove Action Project /
Yayasan Akar Rumput Laut
April 2006 - Yogyakarta, Indonesia

with financial support from:
Working Assets
Global Greengrants
Zoological Society of London
Christensen Foundation
USAID - Environmental Service Program

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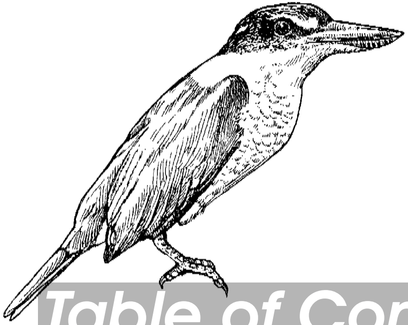

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# Introduction

Restoration and rehabilitation* of existing or former mangrove forest areas is extremely important today. In fact, given the importance of mangrove forest ecosystems, and the current threat to these coastal forests, this is an imperative. But actual planting of mangroves is rarely needed as mangroves annually produce hundreds or thousands of seeds or seedlings per tree, which under the proper hydrologic conditions can recolonize former mangrove areas (returned to normal hydrology) very rapidly.

There are many different techniques and methods utilized in restoring mangroves. Because some of these have resulted in identifiable successes or failures, we wish to present herein a summary description of several preferred methods for planning and implementing mangrove rehabilitation.

***In summary, five critical steps are necessary to achieve successful mangrove restoration:***

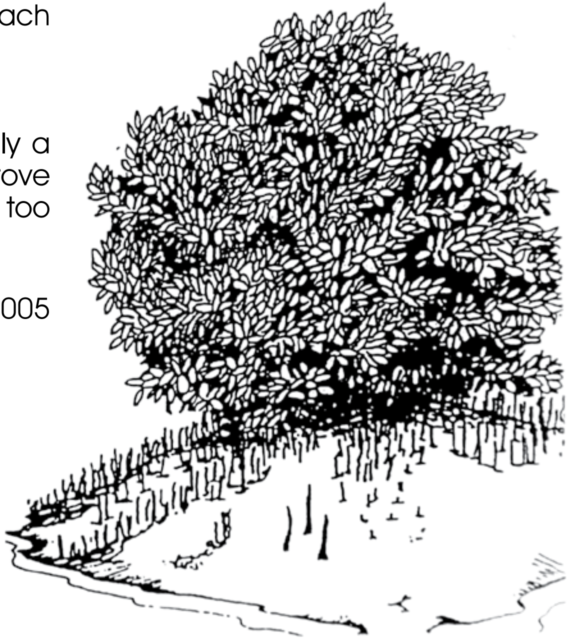
1. Understand the autecology (individual species ecology) of the mangrove species at the site; in particular the patterns of reproduction, propagule distribution, and successful seedling establishment.
2. Understand the normal hydrologic patterns that control the distribution and successful establishment and growth of targeted mangrove species.
3. Assess modifications of the original mangrove environment that currently prevent natural secondary succession (recovery after damage).
4. Design the restoration program to restore appropriate hydrology and, if possible, utilize natural volunteer mangrove propagule recruitment for plant establishment.
5. Only utilize actual planting of propagules, collected seedlings, or cultivated seedlings after determining (through steps a-d) that natural recruitment will not provide the quantity of successfully established seedlings, rate of stabilization, or rate of growth of saplings established as objectives for the restoration project (Lewis and Marshall 1997).

This manual provides an illustration of these five important steps, in order to make the methodology accessible to a wider range of coastal resource managers and mangrove restoration practitioners. It should be noted that this is not a comprehensive guide to mangrove restoration. For a fuller understanding and a more certain approach to restoration, the reader should research more thoroughly this subject, and consult more directly with those who are experienced experts in hands-on restoration techniques (see resources section at the end of this booklet). The techniques outlined herein are only a basic guide, and should be tailored to each unique situation and coastal region where restoration is being attempted.

It should also be made clear that ***restoring*** mangroves is only a partial solution. ***Protection*** of those precious remaining mangrove ecosystems must become an imperative for all nations, before too much is lost, and our restoration efforts are in vain.

- Mangrove Action Project Restoration Team, 2005

**The terms restoration and rehabilitation are used throughout this manual in the following way; The term "restoration" has been adopted to specifically mean any activity that aims to return system to a preexisting condition (whether or not this was pristine) (sensu Lewis 1990b), whereas the term "rehabilitation" is applied more generally and is used to denote any activity (including restoration and habitat creation) that aims to convert a degraded system to a stable alternative.*



## About the Manual

## Introduction

Involvement of the local community where mangrove rehabilitation is taking place is essential to the long term survival of the restored forest. This manual can not go into detail on the community organizing process, but will provide a few insights into ways that the community should be involved.

It may be best to think in terms of PAST, PRESENT and FUTURE when contemplating community involvement.

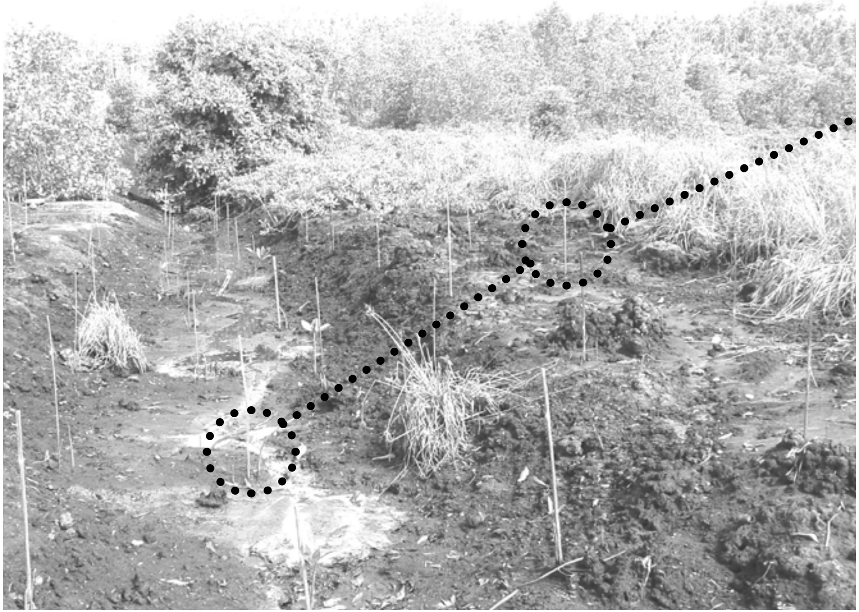
**PAST** - Why and how were the mangroves destroyed in the first place? What did the original mangrove forest look like? How did the community use the mangroves?

**PRESENT** - Who currently owns the land or has use rights to the land? Is the area currently productive? Who are the local actors interested in restoring the mangrove? What are the tidal levels of this region? Where does the water come from that feeds this mangrove area? How will we restore this mangrove area?

**FUTURE** - How will the community look after this mangrove once it is restored? What activities will be allowed/dis-allowed in the mangrove area? Who will enforce village regulations on mangrove protection and sustainable use? Is co-management with the government an option? How will you protect the mangroves from outside developers/investors?

## technical failures

There have been many failed restoration projects over the years, invariably wasting both time and money. One case study from North Sulawesi, Indonesia shows that the government planted the same disused shrimp pond area 5 times over a period of 8 years. Seedlings were planted without regard to ecological requirements (substrate height, water flow, appropriate species selection) and resultantly died within a year after each planting (below). Nonetheless project money was continually made available for re-planting without addressing the cause of the failure.



seedlings planted without regard to substrate height, both in ditches and on dike walls.

## social failures

In Kwandang Bay, Gorontalo Province, Indonesia the Forestry Department paid the village leader and seven of his family members 5 cents a piece to raise 60,000 seedlings, and promised another 5 cents for planting when the seedlings matured. The second payment never came, and the seedlings remain to this day, rooted in the nursery. The community at large was never involved in the project.

# Introduction

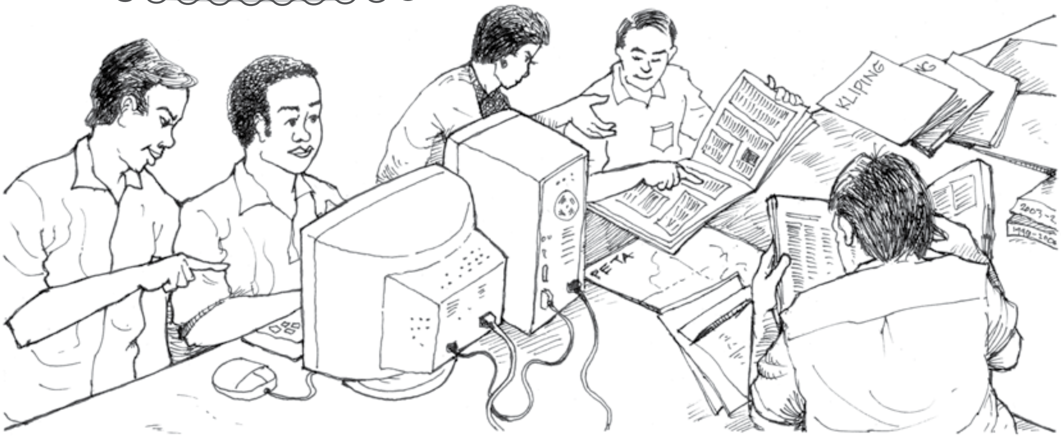
"Ecological restoration" has been defined by the Society for Ecological Restoration (SER, 2002) as the "process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed".

Restoration or rehabilitation may be recommended when an ecosystem has been altered to such an extent that it can no longer self-correct or self-renew. Under such condtions, ecosystem homeostasis has been permanently stopped and the normal processes of secondary succession (Clements, 1929) or natural recovery from damage are inhibited in some way.

This manual is going to highlight the importance of assessing the existing hydrology of natural extant mangrove ecosystems, and applying this knowledge to first protect existing mangroves, and second to achieve successful and cost-effective ecological restoration if needed.

## Key Concepts

**Some homework is needed in advance of starting to plan a mangrove restoration project.**



Examples of things to look into might include reading tide tables and measuring tidal levels. Look for literature about the mangroves of your area and if possible their distribution and tidal requirements. Can you find any recent or even historical aerial photos? Has anyone ever tried to restore mangroves in your area? If so, what were their successes and failures? Were there any lessons learned from these previous efforts?

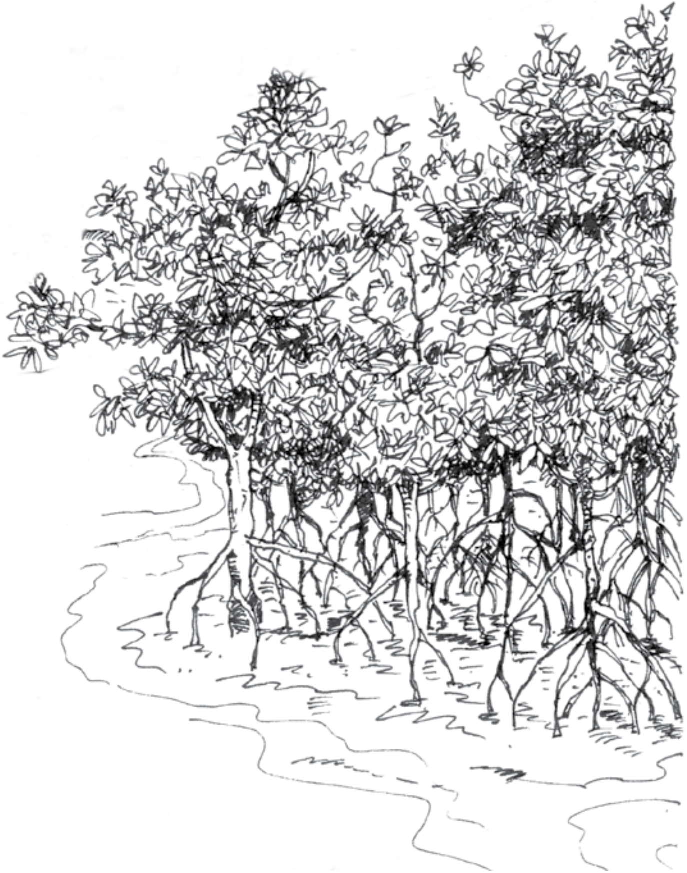
**Things Your May Need:**

- Map of location (scale 1:25,000)
- Forestry management map (scale 1:5000)
- Land use map
- Tide tables from nearest port
- Survey equipment such as compass, rope, stakes, notebook, measuring tape, GPS unit.

