NIGER DELTA

MANGROVE RESTORATION

BRIEF FIELD GUIDE.

HYDROCARBON POLLUTION REMEDIATION PROJECT
(HYPREP)

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Federal Ministry Of Environment

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FORWORD

Attempts are now made in many countries to rehabilitate and restore mangrove areas which have been destroyed, damaged or degraded.

This manual is intended to be used as a handbook for mangrove rehabilitation in the Niger Delta. It describes the appropriate strategies and methods with a focus on areas where oil contamination has caused destruction to the mangroves. In many such damaged areas, the invasive nipa-palm ***(Nypa fruticans)*** is taking over.

This manual is a short version of a longer report entitled Mangroves in the Niger Delta - Restoration Manual which can be found at the following. It contains considerably more information related to the background of the different recommendations as well as illustrations, photos, etc.

A complementary document, the Ogoniland and the Niger Delta - Mangrove Restoration and Conservation Strategy, which can be found at the following, provides a roadmap for mangrove conservation and rehabilitation in the Niger River Delta.

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1. MANGROVES OF THE NIGER DELTA

Mangrove vegetation is adapted to grow and survive in the intertidal zone along more or less sheltered shallow water and soft-muddy bottom coasts and in river deltas.

Mangroves are highly productive trees, shrubs, herbs, patima and fems which are hosts to a rich and diverse association of plants and animals which interact with, and depend on, the mangrove habitat for their lifecycles.

Mangroves are adapted to the difficult environment between land and ses-including a multitude of roots and trunks which enable the trees and bushes to remain in place when the tides are nsing and falling.

The complex root and trurik architecture provides protection to young stages of fish and shelffish, many of which are fished as adults in waters within and outside the mangrove covered coastlines and river deltas.

Other services of mangrove forests include carbon sequestration, shoreline protection, water purification and cultural and educational support.

Mangroves are characteristic vegetation in the Niger River Delta. However, large areas of mangroves havebeen lost in the region during the last several decades due to expansion of urban ansas, road

construction over harvesting for timber and fuel, and illegal dredging for sand in the creeks and rivers which leads to erosion of sediments in mangrove areas.

Furthermore, in the Niger Delta mangroves over large areas have been destroyed as a result of oil spills. In addition, the continuous spread of nipa palm ***(Nypa fruticans),*** an introduced invasive mangrove palm, is another major threat to the native mangroves of the Niger Delta.

During the last ten years increasing attempts have been made to rehabilitate and restore mangrove areas in the Niger River Delta which have been destroyed, damaged or degraded.

The present field guide is intended to be used as a handbook for mangrove rehabilitation in the Niger Delta. It incorporates the ten principles for ecosystem restoration to guide the United Nations Decade on Ecosystem Restoration (2021-2030).

The manual describes the strategies and methods for mangrove rehabilitation with a focus on areas where oil contamination has caused destruction to the mangroves and areas invaded by nipa palm

Figure 1. *A view of a well-developed mangrove forest at high tide. (Photo UNEP)*

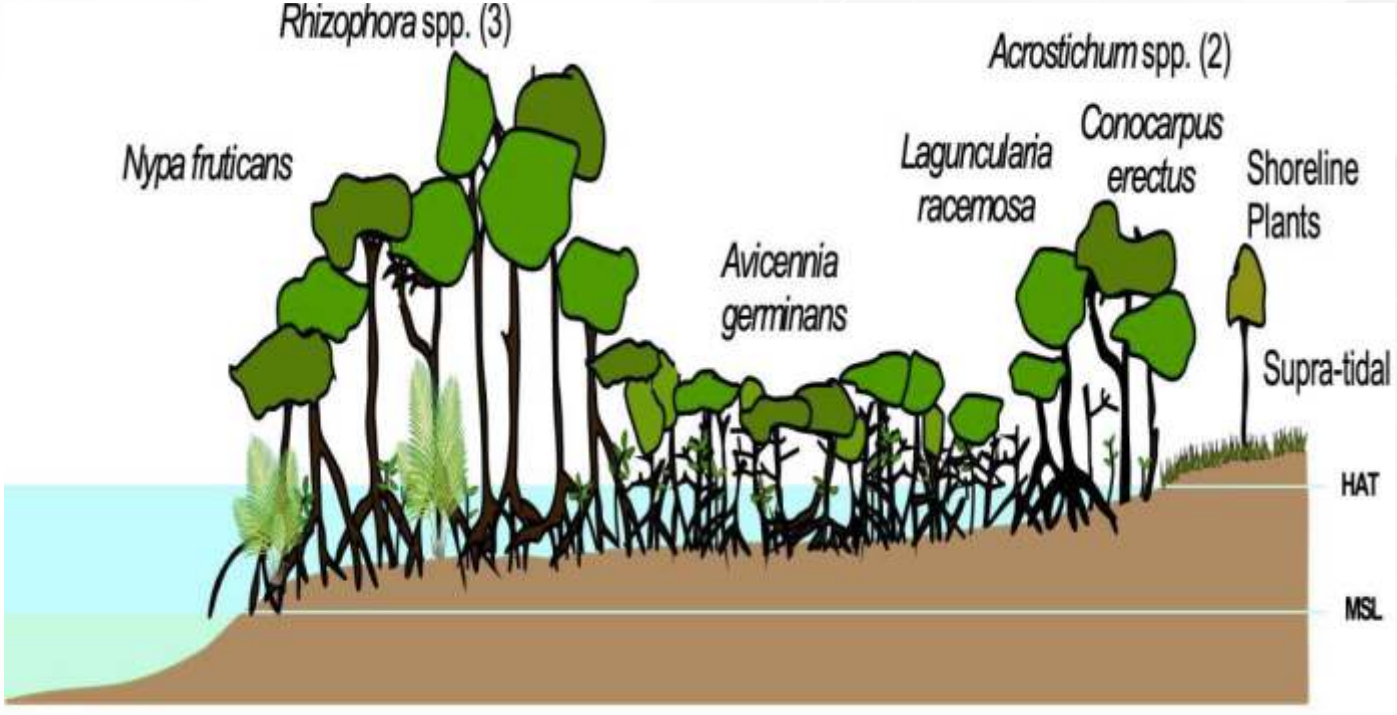

Figure 2. *Shows a typical zonation pattern of mangrove plants in the Niger Delta (Illustration by Norman Duke).*

