Mangrove Restoration: It's More Than Just Planting

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Introduction – The Importance of Conservation Before Restoration

This article is a practical summary of Mangrove Action Project's (MAP) 'Community-Based Ecological Mangrove Restoration' (CBEMR) technique for restoring mangroves, which focuses on facilitating natural regeneration of the trees and plants. This summary has been developed for groups who wish to understand the CBEMR process or take on their own restoration project. However, MAP encourages the **conservation of existing mangroves before the restoration** of degraded forests. The full complement of ecosystem goods and services only come from mature mangroves. Well established stands of mangrove are likely to be much more biodiverse than restoration efforts and can act as a seed and propagule source for many species. Restoration is a risk and many projects have failed in the past. Disturbing the soils of mature forests, particularly for aquaculture, risks rapidly losing huge amounts of carbon stored in the soil, as the organic material comes in contact with air and decomposes. Live mangrove roots enhance the quality of the soil around their fine root hairs by leaking oxygen and carbohydrate into the soil nearby. Losing live roots is likely to lead to poorer quality soils that might be much more difficult to restore. For all these reasons, when considering budgets, effort and time we encourage groups to conserve existing mangroves and ensure their health with good hydrology and limited use, before restoration.

Every site is different and there is no one-size-fits-all solution to restoration. However, there are some general scientific principles which all mangroves around the world adhere to. Mangrove restoration is NOT like dry-land forestry planting as mangroves have to contend with salt and flooded, low-oxygen soils and the objectives are likely to be different. Elevation relative to sea level is extremely important and normally the key factor controlling species distribution. Fortunately, there is a significant amount of published research as well as MAP's practical experience to draw on, to avoid the mistakes that have compromised previous projects.

Figure 1: Where mangrove forests meet mudflats. No mangroves should be planted in the mudflat zone (left side of this photo), lower than this mangrove fringe. This fringe will be located at approximately at mean sea level. Careful observation of nature reveals where mangroves can and cannot live, confirmed by a lack of natural regeneration on the mudflats (left).

Getting Started - Community Collaboration & Background Research

1. First, we recommend that you get to know the site and its context in great detail. This is much more than a morning's visit with a GPS and camera. From a **socio-economic** point of view, discuss with local people **who owns the site** and what's going to happen to it in the future. There needs to be absolute clarity about who owns and controls the site as there is no point working on a site, only to see it built on or turned into an aquaculture pond a few years later. Further, what do the local people want from their mangroves? Men and women may use different resources and have different views of the root problems. The same goes for fishers, farmers and business people. Additionally, what local knowledge do they have and what is their advice? How do they use the restoration site (as it could be where they moor their boats, or where their animals graze, etc.)? Have the local people been over-harvesting mangrove wood? What materials do they build with and how do they earn a living? What fuel do they cook with? Is there a need to introduce 'Improved Cooked Stoves' (ICS) which reduces fuel consumption by about 30%, or to introduce alternative cooking fuels or building materials as part of the project?

Figure 2: Collaboration with the local community is key to getting to know the site's social, historical, geographical, economic details and project success in general. Start working with and training the local conservation group right from the first visit. Time spent conducting informal 'scoping' interviews around the community is time well spent. This will help to dissipate misunderstandings held by villagers. Informal discussions will also reveal mangrove stressors, village needs, provide understanding about village politics and help identify a local mangrove expert.

Do not assume that the community does not understand the mangrove forests around them, as they have lived their entire lives near them and will have seen many changes including seasonal changes which may not be evident to outsiders on brief visits. Their local knowledge of the site, its history and how it's utilized are immensely important. Conversely, don't assume that all villagers are aware of all the mangrove benefits, know how to restore them or are able / willing to manage them sustainably. Talk to as many members of the community as possible, both male and female, especially the fishers whose livelihoods depend on the mangroves. Conducting a number of community consultation meetings is essential (Fig. 2) and take great care to set appropriate expectations. Reaching a consensus is often difficult or may not even be possible. More broadly, conduct a stakeholder analysis or your site to establish which groups are interested in the restoration site and how much influence they have. This might include local government units; NGOs; national government (policy); ministries of Fisheries, Land Development, Agriculture, Aquaculture, Forestry, Environment; the military & coast guard; local businesses, etc.