# *Do Your Homework*

# 1

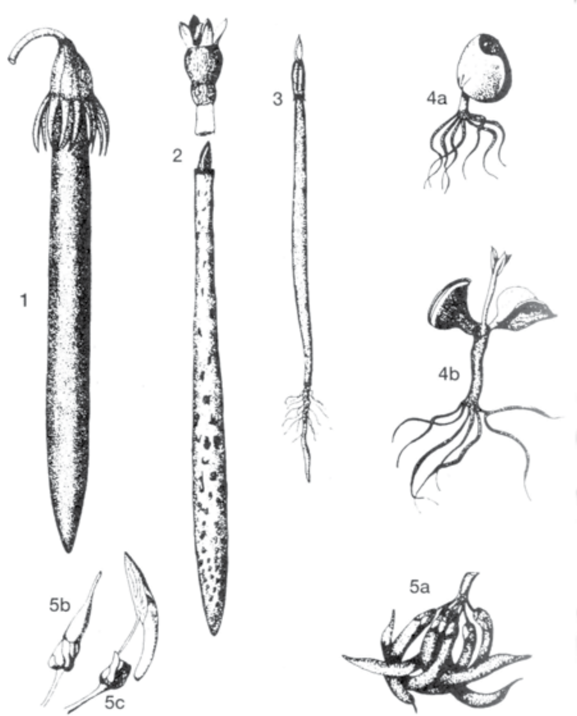
# AUTECOLOGY



**Step One:**
To understand the *autecology* (individual species ecology) of the mangrove species at the site, in particular the patterns of reproduction, propagule distribution, and successful seedling establishment.

# Pattern of Mangrove Reproduction

Seedlings of selected viviparous mangrove species from Indonesia.
1) Brugeira gymnorrhiza; 2) Rhizophora mucronata; 3) B. paviflora;
4) Avicennia marina (a) newly germinated, (b) plumule elongating,
5) Aegiceras corniculatum (a) fruits, (b) single young fruit and (c)
germinating fruit. From MacNae 1968.



After flowering and pollination, many mangroves develop viviparous seeds called *propagules*.

*Vivipary* is a characteristic in which the propagules develop early and germinate while still on the parent tree receiving food to keep the propagule healthy for a long time after they fall into the water. This enables the propagule to float with the tides until it comes to rest in a good place to grow.

The propagules then put down roots into the mud and use stored food to grow quickly into a young tree.

In order to understand the patterns of mangroves reproduction in your area, it will be useful to create a table similar to the table below.

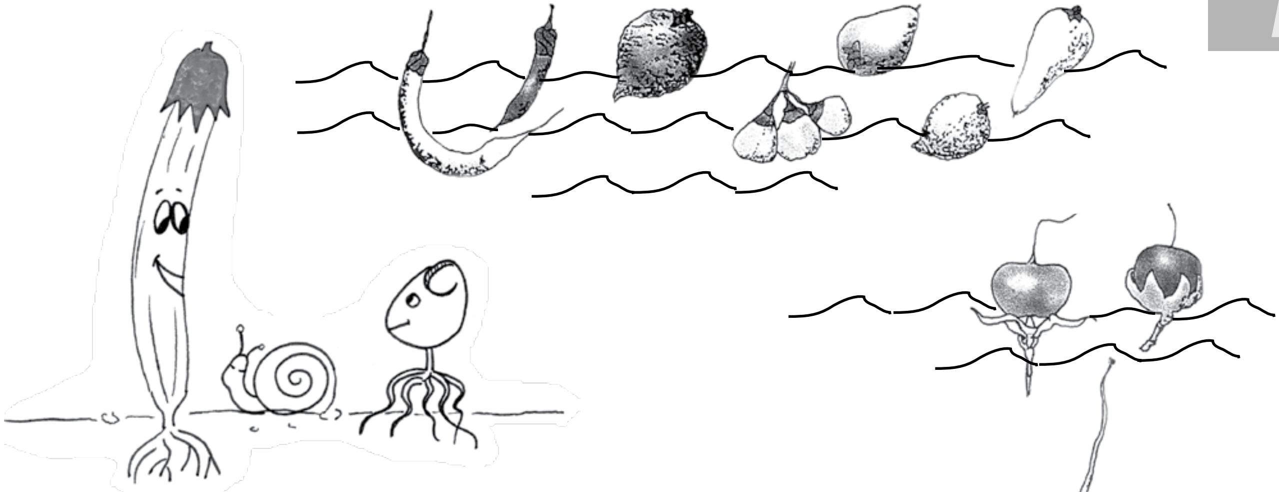
| Species | Type of Seed | Months | Indicator of Maturity | Size at Maturity |
|---|---|---|---|---|
| *Avicennia marina* | Propagule | D,***J**, F | Yellow fruit skin | Weight of seed > 30 g |
| *Brugeira gymnorrhiza* | Propagule | M, J, J, A, S, O, N, D | Reddish brown body | length > 20 cm |
| *Ceriops tagal* | Propagule | **A,** S | Yellow collar, brown/ green body | length > 20 cm |
| *Rhizophora apiculata* | Propagule | D, **J, M,** A | Reddish collar | length > 20 cm, diameter > 14 mm |
| *Rhizophora mucronata* | Propagule | S, O, N, D | Yellow collar, green body | length > 50 cm |
| *Sonneratia alba* | Fruit | A, **M**, J, **S**, O | Float in water | fruit > 4 cm |
| *Xylocarpus granatum* | Fruit | S, **O**, N | Yellow/brown fruit<br>Floats in Water | Weight of seeds inside fruit 30 g each |

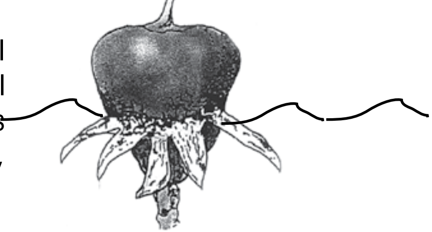
* Bold type indicates peak season

Adapted from Hachinohe et. AL, "Nursery Manual for Mangrove Species - At Benoa Port in Bali," JICA, 1998.

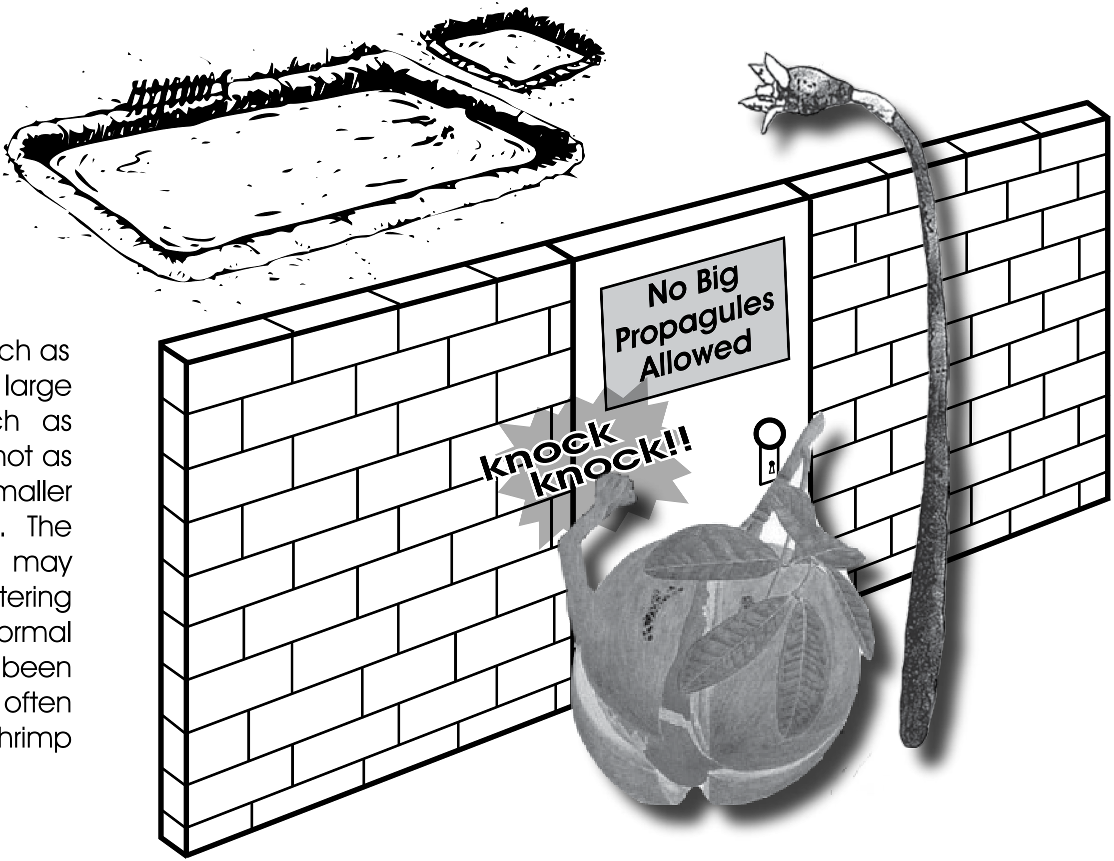
## Understanding Local Reproduction

Like the coconut palm, mangroves have floating propagules. Because of their various shapes and sizes propagules of separate mangrove species float differently.





**Small propagules** such as *Avicennia* spp., *Aegiceras* spp. and small mangrove fruits such as *Sonneratia* spp. float far and wide on normal tidal currents. Because of their small size, these fruits and propagules easily reach new or disturbed areas and, if the soil conditions are right, become quickly established. These species are known as *colonizers*.



**Large propagules** such as *Rhizophora* spp. and large mangrove fruits such as *Xylocarpus* spp. are not as easily dispersed as smaller fruits and propagules. The larger propagules may have difficulty entering into areas where normal tidal exchange has been blocked such as is often the case in disused shrimp ponds

Before addressing local issues concerning hydrology (Step Two), it will be useful to understand local mangrove seedling dispersal. Completing the table below will help you understand the availability of local seeds/propagules.

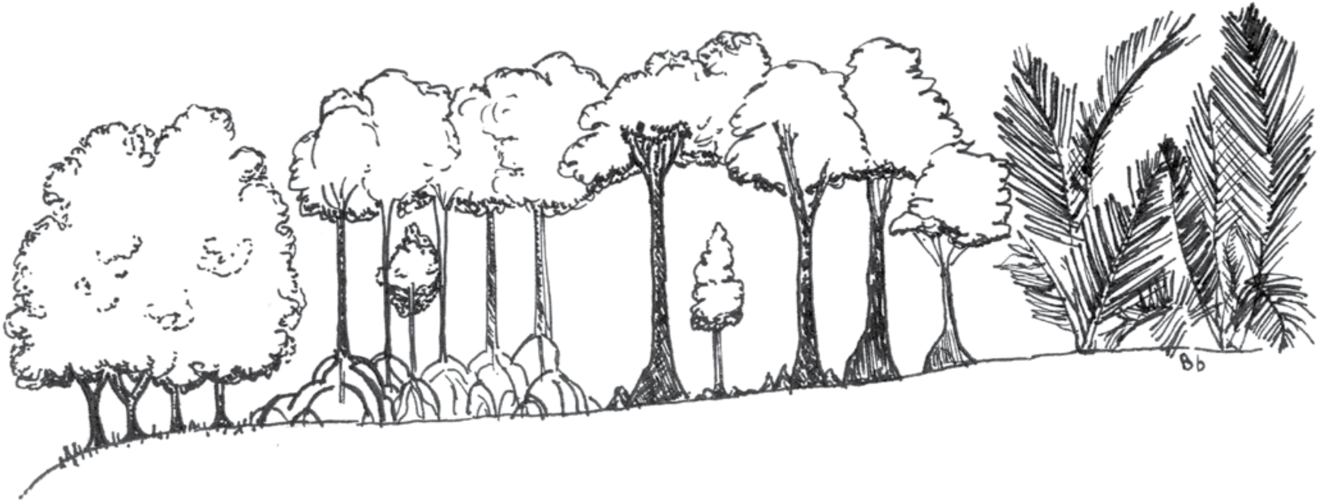
| Species | Season | Distance from rehab site to seed source | *Presence/absence of propagules in rehab area |
|---|---|---|---|
| *Avicennia marina* | D, J, F | < 1km, [✓ 1-5 km] >5km | Yes ☑ No ☐ |
| *Brugeira gymnorrhiza* | May - Dec | < 1km, 1-5 km, [✓ >5km] | Yes ☐ No ☑ |
| *Ceriops tagal* | A, S | < 1km, [✓ 1-5 km] >5km | Yes ☑ No ☐ |
| *Rhizophora apiculata* | D, J, M, A | < 1km, 1-5 km, [✓ >5km] | Yes ☐ No ☑ |
| *Rhizophora mucronata* | S, O, N, D | [✓ < 1km] 1-5 km, >5km | Yes ☐ No ☑ |
| *Sonneratia alba* | A, M, J, S, O | < 1km, [✓ 1-5 km] >5km | Yes ☑ No ☐ |
| *Xylocarpus granatum* | S, O, N | < 1km, 1-5 km, [✓ >5km] | Yes ☐ No ☑ |
| *Other* | | | |
| *Other* | | | |

* Includes seeds/propagules (rooted, alive or dead) in the rehab area, or stranded on a barrier such as a dike wall just outside of the area.