Figure 3. *Oil spills have killed the mangroves in this area in the Niger River. With time the trunks and prop roots have disappeared (Photo UNEP)*

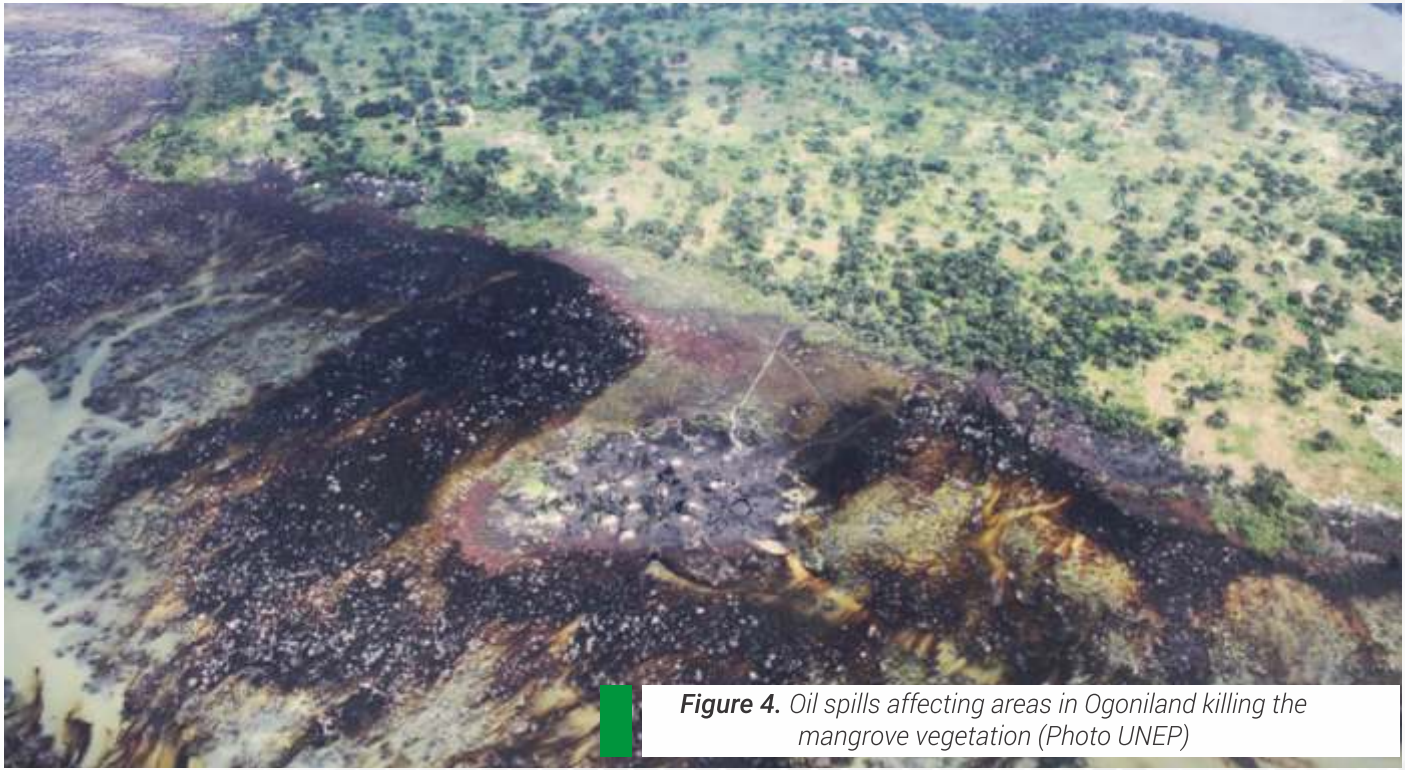

Figure 4. *Oil spills affecting areas in Ogoniland killing the mangrove vegetation (Photo UNEP)*

Figure 5. *Extensive mangrove loss caused by oil spills in Bodo Creek, Niger Delta (Photo: Nenibarini Zabbey).*

2. PREREQUISITES FOR SUCCESSFUL MANGROVE REHABILITATION AND RESTORATIONA.

a. **Defining the objective(s):** In the context of the Niger Delta, the recovery of ecological and economic functions of the rehabilitated mangroves is crucial because the local communities depend largely on the mangrove ecosystem for their livelihoods.

Therefore, the objectives of mangrove restoration should include emphasis on the ecological values, livelihoods of the local population, coastal stabilization, provisioning of fuelwood, habitat for animals, support of fisheries, stable employment for the local communities, and contribution to sustainable development

b. **Support from local communities:** Once a restoration site is identified, the local community needs to be consulted to understand and resolve issues of landownership and secure the buy-in of the local population. Consultation would foster the incorporation of community use expectations into the restoration goal so that the project would benefit from local support.

