Mangrove Rehabilitation Guidebook

Published in the framework of the EU-ASIA PRO ECO II B Post Tsunami Project in Sri Lanka

Imprint

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Pref

Preface

Water is the essence of life - people need wetlands, lakes and rivers, for many reasons. These diverse ecosystems provide fish and reeds, help prevent floods and reduce levels of pollutants. But they are also sensitive and vulnerable habitats. The dramatic Tsunami flood disaster in Asia on 26 December 2004 will never be forgotten. However, if possible we must learn from the calamity in order to prevent future destruction. In the spring of 2005, the Global Nature Fund (GNF), in close collaboration with its Living Lakes partner organisations in Sri Lanka, started a project with the aim of offering new life perspectives to the affected people in the South-Western Sri Lanka. With the help of donors from Germany and a grant from the Swiss company „Sika“, the first small restoration activities were started. In December 2005, GNF and its partners won a grant from the European Commission in order to implement a prestigious project in Sri Lanka. A central activity of the three-year project is the protection and rehabilitation of threatened mangrove forests in the Bolgoda, Maduganga and Madampeganga wetland regions.

Mangrove forests are universally unique habitats. They are perfectly adapted to the brackish living conditions in marine river estuaries. Nowhere else do so many fresh and saltwater species, sea and land organisms share the same living space. In Sri Lanka alone over 25 different mangrove species are found. Their vast and dense root systems slow down tidal waves and protect shorelines from erosion. But mangroves - like coral reefs - are among the most threatened ecosystems in the world and also the most diverse. Approximately 50 percent of all mangrove forests have already been destroyed, drained, converted to rice paddies or prawn farms. The Tsunami has demonstrated that intact mangrove belts can save lives.

The project in Sri Lanka shows many tangible results. In Pathamulla, at Maduganga, new nurseries were established. Many families are involved in the project, and to date over 60,000 mangrove plants have been grown. The trees are replanted in areas where intact mangrove forests have been destroyed in the past. This measure offers new protection belts for the people living in the coastal zones as well as new habitat for endangered species. The project, however, is more than simply mangrove rehabilitation. The re-establishment of livelihoods is also a crucial element of ongoing restoration work. In this respect a close collaboration with inland fishermen and village fishing societies as well as women's associations have been established in order to foster traditional fishing and handicraft skills and generate income in the rural areas.

Global Nature Fund is a non-profit NGO that launched the Living Lakes partnership in 1998. The aim of the Living Lakes network is to promote sustainable development objectives for the world's lakes at international level. The underlying idea of the international lake network is to safeguard the world's freshwater reserves that are so vitally important. Currently there are 45 member lakes and wetlands spread across all continents. More than 55 partner organisations - NGOs and public institutions - provide a fantastic wealth of experience and expertise and maintain a lively dialogue between stakeholders involved in water issues.

Introduction

Sri Lanka lies in the south-eastern part of the Indian subcontinent in the Indian Ocean between 6° and 10° northern latitude and 79° and 82° eastern longitude. The highest elevation in the central mountain area is the Pidurutalagala (2,524 metres above sea level). The island is characterised by a tropical climate and affected by the monsoon. The mean annual temperature is about 22°C in higher areas, rising to 33°C in the coastal regions. From about 1.900 metres above sea level temperatures can drop below freezing point. Sri Lanka has a history of multiple challenges. In 1972 Ceylon, as it was called in former times, became a republic and was given the name Sri Lanka. A problem for today's Sri Lanka lies in the still unresolved conflict between the Tamil and Singhalese population.

Post Tsunami Restoration of Mangroves, Education and Re-establishment of Livelihoods – Project in Sri Lanka

In response to the urgent need to rehabilitate areas affected by the Indian Ocean Tsunami of 26 December 2004, EuropeAid prepared a specific Asia Pro Eco II Post Tsunami Programme. The Programme provides funds for partnerships and capacity building project proposals, which respond to the urgent need for reconstruction and rehabilitation efforts in the areas of the Asian countries which have been affected by the catastrophe (Maldives, Indonesia, Sri Lanka, Thailand and India). In December 2005, Global Nature Fund started its three-year project „Post Tsunami Restoration of Mangroves, Education and Re-establishment of Livelihoods", which aims at the re-establishment of livelihoods in affected communities, restoration of Tsunami affected areas and long-term environmental education.

Objectives

In former times the mangroves provided a safe protection against tempestuous storm winds, tsunamis, or tidal waves, because healthy natural buffers like mangroves mitigated their force. This is a fact that indigenous people have known for centuries. The need to integrate the traditional wisdom of coastal dwellers into the so-called modern approaches to protect coastal strips and their dwellers, is obvious. The damage and loss of life from the tsunamis in December

In December 2005 Global Nature Fund started its three-year project "Post Tsunami Restoration of Mangroves, Education and Reestablishment of Livelihoods"

The overall objectives can be divided into the following sub-goals

- Mangrove restoration and protection of biodiversity
- Capacity building and knowledge transfer
- Promotion of environmentally friendly alternative technologies
- Sensitisation of the population and awareness raising
- Wide dissemination of the results

2004 could have been reduced, had those zones with healthy coastal buffers not been destroyed in previous years. In those places where the natural protection was still intact, the destructive impact of the wave was noticeably less.

It is imperative to gain a holistic view of the link between disaster precaution and the improvement and rehabilitation of mangrove forests. Sustaining and recreating the biodiversity is the only way to secure the protection of life in future decades.

One of the central goals is to improve peoples' self-reliance, mitigate poverty effects, increase inhabitants' long-term access to sustainable use of natural resources, and to protect the local communities against potential disasters by the implementation of precautionary measures. Among the main activities are the installation of mangrove nurseries, the re-plantating of damaged mangrove forests and the establishment and operation of regional education centres.


Mangrove Nursery


Juvenile mangrove plant

The latter serves to educate and inform the local people of negative impacts from logging in forested areas and coral reef harvesting in order to reduce or avoid these impacts as much as possible. The project results will be transferred to Tsunami-affected regions in India and other Asian countries.

Target Groups

The project addresses Tsunami affected families and aims to create new livelihoods and restore land and water resources. The main target groups are about 1,000 families from poor communities in the lake areas of Bolgoda, Maduganga and Madampe in Sri Lanka.

Project C

Project Coordination and Partners

The project is coordinated by the Global Nature Fund as the main facilitator. The project implementation is realised by the two Sri Lankan Living Lakes Partner Organisations EMACE and Nagenahiru Foundation. They are also responsible for the coordination of all measures at regional level and the contacts to important third parties such as the Ministry of Environment, Ministry of Tourism, Department of Coast Conservation, Department of Fisheries, RADA, SLIDA, and others. Additional project partners involved are the Fundación Global Nature from Spain to give technical input and CReNIEO from India.

Global Nature Fund

Global Nature Fund is a non-profit, private, independent foundation for the protection of environment and nature. The headquarters is located at Lake Constance in Radolfzell, Germany. Global Nature Fund was founded in 1998. GNF's work focuses on the protection of nature and the environment with particular emphasis on lake ecosystems.

EMACE Foundation

EMACE is an acronym for Environment and Science, Manpower and Skills, Adult and Parenthood Development Assistance, Childcare and Women's Rights, Education and Culture. The EMACE Foundation has been active since 1970. It is a non-profit NGO, approved in 1994. Since 2004, it has been a partner organisation of the Living Lakes Network. The organisation is in constant interaction with other NGOs and community-based organisations, the government and the private sector. EMACE has built strong local networks as well as international contacts. Main activities of EMACE are environmental conservation, empowerment, gender equity, legal rights and skills training for employment, human rights and education. Furthermore EMACE has experience in renewable energy, composting, recycling, conservation projects and forestry.

Members of the EMACE Team

Nagenahiru Foundation

Members of the Nagenahiru Foundation Team with villagers

The Nagenahiru Foundation is a non-commercial and non-profit NGO, registered in 1991 and based in Ambalangoda. It has been engaged in environmental conservation since 1996 and is a partner organisation of the Living Lakes Network since 2004. Nagenahiru Foundation is experienced in education, managing mangrove nurseries and promoting sustainable livelihoods among disadvantaged sectors of the society. Presently Nagenahiru Foundation plans the development of a „Wetland Education Centre“ to create awareness and provide information for local stakeholders about the sustainable utilisation of natural resources as well as the conservation and restoration of the wetland system and its resources.

Fundación Global Nature

The Fundación Global Nature, registered in 1993 and based in Spain, is a non-profit private foundation for the restoration and protection of nature and environment in Spain and in Iberoamerica. Its projects contribute to the maintenance and restoration of the habitats of endangered species, technological innovations and revival of traditional agricultural activities. Under this educational remit, the foundation manages three environmental information centres organising seminars, conferences, youth exchanges, holiday camps, nature conservation projects and the coordination of scientific investigations. In all project fields the foundation works closely together with regional and local environmental organisations, public authorities, local population and scientific institutions. Long lasting intensive contacts to other countries as well as active membership in international networks such as Living Lakes and Ecotrans guarantee the exchange of experiences beyond borders.