# Understanding Local Dispersal

Mangroves often occur in zones, which are groupings of the same species of mangrove within a whole mangrove forest. Zonation occurs because different species of mangrove need particular conditions to grow. Some species require more water than others. Some species are able to tolerate more saline soils than others. The species occurring in a zone depends on:

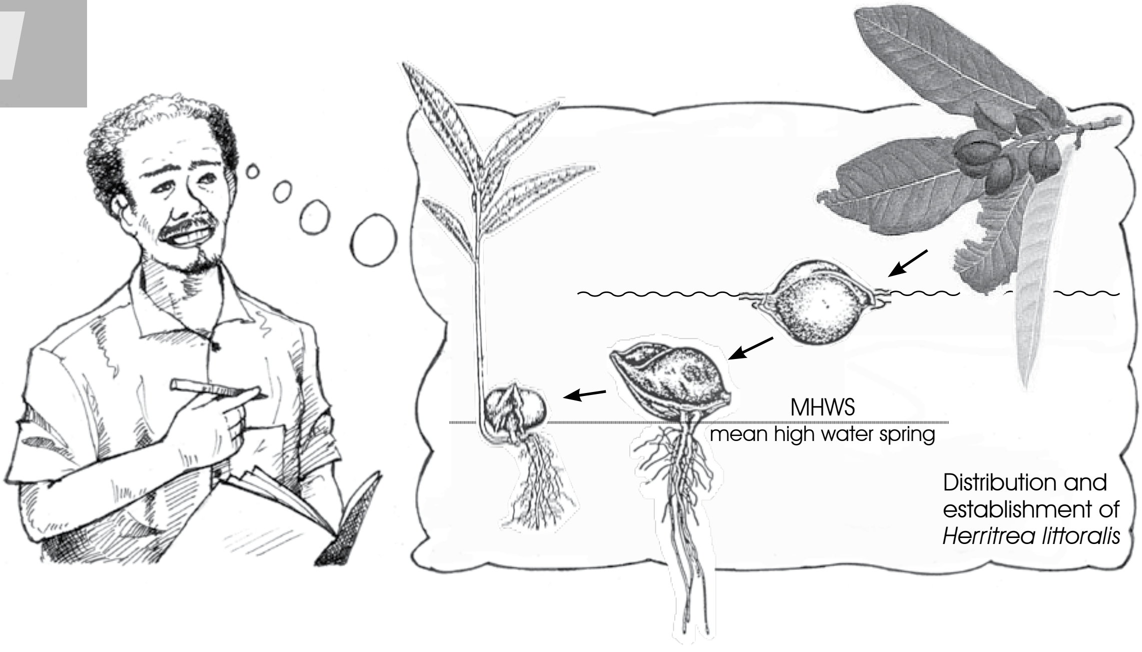
a) depth, duration and frequency of tidal inundation
b) soil salinity
c) amount of fresh water available



2

# HYDROLOGY

**Step Two:**
Understand the normal hydrologic patterns that control the distribution and successful establishment and growth of targeted mangrove species.

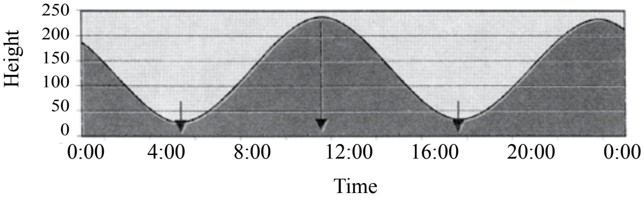


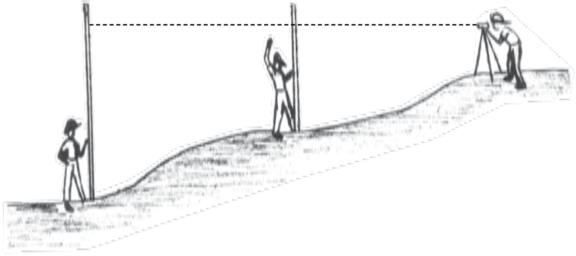
Distribution and establishment of *Herritrea littoralis*

# 2 Hydrology

**The single most important factor in designing a successful mangrove restoration project is determining the normal hydrology (depth, duration and frequency of tidal inundation, and of tidal flooding) of existing natural mangrove plant communities (a reference site) in the area you wish to restore.**

Table 3 - Changes of Tide Height Level at Benoa Port in Bali





## Water Depth/ Substrate Height

☒ Each mangrove species thrives at a different substrate level which in some part dictates the amount of exposure the mangrove will have to tidal waters. For instance most *Avicennia* species thrive at lower substrate levels (deeper water) while *Herritrea* sp. thrive inland at higher substrate levels (shallower water)

☒ You will need to study tide charts for your area and begin to take measurements in healthy mangroves relating substrate height/depth to the various species of mangroves that exist at each depth.

☒ When it comes time to rehabilitate a destroyed mangrove area, one of the keys is going to be to imitate the slope and topography (relative height) of the substrate from a nearby healthy mangrove forest.

## Frequency of Inundation

It will be essential to note the critical periods of inundation and dryness that govern the health of the forest.

Among the most widely used approaches for mangrove zonation is the following scheme based on degree and frequency of tidal inundation developed by Watson (1928) from his work on Malayan mangroves.

| Class | Flooded By | Height above chart datum in feet (meters) | Flooding Frequency (times/month) |
|---|---|---|---|
| 1 | All high tides | 0-8 (2.44) | 56-62 |
| 2 | Medium high tides | 8-11 (3.35) | 45-59 |
| 3 | Normal high tides | 11-13 (3.96) | 20-45 |
| 4 | Spring high tides | 13-15 (4.57) | 2-20 |
| 5 | Abnormal (equinoctial tides*) | 15 | 2 |

**Equinotical tides are extremely high or low tides which occur twice a year around March 21 and September 23.*

An example of how Watson’s inundation classes can be applied may help to clarify things. Below Watson’s “Inundation Classes” are applied to the mangroves of Indonesia.

**Class 1:** Mangroves in this class are inundated by all high tides. Predominant species found in these environments are *Rhizophora mucronata*, *R. stylosa* and *R. apiculata*. *R. mucronata* prefers areas under greater freshwater influence. In East Indonesia pioneering *Avicennia* and *Sonneratia* forests may dominate this zone.

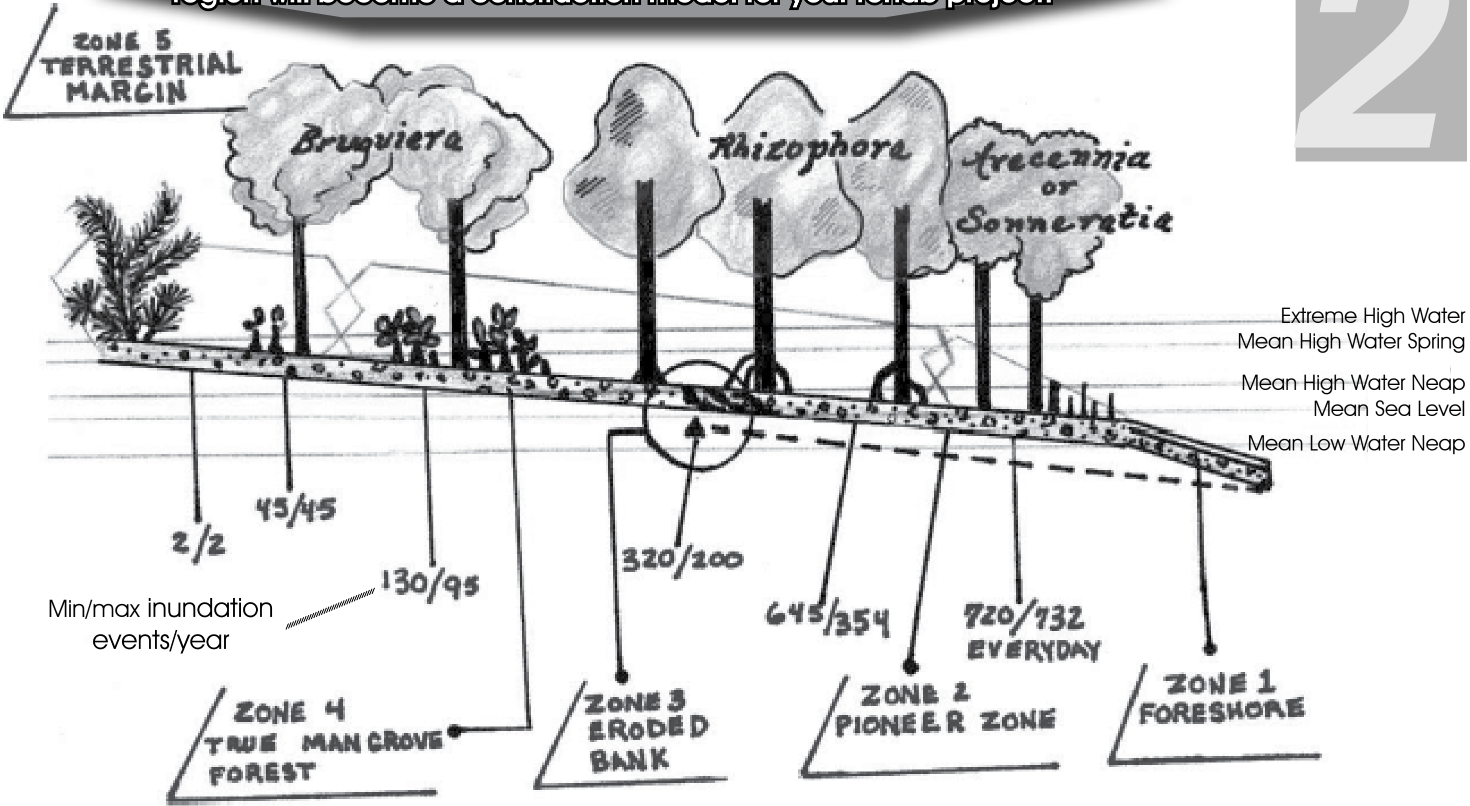
**Class 2:** Mangroves in this class are inundated by all medium-high tides. Predominant species are *Avicennia alba*, *A. marina*, *Sonneratia alba* and *R. mucronata*.

**Class 3:** Inundation by normal high tides. Most species thrive under these conditions. A large part of the mangrove ecosystem falls into this class which exhibits the highest biodiversity of mangroves. Common species are *Rhizophora* spp. (often dominates), *Ceriops tagal*, *Xylocarpus granatum*, *Lumnitzera littorea* and *Exoecaria agallocha*.

**Class 4:** Inundation only during spring tides. Area generally too dry for *Rhizophora* spp., but it may be present in low numbers. Common species are *Bruguiera* spp., *Xylocarpus* spp., *Lumnitzera littorea* and *Exoecaria agallocha*.

**Class 5:** Inundation only during equinoctial or other exceptionally high tides. Predominant species are *Brugeira gymnorrhiza* (dominates), *Instia bijuga*, *Nypa fruticans*, *Herritera littoralis*, *Exoecaria agallocha*, and *Aegiceras* spp.