Figure 6. Local communities are consulted before any field work is carried out

The buy in and active involvement of the local people have long-term advantages. Community folks learn the science and art of mangrove restoration by participating in the process. The skill legacy of the project would engender future voluntary rehabilitation and sustainable management efforts of some of the locals. It would aid a seamless co-management model. The pool of volunteers (community scientists) can be leveraged by research institutions that would be assigned the role of long-term research and monitoring of the restoration site (see recommendation in Section 5)

c. **Oil spills and/or other stress factors have ceased:** As oil pollution is one of the major stressors/threats to mangroves in the Niger Delta, a given prerequisite for successful restoration is that oil spills cease. Hence, stopping oil theft and artisanal refining operations as well as improving the maintenance of oil infrastructure must be undertaken in parallel with cleanup and restoration. The contrary would amount to leaving the tap on while mopping the flook For mangrove areas that have been degraded due to altered hydrology as a result of road construction, restoring tidal connectivity is required before restoration starts. It is also important to identify and mitigate at the planning stage potential stressors and disturbances such pest, weeds, animal tramping, etc.

d. **Keeping track of tides and elevations:** An essential prerequisite for success is good knowledge of the tidal conditions and the elevation in the areas to be cleaned and revegetated. The window during which it is possible to reach the affected areas and to be able to carry out work in mangroves is rather limited, possibly a few hours when the tidal flats are exposed at low tide. At high tides it is difficult to do any meaningful work, and during low tides it may not be

possible to reach the interior sites with the workboats. Therefore, careful planning is key to success. Personnel and equipment must be on site at the right time to be able to make use of the conditionse.

e. Preventing re-pollution: For efficient cleanup of mangrove tidal flats and to prevent re-pollution from flushing operations, a tide cooperative strategy is required. Failures of booms typically re-pollute previously cleaned and certified areas. If re-pollution is not prevented, it will be a waste of both manpower and resources. Multiple booming backstops oil lost from the inner boom. Rapid currents, which characterize concave meanders during spring tides, can, however, overwhelm multiple booms. As a result, for efficient cleanup of mangrove tidal flats and prevention of re-pollution, a response strategy that prioritizes convex meanders during periods of swift current is required.f.

f. SCAT: The Shoreline Cleanup Assessment Technique (SCAT) is an internationally accepted rapid tool for assessing the quantities of oil on shorelines and in mangrove swamps and establishing the degree of contamination. It is a method of documenting oil pollution levels, recommending management strategies and approving 'satisfactorily' cleaned grids carried out by multi-stakeholder teams

Figure 7. *Scat surveys to determine the degree of oil contamination (Photos Olof Linden).*

The SCAT process reduces stakeholder disputes and facilitates collaborative learning and decision-making. The technique was applied and modified throughout the Bodo Mediation Initiative (BMI) and is now generally accepted as a method to establish the degree of oiling in the Niger Delta.

In addition to assessing the levels of oiling by visual observations, SCAT surveys also map areas that have natural growth of mangrove seedlings (so called "wildings or volunteers") in oil degraded areas. Net environmental benefit analysis (NEBA) is a guiding principle of remediation and restoration. Therefore, in areas with significant numbers of "wildings and based on the result of SCAT surveys, the project leaders should determine whether cleanup efforts would cause more harm than good to the site.

By carefully using low-pressure, ambient-temperature, flushing and the removal of dead stumps of mangrove covered with tar and oil it may be possible to clean the sites without damaging the naturally recruited mangroves (the "wildlings"). However, if such actions are likely to cause damage to the existing mangroves, the area should be left for natural recovery.

Figure 8 (A-C). *Flushing to remove oil from sediment where mangroves will be replanted (Photos Nick Story).*

g. Presence of volunteer seedlings (setting up of nursery if necessary): Deforested mangroves could naturally be reforested with tidally-borne propagules and seedlings if some basic conditions exist: i) the factors that caused the degradation of the mangroves is no longer present or reduced to tolerable levels, ii) seedlings are available to be dispersed naturally by tide to the affected area, iii) the hydrology is sufficient to facilitate transport of propagules/seedlings to the restoration area, and iv) for disused dugout ponds, sufficient sediment siltation has taken place to prevent perennial flooding of newly settled recruitsAnother influencing factor is the trapping of the seedling in the high and mid-intertidal zones where mangrove plants thrive. However, seedlings stuck in the low intertidal zone (mud/sand flat) might sprout but would perish overtime due to too long periods of inundation. The natural recruits (volunteers/wildings) can potentially restore a degraded mangrove area with or without human intervention when the above conditions are met.

Within mangrove areas destroyed by oil pollution in the Delta, the presence of volunteer seedlings indicates a reduced (at least, tolerable to the seedlings) level of contamination in the immediate subsurface sediment This implies that such an area is being naturally colonized by volunteer seedlings and may not necessarily require intensive cleanup. The oil level can be double-checked with the results of chemical samples taken from random spots within the designated area.