CReNIEO - Centre for Research on New International Economic Order

CReNIEO was established in 1979 in India. The Centre is an accredited Vocational Institute for Courses of National School of Open Learning, Ministry of Human Resources Development, and Government of India. CReNIEO is especially committed to the weaker sections of the Indian society (women, children, fishermen and tribal communities) with a focus on natural resource management at Pulicat Lake. CReNIEO's development plans include promoting better health, formal education, skills for natural resource management and entrepreneurial skills for economic self-reliance and at the same time ensuring permanence of social change by capacity building and motivating the poor for upholding their rights in society. Gender equality and environmental care is the basis for sustainable development of people around the lakes as well as in the forests who are the target groups of CReNIEO's development schemes.

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The Living Lakes Network

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● **Living Lakes** Member & Candidate Lakes ● **Living Lake**

The Living Lakes Network

All three wetlands are members in the Living Lakes Network. Living Lakes is an international network and partnership with the mission to enhance the protection, restoration and rehabilitation of lakes and wetlands and their catchment areas. All lakes, wetlands and freshwater bodies of the world should be healthy ecosystems and where they are used by human-kind that use should be sustainable and not damaging the environment.

The Objectives of this Global Network are

- Conservation and protection of fresh water resources, lakes and wetland ecosystems and their biodiversity.
- The restoration of altered and disappearing wetlands and lake ecosystems.

Lakes

or the future"

s Associate Members **Living Lakes** Honorary Members

- Improving the quality of life for the local communities (Agenda 21) and participation of local stakeholders in development processes.
- Commitment building towards sustainable use and development of these ecosystems (sustainable development of agriculture, fisheries, tourism, settlement and water use).
- Promoting the use of applied sciences and innovative technologies towards the conservation of these ecosystems.
- Supporting educational programs and cooperation with local communities towards sustainable development of the region including the long-term protection of ecosystems and biodiversity.
- Spreading information relevant to these ecosystems and the activities of the Living Lakes partners.

Project Areas

Bolgoda Lake is intensively used for leisure and recreation

Only few mangroves are left at Bolgoda

Bolgoda Lake, Sri Lanka

Facts

- Bolgoda Lake is situated in the western part of Sri Lanka, 19 kilometres south of Colombo in the Colombo and Kalutara districts.
- The lake consists of two major water bodies and covers 374 square kilometres partly fresh and partly brackish water, which opens into the sea via the Panadura estuary.
- The size of the Bolgoda wetlands is close to 400 km^2. It is one of the biggest sources of freshwater within the western district of Sri Lanka.

Threats

The natural beauty of the Bolgoda wetlands has great potential for developing tourism and fisheries, but it is gravely threatened by industrial pollution and urban sprawl. Industrial chemicals, effluents from the hotel industry and pollution from sawmills are the main reasons for the destruction of wetlands and mangrove swamps. Sewage that has not been purified is the worst problem in the area. This pollution has directly affected the surrounding drinking water and led to the growth of the weed that is slowly asphyxiating the lake's fauna and flora.

Approaches

As a consequence of this situation, the Living Lakes partner organisation EMACE has decided to take a double approach to the problem. The first approach involves a conservation project seeking to clean up the lake and increase the interest of the local inhabitants via economic incentives to protect the lake from further pollution. Secondly EMACE aims to develop an industry with a local or foreign business to transform the sawdust into energy, reducing the negative impacts of the mills on the lake.

Dumping of sawdust is a common threat for Sri Lanka's wetlands

Maduganga and Madampe Lakes, Sri Lanka

Facts

- The lakes Maduganga and Madampe are located on the south-western coast of Sri Lanka in the Indian Ocean.
- They are twin lakes connected by a narrow channel of three kilometres in length. The surface areas of the lakes cover 915 hectares and 390 hectares, respectively.
- According to a study conducted by the IUCN in 2000, Maduganga has one of the most unique biodiversities.
- The Maduganga wetland consists of ten major vegetation types including the predominant mangroves and marshlands. These vegetation types comprise a total of 303 species of plants belonging to 95 families. The total plant species include 19 endemic and nationally threatened species and nine invasive alien species.
- Due to the great variety of plants, a large number of invertebrates, reptiles including snakes, birds, amphibians and mammals can be found around Lakes Maduganga and Madampe. The mixture of vegetation types and the presence of 21 small and large islands within this twin lake have made these two wetlands an ideal habitat for a total of 111 bird species.

Threats and Approaches

The people living in the vicinity of the Lakes Madampe and Maduganga depend on the resources available from the lakes and surrounding wetland systems. Unfortunately, there is neither an adequate management plan nor an environmental awareness programme, by which the local farmers and fishermen can learn about sustainable use of the environment. The area has already encountered severe damage due, for example, to over-fishing, emissions of pollutants into the water system and the extensive use of chemical fertilizers. Such issues need to be addressed not only for the sake of the local population, but also with respect to recreational use, potentially turning this area into an economic pillar.

Madampe is a paradise for birds

Pulicat Lake, India - 'The Transfer Project'

Facts

- The lake lies at the border of Tamil Nadu and Andhra Pradesh states, 60 kilometres north of Chennai City.
- Pulicat Lake is the second largest brackish-water eco-system on the East Coast of India.
- The lake has a length of 60 km and a breadth of 0.2 to 17.5 km and is a shallow lake with an average depth of one metre.
- The lagoon is an important habitat for 65 different fish species, 30 varieties of terrestrial and aquatic birds and small mammals and reptiles.
- Flamingoes are the most frequent visitors to the lake, about 15,000 of them visit it every year. Pelican, Kingfisher, Heron, Painted Stork, Spoonbill and Little Grebe are some of the other birds that show up at Pulicat Lake every year. Likewise the lake is home to Black-headed Ibis and Whistling.
- Distinguished fish species such as Milkfish, Sea Mullet, Goldspot Mullet as well as Indian Catfish are found.

Threats

Pollution from pesticides, sewage, agricultural chemicals and industrial effluents are gradually becoming the major threats. Many fisher-folk communities at the lake and the sea have lost all means of livelihood since the Tsunami on 26th December 2004.

Approaches

Due to the similar problems in Sri Lankan and Indian lake regions the project will contribute to disseminating the project results and experiences found in India. With the support of GNF the project partner CReNIEO will exchange know-how from the Sri Lankan project activities and discuss ways for transferability. Likewise in Sri Lanka, the local project coordinator will educate and inform Indian people with a main focus on environmental education, sustainable land use, new job opportunities and sustainable fishery to avoid over-fishing of Lake Pulicat. The Lake Pulicat project then is also contributing to the reconstruction and development in other Tsunami affected countries.

CReNIEO educates and informs people in India on sustainable land use, new job opportunities and sustainable fishery in order to avoid over-fishing at Lake Pulicat and promote a sustainable development.

Fisheries is an important source of livelihood at Pulicat

Project

Project Measures in Sri Lanka

Project Measures in the framework of the EU ASIA PRO ECO IIB - Post Tsunami

Two larger mangrove nurseries and ten household nurseries have already been established in the framework of this project in the wetland areas Maduganga and Madampe. Sufficient number of plants have been grown in order to restore a total of ten hectares of mangroves in the two wetlands. Approximately 2,200 plants are needed per hectare. The Nagenahiru Foundation carries out workshops for women managing household nurseries. One of the larger mangrove nurseries situated in Pathamulla is used as a mangrove demonstration and education site. More than 5,000 seedlings are grown at Pathamulla at any given time. Various autochtonous mangrove varieties have been selected and tested, including species such as Rhizophora mucronata, Bruguiera gymnorhiza and Xylocarpus granatum.

The household nurseries provide new livelihoods for local women who have lost their income because of the destruction caused by the Tsunami. In the first phase various mangrove species were grown over a period of six months. Subsequently, a second phase of mangrove production was carried out. The families received a small amount of money for each plant successfully grown in the two instalments. After the first phase, a part of the nursery has been used for growing economically viable plants such as fruits. This strategy helps to ensure a long-term income and self-sustainability of the nurseries. In each nursery three families are engaged.

Three more nurseries were established at the Madampe Wetland, in Godahenne, Dhalsgoda and in Duwa. Each nursery grows 4,000 plants per year on average. The household nurseries also serve as centres in the villages to create awareness of the value of mangroves they are also used for disaster prevention and as a breeding site for lake fish species. This helps to stabilize the fish population and ensure at long-term income for freshwater fishermen.

Environmental Education - Visitor Centres

The Nagenahiru Foundation organised various "Do-You-Know-Contests" for school children

The Nagenahiru Foundation is establishing Environmental Education Centres (EEC) close to the wetlands. The objective of the centres is to inform the local population, particularly young people, women and school children living in the wetlands around Maduganga and Madampeganga. A central goal is to involve the stakeholders in concrete actions combining „practice and knowledge“ and to assist them in developing solutions for environmental issues through a participatory approach. The Department of Education of the southern provincial council is involved in this activity. Through this collaboration students and teachers can be linked to the project. As a way of developing Future leaders for conservation the project has already developed strong linkage with National Youth Services Council of the Ministry of Youth affairs Sri Lanka. 52 youth leaders are already provided with the training program on wetland conservation.