**Creating a similar figure like the one below appropriate to your region will become a construction model for your rehab project.**



Mangrove zonation related to tidal datums in Sumatera, Indonesia (modified from Whitten et al., 1987)

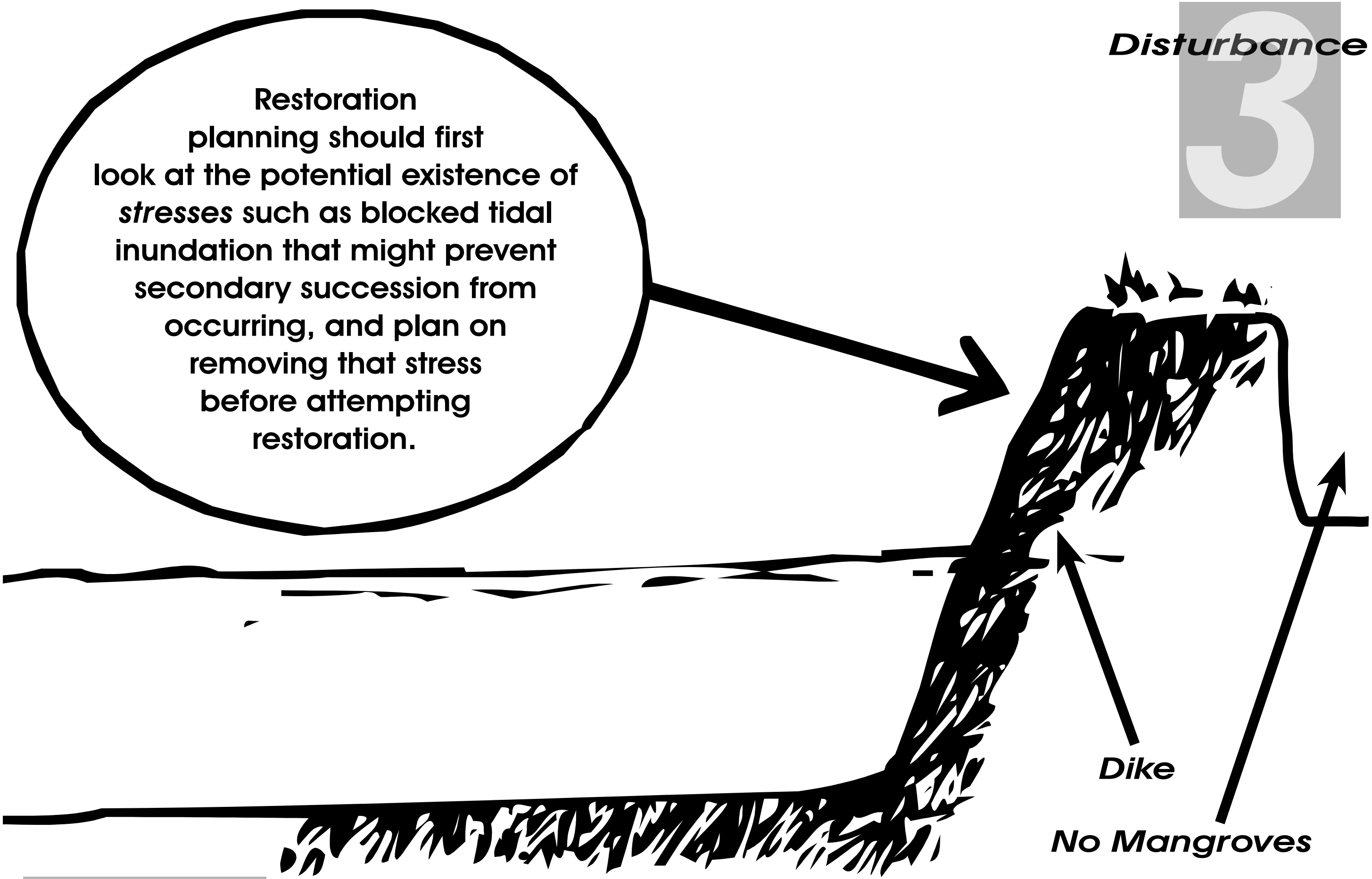
# Example of Mangrove Zonation

# 3

# DISTURBANCE

**Step Three:**

Assess modifications of the original mangrove environment that currently prevent natural secondary succession.



Restoration planning should first look at the potential existence of *stresses* such as blocked tidal inundation that might prevent secondary succession from occurring, and plan on removing that stress before attempting restoration.

## Stresses

# 3

## Disturbance

It is important to understand the past use of the area. First and foremost was the area intended for restoration actually a mangrove area in the past. Oftentimes, mangroves are planted in areas such as mud flats, salt marshes, or lagoons assuming that the area would be better off or more productive as a mangrove forest. But mud flats have their own ecological purposes such as a feeding grounds for migratory shorebirds.

A Department of Forestry program in Thailand unsuccessfully planted mangroves twice in an area of salt pans, apparently not learning from their mistakes.

Many times; however, human activities have damaged or destroyed mangrove ecosystems. Disused shrimp ponds, clear-cut mangrove areas for charcoal production, or mangroves which are drying out as a result of nearby changes in hydrology (due to construction of dikes, levees, roads, upland deforestation) are all areas where mangrove rehabilitation may be attempted. In these cases, before planting mangroves or attempting another type of restoration it is imperative to determine if the area is presently suitable for mangrove growth. If not, what are the stresses preventing growth of mangroves? Work together with the local community to help determine how the mangrove area has changed over time and why.

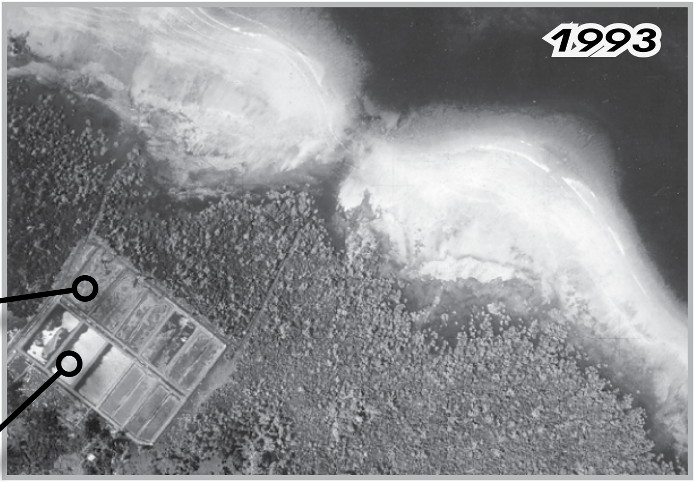
**Examples of Stresses:**

- Lack of groundwater
- Blockage of tidal exchange
- Hypersaline or acid sulfate soils (usually after intensive shrimp farming)
- Overgrazing by goats, camels etc.
- Shoreline abrasion and lowered substrate level

The disused shrimp ponds in the following case study were replanted by local and regional government five (5) times unsuccessfully without addressing the root causes of why mangroves did not grow in that area. This "project-oriented" mindset, planting for the sake of spending available budget is also a form of stress that has to be overcome.

## Determining Stresses

# 3 Disturbance



**Case Study:** This 20 hectare shrimp pond complex in Tiwoho, North Sulawesi was in operation for a period of 6 months during 1991. After abandonment the dike wall nearest to the sea degraded due to stronger wave action. Natural mangrove revegetation took place within the 5 seaward ponds. A density of 2500 seedlings per hectare was measured in 2000, with some trees nearly 10 meters tall

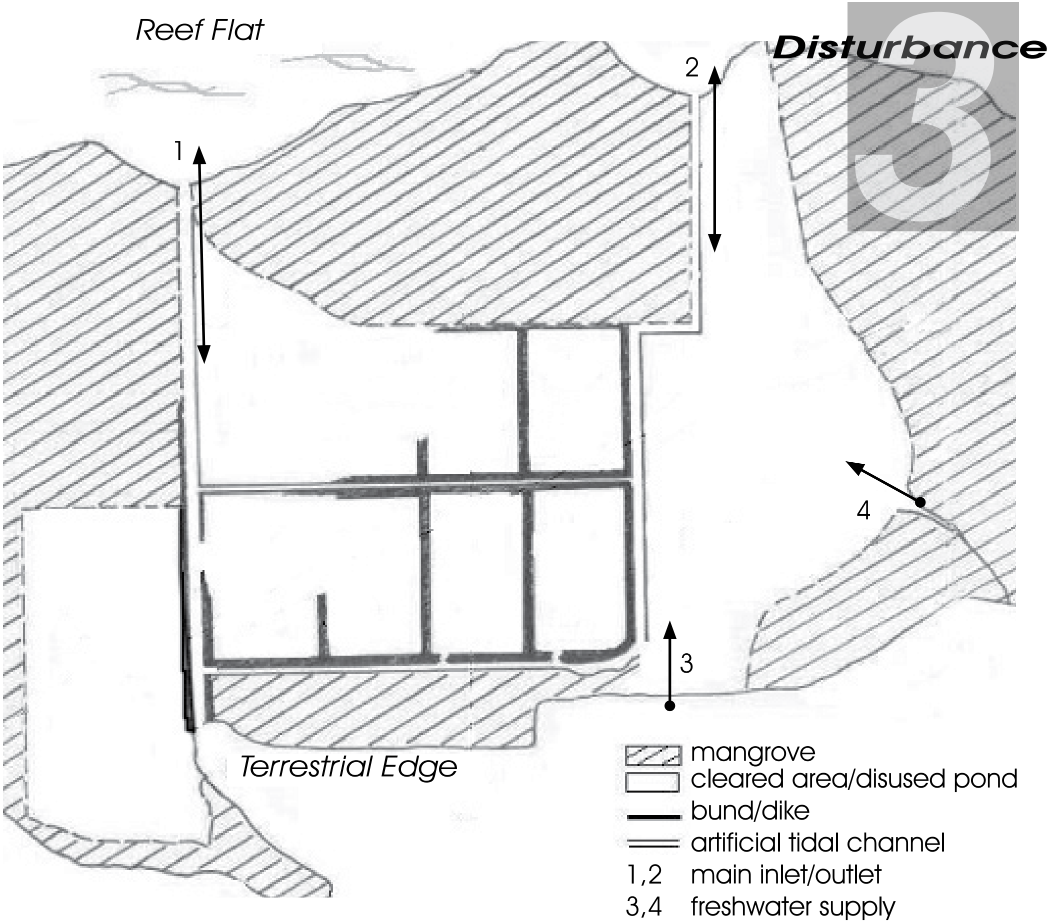
The five leeward ponds have experienced little to no natural regrowth due to the presence of intact dike walls and deep channels robbing the landward mangroves of regular tidal inundation.

**Case Study**

The map to the left depicts the same disused shrimp pond complex from Tiwoho, North Sulawesi.

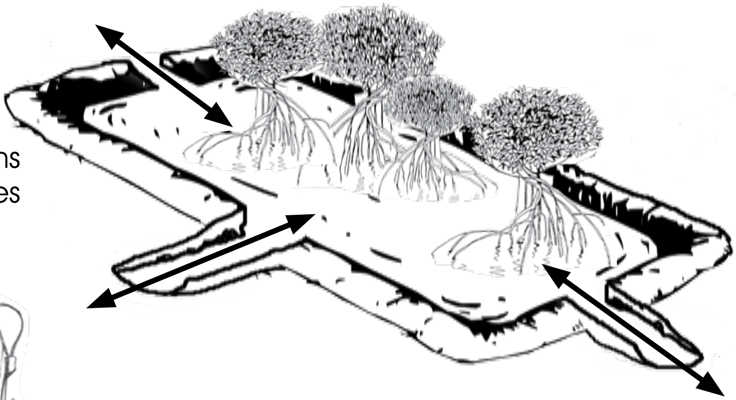
Illustrated are natural inflows and outflows of tidal and fresh water (numbered 1-4) as well as disturbances to normal tidal inundation. In this case the disturbances are both intact and partially intact dike walls as well as artificial tidal channels or troughs.

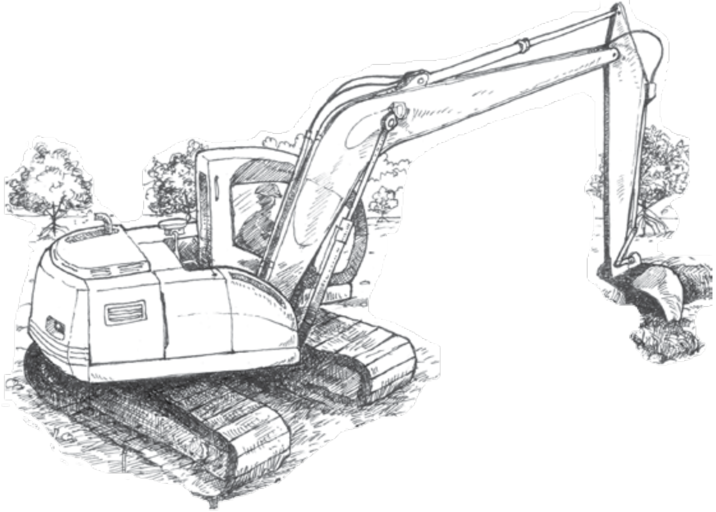
The dike walls obviously disturb tidal inundation by blocking the natural entry and exit of tidal waters. The artificially low elevation of the troughs rob the areas within the shrimp ponds of tidal waters during times of the month when tidal fluctuations are minimal.



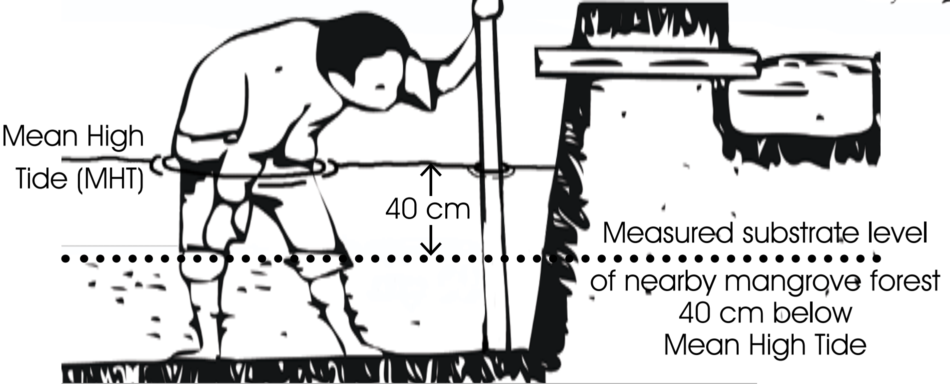
***Options for restoration of aquaculture ponds include...***

a) Simply restoring hydrologic connections to impounded mangroves. Breaching dikes and filling/blocking ditches.





b) The construction, by excavation of fill or back-filling of an excavated area, to create a target restoration site with the same general slope, and the exact tidal elevations relative to a benchmark as the reference site, thus insuring that the hydrology is correct.