The rate of natural seedling recruitment may determine whether planting is required. Other factors

that will drive the decision on the restoration approach include the availability of waterborne seedlings, the potential duration it would take to attain natural colonization of the site and having the right hydrology in place

Mapping: Mapping is key in order to establish where specific species should be planted. About 90% of mangrove plants in the Niger Delta are red mangroves (Rhizophoracae). Generally, the zonation pattern of the mangrove swamps in the Niger Delta has the red mangrove in the front, followed landward by the black mangrove ***(Avicennia germinas),*** then white mangrove ***(Laguncularia racemosa).*** The buttonwood ***(Conocarpus erectus)*** occupies the highest astronomical tide level (HAT). Figure 2 illustrates the typical zonation of mangroves in the Niger Delta.

h. The invasive nypa palm is mostly confined to the creek (mangrove) fringes but also thrives landward in the high intertidal zone where black mangrove dominates. The mangrove ferns ***(Acrosticum aureum*** and ***A danaeifolium)*** exist mainly in the high intertidal zone, but their distribution may extend to the mid intertidal zone forest fringes. However, in some cases the mangrove distribution patterns deviate from what is described above. For example, white mangroves may occupy the creek fringe with red mangroves behind and there are also swamps with nearly homogenous species

I. Obtaining mangrove seeds/seedlings: There is a global preference of planting Rhizophora

species because they are easier to plant and maintain than other species. However, the primary aim of mangrove restoration in the Niger Delta is to restore the ecosystem structure and functions to support the local communities (e.g., in the form of seafood, livelihoods, and coastal protection). Hence monospecific reforestation would fail to re establish a functionally diverse mangrove ecosystem. Thus, *restoration efforts should mimic and preserve the natural species diversity, complexity and trophic integrity of the region's mangrove ecosystem*

As much as possible, seedlings of the different species should be sourced from the wild and planted according to the natural zonation pattern of mangroves in the area. This means, monospecific reforestation of Rhizophora should be avoided. Aside compromising diversity of the ecosystem, pest infestation has been associated with monocultural plantation.

However, seedling limitation can be a challenge, especially for the non-Rhizophora taxa given their relatively low density and the difficulty of raising the seedlings in the nursery. White mangrove seedlings can be accessed by transplanting wildlings (seedlings) from around the base of a mother plant at a reference (natural) site. Newly dropped and un-established black mangrove propagules can be entrapped by setting nets round the parent plants or by hand-picking stranded seedlings from the highwater tide mark.

j. **Site preparation:** This takes on different dimensions depending on the restoration approach. Assisted natural restoration might simply require enhancing the local hydrology by removing

blockages along tidal creeks of the area to enable seamless flow and dispersal of naturally waterborne or broadcast seedlings (propagules) if normal tidal hydrology is not disrupted and waterborne seedlings are available, and there is absence of contaminants, or a tolerable level of contaminants, in the environment, damaged mangroves can self-repair in 15-30 years. The following section describes the different approaches to site preparationapplicable to the Niger Delta where natural restoration is impeded.

k. Removal of nipa palm that colonized unoiled areas: In order to encourage the re-establishment of nativespecies, restoration activities should incorporate competitive control strategies and the removal of alien plant species. Thus, to restore native mangroves at sites colonized, or newly invaded by nipa palm in the Delta, removing the palms will be unavoidable..

l. Removing oiled dead stumps: Free phase oil removal is intended to remove coated oil on dead wood 1(main stem or the roots), on downed wood, as well as the sedimentary surface and oil buried in shallow subsurface sediment. However, retained cleaned dead wood at the restoration site has a lot of benefits, namely, trapping waterborne propagules for natural recruitment, habitat provisioning (eg, for crabs), reducing boating wave shocks, and preventing foreshore erosion, evaporation, and desiccation that would increase salinity. Thus, only dead wood that is heavily oil-clogged and recalcitrant to flushing should be removed from the restoration site.

3. METHODS FOR REHABILITATION AND RESTORATION

Restoring degraded mangroves in the Niger Delta should require human intervention, through planting. More so, natural reforestation is not a viable option for the Delta because of harvesting pressure, the cause of mangrove loss (predominantly oil pollution), and the paucity of viable propagules (seeds) or recolonization.

Limited floating seeds in some parts of the Niger Delta could be a result of overharvesting mature seed-bearing mangroves for energy and other uses. Unregulated harvesting of mangroves leads to a scarcity of propagules. In the Delta, it is "normal practice" to cut down mature mangrove trees loaded with propagules to harvest wood.

a. **Mangrove nursery (red, white and black mangroves):** The different mangrove species in the Delta are ecologically important. However, amongst the mangrove trees the red, black and white mangroves deserve restoration priority.

   Virtually all mangrove restoration in the Delta (past and ongoing) had taken the trajectory of planting only the red mangroves because of convenience. As at the time of writing this manual, there is no black and white mangrove nursery in the region. This must change if the genetic diversity and ecological health integrity of the Delta mangrove ecosystem are to be preserved.

b. **Importance of nursery:** If seedlings are nursery-grown before planting out, they have a better chance of survival and growth. This allows the seedling to develop a strong root system before being implanted, therefore seedlings grown in a nursery have a higher success rate than propagules. Nurseries guarantee the supply of large seedlings with more leaves, which are known to have higher survival rates in the field than seedlings of propagules planted directly.

Furthermore, the season of mangrove fruiting and the availability of mature propagules or wildlings may not coincide with the period of out-planting at restoration sites, but nurseries provide necessary seedlings all year. Another important function of the nursery is the protection of propagules and seedlings from pests (eg. crabs and barnacles) and to enable the out-planting of seedling sizes that will withstand the inhospitable conditions of a degraded environment.

c. **Collection of propagules:** Matured propagules, or seedlings, can be collected directly from the parent plant or handpicked afloat or from the forest floor. In the Delta, propagules are produced throughout the year, with a peak season in January and February. The following instructions for collection of the mangrove propagules are recommended:

I. Collect only mature, healthy propagules that have not been rotted or attacked by insects.
ii. Pick off propagules from healthy, mature trees Rhizophora produces propagules from three years of age when the plant could be less than a meter tall. However, propagules from trees at least over 5 years old with the heights greater than 5-6 m are preferable..
iii. Only gather large propagules since they tend to grow more vigorously than smaller ones.