From a **technical / biophysical** point of view, explore with local people why are there no mangroves or degraded mangroves on the site now? This might need some careful and honest reviewing. Are there stressors (problems) which have degraded or killed the mangroves, and will you be able to remove or reduce these stressors (e.g. fresh water being diverted away from the mangrove system; road building cutting off hydrological tidal connection or aquaculture pond walls isolating areas). Sometimes mangroves can be restored by reconnecting and improving the **hydrology** and topography to improve tidal flushing,

Figure 3: Researchers assessing the high and low tide points at a restoration site. It is important to understand the elevation of a restoration site relative to sea level as mangroves grown in the top half or top third of the intertidal zone only. Working too low down within the intertidal zone (below mean sea level) will result in poor results or project failure.

drainage and letting natural regeneration do the rest. Therefore, it is important to walk the site and the water channels to observe how well water flows in and drains out, fresh water input, tidal range and context of the site. Make sure you understand how often your site is inundated and for how long. This is because the soil around mangrove roots should be drained and therefore oxygenated >50% of the time. If it's a former aquaculture pond, there might be no or insufficient flushing at this stage or waterlogged soils caused by poor drainage of the flat bottom of the pond. You should observe the site at various times of the tidal cycle and at different times of the lunar cycle - Spring tide (full moon), and Neap tide (just after the first or third quarters of the moon) when there is least difference between high and low water. Different seasons will also affect freshwater input, wave energy and av. temperature.

Figure 4: Mangrove area suffering from soil erosion with roots exposed

Next, is there **natural regeneration** on the site? If so, which species? If not, why not? This is a crucial indicator suggesting whether the site is appropriate for restoration or not. For example, much planting of mangroves is attempted on mudflats. Mudflats are unsuitable for mangroves for many reasons and natural regeneration is very unlikely to be present, as shown on the left side of Fig. 1. We strongly advise you not to utilize these areas (or coral flats, seagrass beds or salt pans). MAP staff have personally witnessed many planting attempts on mudflats and unless the area is accreting soil rapidly, and this soil is becoming firm enough to support mangroves, these projects have failed. Also check soil pH, soil type (sand / silt / clay), soil pore water salinity (because this is the water the roots are in contact with), erosive forces (see Fig. 4), levels of wave / wind energy the site will be exposed to (particularly in the monsoon season) and what species are expected to thrive on the site. Conduct all this research with local people to encourage their involvement and build their capacity.

If you are trying to produce **new mangrove** where mangroves did not grow previously (afforestation), you need to answer the question, *why is nature not colonizing this area naturally?* If a site is not being colonized by pioneer species such as *Sonneratia alba, S. apetala, Avicennia marina, A. alba* your planting effort is unlikely to succeed.

2. Many Answers are at a Reference Mangrove Site

Second, again with local people, visit a reference mangrove site nearby. By this we mean find a local mangrove, natural (not planted[1]), or at least one that is healthy, and study it carefully. Try to ensure that it is subject to the same inundation regime and conditions as the restoration site. A 'healthy' mangrove will have a canopy that has closed over your head, the tops of the trees have a full complement of leaves and the water flows through this area and drains unimpeded. Get to know the tides. See what species are thriving, where plants are growing relative to mean sea level ('species zoning'), which seeds and propagules are floating about (in the seeding season), the salinity of the water and soil pore water, soil conditions, and record how long the mangrove soil is drained of water before an incoming tide covers the site again. Mangroves live naturally within the upper half to the top third of the intertidal range. Again, if the restoration site you are interested in has constantly saturated soil or standing water at low tide, these areas will not work, as mangrove roots need to breath.

[1] Note that in many countries, much of the nation's mangrove has been previous cut for charcoal and replanted. There might be very little original, old-growth forest left. Replanted mangrove tends to feature very few species and planted in rows like terrestrial plantation forestry. Low zone and back mangrove species are either marginal or absent altogether and the mangrove trees all of the same age. There will be very limited species zonation evident and little variation within stands. Use these sorts of reference sites with care.