Measure the average substrate height in a nearby healthy mangrove during a known tidal level and then again during the same tidal level at your mangrove rehabilitation site to determine a suitable substrate level as your target for hydrological restoration.

## Taking Measurements

## Survey Techniques

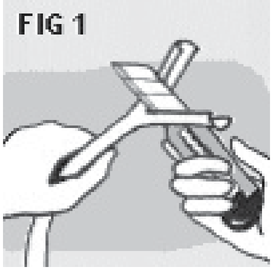
You may wish to employ topographic survey techniques to assist you in determining relative substrate elevation.

Two main types of survey techniques are:

A) Use of surveyor's equipment; levels, transits, theodolites

B) Use of a water level; rubber tubing, water and meter sticks. (low-tech method below)

FIG 1



## How to Make and Use A Bucket and Hose Water Level

### Material Requirements

You will need a standard plastic bucket and 12 metres (40 ft.) of 6 mm (1/4") nylex clear plastic tube or similar. Both items can be purchased from any major building suppliers.

### Instructions

1. Drill a hole in the bucket 50 mm (2") up from the bottom. The hole size should be slightly smaller than the plastic tube.

2. Slice one end of the plastic tube about 50 mm (2") down. Fig 1 This enables the tube to be threaded into the slightly smaller hole in the bucket. Fig 2

3. Pull the tube from the inside of the bucket until tight. Fig 3

FIG 2

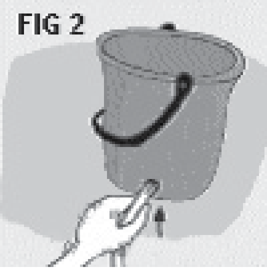
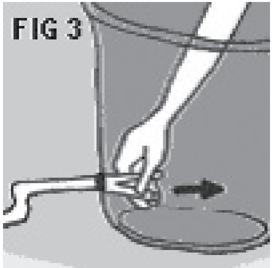


FIG 3



**Method A:** This method is good for determining a *Datum Line* which can be used as a reference height when re-creating a sloped substrate. A "datum" is just a convenient reference point for other elevation measurements. It is usually given the designation "O", and thus an elevation 30 cm higher than the datum would correctly be called +30cm relative to the datum. In some areas "surveyed datums" exist and can be found and referenced. A marker is usually place to use as a reference point.

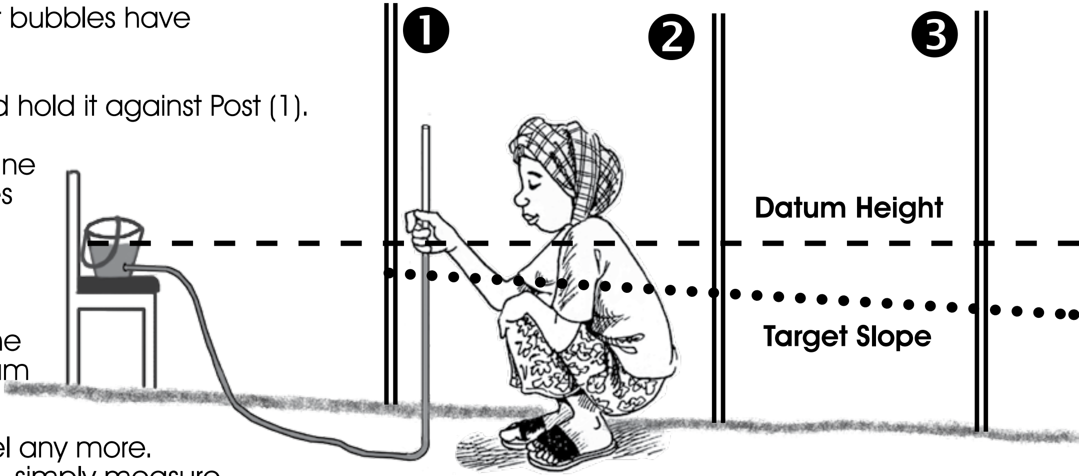
Place the bucket on a chair and fill to the top with water. The height of the bucket does not matter.

Let the hose loose on the ground until water is running out freely and all the air bubbles have come through.

Pick up the end of the hose and hold it against Post (1).

Mark the post where the water line shows in the hose. This becomes the datum line (not the known required height).

Mark the datum height on post (2), and post (3) in the same way. You now have a level datum line on all three objects.



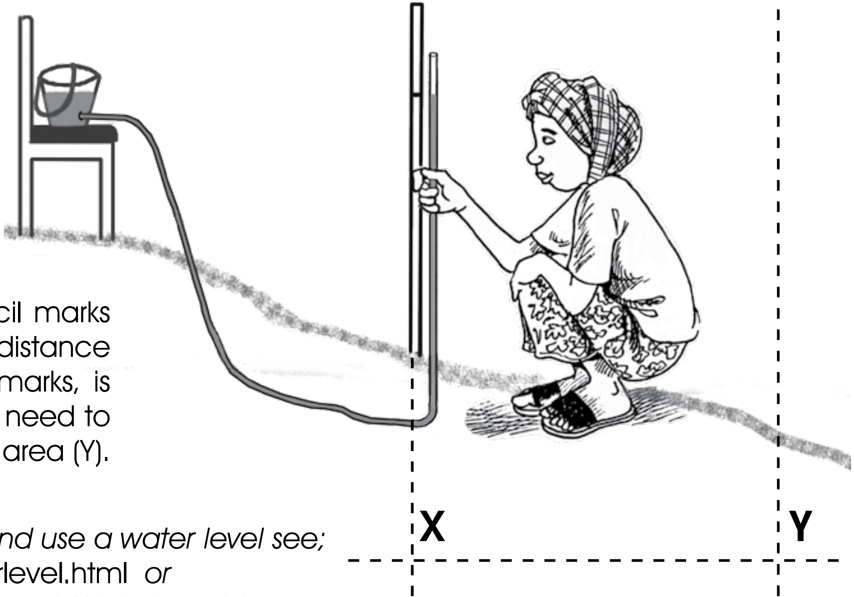
You do not need the water level any more.
To re-create a sloped substrate, simply measure up or down from the datum height marked on each post.
For instance if datum height is the Mean Sea Level, you may want to mark 5 cm above the datum line on post (1), 5 cm below the datum line on post (2), and 15 cm below the datum line on post (3) to create a slope that drops 10 cm between each post.

**Method B:** This method is good for determining heights compared with a known benchmark in shrimp ponds, ditches, or in the mangrove forest.

- Pick up the end of the hose and hold in against a piece of rod held up right on area (X).

- Mark a pencil line on the rod where the water line shows in the hose.

- Walk down the hill and do the same over area (Y).



- You will now have two pencil marks on the rod. Whatever the distance measures between the two marks, is also the distance area (X) will need to be dug down to be level with area (Y).

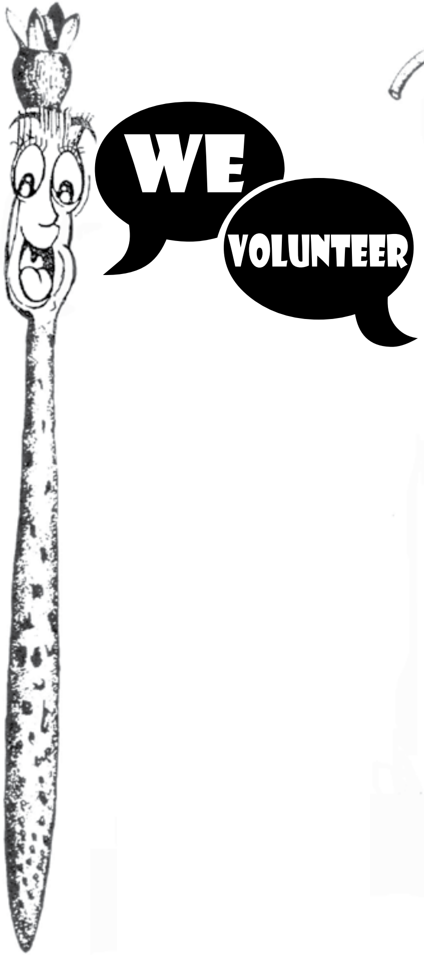
*For more information on how to make and use a water level see;*
www.buildeazy.com/fp_waterlevel.html *or*
http://www.factsfacts.com/MyHomeRepair/WaterLevel.htm

# 4

# Hydro Rehab Design

**Step Four:**

Design the restoration program to restore appropriate hydrology and, if possible, utilize natural volunteer mangrove propagule recruitment for plant establishment.

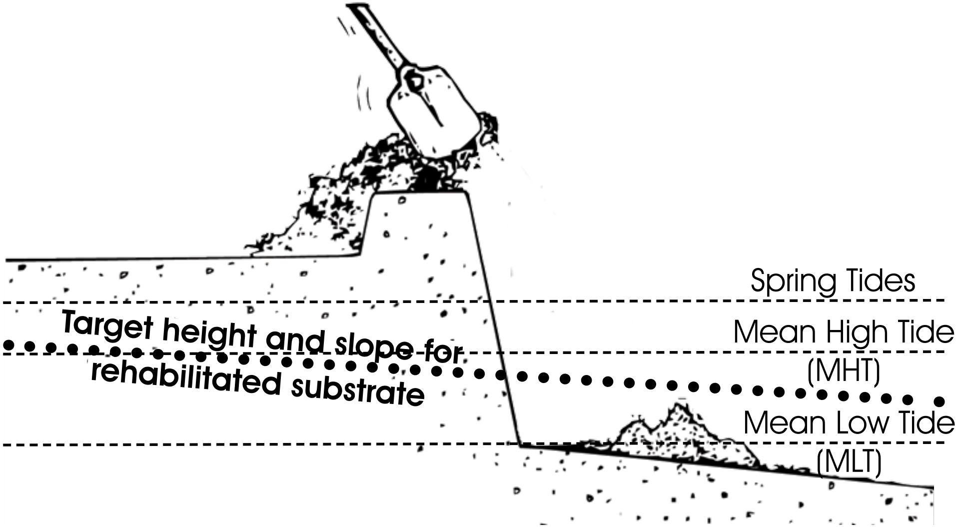


One basic theory behind hydrological rehabilitation is to recreate a natural slope and substrate height which will support normal tidal flow, and the natural re-establishment and growth of mangrove seedlings.

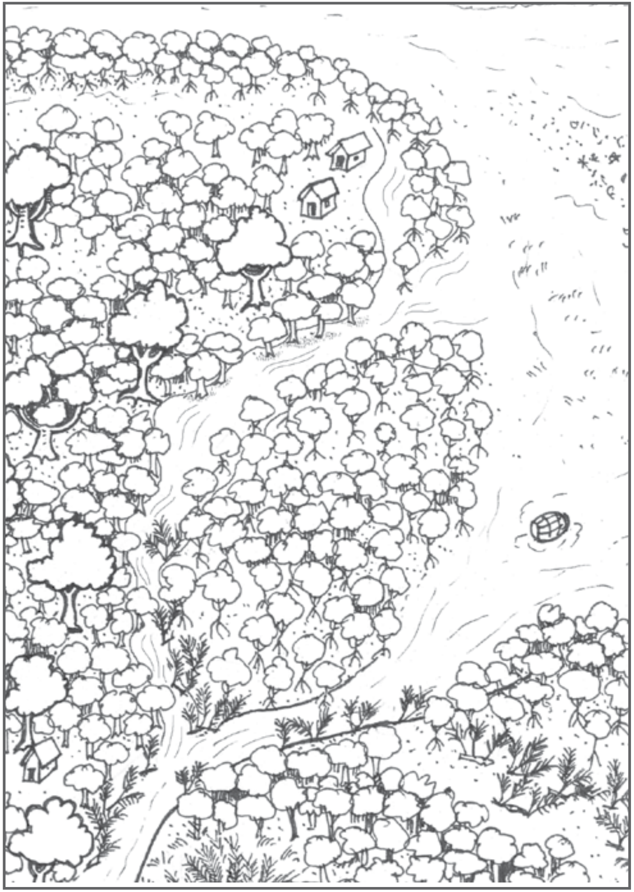
Dike walls of disused shrimp ponds need to be levelled, and ditches need to be filled. If you can not level dike walls entirely, opening strategic breaches may be enough to support the exchange of tidal waters and should lead to further degradation of the dike walls over time.

***Note:***

The final graded topography of a site needs to be designed to match that found in an adjacent reference forest and checked carefully by survey during and at the completion of construction.