Agriculture - New Livelihoods and Organic Farming

EMACE has identified farmers in the Bandaragama area in the South Bolgoda lake region who are interested in organic farming methods. EMACE is establishing a model farm for the demonstration of organic farming practises. This model farm will be used to practically explain the making and use of compost, manure etc. Experts from the Rural Agro-services Centre situated in Peradeniya near Kandy, assist with their expertise.

Handicraft Products from Wetlands

The project focuses on two activities: doormats production by using coconut fibres, ornamental handbags and other products made of reeds and other local grass species found in the wetlands. Both handicraft sectors are traditional forms of generating income and were concentrated in the coastal areas of the Maduganga wetland. They have therefore been severely affected by the Tsunami. The selection criteria and procedure for the families to receive a donation are similar to that of the fishing gear.

Wetland Craft Centre in Polatukanda

In a first stage six sets of mat-weaving machines were distributed. Five families directly benefit from one set of machines. Ten families were given intensive training in a new Wetland Craft Centre in Polatukanda. The centre is managed by the Women Association Rantaru („Golden Star“) in close collaboration with the Nagenahiru Foundation. In the centre women are educated in traditional handicraft techniques. Two types of local reed grass species (Watake and Galagha) are used for the production of environmentally friendly traditional handicraft products such as bags, slippers and maps. The products are sold locally, as there is a good market for these manufactured items. The aim is to develop export opportunities, therefore close relationship to the Ministry of Rural Industries and Self Employment was established.

Nets handed over to fishermen at Madampeganga

Fisheries - Distribution of Fishing Gear

Fishing nets were distributed to 60 Tsunami affected families selected from the regions of Maduganga and Madampaganga. The nominations for receiving fishing nets were made by the village fisher societies of the respective villages. An independent committee appointed by the Nagenahiru Foundation visited each nominated family and carried out personal interviews. Those found eligible to receive fishing nets were forwarded to the Divisional Secretary for a final official approval to receive this donation. At the fishermen island of Galmanduwa a prawn nursery was established in order to stabilize the income of the fishermen families.

LED Lamp Project

Kerosene lamps used for night fishing can harm the environment

An initial project in 2006 with the title „LED Lamps for Fishing and Housing at Bolgoda Lake and Maduganga/Madampe Lakes“ was supported by GTZ/GATE. The long-term objective is to support the use of energy-saving LED lamps for night fishing and other purposes such as internal illumination of houses and public buildings in Sri Lanka. In Sri Lanka there is little experience in the use of solar power and energy saving CFLs, and no knowledge on LED lamps for night fishing in the wetlands at all. Under the guidance of the Global Nature Fund, the Nagenahiru Foundation conducted an experimental project to identify possible ways to use solar power for night fishing in the traditional prawn catching traps (Ja-Kotu) in Maduganga and develop an appropriate technology. Those experiments showed positive results and the lessons learned will be utilized within the framework of the EU Post Tsunami project.

Disadvantages of the traditional night fishing system

- Unreliable technique: lamps do not work with strong wind and have to be rekindled several times.
- Leaking kerosene can pollute water bodies and breeding areas.
- Health risks for the fishermen through smoke emissions, skin contact with kerosene and through burning by kerosene ignition.

Tests with LED Lamps

Traditional prawn trap (Ja-kotu) at Maduganga

Experts from EMACE and Nagenahiru have carried out comprehensive tests in order to find out how kerosene lamps for night prawn fishing can be substituted by LED lamps. The new LED lamps operate above-water but should be protected from splash water. LEDs from Europe and China were tested. The output of the LED lamps was a maximum of 3 Watts. It is recommended to use LED lamps with a maximum of 5 Watts to avoid over-fishing effects. With the 3 Watts LEDs, a NiMH battery with 2,200 mAh was used. The results have shown that with 8 to 10 operation hours per night and using normal metal hydride rechargeable batteries and orange coloured LEDs the best catch results were achieved. Catch results were comparable or even better than those made with conventional kerosene lamps. Tested LEDs with the white and blue light colours showed very poor results. Emphasis was also given to the comparison of different energy storage systems (lead-gel-batteries, nickel-metal-hydride, nickel-cadmium, lithium ions), on the required battery capacity as well as the light intensity and the light angle of the tested lamps. In case of the lead gel batteries, different rating classes of 4 Ah to 16 Ah were used. Tests were also carried out with LED prototypes in amber and red-orange. A test arrangement with direct current entry from power lines nearby riparian situated bow nets was also installed. The tested solar LED lighting systems are also recommended for house lighting, particularly if there is a poor supply of the electricity from the grid.

Solar lamps can replace kerosene lamps

Tamil fisherman

Case

Case Studies

The Green Coast Project Indonesia

Text by Nyoman N. Suryadiputra

The Green Coast project was developed in early 2005 by Wetlands International, WWF, IUCN and Both ENDS as a tsunami response initiative. The aim of Green Coast is to restore coastal ecosystems which provide natural shelter and other benefits and services to people that live in vulnerable coastal regions. The project is operated in Indonesia, Sri Lanka, India, Thailand and Malaysia. Green Coast is led and managed by Wetlands International and is financed by Oxfam NOVIB since June 2005.The initial, emergency response phase of Green Coast will be completed in March 2007.

The main objectives

- Assess the tsunami impacts on ecosystems and livelihoods as well as local communities views and rights.
- Influence governments, aid agencies and the corporate sector to sustainably manage and restore coastal natural resources.
- Facilitate small grants for community-based rehabilitation projects.

In Indonesia, Wetlands International Indonesia Programme (WIIP), in collaboration with other partner organisations such as local NGOs and the Syahkuala University, conducted comprehensive assessments that identified at least 31 specific areas that need priority rehabilitation. Along the Aceh east coast the evaluation team found that there used to be very thick mangrove forests. These were converted into fishponds long before this area was hit by the tsunami. Some of the destroyed ponds are now being restored, but for most of them this solution will be too expensive due to heavy degradation.

Hence, the Green Coast project recommends a rapid adoption of a greenbelt policy restoring the coast into mangrove forest. Otherwise lots of ponds and villages will disappear. Reconstruction of the existing ponds' must be modified by planting mangroves in the middle and on the dikes of the ponds as well as behind the coastline. This system is called silvofishery. Silvofishery is a combination of mangrove trees with shrimp/fish pond culture. The mangroves are planted on both the pond's dikes as well as in the middle of the pond. This model ensures the pond dikes are held firmly by the mangrove roots and the pond itself is protected from storm or sea-current erosion.

Mangrove restoration might be very difficult if the wrong species have been planted in the wrong places or the people living close to the mangroves have not been involved. As a result, many seedlings may die.

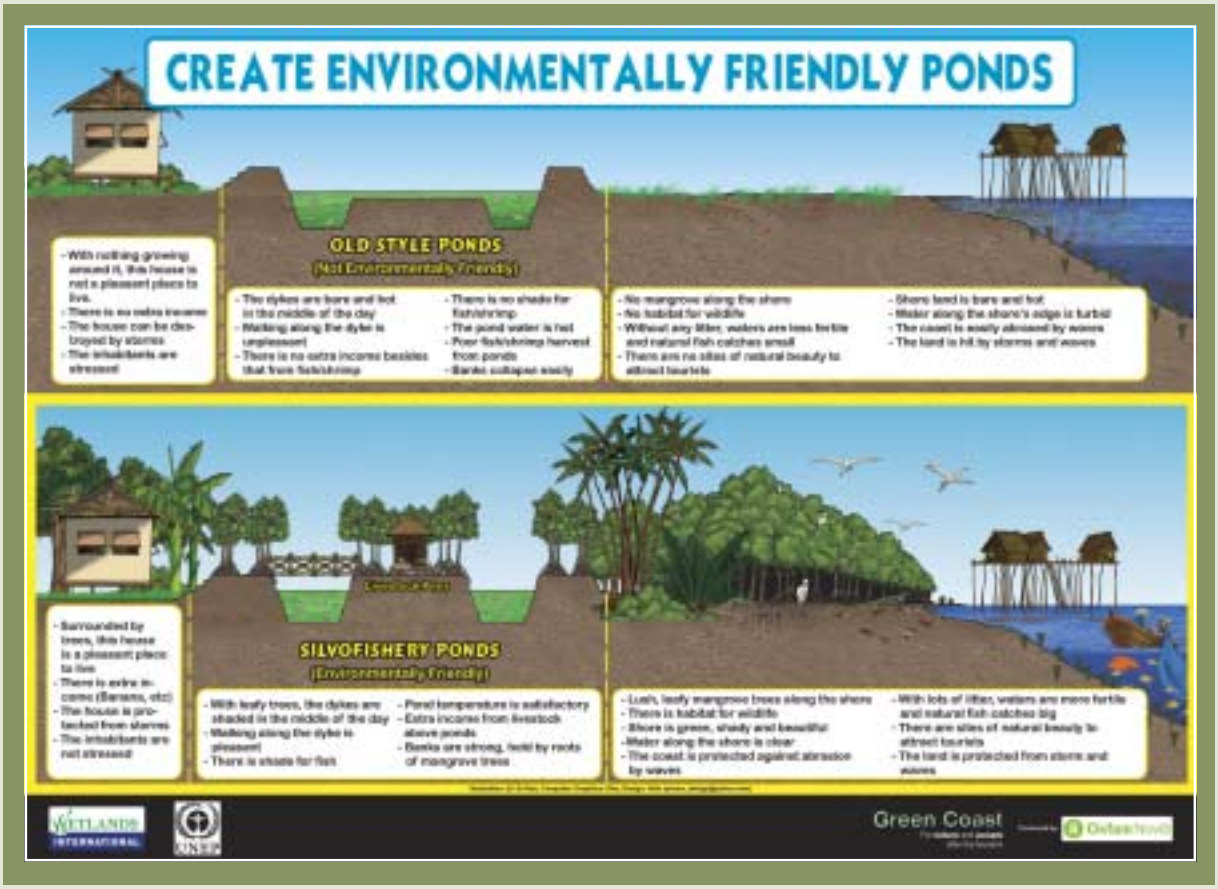

Figure: the new fish/shrimp coastal pond model (silvo-fishery) against the old model