3. Detailed Knowledge of the Expected Species

Third, work out which species are expected to grow on the restoration site, and their preferences including zoning. This might not be what local people want. There are some species that will grow only in the upper zone of the tidal range, tolerating being inundated only once or twice a month maximum and like free-draining sandy soils. Other species are happy to be flooded every day, with their roots in clay. Pioneer species will often be first to appear on a new site as they are best adapted to colonize new, wet sites in the lower mangrove zone. At higher elevations, plants such as *Acrostichum* sp. fern or *Acanthus* sp. might arrive first on site. Other species will survive somewhere in the middle of the mangrove range such as *Rhizophora* sp. Additionally, there are plenty of species which cannot tolerate full sea water but need mixed, brackish water or indeed almost fresh water. For information on species preferences try local mangrove guidebooks or the internet. E.g. http://www.fao.org/3/ai387e/ai387e06.htm

The good news is that if your activity (see step #5) facilitates natural regeneration which we strongly recommend, rather than planting, nature will automatically put each species where they should grow, rather than you having to work out where to plant each species. Unfortunately, what many mangrove restoration projects do is jump straight into planting *Rhizophora* sp. (a mid and low-mid mangrove species) too low down, in saturated, soft mudflat or indeed anywhere. This usually fails or at best produces stunted mangroves due to stress from difficult soil conditions and a lack of oxygen. Sometimes the planted species is whatever is available in the nursery at the time or ones that are easily grown from seed. Government mangrove agencies are as guilty of putting the wrong species on the wrong site as any other group. Do not assume they know what they are doing, either.

4. Sharing your Research, Discuss and Agree Objectives, Plan Activities

Fourth, now that the complexity of mangroves and the surrounding social situation is understood, we suggest you **discuss and plan** activities with local villagers and other key stakeholders. Take great care to discuss and **agree** on **project objectives**, now it is clear what is possible on the restoration site. Keep in mind that different stakeholders might have different objectives, and these might change over time. Objectives will affect implementation activity and monitoring emphasis, therefore take the time to debate and agree objectives. Also agree before any work starts, who can receive benefits from the restored mangrove, whether wise use is permitted or if the mangroves will be left to grow up untouched.

Draw a map of the site or have some way that allows all local stakeholders and villagers to see what's going to happen. This is particularly useful and inclusive if literacy is an issue, and / or a lack of internet, electricity or mobile phone signal. Community map drawing, pictures from Google Earth (GE, see Fig. 5) which can have boundaries drawn on them before printing, drone imagery and maps from the local authority can all help.

Figure 5: A Google Earth 'screen grab', saved as a high-resolution jpeg, printed on vinyl, makes it easier for villagers to understand and discuss the next steps of restoration and conservation efforts. These maps cost only a few dollars to produce and villagers find them very useful.

Ensure the project has the co-operation, support and assistance of local people. Better, if they are willing and interested, encourage the local people to take on and lead this mangrove project - outside groups acting only as (technical and facilitation) support. It is likely that the village team will need training to raise their capacity and understanding, as well as other nearby stakeholders, such as local government units, local government mangrove agency field office staff, local businesses, local fishers, forestry department officials and so on. Therefore, make sure that in the plan, there is time and budget

for this training (which MAP will be able to help with) in advance of any implementation. Mangrove restoration should not be just a short-term photo opportunity for websites and corporate brochures, but should improve ecosystems, build capacities and empower local stakeholders.

5. Implementation

Fifth, keep a holistic view of the village and its needs. Solutions and work needed might be predominantly social, rather than biophysical. For example, the reason why a restoration site is degraded or the mangroves are missing might be the lack of income generating opportunities. Please note that **conservation of existing mangroves should always be the priority** over restoration activity. The full set of ecosystem goods and services only come from mature mangroves that are well connected to daily tidal inundation.