iv. Gather propagules early in the day and keep them in the shade because the sun's heat could harm them
v. Propagules and seeds should be handled carefully to avoid damage.
vi. The seedlings should not be kept out in the rain or in a moist environment for an extended amount of time as this could cause rot and death.
vii. However, a 24-hour soaking in salt water is needed to remove the seed coat of black and whitemangrove propagules (see description below)
viii. Collected propagules should not be kept in plastic bags since this could cause the seedlings to overheat and perish. Use a basket or jute bag instead. The viability of the seeds may be reduced if they are not planted within 48 hours of harvesting of the propagules

d. **Hardening-off:** Hardening-off is a process of making the seedlings to experience the typical weather conditions in the field. It is not required for in-creek nurseries whereby the seedlings are inundated daily with tidal waters. The seedlings must be tough to survive conditions at the restoration site. Hardening off is done two (2) months before planting in the field. It is done by:
i. Decreasing water one month before seedlings are transplanted. This is necessary to prepare the plants for the harsh environment at planting.
ii. Seedlings should be watered half the amount it was previously watered with every other day.
iii. Seedlings should be wet thoroughly one day followed by being moist the next day. The soil should not be allowed to dry-out or let the leaves of the plant to dry up (appear burnt).

All seedlings that have undergone these processes are ready for planting and should now be carefully transported to the restoration site for planting. The nursery duration before transplanting is between 3-8 months

e. Red mangrove nursery. Whether the nursery is temporary or permanent, the method of raising the seedlings is the same. Mature red mangrove propagules show brown coloration, darker coloration and swelling of the radicle/root portion when they are more mature. Propagules with red or orange color exhibit poor germination success.
   i. Standard black nursery polypat (polythene) bags of 5"x8" should be used for the raising of red mangrove propagules. Such material allows the seedlings to have the required space to grow to a height of 35 cm or more without the roots curling up. It is possible to improvise the above by using empty bags of sachet water locally called pure water littered in the streets. Small holes should be made at the bottom of the bags to allow for effective draining of water.
   ii. Chicoco mud should be collected from the mudflats during low tides. This is the ideal soil to be used in the nursery However, loamy soil can also support good nursery growth.
   iii. The soil in the polybags should be watered before planting the propagule.
   iv. Planting should be done either in the early morning or later in the evening to avoid the scotching effect of the sun
   v. The root part (swollen part) propagule should be pushed straight 7-8 cm into the soil at the center of the polythene bag. Plant only one propagule in each bag.

Figure 9. *Red mangrove with propagules (Photo: Nenibarini Zabbey).*

f. Black mangrove nursery. The propagules of the black mangrove when dropped from the tree are lima-bean shaped or oblong-elliptical (resembling a flattened olive), weigh about 1 g and are about 2 cm long. Mature black mangrove seedlings have light green to a light purple and/or brown coloration.

i. Larger propagules greater than 1 cm in diameter should be collected.
ii. Collect fallen propagules from the floor beneath the mother tree, or pluck mature seeds directly from the parent plant
iii. The seeds can also be handpicked from stranded water marks or by net-fencing the fruited trees
iv. Selected mature and healthy seeds (removed diseased and insect-damaged seeds)
v. Soak the propagules in brackish water ovemight to remove the seed coats. This treatment reduces the establishment time by two to three days.
vi. Propagules without seed coats should be used for planting in polythene bags. After 24 hours of soaking, planted seeds with an unbroken seed coat break their seed coat 2-3 days later. However, seedlings that break out of seed coats after 24-hour soaking in brackish water show relatively faster growth rate.
vii. The selected propagules must be planted in the polythene bags immediately. Fill the perforated polypots with up to 3 cm of sediment to the top with Chicoco sediment or loamy soil. Allow the soil to harden by placing in the sun outside the nursery bed, then water the soil to make it completely wet Plant the seeds by gently pushing the radicle (1/3 of the seed) into the soil.

viii. Plant one seed per polythene bag. Trials show that seeds raised in loamy soil tend to do better than those in Chicoco.

ix. When storage of propagules is unavoidable, the seeds should only be kept in the shade for one or two days at most.

x. During the initial stages, water should be sprinkled twice (early in the morning and late evening) during the day.

xi. After germination, the polythene bags can be transported to intertidal nursery beds where the seedlings will be watered naturally by tidal flooding.xii. Transplant seedlings about 3-8 months old, 35-50 cm tall with about 4-12 leaves