Green Coast reviewed 43 regulations and related policies in Coastal Resources Management (CRM) for Aceh and analysed them for their post-tsunami relevance. A forum in Aceh was established that meets regularly to discuss CRM-related issues, involving NGOs, women groups, local government, BRR (Aceh Board for Reconstruction and Rehabilitation), scientists and Panglima Laot, the traditional local leaders of fishing communities. Green Coast and WIIP teams provide technical training to communities and CBOs that range from mangrove planting techniques to a number of alternative income generation training. Women traditionally play an important role in activities such as rice farming or collecting shellfish in mangroves. Therefore Green Coast projects focus specifically on regaining an income for these women. Between May 2005 up to March 2007, 60 rehabilitation projects will be implemented for a total sum of 800,000 Euro, from which over 10,000 people will benefit directly. Livelihoods are recovered by the provision of fishing gear, fish processing, sewing machines or goat farming. In planting coastal vegetation with a variety of coastal seedlings, including fruit trees, over 600 hectares have been rehabilitated with not less than 1.2 million plants.

Mangrove restoration is notoriously difficult: too often the wrong species have been planted in the wrong places or the people living close to the mangroves have not been involved. As a result, many seedlings died. Green Coast in Indonesia uses an approach to offer local communities technical and financial support such as micro-credits to enable them to restore their livelihoods. In return the communities provide environmental services such as like replanting and maintaining coastal forest and fruit trees or establishing nurseries. If more than 75% of the planted seedlings are still alive after a ten month period, the credit becomes a grant.

Understanding Linkages of Mangrove Forest and Livelihoods. A Best Practice Model from Indonesia

The project at a glance...

Location:	Ujung Blang, Ule Jalan and Teungah sub-villages of Lam Ujong Village located in Aceh Besar District
Period:	28 February 2006 to 28 February 2007
Targeted number of Beneficiaries:	Approximately 150 families
Approved Budget:	Euro 26,000 for 3 sub-villages
Rehabilitated Targeted Area:	45 ha

Lam Ujong is a village located in Baitussalam subdistrict of the Aceh Besar district. In this village 189 people from a total of 600 were killed by the tsunami. As a result of the tsunami, ponds and saltpans silted up with mud. This left the community with very limited option for continuing their livelihood activities. Within the project implementation, community groups from three sub-villages are provided with working capital to run small-scale silvofisheries. In this concept fishponds are combined with mangrove trees in the ponds. A certain percentage of the pond forms a gutter where fish and shrimps can live, while in the middle of the pond and also on the dikes, mangroves are allowed to grow. By doing this, the mangroves also act as shelter for the fish and provide natural fertilizers to the pond. In order to protect river banks from abrasion and to obtain a better water quality - including less turbid water - the river banks are also planted with mangroves.

Having mangrove trees both in the ponds and at the rivers, not only improves the water quality and strengthens the pond and river bank structures, but it also protects the fishermen's settlements, usually located close to the ponds from future disasters. In this silvofishery concept in the three sub-villages, the community groups planted over 80,000 mangrove seedlings in their ponds and dikes and over 20,000 seedlings at the river banks. In return for these works, the groups are provided with small grants from the Green Coast Project as well as from UNEP that can be used as a working capital to implement fish farming in their replanted ponds and cattle farming on their own land. The project is implemented by community based organisations in Ujung Blang, Ule Jalan and Teungah subvillages of Lam Ujong village under Wetlands International Indonesia Program advisory and supervision.

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MANGREEN - Mangrove Restoration and Ecology in India

A project by OMCAR and DEEPWAVE Mangroves
"Save PEOPLE save Mangroves!"

The coastline of Tamil Nadu in southern India - the land of the temples - has been hit severely by the waves of the 2004 Sumatra-Tsunami. Thus the initiatives DEEPWAVE and OMCAR developed the project MANGREEN - Ecological Mangrove Restoration (EMR) in India - that has been restoring mangroves in northern Palk Bay coastal villages with the participation and support of the fishing communities.

Mangrove forests are a natural protection from cyclones, coastal erosion and caustic effects of Tsunami. However, most of these forests along the Indian coastlines have been destroyed and are in peril. Long before the Tsunami the lives of local people had been already affected by the destruction of the mangroves already. Fishing, which is one of the main sources of income and cheap protein, depends to a noticeable extend on a healthy coastline and has decreased significantly over the last decades. On the other hand UN-projects in Asia have already proven that mangrove forests can successfully be restored. The MANGREEN project intends to be a model for the community-based ecological restoration of mangroves through the application of scientific knowledge along with socio-economic development.

To start a long lasting project such as MANGREEN you need to know the local situation and circumstances in great detail. DEEPWAVE and OMCAR tried to focus on four pillars in their work:

1 Mangrove restoration.
2 Community awareness programmes.
3 Community development programmes.
4 Establishment of a network of NGOs, the scientific institutes and the government of Tamil Nadu.

In September 2005, the project was initiated in two villages: Keezhathottam and Velivayal located at Agni estuary in the northern Palk Bay, where the natural and artificial regeneration sites have been successfully established after a careful study on the soil quality, suitable species composition, availability of natural recruitment, land elevation, distance from the water source, grazing effect and land-use. With the continuous good rapport of OMCAR staff, the villagers were addressed to support the activities for establishing protected EMR sites. Convincing the fishing community was one of the first tasks, followed by official permission and support.

Dog-faced Water Snake, *Cerberus r. rynchops*

International students are welcomed by workers on the project

Fencing mangroves helps to prevent grazing pressure

Creating community awareness was another constant aspect of the project.

The villagers have been recruited for establishment of EMR sites that includes excavation and cleaning of water channels, fencing, seed collection, plantation and maintenance. The EMR sites represent the outstanding achievement of the MANGREEN project and people.

We have now planted more than 10, 000 mangrove seedlings in the selected sites of artificial regeneration, where there is little opportunity of natural recruitment and 3,850 saplings are under constant observation in the nurseries. The nursery-raised seedlings have shown a higher survival rate. This may be attributed to the protection, care and intense monitoring of the seedlings in the earlier development stage at MANGREEN nurseries, the perfect and original soil where the seedlings can grow.

Creating community awareness was another constant aspect of the project. A variety of lectures in local schools, in summer school programmes with the support of OMCAR volunteers and in student eco-clubs have been regularly performed. Street plays and media work spread our work to the public. Now it is planned to build an information office about the environment and treasures of the Palk Bay Area and OMCAR is raising awareness about the projects along the entire Tamil Nadu coast. The villagers support the project as they learned about the importance of a healthy mangroves and fishery.

The third pillar of the efforts, community development, is in general, a responsible task, which mutually has an effect on the restoration activities. The project coordinators concentrated first on quick improvements, such as building water pipes and other infrastructure help. Village self-help groups were encouraged to save money and establish coconut rope, making units target for woman empowerment. Professional training was provided as well as rope making machines. Coconut, a cheap raw material from the backyard of each family has now turned into ropes from the skilled hands of village women. From a psychological perspective, the daily income and personal skill of coir-making women is building their self-confidence, independence in addition to a positive consideration on the MANGREEN project and an alternative lending money from moneylenders.

The stakeholders work with government and local and international NGOs has been concretely developed through the participation in seminars, conferences and training programs. Experts from the local University of Bharathidasan and other institutes have been early involved in the planning. Also the international Mangrove Action Project (MAP) is following the work with great interest and accepted MANGREEN site as one of the Ecological Mangrove Restoration site. Ten international students and volunteers from Germany, Croatia, Australia accomplished the research and community studies and more students are welcome to participate.

The MANGREEN project intends to be a sustainable support to the coastal protection of India and thus wants and has to run at least for ten years. The project coordinators are very much thankful to the LIGHTHOUSE FOUNDATION, Germany, and many other private donors for their substantial financial support and trust in the goals, in order to conserve the mangroves and coast of the Palk Bay in Tamil Nadu. DEEPWAVE and OMCAR are convinced that with united efforts some of this pristine and delicate coastal areas can be preserved for the future.