From the plan, and depending on the project objectives, your activity list might include the below:

- Build awareness about the benefits of mangroves (local people are generally only aware of what they can see), mangrove ecology & biology, what climate change adaptation means, restoration work, and the importance of hydrology, topography, and biodiversity. Arranging for older members of the community to share mangrove knowledge with students at the local school is an effective way to pass-on traditional knowledge. Environmental education for the community's students, a mangrove study visit, small-scale test planting or field maintenance work by youth on the restoration site will all help ensure long-term community support for the project. Explain what will happen if they lose their mangroves. This is a good way to reduce or tame over-harvesting of mangroves.
- Co-operation from the local people might include finding a way to exclude grazing livestock from the site to allow natural regeneration to establish and thrive. We have seen a government project in Myanmar where planting was conducted on areas where local people landed their boats. After a short period, only the project sign remained, with zero survival of planted mangrove seedlings.
- Initiate wider community meetings to explain the project and why it is NOT just building a nursery and planting in straight rows. Explain what is feasible on the given restoration site. (Note that from your research you might have concluded that the choice of site was inappropriate, for social or technical reasons.)
- If the research has shown that the **hydrological connectivity** was insufficient or the drainage was poor, make the necessary adjustments to the topography (see Fig. 6) and hydrology, which might well be followed by a long period to observe whether the work the community has done is sufficient, and whether natural mangrove regeneration occurs on its own. A project in El Salvador had to dig out and improve almost 10km of channels to bring their mangrove back to life. No planting was needed. If restoring a former aquaculture pond, this has more technical challenges and we suggest you get in contact with MAP for specific help.
- Clear all **debris** which is likely to float over the site and damage young plants. Make sure young plants are not broken by entanglement with seaweed or smothered by mangrove vines and creepers like *Finlaysonia* sp. or *Derris* sp. **Weeding** of natural regeneration might be all that is needed.
- If the community members are expecting to show people around the site, you might want to **'interpret' the site**, by installing signs, producing leaflets, roping off test monitoring plots, training village guides and so on, so visitors will be able to understand what has been done.

Figure 6: Villagers regrading shrimp pond embankment to increase the area where mangroves will grow. Before this work, the pond had steep walls and a flat, poorly drained bottom. This work produced more area at an elevation suitable for mangrove growth and improved the pond drainage.

- Other possible activities might include: establishing a community forest management group to monitor and control wise use; removing mangroves growing in channels; providing alternative livelihoods; encouraging the change of species if the salinity is high; providing more fuel efficient 'improved cook stoves'; establishing terrestrial woodlots to take the pressure of mangroves; providing alternative fuels for cooking; cutting back *Acrostichum* sp. (a fern) until mangroves can grow over it and shade it out; talking with neighbouring village leaders to stop timber poaching by outsiders; asking the government to ban sales of mangrove wood in local markets; and broadcasting additional seeds and propagules onto an incoming tide if there is insufficient natural regeneration on site. This is not an exhaustive list.
- We would encourage you to grow as many different species which would naturally occur as possible, without importing species from far away or another country. **Biodiversity** helps ensure that as conditions change due to sea level rise and climate change, at least some of the species will be able to survive, adding to mangrove resilience.

6. Monitoring

- Six, make sure you collect sufficient **baseline data** before any work starts.
- The project **objectives** will suggest what should be monitored beyond making sure that the initial mangrove stressors have been mitigated. Continue to **monitor**, patrol and protect the site for at least 3-5 years. The only way to make sure this happens over the long-term is to ensure that local people are trained how to monitor and provided with appropriate support.
- Key elements to monitor are: whether the hydrology is still working well or whether the water channels need constant re-digging; if the soil is well drained at low tide; if natural regeneration is coming back on its own; and whether other issues have been resolved such as salinity levels and social agreements. Some governments use a 'fishbone'-shape hydrological solution in all situations, even though research has shown that it needs continuous maintenance after it is excavated due to its inappropriate shape. MAP does not recommend its use: restoration requires flexible, adaptive solutions.
- If natural regeneration proves to be insufficient, understand why. Are there no sources of seeds locally? (This should have been discovered in your initial research.) Is something blocking their arrival? Are crabs / goats / water buffaloes / pigs / feral camels eating the seeds or natural regeneration? If this is the case you can supplement the natural regeneration by collecting seeds and propagules from nearby areas and 'broadcasting' (throwing) them on an incoming neap tide. Maybe there is something wrong with the soils, such as high acidity, pollution (e.g. an oil spill) or high salt levels. Are inappropriate species such as *Acrostichum* sp. arriving and adversely affecting your site conditions?