Figure 10. *Black mangrove with propagules (Photo: Nenibarini Zabbey).*


A


B

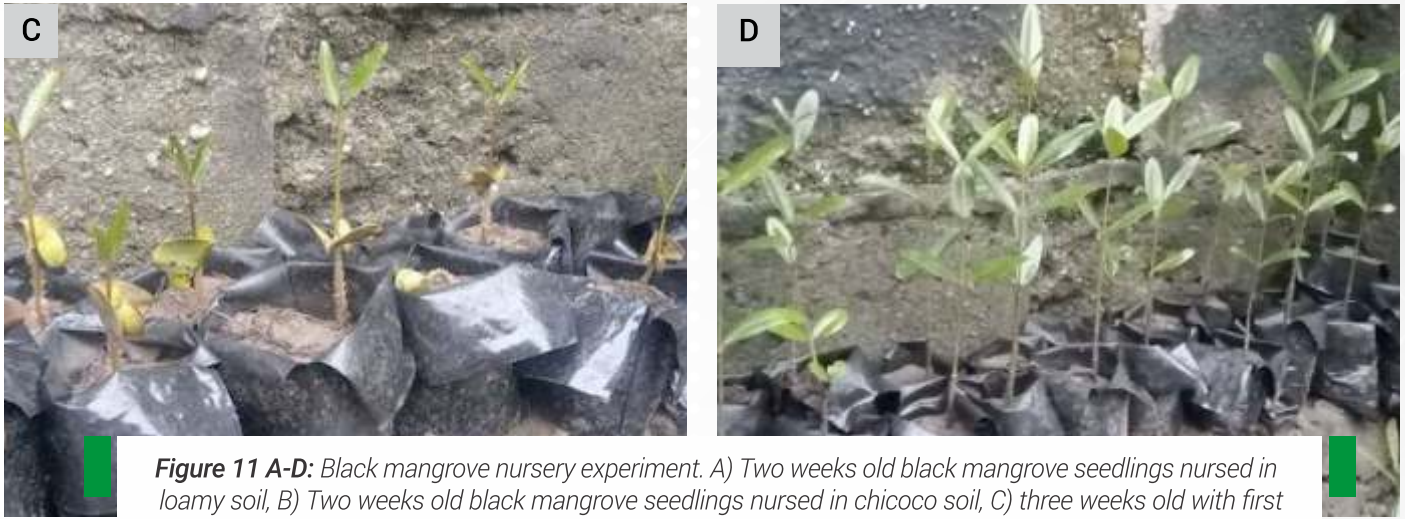

Figure 11 A-D: *Black mangrove nursery experiment. A) Two weeks old black mangrove seedlings nursed in loamy soil, B) Two weeks old black mangrove seedlings nursed in chicoco soil, C) three weeks old with first leaves, and D) two months old seedlings (Photos: Nenibarini Zabbey).*

g. **White mangrove nursery:** The seeds are small almond shaped and change from their original light green to a golden brown or dark brown coloration. The seeds can be collected as discussed for the black mangrove. Similarly, adopt the nursery steps for the black mangrove. However, soaking of the seeds should be done within 3-5 days. The soaking may last 5-10 days until the radicle emerges about 1 cm, and then the seed is carefully sown in the nursery bag by inserting

the radicle into the soil. It is important to renew the soaking water daily

i. Shading at the early stage of upland nursery is important as it serves to protect the propagules and seedlings from direct contact to heavy rains and sunlight. Always use transplant shade such as the roofing with palm fronds. It allows for light penetration and natural watering by rainfall.

ii. After the germination of propagules to become seedlings, the health of seedlings should be monitored 2-3 times weekly including checking for the presence of pests. Watering with brackish water is effective in getting rid of insect larvae that attack the seedlings of mangrove plants such as Avicennia.

iii. Seedlings should be watered with freshwater and brackish water. Brackish water is recommended over seawater as salinity (above 34 ppt.) causes stunting and wilting of the seedlings. Watering should be done twice daily (early morning and late evening). Before watering, always check soil moisture on a daily basis. This is because if the soil is too dry, the roots will die and plants may appear wilted or burnt, whereas too much water can cause poor growth, damping off disease and root rot of seedlings. Watering can be done with a watering-can or perforated jerrycan. Fertilizer should be applied if the soil nutrient is found to be extremely low which is rarely the case. About 3-4 g of NPK (15:15:15) dissolved in 1 litre of water can be used to irrigate seedlings. Coconut coir dust (2:1 soil to coconut coir dust) may be a viable alternative to conventional fertilizer. However, the use of fertilizers and manure is highly discouraged as this does not encourage roots to spread in search of their own nutrients. In- creek nurseries will benefit from nutrients exported from adjacent mangroves

iv. Regular weeding should be done when the need arises.
v. The use of chemical control method should be the last option when other methods (eg, physical removal) have proved abortive.
vi. Diseased plants should be removed and buried.
vii. If seedlings will be grown in the nursery for more than 6 months (to grow up to 1m tall), recycled plastics sheets can be used to line the floor of the nursery to prevent the roots from reaching the ground and becoming damaged during transfer for field planting. Bigger bags should also be used to prevent stunting

Figure 12. *Planted propagules under the palm frond shade of a makeshift nursery (Photo: CEHRD).*

h. **Investment costs:** Investment costs are a critical factor in establishing and managing mangrove nurseries. Transportation and the cost of irrigation could escalate the overall cost if the distance between the nursery site and the water source is great. As a cost compromise, and to enable landless locals in the Delta to have free space to set up nurseries, establishing the nurseries on open landward intertidal shores is recommended. Such nurseries will be inundated twice daily and acclimatized to dynamic conditions of the environment. However, such open- space nurseries are more prone to theft and other physical stressors (e.g., oil re-pollution and plastic smothering).

I. **Sourcing wild established seedlings and saplings:** In some places, a considerable number of seedlings get trapped and grow near the parent plant, which can be transplanted to the restoration site. It is important to collect the wildlings from a nearby forest to maintain the region's genetic stock and reduce the handling duration (transportation stress and cost)The seedlings and saplings (>1m height) carefully dug from the wildling bank need to be carefully transplanted by avoiding as much as possible root damage and retain the ball of soil round the roots.

j. **Planting:** Planting can be by direct planting of mature propagules and seeds by dibbing, by broadcasting the propagules on the water surface to be dispersed naturally by tidal water, by transplanting wildlings, and by out-planting nursery-raised seedlingsHowever, same of the broadcasted propagules will not strand and establish at the restoration site. Planting nursery-raised or wild seedlings having at least 6-12 leaves is preferable, the older the seedling, the better

the growth performance. Seedlings or saplings of red, black and white mangroves can be carefully transplanted from wild or wildling banks near the mother plant.It has been demonstrated that nursery-raised seedlings show 50% greater survival than those planted by direct dibbing. Nursery raised seedlings or saplings have well established root systems. However, the relative survival advantage of nursery seedlings over direct dibbing would depend on the availability and intensity of crab herbivory in the restoration site.