For more information please visit: http://www.mangreen.org

Involvement and information of all local stakeholders is crucial

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Mangroves-
Functions and Threats

Characterisations of Mangroves

Text by Prof. Jayamanne

Mangrove habitats show a high diversity

Mangrove forests can be seen as an evolutionary wonder. They literally live in two worlds at once, acting as the interface between land and sea. Mangroves are generally an assemblage of trees and shrubs that grow in the inter-tidal zone in saline coastal habitats. The majority of populations occurring between the latitudes of 30° North and South; but mangrove wetland ecosystem can be found in many tropical and subtropical regions of the world. Two thirds of the equatorial coastal regions are home to Mangroves. The world has 1.5 million hectares of it. It is species-diversity, which differentiates the mangrove communities of the Indian Ocean and the western Pacific from the Caribbean and the West coasts of America and Africa. The Indo-Pacific group, which generally forms denser and taller stands, is more species-rich overall. Mangroves are trees and shrubs from different plant families, up to 30 metres in height. 16 to 24 families and 54 to 75 species are found worldwide. The greatest diversity of mangrove species exists in Southeast Asia. Twelve mangrove species can be found in the New World and only four species of mangroves exist along portions of the coasts of the southern USA.

Mangroves are mostly distributed in lagoons, shores, bays and estuaries where land meets the sea. They are superbly adapted for life in the conditions found on salty shores. Mangroves receive salt water from regular tidal flushing and freshwater from streams and rivers and live between the mean sea level and the highest tides on a substrate of mud and sand. This makes mangrove habitats a unique wetland, which is characterised by high temperature, fluctuating salinity, anoxic and water logged soil and an unstable environment. Mangroves have extended buttress roots, which slow the tidal flow and promote the deposition of mud and silt. Nowhere else do sea and land organisms share the same habitat to such a great extent as in the mangrove swamps of the tropical and subtropical coasts. Terrestrial organisms colonise the upper storeys of the tree and shrub layer, while marine organisms live underneath them. The flora and fauna living in mangrove ecosystems have adapted in special ways to cope with the unusual conditions of this ecosystem, so that the biotic communities of the mangroves are unique. Together they form an intricate food web that is very easily disturbed and their extent is seriously reduced due to human activities.

Next to branches of corals, mangroves can be counted as an important carbon sink of tropical oceans. They are able to regulate the global natural balance and have similar effects to peatland carbon sinks.

Mangrove Soil

Mangrove soil is always under the influence of the semi-diurnal tides and is wet and loose. Top-soil which is generally lighter in colour could be sandy or clayey. Sandy top-soils are porous and facilitate aeration and percolation during the low tide. The clayey soil, however, is less aerated. Sub-soils below the surface are typically water logged and contain a lot of organic matter. The organic matter in the soil originates from the decomposition of plant litter produced by the mangrove trees themselves. Aeration in this part is very poor and anaerobic bacteria thrive in the soil. The debris is slowly broken down under slightly acid conditions by microscopic sulphur-reducing bacteria and fungi which release Hydrogen Sulphide gas which smells rotten eggs and is typical of mangrove environments. Soil type also determines the animals and plants, which can live in it. For example, Avicennia prefers sandy soil while Rhizophora thrives in humus-rich soft mud. pH of mangrove soil varies from neutral to highly acidic. The latter could be found in areas where decomposition of organic matter by sulphur-reducing bacteria is high. Oxygen in mangrove areas is generally lower. Interstitial oxygen - oxygen in between the soil sediment particles - is used up by the decay and respiration of bacteria. Only the oxygen content of first few millimetres of soil is replenished by the tide and in exchange with the atmosphere. Thus, anaerobic conditions occur below the surface soil.

The mangrove environment receives nutrients fom both from within the environment and the rivers and sea as dissolved and suspended organic matter with numerous microscopic organisms. Litters produced by the mangrove trees are consumed by grazers and detritus feeders and is transported to lagoons and sea with the receding tide. Thus, an exchange of nutrients occurs between mangroves and adjacent lagoon, estuaries or sea. Salinity in the mangrove environment varies from 0 to 3.5 %. During the dry period mangroves are flooded with saline water and the water salinity in the pools and streams in mangrove areas increases with the evaporation. During the monsoon season salinity may reduce to 0 ppt due to influence of precipitation and storm water.

Mangroves grow in areas between Mid Tide Level and the Highest High Water Spring Tide. High tide and low tide occurs twice daily in Sri Lanka, the tidal height in the project region is about 0.5 m.

Mangrove Facts

- Mangrove ecosystems are high-specialised habitats of tropical coasts. The majority of populations occurring on both sides of the equator between the latitudes of 30° north and south in areas with an average water temperature of about 23° Celsius per annum.
- In the past, their surface area has been estimated at 170,000 square kilometres. Since 1980 this has been reduced by a third worldwide.
- Indonesia once had the largest proportion of mangrove surface area. This is now half what it was before.
- The Philippines lost 70 % and Puerto Rico 90 % of their mangrove forests. In the Indian state Kerala the mangroves are almost entirely extinct.

- In addition to branches of corals, mangroves can be counted as an important carbon sink of tropical oceans. They are able to regulate the global natural balance and have similar effects to peatlands carbon sinks, through sedimentation they can accumulate perpetually organic matter and harmful substances and abstract them from the cycle of matter.
- With regard to the climate change caused by anthropogenic factors, the destruction of mangrove ecosystems and thus their functional efficiency is indeed particularly irresponsible.
- 200 metres of mangroves are able to scale down the power of a marine surge to 75 %. As a result of adherence of oceanic sediments, intact mangroves can cope with the temporary swelling of sea level, which accompanies it. In case of a potential sea level rise as a consequence of human development, the mangroves would lose the ability to protect their habitats. An important regulatory factor for the stabilisation of global nature processes would fail.
- In January 2006 the conservation agency UNEP published a study of the value added-chain of coral reefs and mangroves, with the resulting conclusion that one square kilometre of mangrove forest creates a value of US$ 200 to US$ 900 annually from fisheries, natural protection of tropical coasts and tourism.
- The biggest threat for the survival of mangrove ecosystems, are new established shrimp aquaculture industries. Since in 1975 the World Bank financed a program to set up shrimp farms, that on the one hand met the protein need of local people of the third world and on the other hand allowed them to repay credits and accrued debts to the first world. As a result of this program ten thousands of hectares of mangrove forests in Brazil, Ecuador, Thailand, Indonesia, the Philippines and India had been destroyed. At least 300,000 ha in the province of Aceh in Sumatra.

  After ten years however shrimp aqua cultures have normally become highly contaminated as a consequence of the high input of fertilizers, pesticides and antibiotics used in diseases control, requiring the development of new areas. In 1990 the price for one kilogram of shrimps was about ten dollars, however due to mass farming - a six-fold increase in shrimp production in the last 25 years - the price severly declined. The same amount of shrimps costs only US$ 4.70 to US$ 1.60 at present. Once one hectare of mangrove forest offered livelihood for about ten families - nowadays a 500 hectares shrimp-farm provides only five jobs.
- The so called „blue revolution“ has radically changed the sea coasts in the tropical regions and irreversibly destroyed the ecosystems.

Text by Prof. Dr. M. Succow, Germany, Greifswald

Social and Economical Significance

Mangroves along with the abiotic environment surrounding it, make up a unique ecosystem that is distributed in the coastal regions known as the Mangrove Ecosystem. Together with coral reefs and tropical rainforests, it is the most productive ecosystem on earth. Mangroves are a diverse habitat that is rich in living resources and have direct impact on the people living in mangrove areas.

Mangrove ecosystems have traditionally been sustainably managed by local populations for the production of food, medicines, tannins, fuel wood, and construction materials. For millions of indigenous coastal residents, mangrove forests offer dependable, basic livelihoods and sustain their traditional cultures.

Social and economic values of mangroves

- Provide livelihoods for local people
- Provide timber and firewood
- Supplementary food for humans and animals (e.g. Kirala)
- Supply food and feed for fisheries and aquaculture
- Provide natural dyes (e.g. Bruguiera, Ceriops)
- Medicinal value
- Recreational value

(by Prof. Jayamanne)

Ecological and Environmental Significance

Mangroves' falling leaves, flowers and fruits supply more than three kilograms of organic matter per square metre per year, to be decomposed by bacteria and fungi and returned to the food chain. The biodiversity of the dense mangrove root systems multiplies the available space for other organisms and offering them a large number of microhabitats in a confined space. Countless fish, crustaceans and bivalves populate the water. The roots of the trees are colonised by algae, barnacles, oysters, sponges and molluscs. In the free-flowing channels, pistol shrimps and fish abound. Large numbers of fiddler crabs are found on the silt surfaces. The upper storeys of the mangrove forest overhead are home to reptiles, birds and mammals. Sea cows head for the sheltered mangroves to calve, and monkeys catch crabs onto the shore.