7. Planting only if Long-Term Monitoring Shows it is Necessary

Seven, if natural regeneration is still insufficient, but the hydrology is working well, **consider planting**. Please note that in general, planting is only considered at this stage, after having completed the other stages, described above. If you decide that planting is necessary, it is advised that **test planting** is conducted first, to see if the conditions and species choices are suitable, before planting on a larger scale. Planting (the correct species in the right zone) is no substitute for well-functioning hydrology and good drainage.

There are several different methods of planting, and much advice on the internet. Most importantly, be aware of what mangrove zone the planting will take place in, and for how long that area is inundated. *Rhizophora* sp. is NOT the one-size-fits-all planting solution for every zone. Planting methods include direct 'dibbling' or insertion of seeds/propagules into the soil, growing material in plastic 'polybags' and planting out after a few months, transferring young 'wildlings' which have been uprooted or dug up from one area to another, amongst other methods. Each method has pros and cons. If you are transferring propagules, and wildlings in particular, make sure they are planted as soon as possible after collection. Wildling roots, exposed to the air and hot sun will die off in minutes. Propagules will quickly lose water and viability if not stored well, or be attacked by wasps and insects. Proper storage is vital if they're not planted right away. Ensure that propagules are firm and ripe. They should be picked up from the ground or if collected from a tree, come away easily from the tree with only a gentle pull. Discard propagules with small holes in them as an insect has already laid an egg inside and it will break later. If the propagules are

dry, bendy or rubbery-feeling they will not be worth planting. If you're not sure ask an experienced community member about seed collection. We would also recommend that you test your direct planting before doing anything on a large scale. Plant as many species as possible over your site with zonation in mind. Do not rely on just one or two species. **Test** any planting first, before planting on a large scale. Plant near existing mangroves, noting which species they are, but do NOT plant in channels.

A planting example. A community near Sittwe and NGO 'Mangrove Service Network' in Myanmar wanted to establish a greenbelt to slow coastal erosion. MSN took the village conservation group through MAP's CBEMR process, above. The site was just above mean sea level, i.e. low mangrove zone, suitable for pioneer mangrove species. (There is plenty of advice on the internet about where to site a nursery and how to do this.) Note that low mangrove zone pioneer species listed earlier need to be grown up in polybags until their stems turn woody (probably beyond six months) to avoid crab damage, and planted out as seedlings. Being a slightly energetic site, with wet clay that was inundated every day, MSN grew the seedlings for a year before the community planted them out. They used several pioneer species. They also fenced the planting to exclude grazing animals and the community monitored and maintained the mangroves in the early stages. They now have a healthy greenbelt and the erosion has slowed considerably.

*Figure 7: An example of what **not** to do: planting in straight lines and in the water channel contradicts nature's processes, and will block tidal inundation, if they survive at all.*

DO NOT PLANT IN STRAIGHT LINES. **DO NOT PLANT IN CHANNELS.** Fig. 7 is a good example of what NOT to do. Just because the government plants in rows, and plantations are in straight lines, this is no reason for your planting to be conducted in rows, unless your objective is production forestry. Planting in lines often results in changes in micro-topography being ignored and channels filled with mangroves. You might find that the activity needed on the site is to REMOVE mangroves which are growing in water channels. If they have naturally developed in a channel, this is a good indicator that the hydrology needs assistance.

Mangroves are quite different to dryland forests and forestry. Rarely are sites flat. We recommend that you plant in clumps or clusters, by which we mean groups of propagules perhaps 5-10cm apart, on the more elevated parts of your site. Nature will self-thin, as it has been doing for millions of years. Groups of seeds planted close together enjoy advantages which will help establishment. Physically, they protect each other from impact damage, share soil they have improved as the roots leak oxygen and carbohydrate, thereby reducing acidity and promoting beneficial bacteria, and seed clusters are more likely to encourage appropriate hydrology by allowing water to flow around the developing clumps. Nature itself does this, as you will observe, as the majority of seeds and propagules stay close together under the canopy of the mother tree.