k. Planting guide

I. Make sure the holes you dig are big enough to fit the seedling's roots. The length of the mangrove seedling's roots will determine how deep the hole needs to be dug.
ii. Place the seedling vertically in the hole, being careful to avoid having the roots curl upward. Curled roots may cause the seedlings to grow slowly or even die. Give the roots room to hang out in the hole.
iii. If the seedlings are from nursery bags, carefully rip the bag off and plant the seedling with the soil from the nursery still at the root.
iv. To guarantee adequate aeration, fill the hole with the seedling with loose sediment.
v. Planting spaces need to be spaced between 1.2 and 1.5 meters.
vi. Mangrove ecosystems should be replicated by mimicking the natural distribution pattern. There are no straight lines where mangroves grow. As a result, planting should not be done in a row. Planting should be done in a zigzag pattern.
vii. Planting is only one step the larger picture will include maintaining the hydrologic regime,

preventing new spills (re-oiling), and preventing the cutting of newly planted and immature mangroves.

l. **Spacing:** A planting spacing of 1.2-1.5m is recommended, depending on the proximity of the site to natural mangrove forest, and the potential supply of propagules to minimize the time-lag for natural recruitment of any gaps.

m. **Replanting:** Replanting is required to replace the dead plants. Die-back can occur a few years after planting and should be remedied as part of monitoring.

n. **Planting precautions:** Minimize transplantation stress it is important to reduce out-planting stress to the barest minimum to optimize the survival of planted seedlings.

i. A sure way would be to site the nursery at, or close to, the restoration site.
ii. Avoid root damage by raising seedlings individually in polybags. This will prevent root damage associated with separating seedlings raised together in one bag during transplanting.
iii. In the field, the polybags need only be torn and removed gently to retain the ball of soil/sediment that enclosed the seedling roots.
iv. Disused polybags (nursery bags) should be removed from the restoration site and disposed of following best practice.
v. Planting of non-native species is absolutely discouraged.
vi. Similarly, planting mangroves in naturally unvegetated, low intertidal flats should be avoided.

4. MONITORING REHABILITATION SUCCESS

Overall, it takes an average of 25 years for rehabilitated mangroves to be fully established and to compare in status to a reference natural forest. Based on the duration and the aspect of restoration parameters, monitoring is divided into short, medium and long-term.

a. **Monitoring protocol:** The first 3 years of monitoring would require assessing the plants physically on- site. Following the 3 years, monitoring could be achieved by combining remote sensing with occasional ground-truth visits. Remote sensing datasets, in other words, are only complementary to on-the-ground site performance data. This is due to the fact that, while satellite measurements provide information about mangrove cover, they do not provide minute, useful details like flowering and fruiting.

   A select number of plants (5 plants) in the monitoring plots (5m x 5m) should be tagged. It is critical to use tags with a unique code that will not easily wear and tear, and to leave tag-space that will allow for future growth. Tag the five plants within 5 meters of a central point and photograph them with a GPS camera from a fixed location where future photos will be taken. Also photograph each tagged plant and measure the plant features listed on the monitoring sheet.

b. Monitoring parameters: These depend on the objectives of the restoration project. For the Niger Delta, broadly, mangrove restoration should recover the goods and services that mangroves provide because of the high dependency of the coastal population on the ecosystem for livelihoods. The monitoring parameters for a) the mangrove plants and associated fauna, b) for the ecological parameters, and c) for the socioeconomic performance (aspects) are provided in the table below.

Table 1. Some variables monitored in mangrove rehabilitation sites.

Broad category	Variables monitored	
Plant	Species	Number of voluntary (natural) regeneration (colonization of natural recruits in the case of planted area)
		Number of voluntary new species
		Changes in relative abundance (e.g., dominance)
	Structure and growth	Percentage of survival
		Growth rate (total height to the topmost leaf node, hypocotyl height, girth just above the hypocotyl)
		Branching
		Development of prop roots
		First flowering and fruiting
Fauna	Macrobenthos and shellfishes	Species richness (crabs, periwinkle, dog whelk, etc.) and abundance
	Fin fishes	Species richness and abundance
Environmental	Substrate	Litterfall and litter decomposition, nutrients, soil organic matter, soil particle sizes

	Water quality	Salinity, pH, residence time
	Topography/hydrology	Elevation (accretion), tidal height, current
Impacts	Pests and diseases	Outbreak of pest (e.g., insect larvae, barnacles, algae)
	Land use practices	Wood harvesting

c. **Monitoring phases:** in practice, the project funds, or life cycle, of most mangrove restoration projects do not exceed five years. Post five years, physical assessment of the monitored parameters should be done yearly or once every two years. Remote sensing mapping can generate useful off-site datasets on the vegetative conditions of the restored mangrove. This means remote sensing analysis could inform an unanticipated ground-truth visit to the site when obvious loss is detected. In addition, this monitoring phase include mining data on the economic benefits (ie, the return of ecosystem goods and services) the local communities derive from the restoration project.

d. **How to sustain monitoring of rehabilitated sites in the Niger Delta:** To manage mangrove resources sustainably, a contextual co-management framework involving the state and local government, the communities, environment-focused civil society organizations, and the private sector is necessary. These stakeholders would perform different but mutually inclusive or reinforcing roles. The co-management framework should be worked out by means of participatory consultations. Mangrove research, conservation and restoration should form an integral component of the HYPREP's Centre of Excellence for Environmental Restoration

(CEER) and the region.

Besides monitoring the planted or restored mangrove performance, faculties, students and research fellows of the monitoring department(s) or CEER should undertake state-of-the-art research within and outside the rehabilitation sites to advance knowledge and management of mangroves in the region.