## Regrading Substrate



# Tidal Streams

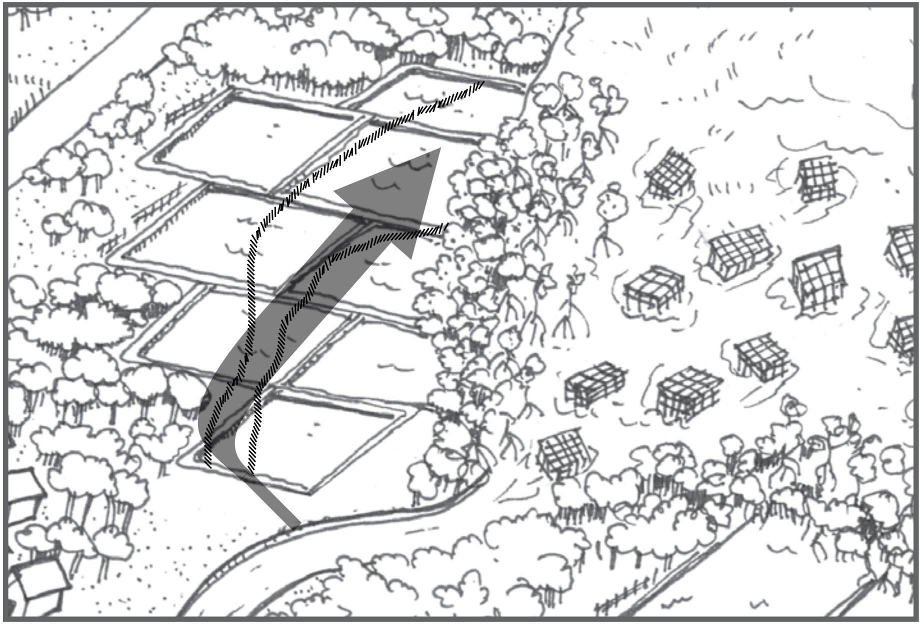
Tidal streams run through mangrove areas from the terrestrial edge to the sea. They are narrower upstream, widening as they meander to the coast.

Tidal streams are fed from the landward edge by ground water, springs, runoff and streams. Because they are connected to the sea, tidal streams facilitate the exchange of tidal waters in and out of the mangrove area.

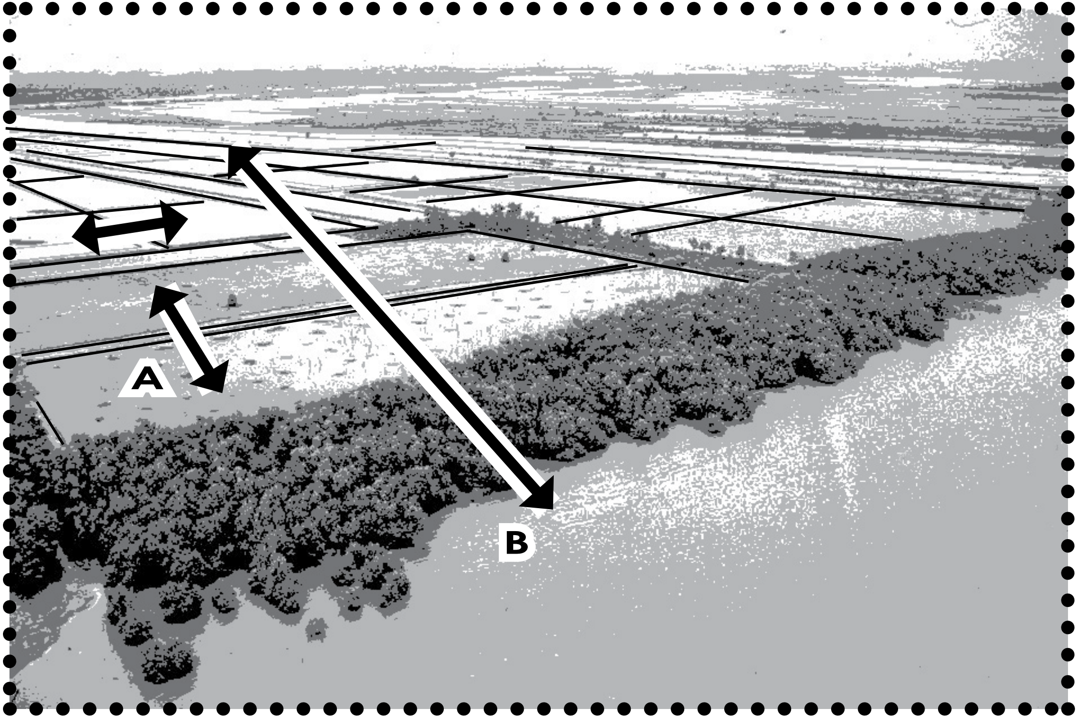
When tidal streams are disturbed, a mangrove may dry out, and die over time.

*The arrow in the diagram at right indicates the historical flow of the natural tidal stream.*

*The hashed lines indicate the path of the desired tidal stream.*



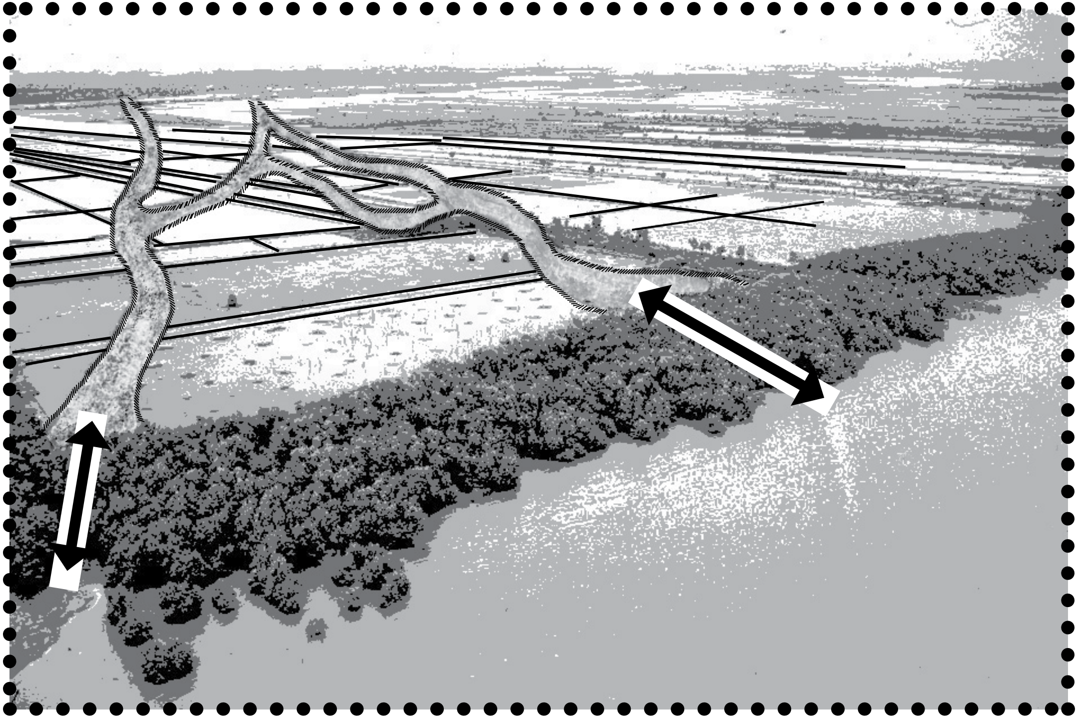
In the case of rehabilitating disused shrimp ponds, it may be enough to create "strategic breeches" in the dike walls. In this case, less rather than more cuts in dikes is better. The reason is that the *tidal prism* (the amount of water that can enter an opened pond between high and low tide) needs to be channeled to the extent possible through a few key openings that are wider downstream than upstream. This mimics the normal operation of tidal streams in mangroves (see previous page). Fewer openings produce greater velocities as the flow is restricted, which in turn produces scouring, which keeps the human-made openings open and reduces the chances of siltation and closure. Too many openings distribute the tidal prism over many points, reduces the velocity, and induces less scour and more siltation.



*A) Breaching of dikes without proper hydrological design.*

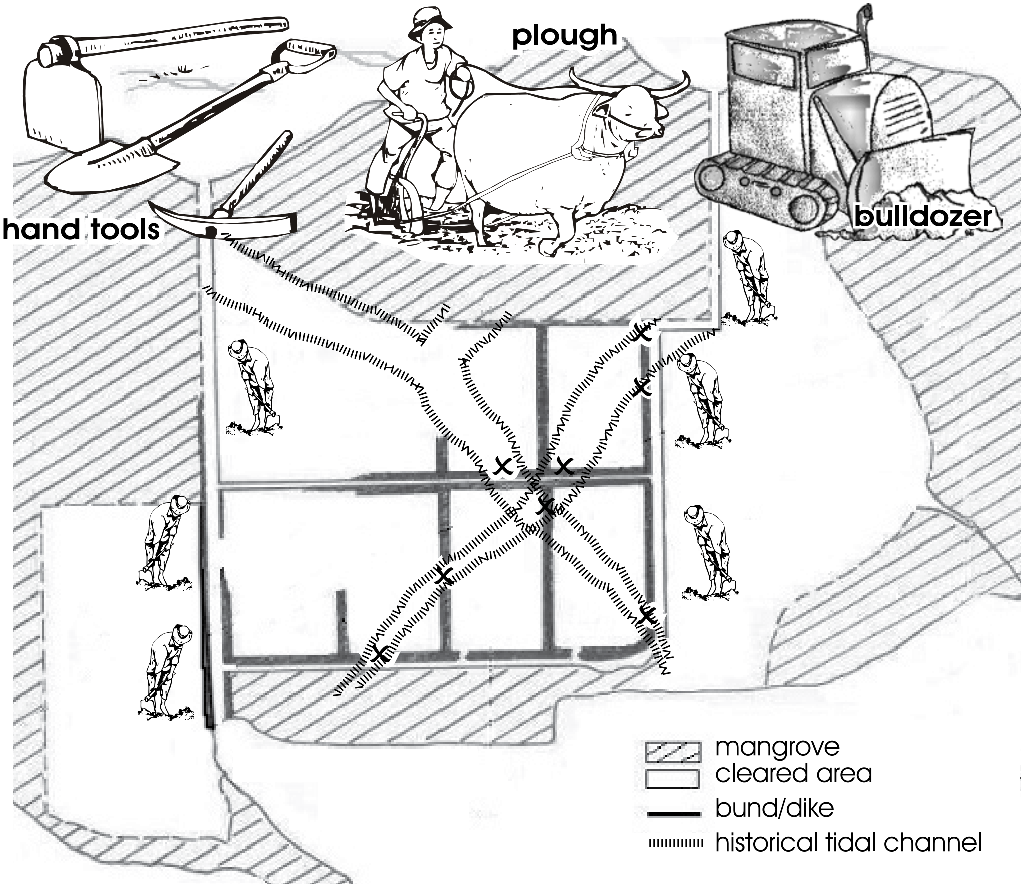
*B) Creation of a straight, unnatural looking canal.*

## Poorly Designed Project



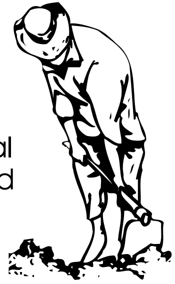
Do It Right! Connect the ponds with the sea by creating well designed tidal channels. Note the channels meander and widen as they flow toward the sea.

***Fill in the ditches and breach the dike walls with...***



This "x" indicates strategic positions to breach dike walls in order to mimic the flow of a historical tidal stream through the mangroves. These natural tidal streams within the mangrove are more narrow at the landward edge spreading outward as they flow to the sea

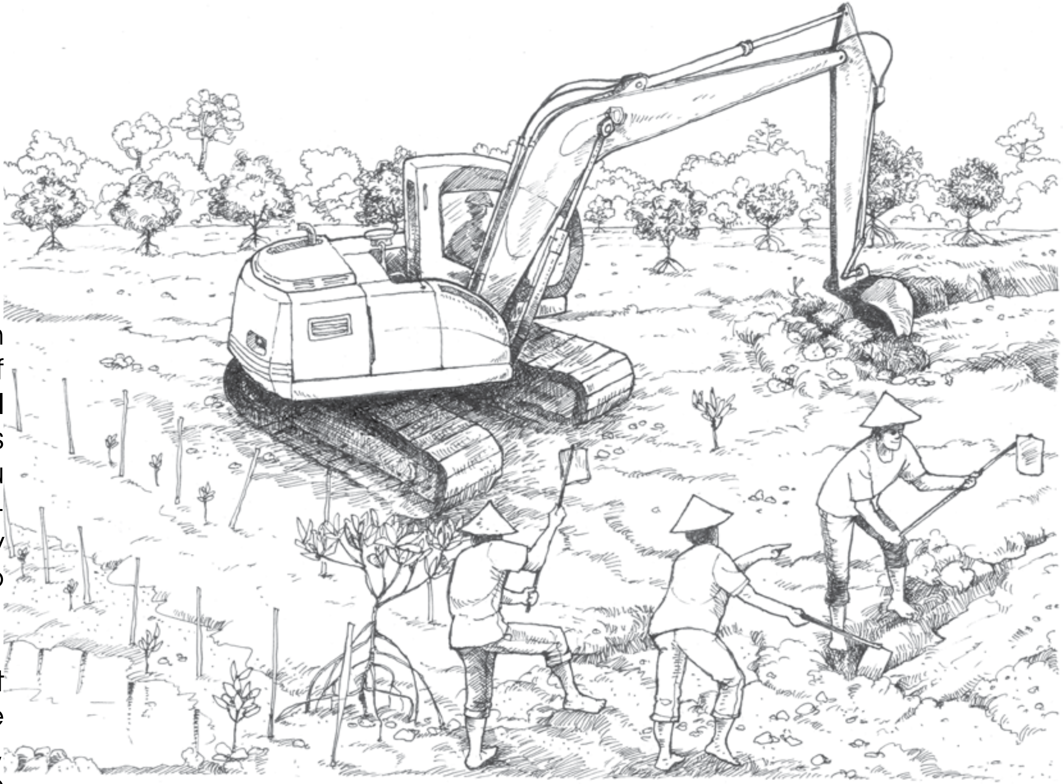
This figure indicates where ditches or artificial tidal channels need to be filled.