Crafting of a traditional Ja-kotu

Doormates made of coir

Numerous water birds including cormorants, kingfishers, ibises, herons and frigate birds take advantage of the rich pickings, and nest in the treetops. The protective mangrove buffer zone helps to minimize damage to property and loss of life from hurricanes and storms. In regions where these coastal fringe forests have been cleared, loss of human life and property can occur due to destructive storms. Additionally serious problems of erosion and siltation have arisen after felling the mangroves.

A primary factor of the natural environment that affects mangroves over the long term is sea level and its fluctuations. Beside the above incomparable advantages mentioned, mangroves provide a natural protection from the strong Tsunami waves. Coastlines with existing forests were noticeably less affected by the Sumatra-Tsunami. For instance, 200 metres of mangroves are able to scale down the power of a wave to 75 %.

Other shorter-term factors are air temperature, salinity, ocean currents, storms, shore slope, and soil substrate. Mangroves have also been useful in treating effluents, as the plants absorb excess nitrates and phosphates thereby preventing contamination of nearshore waters.

Ecological and environmental values of mangroves

- The biodiversity of the dense mangrove root systems multiplies the available space for other organisms, offering them a large number of microhabitats.
- Provide breeding grounds and feeding grounds for many coastal fishspecies and crustaceans.
- Provide nutrients to the coastal water bodies and maintain ecological balance of the coastal ecosystems. Vital coral reefs and sea grass beds are also protected from damaging siltation.
- Protect the shoreline from wave action, currents, winds and prevent erosion by acting as buffers and catch alluvial materials, thus stabilizing land elevation by sediment accretion that balances sediment loss.
- Serves as a natural water treatment plant by retaining heavy metals.
- Trap sediments.
- Valuable resource for research and education.

(by Prof. Jayamanne)

Threats to Mangroves

Naturally resilient, mangrove forests have withstood severe storms and changing tides for many millennia, but they are now being devastated by modern encroachments. In the past, their surface area has been estimated at 170,000 square kilometres. Since 1980 this has been reduced by a third worldwide. An estimated 50 percent of the mangrove forests that once existed worldwide have been destroyed in recent

Shrimp farming can harm mangroves

Shrimps for sale on a Marketplace

Illegal Waste Dumping

decades, so that mangrove forests are among the most threatened habitats in the world - even more threatened by destruction than tropical rainforests. With the damage to mangroves, tropical coasts will lose the habitat for diverse high-specialised species, of which probably one third still aren't even scientifically registered at present.

Environmental stress can kill large numbers of mangrove trees. In addition, the charcoal and timber industries have also severely impacted mangrove forests, as well as tourism and other coastal developments. Wherever mangrove forests have been cleared, the yields of coastal fisheries have drastically fallen. The reason is that many economically important fish species use the mangroves for their reproduction. The loss of these refuges removes a life-supporting resource, not just for these fish populations but also for the coastal population. With the felling of the forest, a natural protective belt is lost.

The gravest threat to the world's remaining mangroves is the rapidly expanding shrimp aquaculture industry. Since mangrove forests have been classified by many governments and industries alike as useless swamps, it has made it easier to exploit mangrove forests as cheap and unprotected sources of land and water for shrimp farming. Thousands of hectares have been cleared to make room for artificial shrimp ponds. The amount of mangrove forest destruction is alarming. For instance, in Ecuador and the Philippines, the Shrimp Aquaculture Industry has been responsible for deforesting 70 % of mangrove forests in those regions. The use of an area for shrimp breeding is problematic because after a maximum of ten years' use, shrimp ponds have to be abandoned due to contamination of the pond bottoms with chemicals, over-fertilisation, pesticides and antibiotics. Reforestation is usually impossible for decades afterwards. That means that new areas have to be developed. In 1990 the price for one kilogram of shrimps was about ten dollars, however due to mass farming - a six-fold increase in shrimp production in the last 25 years - the price began a severe decline. The same amount of shrimps costs only US$ 4.70 to US$ 1.60 at present. Once one hectare of mangrove forest offered livelihood for about ten families - nowadays a 500 hectare shrimp-farm provides only five jobs. Globally, as much as 50 % percent of mangrove destruction in recent years has been due to clear cutting for shrimp farms. Mangrove forests are in danger of disappearing from the coasts in the next twenty years.

It has to be in our interest to do everything possible to preserve the mangroves ecological functions. Each further destruction of mangroves for shrimp farms or constructions or degeneration because of waste concerns the whole world community and can no longer be accepted.

Mangrove Distribution

Text by Prof. Jayamanne

Mangrove distribution is limited by several factors. Since mangroves are tropical species, they depend on air and water temperature. The plants do not tolerate freezing temperatures. They do not cope with aridity and are therefore more developed in coastal areas that have high inputs of rainfall. Another important factor is the salinity of the water in which mangroves are growing. Mangroves can grow in freshwater conditions but normally the competition with freshwater species is too high so that in areas with higher salinity they are favoured. Tidal fluctuation plays another important indirect role for mangrove distribution, because they bring saltwater up estuaries against the outflow of freshwater, transport sediments, nutrients and clean water into the mangrove habitat. Also important are the combined energy levels of sediments and waves, as mangroves grow best in an environment with a low wave energy. High waves limit the accumulation of fine sediments.

Coping with Rough Environmental Conditions and Reproductive Strategies

In comparison to land plants, mangroves experience various problems because they live in an environment that is 'physiologically dry' due to their proximity to sea or salt water. To survive under these tough conditions, mangrove plants have adapted to cope with this special environment. The main problems faced by the mangroves and their adaptations:

1. Lack of Freshwater or High Salinity Condition

Mangroves are surrounded by salt water, and the trees have to absorb salt water instead of freshwater. Thus mangroves have developed various mechanisms to regulate the salt concentration in the plant. These mechanisms include extraction of freshwater from salty water, blocking out the salt at the root level, getting rid of excess salt on their leaves, salt secreting leaves and storage of salt and abscission.

In order to be able to absorb any water at all from the salty brine, their plant cells maintain a very high osmotic pressure. In other words, the salt concentration inside the cell is higher than that of seawater. A complicated ultrafiltration mechanism in the mangrove roots allows the diffusion of water towards the higher salt concentration within the cells, but prevents any intake of salt.

Mangrove plants in a nursery

Variation of salt concentration influences the distribution of mangrove species in the mangrove forest. Certain species of mangroves exclude salt from their systems, others actually excrete the salt they take in via their leaves, roots, or branches. Some mangrove plants can also store water (salt succulence) in order to dilute high salt concentrations. In addition, they can shed leaves impregnated with salt, and some have salt glands and salt hairs for the purposes of excreting excess salt. Since the different species have varying degrees of success in coping with the excessive salt levels. The progressively higher concentrations of salt moving inland, influence the distribution of species in the mangrove forest.

In salt excluding mangrove species the mangrove root system is so effective in filtering out salt that a thirsty traveller could drink fresh water from a cut root, though the tree itself stands in saline soil.

2. Lack of Oxygen (anaerobic condition)

There is little oxygen in the fine mud usually found in mangroves. Mangrove trees have special breathing roots to absorb oxygen from the air. The mangrove soil is anaerobic and to overcome this problem mangrove plants have developed aerial roots. Aerial roots are exposed to the air at least for a part of the day. Different species of mangroves have developed different kind of roots for this purpose but the function is the same.

3. Unstable Substratum

To cope with unstable substratum, mangroves have developed root systems that are capable of anchoring the tree firmly to the substratum.

4. Germination of Seeds

Certain mangrove species can propagate successfully in a marine environment because of special adaptations. The seeds germinate on the mother tree instead of simply dropping off when ripe. This is called viviparity. That system may have evolved as an adaptive mechanism to prepare the seedlings for long-distance dispersal, and survival and growth within a harsh saline environment. During this viviparous development, there are additional strategies to enhance the success in reproduction. Mangroves often produce many seeds annually and provide a large food store for their seeds, required for later autonomous growth, before sending them off. The structural complexity achieved by the seedlings at this early stage of plant development helps acclimate the seedlings to extreme physical conditions which otherwise might preclude normal seed germination. Mangrove seeds and seedlings are dispersed by water. Ideally, the seedling would float and settle far away from the mother plant. The seedling will probably not do well, if it grows under the shade of the mother tree.

Another special adaptation is the dispersal of certain mangroves' „propagules" which hang from the branches of mature trees. These fall off and eventually take root in the soil surrounding the parent tree or are carried to distant shorelines. Depending on the species, these propagules may float for extended periods, up to a year, and still remain viable. Viviparity and the long-lived propagules allow these mangrove species to disperse over wide areas.

5. Desiccation

Similar to desert plants, mangroves store the precious extracted freshwater in thick leaves, hairy or waxy leaves help additionally to reduce evaporation and water loss in the drying coastal winds.