More on hydrology. Whether using natural regeneration or planting, aquaculture pond (Fig. 8) or open site, the hydrology and drainage of a site HAS to work. Natural river-delta mangroves have big, wide, snaking channels, which are narrower upstream, and wider at the river mouth where they meet the sea, allowing the free flow of water. If you are having to excavate new channels, they should mimic these natural dimensions. Soil that is regularly well drained is much 'healthier' than soil that is constantly saturated. Good hydrology brings in seeds and propagules for natural regeneration; brings in bacteria which the soil needs; keeps the soil salinity level low; washes away toxic substances and acid build-up in the soil; and exports leaf and plant litter which form the basis of the local in-shore food web. Algae, fungi and bacteria grow on this litter, and this combined organic matter provides food for fish, crabs and shrimp and other animals. These in turn provide food and livelihoods for local people.

Figure 8: Hydrology is essential to success in restoration. The drainage rate needs to be the same at the restoration site as in the natural mangrove outside the pond. If the channel has a bottleneck at some point (here, the entrance to a former shrimp pond) widen by digging (as done here to the side of the former sluice gate) until drain rates equalize.

What should a Natural Mangrove look like?

Figure 9. View of a section of back mangrove, Pangani, Tanzania. Note the undulation of the mangrove floor, with a well-formed clear channel for the water to flow in and out unimpeded. There is no standing water on the higher ground. The channel is not straight, but bends and curves. Nothing is growing in the channel. Various trees are growing on the higher elevations, in a mix of heights, densities, species and forming a variety of light intensities on the mangrove floor. (There is limited natural regeneration evident here as mangroves are generally shade intolerant with little understory when the canopy has closed.)

Next Steps- Resources and Readings

Thank you again for your interest in mangrove forests. We hope that you found this information sheet helpful and informative. Please remember that this is an introduction into the complexities of mangrove restoration, and not an exhaustive guide. From this point on we suggest that you get very familiar with the CBEMR methodology before you do anything else. There are many other resources to download on MAP's site:

https://mangroveactionproject.org/mangrove-restoration/

Please join MAP's Groups.IO e-group of 400 mangrove practitioners at

https://groups.io/g/MAP-CBEMR

CBEMR Blogs: http://www.mangroveactionproject.org/cbemr/blog/
https://mangroveactionproject.org/blog-full-width-masonry/

CBEMR on MAP's YouTube: https://www.youtube.com/user/MAPmangrover

If you still have specific questions about a particular site, we encourage you to reach out to MAP, as we would love to try and help! See below for further readings and resource recommendations.

https://mangroveactionproject.org/resources/

Also, please consider inviting MAP to run a training course on CBEMR.
Contact: dominic@mangroveactionproject.org for more information.

Good Luck!

Further Readings:

Mangrove Restoration: To plant or not to plant (available in 9 languages)
https://www.wetlands.org/publications/mangrove-restoration-to-plant-or-not-to-plant/

Mass mangrove restoration: Driven by good intentions but offering limited results
https://www.iucn.org/news/forests/201702/mass-mangrove-restoration-driven-good-intentions-offering-limited-results

Global Nature Fund. 2015. Mangrove restoration guide: Best Practices and lessons learned. GNF. Germany
https://www.globalnature.org/en/themes---projects/sustainable-development---development-cooperation/mangroves-i

Lewis & Brown. 2014. Ecological mangrove restoration- a field manual for practitioners. Version 3. 275 p.
https://blue-forests.org/wp-content/uploads/2020/04/Whole-EMR-Manual-English.pdf

Lewis. 2005. Ecological engineering for successful management and restoration of mangrove forests. Ecol. Eng. 24: 403-418.
https://www.researchgate.net/publication/222821996_Ecological_engineering_for_successful_management_and_restoration_of_mangrove_forests

The Global Mangrove Alliance has posted many resources on their site.
http://www.mangrovealliance.org/resources/

There are also mangrove papers available for download free: (Please see bottom of the page)
http://www.mangroverestoration.com/

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