## Hydro Rehab Design

Now it is time to act upon your rehabilitation plan. If you don't have financial resources for or access to heavy equipment, you may need to recruit community volunteers, university students or ask for help from the government.

Remember, you might not need to re-grade the entire rehabilitation area, strategically breaching the dikes to enhance tidal exchange and filling deep channels may suffice.



***...implement the rehab plan!***

***...take action!***

# 5

# Mangrove Planting

**Step Five:**
Only utilize actual *planting* of propagules, collected seedlings, or cultivated seedlings after determining (through steps a-d) that natural recruitment will not provide the quantity of successfully established seedlings, rate of stabilization, or rate of growth of saplings established as objectives for the restoration project.

Determine by observation if natural seedling recruitment is occurring once the stress has been removed. This means monitoring. Are seedlings coming into the area? Are they taking root? What is the density of seedlings per hectare? You will probably want a minimum of 1000 seedlings per hectare with 2500 seedlings per hectare as a good figure. How are they growing? Have they survived the dry season?

*Note*: Even if mangroves survive for several years in your rehab area they may remain stunted or even die out unless hydrological conditions are truly supportive of mangrove growth.

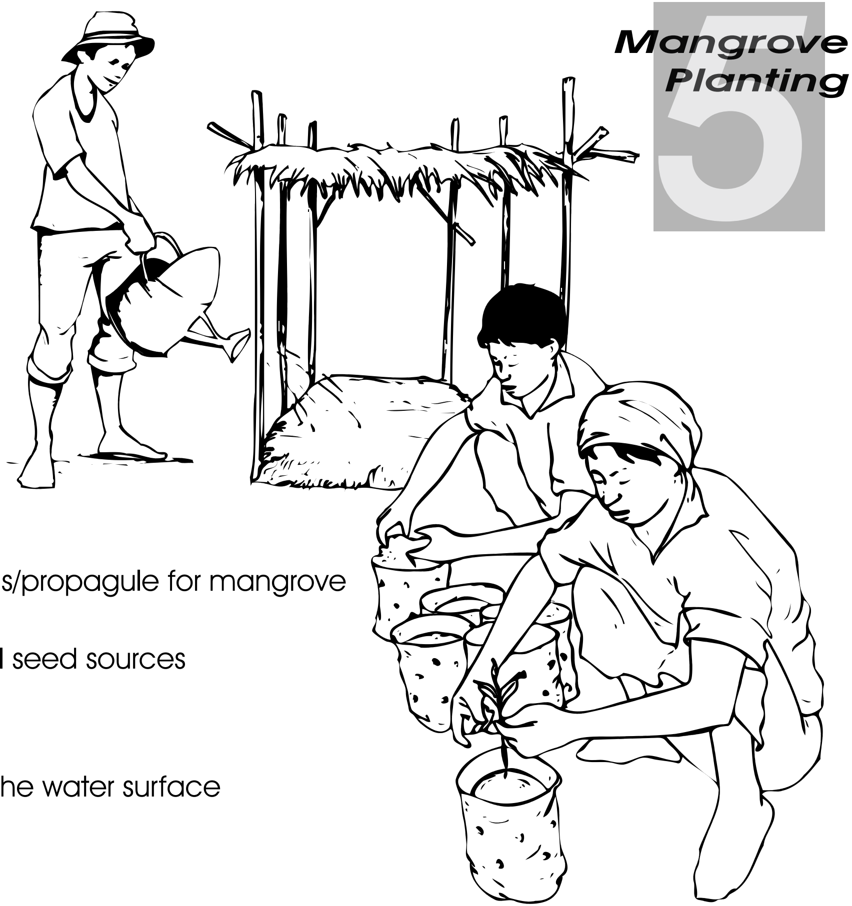
If seedlings have established in the rehabilitation area, but at lower densities than hoped for, you may consider planting. But planting costs can double the overall cost of a project and may limit the biodiversity of the site due to competition from planted mangroves (usually only one or two species) with volunteer species (5-15 species).

If no seedlings have established in the area, even though a natural seed source is nearby, you will have to re-evaluate the effectiveness of your hydrological rehabilitation. Perhaps there are still blockages to normal tidal flow or there is a disturbance in the seed source.

# Assessing Natural Recruitment

There already exist some excellent guides to planting mangroves, which we listed in the resources section at the end of this booklet.

We have provided some tips nonetheless based on our experiences planting mangroves.



**Seed Stock -** There are four sources of seeds/propagule for mangrove planting;

- Raising seedlings in a nursery from local seed sources
- Direct planting of propagules
- Transplanting of wild seedlings
- Broadcast fruits/propagules directly on the water surface during incoming tides.

## Planting Considerations

The following table gives a synopsis of the nursery method for various seedlings. For more information see the JICA Manual "Nursery Method for Mangroves."

| Species | Type of Seed | Months of Seed Collection | Indicators of Maturity | Seed Selection | Seed Storage (max # days) |
|---|---|---|---|---|---|
| *R. mucronata* | Viviparous | S,O,N,D | Yellow cotyledon, green hypocotyl | Length of hypocotyl > 50 cm | 10 |
| *R. apiculata* | Viviparous | D,J,F,M,A | Reddish cotyledon | Length of hypocotyl > 20 cm<br>Diameter: > 14mm | 5 |
| *B. gymnorrhiza* | Viviparous | M,J,J,A,S,O,N,D | Reddish brown or greenish red hypocotyl | Length of hypocotyl > 20 cm | 10 |
| *C. tagal* | Viviparous | A,S | Yellow cotyledon, Brownish green hypocotyl | Length of hypocotyl > 20 cm | 10 |
| *S. alba* | Normal | A,M,J, & S,O | Float in water | Fruit > 40 mm | 5 |
| *A. marina* | Crypto-viviparous | D,J,F | Yellowish fruit skin | Weight of seeds > 1.5 g | 10 |
| *X. granatum* | Normal | S,O,N | Wellow to brown fruit, Float in water | Weight of seeds > 30 g | 10 |

Hachinhoe, Hideki et. Al., "Nursery Manual for Mangrove Species - At Benoa Port in Bali"
Ministry of Forestry and Estate Crops, Indonesia & Japan International Cooperation Agency (1998)

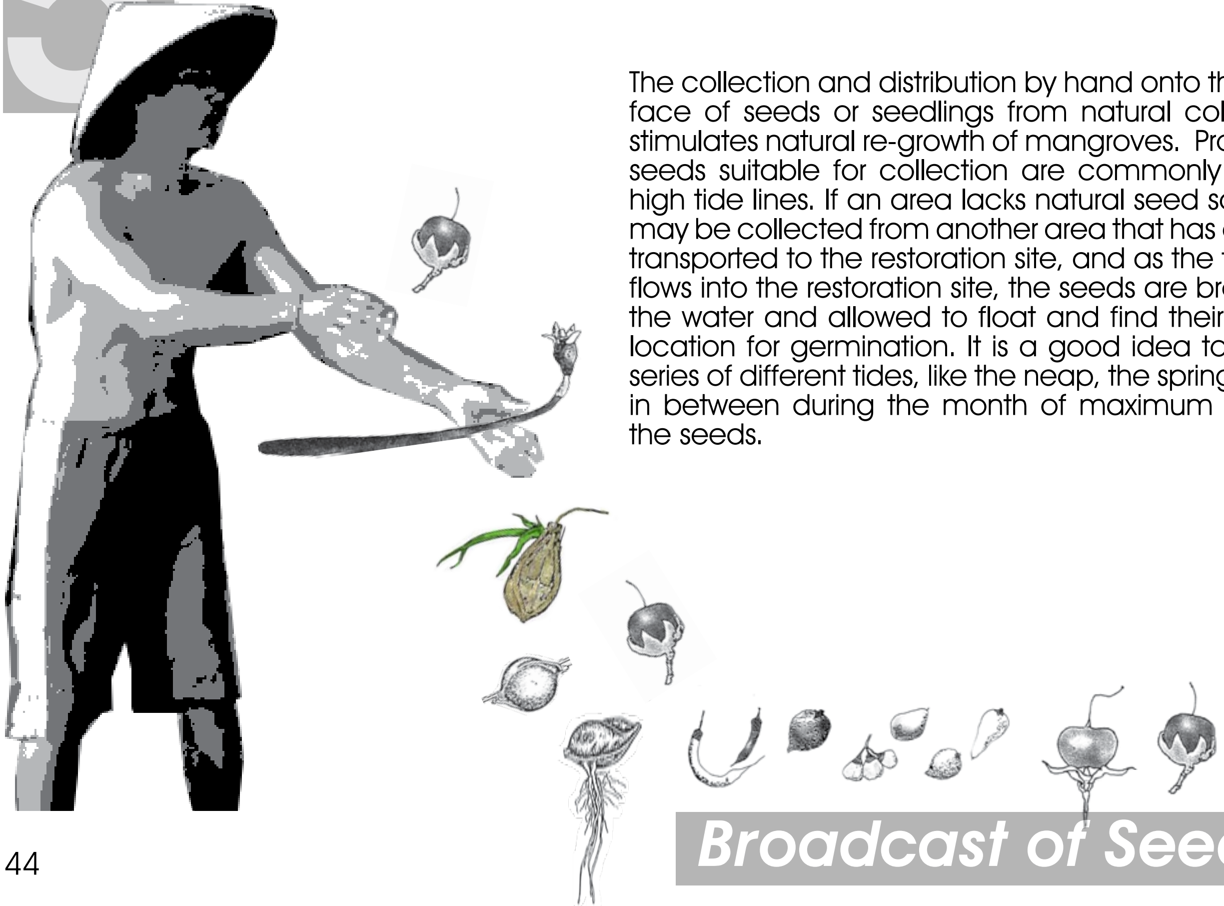
## Summary of Nursery Practices Continued

| Species | Sowing | Shading | Watering | Pest Control | Remarks |
|---|---|---|---|---|---|
| *R. mucronata* | Push ± 7 cm into soil surface | 50%<br>2/3 of sides | at neap tide | insects<br>caterpillars | |
| *R. apiculata* | Push ± 5 cm into soil surface | 50%<br>2/3 of sides | at neap tide | - | |
| *B. gymnorrhiza* | Push ± 5 cm into soil surface | 30%<br>2/3 of sides | at neap tide | - | Don't forcefully remove calyx |
| *C. tagal* | Push ± 5 cm into soil surface | 50%<br>2/3 of sides | at neap tide | - | |
| *S. alba* | Push radicle lightly into soil surface | 30%<br>whole sides | twice a day | rats, crabs<br>caterpillars | Use wire mesh to keep seed in place, add 30% cow dung to soil. |
| *A. marina* | Lay on surface | 30%<br>whole sides | fully once a day | crabs<br>caterpillars | |
| *X. granatum* | Lay on surface, radicle downward | 30%<br>whole sides | fully once a day | crabs | |

Hachinhoe, Hideki et. Al., "Nursery Manual for Mangrove Species - At Benoa Port in Bali"
Ministry of Forestry and Estate Crops, Indonesia & Japan International Cooperation Agency (1998)

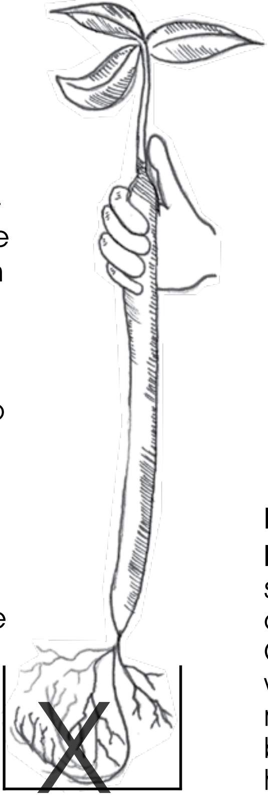
## TIPS FOR PLANTING MANGROVES

The collection and distribution by hand onto the water's surface of seeds or seedlings from natural collection areas stimulates natural re-growth of mangroves. Propagules and seeds suitable for collection are commonly found along high tide lines. If an area lacks natural seed sources, seeds may be collected from another area that has a lot of seeds, transported to the restoration site, and as the tide turns and flows into the restoration site, the seeds are broadcast onto the water and allowed to float and find their own suitable location for germination. It is a good idea to do this on a series of different tides, like the neap, the spring, and several in between during the month of maximum availability of the seeds.