Mangrove Restoration

Since its formation in 1992 the Mangrove Action Project (MAP) has been involved in mangrove restoration projects, advocacy, and educational work. MAP is dedicated to reversing the degradation of mangrove forest ecosystems worldwide and is tangibly contributing to the exchange of ideas and information for mangrove forest protection and restoration worldwide. MAP promotes effective regulations and enforcement to ensure sustainable shrimp aquaculture practices which include participatory coastal resource management, responsible consumer choices, and strategies for the implementation of these and other solutions. MAP has intensified its conservation work and is addressing other serious problems affecting mangrove forests, such as logging, oil and charcoal industries, as well as other developments threatening mangroves and coastal communities. MAP is supporting and initiating mangrove restoration programs worldwide, utilizing effective ecological restoration methods. MAP has supported mangrove restoration efforts in Ecuador, Brazil, Guatemala, Thailand, India, Sri Lanka, the Philippines, Indonesia and Malaysia. In 2000, MAP formed a working partnership with the Small Fishers Federation of Sri Lanka and established the MAP-South Asian Resource Center which is based in Pambala, Sri Lanka. MAP has published a summary description of preferred methods for planning and implementing mangrove rehabilitation. According to MAP's approach six critical steps are necessary to achieve successful mangrove restoration.

Six Steps to Successful Mangrove Restoration

This is a brief summary of a manual first published by MAP in 2005 and updated in March 2007 that provides a comprehensive basic guide to these six steps, in order to make the methodology accessible to coastal managers and mangrove restoration practitioners. It must be stressed that restoring mangroves is only a solution if protection of the remaining mangrove ecosystems is initiated, before too much precious habitat is irretrievably lost. The compiled six steps describe the requirements of appropriate and successful on-site

Local women working in a mangrove nursery at Maduganga

mangrove forest restoration. It is important to work together with communities, organizations and local government. A successful program must reach beyond planting seedlings and consider natural water flows to increase the success rate for restoring large areas of degraded mangrove forest.

Mangrove Action Project is promoting six critical steps for appropriate ecological mangrove restoration.

Working in cooperation with mangrove ecologists, assorted organizations, and communities, MAP promotes a 6-step method of actual natural on-site mangrove rehabilitation that engages local public participation.

1 Recognize both the autecology (individual species ecology) and community ecology of the naturally occurring mangrove species at the site, in particular the patterns of reproduction, distribution, and successful seedling establishment;

2 Identify the normal hydrologic (water) patterns that control the distribution and successful establishment and growth of targeted mangrove species;

3 Assess the modifications of the mangrove environment that occurred and that currently prevent natural secondary succession;

4 Select appropriate restoration areas through application of steps 1-3 above that are both likely to succeed in rehabilitating a forest ecosystem, and are cost effective, given the available/ likely funds and manpower to carry out the projects, including adequate monitoring of their progress towards meeting quantitative goals established prior to restoration. This step includes resolving land ownership/use issues necessary for ensuring long-term access to and conservation of the site and associated wildlife;

5 Design the restoration program at appropriate sites selected in step 4 above to restore the appropriate hydrology and utilize natural volunteer mangrove recruitment for natural plant establishment; and

6 Only utilize actual planting of seedlings as an integral part of the rehabilitation program after determining through steps 1-5 above, that natural recruitment will not provide the quantity of necessary established plants, rate of stabilization, or rate of growth as required for project success.

Usually, the local community does plant some propagules or seedlings as a symbolic and educational exercise whether such planting is or is not necessary as part of the restoration regime to: feel physically engaged, increase community stewardship, raise attention to the area (on site activity) and promote growth of well liked species such as Rhizophora over regular natural colonizers such as Avicennia or Sonneratia. Reaching far beyond just planting of seedlings, our program which restores natural water flows, greatly increases the overall success rate for restoring large areas of degraded mangrove forests. Our method has proven extremely successful in past endeavors, for example in West Lake, Florida.

The described six steps above for successful ecological mangrove restoration must be seen as basic information as this cannot be a comprehensive guide to mangrove restoration. The techniques outlined below, should therefore be tailored to each unique region in which restoration is being attempted. Management objectives of mangrove restoration should be translated into specific actions by developing implementable management plans. Based on the management plan, realistic operational plans should be developed that are suitable for local implementation, simple, practical, transparent and include clear objectives. For optimal management it is necessary to review and adjust periodically the management plans.

Preparations: Do your Homework!

It's always useful to check whether there were any mangrove restoration programs in the chosen area of interest before. If so, it is helpful to gather information regarding criteria of success and failure and to learn from former consolidated findings. Inform yourself about geologic parameters and look for historical photographs, literature about mangroves on site and their distribution as well as tidal conditions. It is useful to have a reference mangrove site for examining normal hydrology for mangroves in the particular area. Additionally it is important to select appropriate restoration areas that might succeed in rehabilitating a forest ecosystem and are cost effective, given the available funds and manpower to carry out the projects. This should include adequate monitoring of their progress towards meeting quantitative goals established prior to restoration. This step includes resolving land ownership and land use issues necessary for ensuring long-term access to and conservation of the site and associated wildlife.

Understanding the normal hydrologic patterns that control the distribution and successful establishment and growth of mangrove species is one of the most important attributes of targeted planning. It is therefore indispensable to define three important points concerning the tides: the height and depth of the area that shall be restored and the duration and the frequency of the tidal currents. Each mangrove species thrives for example at a different substrate level which in some part dictates the amount of exposure the mangrove will have to tidal

Ecological Mangrove Restoration - making transect

Preparation work

Things you may need before starting mangrove restoration activities

- Information on biophysical features of the location (i.e. area maps, land-use maps, ownership situation).
- Major climate parameters (i.e. rainfall, temperature etc) and information on the tidal and hydrological system (tide tables).
- Dominant soil type.
- Water chemistry (salinity, pH, color, transparency and nutrients).
- Type of forest (primary, secondary, degraded). A forestry management map may be available.
- Species inventories (flora and fauna).
- Local knowledge/traditional uses.
- Ecosystem products, functions and attributes.
- Pressures and threats to the area.
- Potential areas available for rehabilitation/restoration.
- Survey equipment (compass, rope, stakes, notebook, measuring tape, GPS unit).

waters. It is necessary to study the tidal activities and consequently the frequency of inundation as well as dryness that influence the forest. There are various tide-classifications to distinguish, like those that are inundated by all high tides, those by all medium-high tides, or those by normal tides. In addition there are those inundations that only happen during spring tides or equinoctial tides. If a nearby healthy mangrove forest exists, it is helpful to imitate the slope and topography of the substrate.

Using salinity meter

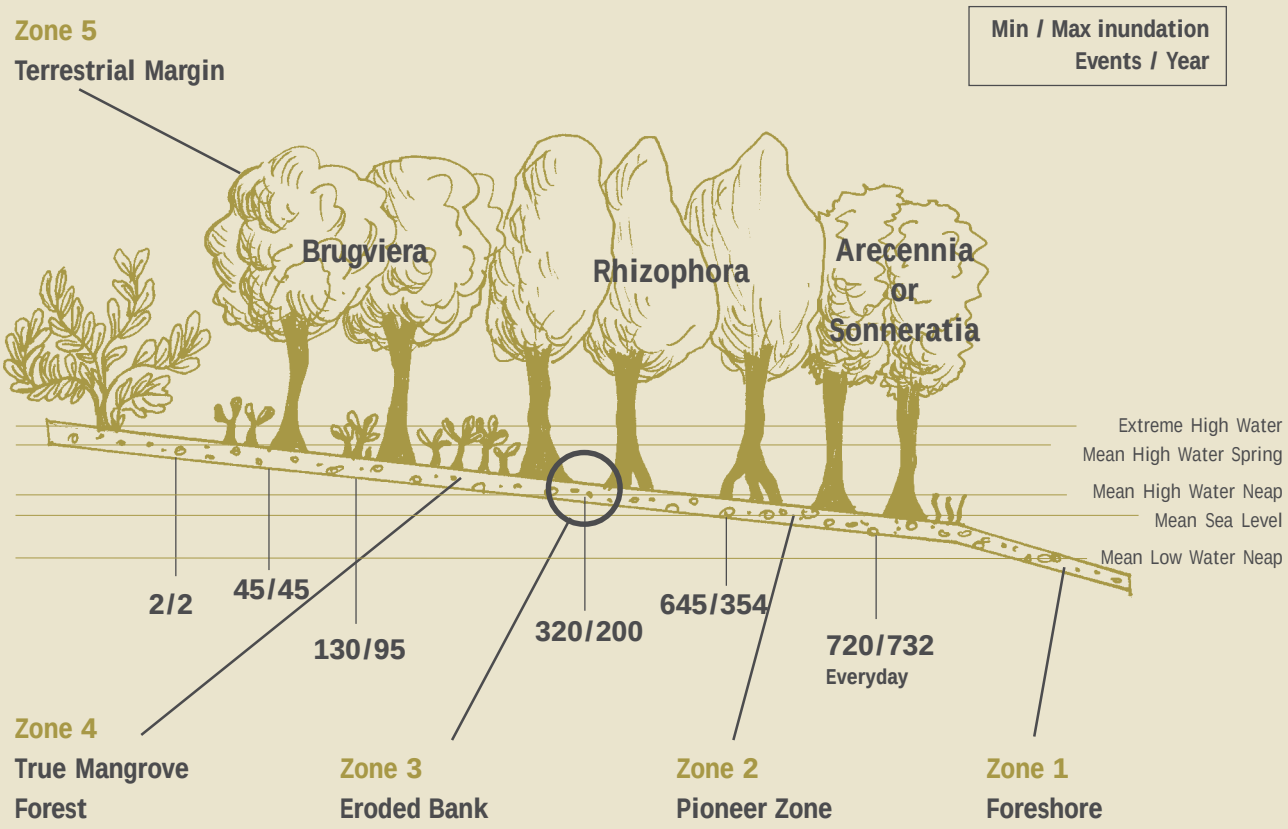
Step 1: Autecology

In order to understand the patterns of reproduction, propagule distribution and successful seedling establishment, it is necessary to have a look at the individual species ecology of the mangroves, their autecology.