At the community level, formal (schools) and informal (out-of-school) environment club members can be trained to collect the time series monitoring data. This underscores the importance of community inclusion from the planning stage of the restoration effort.

The community science data can then be channeled to a research institution or the CEER for archiving and analysis to inform policy and management decisions. This means networking with agencies and ministries of government that formulate and implement policies relating to mangroves and wetland resources is imminent.

e. **Dissemination of results:** A restoration effort is seriously compromised if it does not contribute to knowledge advancement. Therefore, strategy and methodology of the restoration process and the results thereof (positive or negative) should be adequately documented and made publicly accessibleThe bits and pieces of lessons learned (or data generated) from both failed and successful mangrove rehabilitation projects are important to advance knowledge of the science and practice of wetlands restoration. This underscores the need for effective data gathering and curating throughout the entire restoration process.

A

Figure 13. *Monitoring red mangroves planted six months ago (A), and three years ago (B) at BMI pilot site (Photos: Olof Linden and Erich Gundlach).*

5. SUMMARY AND RECOMMENDATIONS

a. The local communities constitute both critical drivers of a successful mangrove restoration project and the direct beneficiaries. It is important to include the local communities in the entire restoration process-from the planning including defining the project objectives to on-the-ground restoration operations, monitoring, and evaluation. Expectations (eg. livelihoods and land-use) of the communities should be integrated into the project design to promote local support and ownership for their optimal benefit

b. The restoration project should create direct jobs for local residents. They can be in the forefront of the supply of propagules, wildlings and nursery-bome seedlings (ie, mangrove seed-prenuers). The trained locals will establish small or medium-sized nurseries in their backyards or along creek banks. Selling the nursery seedlings/saplings creates alternative livelihoods or incentivizes local communities to participate in and own the restoration projects. This could be leveraged as an alternative livelihood option to dissuade youths who are or may want to get involved in artisanal oil refining HYPREP and other restoration investors (eg, oil companies) cari embed in contractual agreements that mangrove restoration contractors buy seedlings from the locals, not create their own nurseries:

c. When planning the cleanup and performing the planting of mangrove seedlings, it is important to consider the shifting water levels due to tides. In most areas there is only a short window of time (a few hours) when it is possible to reach the sites to be cleaned and planted. Forward planning bearing in mind the shifting tides is therefore a critical element in order to be able to accomplish the work successfully

d. Renoval of oil, nipa palm, heavily oiled tree stumps, etc. from sites intended for mangrove restoration is an initial step and should be well planned as part of the overall initiative

e. Presence of mangrove volunteers (natural recruits) indicates the readiness of the designated site for planting. Oil degraded swamps with no significant re-oil can have reduced oil concentration due to natural attenuation processes (microbial degradation and tidal flushing). The ultimate goal of a restoration initiative is to achieve net environmental benefit. Therefore, planting of mangrove seedlings and saplings can start at sites having natural recruits and SCAT-confirmed low levels of oil Flushing may not be necessary

f. Clear cutting of dead mangrove stumps should be avoided as much as possible. They help to strand floating propagules for natural recruitment and also serve as habitat of certain fauna

g. Avoid mono-specific plantations, planting in rows and in the low, naturally unvegetated mudflats, it convenient to plant only the red mangroves but planting multi-species (black and white mangroves alongside the red mangroves) is needed to preserve the biological diversity and the spectrum of mangrove ecosystermi's goods and services. The planting should also mimic the natural mangrove zonation pattem, which is determined by elevation, flooding, salinity and sediment preferences. However, it must be stressed that the re-establishment of mangrove areas is highly desirable, even if only with one species. Thereafter, supplemental planting of other species can be done if natural re-establishment of those species at the restoration site is poor or unrecorded

h. Because of the many years it takes mangrove to re-establish naturally and the likelihood of various degrees of die back, monitoring is required beyond three to five years that most restoration projects last Replacement planting (re-planting) of the dead ones is necessary. The anticipated HYPREP CEER or a Chair for Wetland Research set up in any of the local universities should coordinate long-term monitoring of restored mangroves

I. To the extent possible, take steps to prevent re-pollution as mangrove seedlings are highly vulnerable to fresh oil and are killed by new oil spills.

j. Develop a robust Conservation Plan that will complement restoration efforts to recover lost mangrove areas in the Delta. The Conservation Plan should have co-management principles and practices in order to be sustainable. This implies that the local people will not only participate in the design of the Conservation Plan but will also own and lead its implementation on-the-ground under the coordination of the State Ministry of Environment.

k. Educating local communities on how to harvest mangrove wood sustainably without causing permanent damage to the individual mangrove trees is essential

Annex 1 - identification Guide for the Mangrove Species in the Niger Delta

A Field Guide for Identifying Mangroves in Nigeria — Jackson & Lewis, 2000					
	Rhizophora			*Avicennia*	*Laguncularia*
Leaves	Dark green in clusters			Pointed tips	Rounded tips pair of glands at leaf base
Roots	prop roots drop roots 			pneumatophores 	no prop roots no pneumatophores occasional pneumathodes
Fruit	elongated propagules 			lima-bean shaped fruits 	small almond shaped 
Flowers	small, white			small, white	small, white
Location	fringe waterfront			landward from *Rhizophora*	landward from *Rhizophora*
Species	*R. racemosa*	*R. harrisonii*	*R. mangle*	*A. germinans*	*L. racemosa*
leaves	elongate	broader	broader		
flower buds per stem	multiple with blunt tips 	multiple with pointed tips 	two to four 		

NOTE:

NOTE:

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