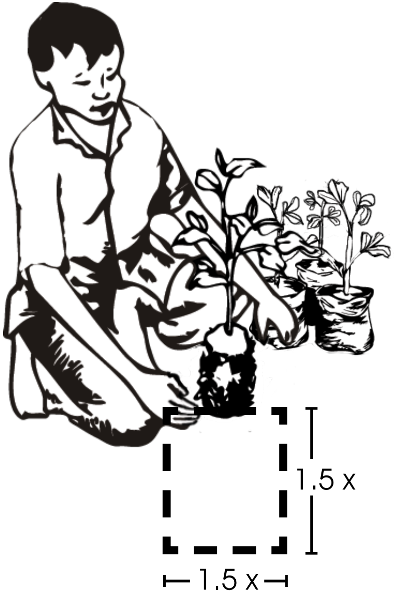
## Broadcast of Seedlings

## *TIPS FOR PLANTING MANGROVES*



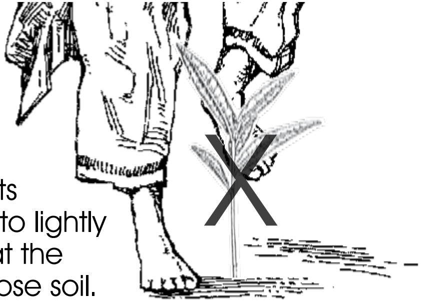
### Avoid "J"-Roots

When placing the seedling in the prepared hole it is good for one person to hold the seedling so that the top of the root ball is even with the surface of the soil. It is also important that the roots be allowed to dangle freely, straight into the hole. Roots in contact with the bottom of the hole will curl upward (like the letter "J") which may stunt growth or even kill the plant.



### Hole Size

The prepared hole for planting should be 1.5 times wider and 1.5 times deeper than the root ball of the seedling.



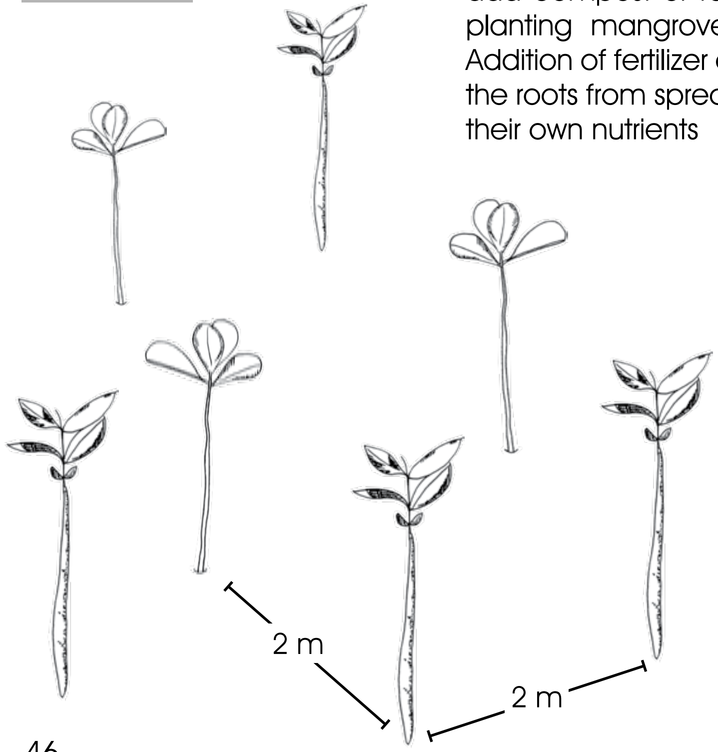
### Loose Soil

It is common for people to stomp on the soil surface after planting a seedling. Compacting the soil in this way eliminates small air pockets needed by the roots. It is best to lightly back-fill soil into the hole so that the hole is completely filled with loose soil. Save the stomping for the dance floor!

## TIPS FOR PLANTING MANGROVES

**_No soil amendments_**

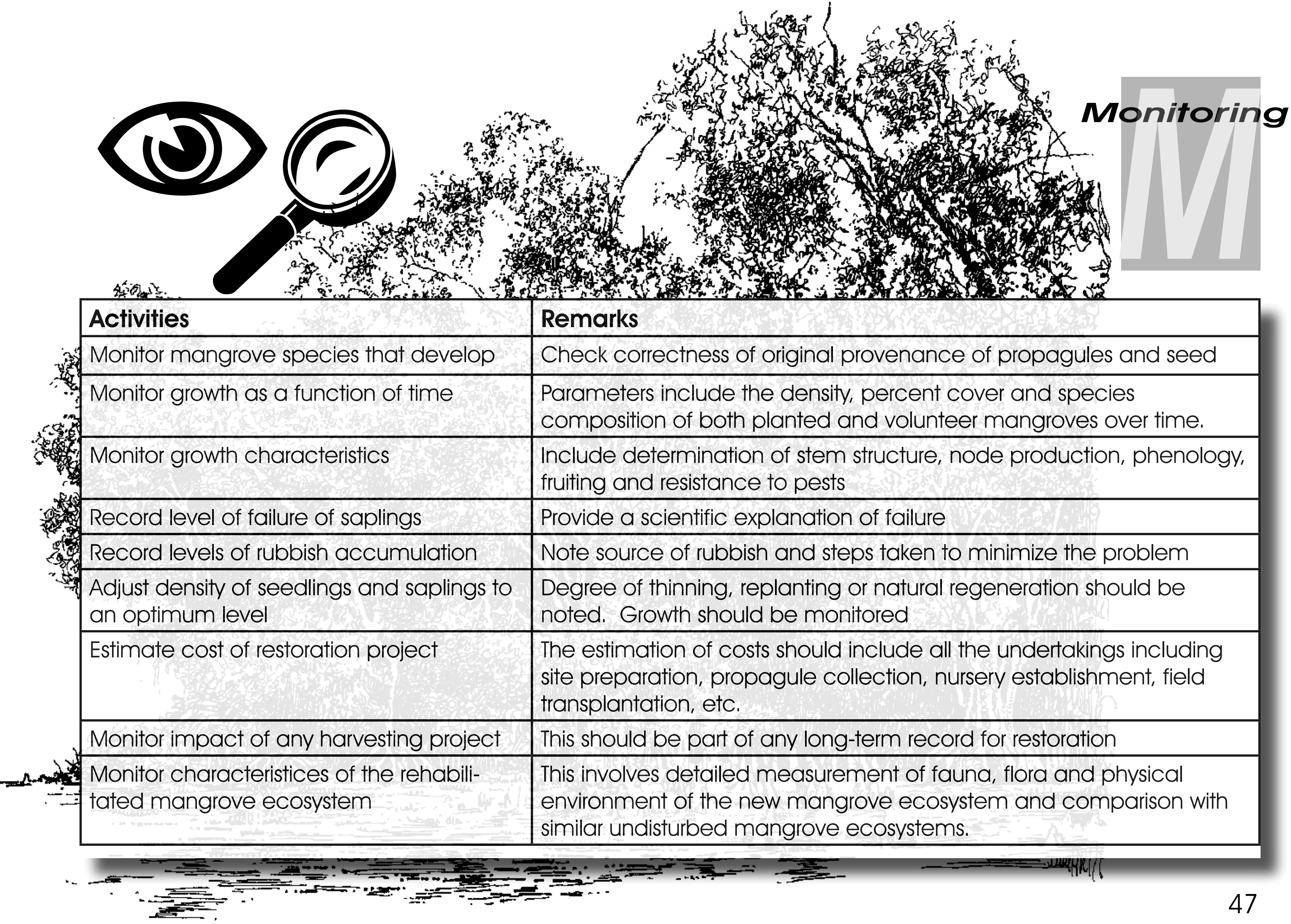
Except in the case of planting *Sonneratia* spp., do not add compost or fertilizer when planting mangrove seedlings. Addition of fertilizer discourages the roots from spreading to find their own nutrients



**_2-meter spacing - random planting._**

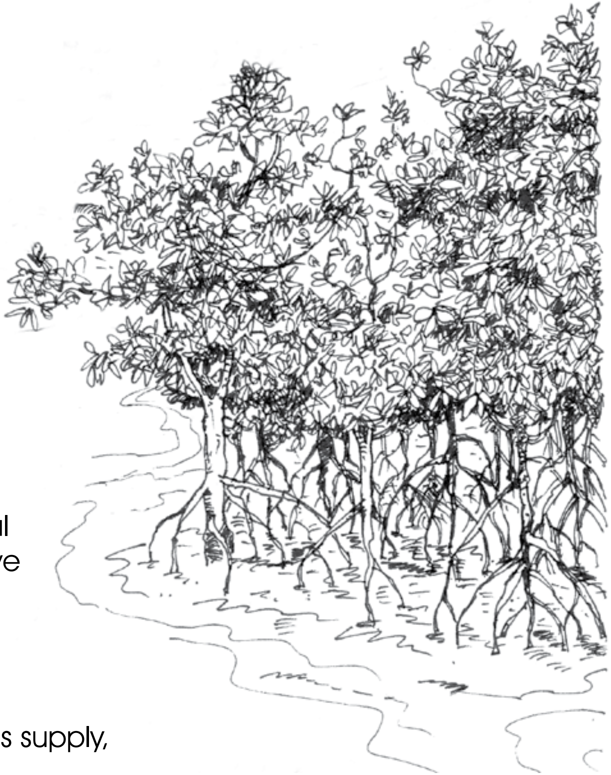
Mangroves do not naturally grow in straight rows! Why plant them in straight rows?

Planting in straight rows can result in artificial channelization between the rows which will rob water from the mangroves.



| Activities | Remarks |
|---|---|
| Monitor mangrove species that develop | Check correctness of original provenance of propagules and seed |
| Monitor growth as a function of time | Parameters include the density, percent cover and species composition of both planted and volunteer mangroves over time. |
| Monitor growth characteristics | Include determination of stem structure, node production, phenology, fruiting and resistance to pests |
| Record level of failure of saplings | Provide a scientific explanation of failure |
| Record levels of rubbish accumulation | Note source of rubbish and steps taken to minimize the problem |
| Adjust density of seedlings and saplings to an optimum level | Degree of thinning, replanting or natural regeneration should be noted. Growth should be monitored |
| Estimate cost of restoration project | The estimation of costs should include all the undertakings including site 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 characteristices of the rehabilitated mangrove ecosystem | This involves detailed measurement of fauna, flora and physical environment of the new mangrove ecosystem and comparison with similar undisturbed mangrove ecosystems. |

# Summary



## Advantages and disadvantages of natural regeneration

**Advantages:**

+ Cheaper to establish,
+ Less subsidy is needed in terms of labour and machinery,
+ Less soil disturbance,
+ Saplings establish more vigorously,
+ Origin of seed sources usually known.
+ Nature will plant the mangroves species in the correct tidal zones. Only those mangroves in the correct zone will survive through competition.

**Disadvantages**:

– Replacement may not be of the same species removed,
– Absence of mother trees may result in low/or no propagules supply,
– Genetically improved stock not easily introduced,
– Excessive wave action may cause poor establishment,
– Predation of propagules by macro benthos (e.g. crabs, snails etc),
– Less control over spacing, initial stocking and composition of seedlings.

## Emerging Restoration Principles

- Get the hydrology right first!

- Do not build a nursery, grow mangroves and just plant some area currently devoid of mangroves (like a convenient mud flat). There is a reason why mangroves are not already there or were not there in the recent past or have disappeared recently. Find out why.

- Once you find out why, see if you can correct the conditions that currently prevent natural colonization of the selected mangrove restoration site. If you cannot correct those conditions, pick another site.

- Use a reference mangrove site for examining normal hydrology for mangroves in your particular area. Either install tide gauges and measure the tidal hydrology of a reference mangrove forest or use the surveyed elevation of a reference mangrove forest floor as a surrogate for hydrology, and establish those same range of elevations at your restoration site or restore the same hydrology to an impounded mangrove by breaching the dikes in the right places. The "right places" are usually the mouths of historic tidal creeks. These are often visible in vertical (preferred) or oblique aerial photographs.

- Remember that mangrove forests do not have flat floors. There are subtle topographic changes that control tidal flooding depth, duration and frequency. Understand the normal topography of your reference forest before attempting to restore another area.

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*For more information on ecological/hydrological mangrove rehabilitation see:*
***www.mangroverestoration.com***

## For Further Information or Consultation

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