Mangrove Reproduction

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. This strategy keeps the propagule healthy for a long time after they have fallen into the water. Like the coconut palm, the mangroves propagules can float.

Propagules are designed to float with the tides until coming to rest in a suitable place to grow. As soon as the propagules come to rest they put down roots into the mud and use the stored energy to grow quickly into a young mangrove tree. Because of their various shapes and sizes, propagules float differently. Smaller ones float far on normal tidal currents and can easily reach new areas. Larger ones may have difficulties to enter into areas where normal tidal exchange has been blocked due to shrimp ponds or fish traps, for example.



Mangrove zonation related to tidal datums in Sumatera, Indonesia

Zonation

Mangrove forests are often characterized by a plant zonation. Typical zones are groupings of the same species within the mangrove forest. This zonation often occurs because different mangrove species need particular conditions to grow, for example in the variety of water provided by tides, salinity of the soil or the amount of fresh water available.

Step 2: Hydrology

The most important factor in designing a successful mangrove restoration project is to understand the normal hydrologic patterns that influence the distribution and growth of existing natural mangrove plant communities in the area you wish to restore. This comprises the determining factors such as depth, duration and frequency of tidal inundation and tidal flooding. It is essential to note and monitor the critical periods of inundation and dryness that influence the health of the mangrove forest.

The following scheme based on degree and frequency of tidal inundation developed by Watson (1928) is often used to describe mangrove hydrology and zones.

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

Source: Mangrove Action Project

Step 3: Eliminate Disturbances

It must be determined whether the target area for an intended restoration was a mangrove area in the past. It is then important to understand and possibly remove disturbances that might prevent the natural succession of mangrove forest in that area. Potential stresses on the location should be investigated and, if possible, eliminated. It is crucial to involve the local communities in this process

Cattles in mangroves

Some potential stressors to be avoided or eliminated are

- Disturbing human activities (shrimps ponds, clear-cuts, dykes, etc.)
- Hypersaline or acid sulphate soils (usually after intensive shrimp farming)
- Overgrazing by animals
- Blocked tidal inundation
- Lack of groundwater
- Shoreline abrasion and lowered substrate level

This four hectare shrimp pond exists in the area with the most extensive shrimp pond development on the island. About half of the ponds in this region are disused, and half of those exist within the 200m coastal mangrove buffer zone "required" by national law.

to determine how mangrove areas have changed and why.

Step 4: Select an Appropriate Restoration Site

Often there are a number of different sites available for possible restoration, so it's important to start by selecting one that has a fairly good chance of achieving your restoration objectives. For example it should be a site that contained mangroves in the recent past or presently contains degraded mangroves. Also like any project one undertakes you should have the capacity and resources, including people, equipment, time and finances to see it thorough to completion. Ownership or user rights issues are critical to have worked out at this stage before any physical work begins. There may be an opportunity to bring the planned restoration area under legal community or co-management arrangements which often can take time but may be important for long term success.

Step 5: Hydrological Rehabilitation Design

A basic theory behind hydrological rehabilitation is the recreation of natural slope and substrate height, which will support normal tidal flow, and the natural re-establishment and growth of mangrove seedlings. Tidal streams run through mangrove areas from the terrestrial edge to the sea. Their unhindered flow is important, because tidal streams are fed from the inland side by ground water, springs, runoff and streams and are connected to the sea thus facilitating 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.

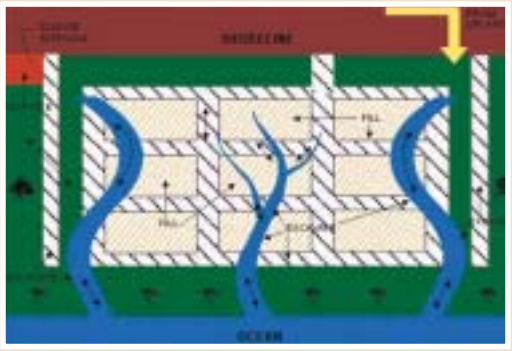
For the restoration one option is to level dike walls of disused shrimp ponds. If you cannot level dike walls entirely, opening strategic breaches in the right places may be enough to support the exchange of tidal waters and should lead to further degradation of the dike walls over time. The „right places“ are usually the mouths of historic tidal creeks. A second option is to backfill an excavated area, to create a target restoration site with the same general slope, and the exact tidal elevations relative to the benchmark reference site, thus insuring that the hydrology is correct.

If you are planning nurseries, it is indispensable to scrutinise the conditions of the potential location. There is a reason why mangroves are not already there or were not there in the recent past or have disappeared recently (see step 3). 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.

Abandoned Shrimp Farm Restoration – Do it right! Connect Ponds with the sea with a well designed tidal channels

Shrimp Farms: Bulungan, Indonesia.

Source: IUCN



Restablish Freshwater Flows; Full Restoration

Some hints referring to proper mangrove planting

- 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.
- 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.
- Loose Soil: It is common for people to trample 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.

Step 6: Mangrove Planting

If seedlings have established in the rehabilitation area, but at lower densities than hoped for, you may consider planting. It's important to only plant mangrove species that occurred naturally on the site previously in the correct zone. If an adequate area for a mangrove nursery is identified, it is recommended to create a table that includes criteria such as species, type of seed, months of seed collection, indicators of maturity, seed selection, seed storage, sowing, shading, watering and pest control.

When you plant mangroves seedlings it is important to raise them without compost or fertilizer. Supplementary nutrients only discourage the roots from spreading to find nutrients. With regard to distribution it is necessary to emulate natural growth patterns, i.e. not planting seedlings in straight rows.

Dissemination of Seedlings

There are four sources of propagules for mangrove planting to be distinguished. The first is raising seedlings in a nursery from local seed sources. The second option is direct planting of propagules. The third is direct planting of wild seedlings. The fourth is broadcast sowing on the water surface during incoming tides. Even if mangroves survive for several years in the rehabilitation area, they may however remain stunted or even die out unless hydrological conditions are truly supportive of mangrove growth. 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 similar 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, such as the neap, the spring, and several inbetween during the month of maximum availability of the seeds.

Appendix: Mangrove Forests in Sri Lanka

Introduction

(Text by Abeyrathne Ekanayake Mudiyanselage)

Sri Lanka consists approximately of about 10,000 – 12,000 ha of Mangroves spread in all its bays, lagoons and estuaries, extending less than a kilometre landwards from the mean low water tidal level. The exact area of mangroves in Sri Lanka has not yet been surveyed. Mangroves are absent along exposed shorelines affected by seasonally high wave energy as in the South-western and North-eastern coasts of Sri Lanka. The highest number of lagoons has the Hambanthota District. The definition of true mangrove species is difficult, for some are obligate dwellers and some are also found in peripheral habitats. The animal species living in mangrove habitats, like mangrove plants, have to face the harsh conditions. Thus, mangrove fauna and flora shows special adaptations to the environment such as desiccation or anoxic conditions.

Adaptations to save water:

- Development of thick cuticle in plants.
- Presence of salt secreting glands in plants (e.g. Acanthus ilicifolius and Avicennia sp.)
- Glossy surfaces of leaves.

Adaptations to overcome soil structure obstacles:

- Prop roots to support the plants establish themselves on shallow soil. e.g. Rhizophora sp.
- Pneumatophores (root structures, which are not submerged) to overcome the anaerobic conditions of the soil (e.g. Avicennia sp., Sonneratia sp.).

Adaptations to overcome reproductive obstacles:

- Viviparity. Here, the seeds grow to juvenile hood while still being attached to the mother plant. When released from the mother plant during relatively favourable environmental conditions, they get attached to the shallow mud with their spike-like hypocotyls (e.g. Rhizophora sp., Bruguiera sp., Ceriops sp.).
- Special morphological structures in fruits that make dispersal more efficient (e.g. Nypa sp., Heretiera sp.).

Adaptations to overcome the amphibious nature of the environment:

- Mudskippers (Periophthalmus sp.) have fins that help them skip on land as well as on water, eyes that can see on land and under water and skins which act as additional respiratory organs.
- Terrestrial crabs are adapted to live on land for a very long time by possessing brachial chambers covering the gills which are kept moist for respiration to continue.

Habitat adaptations:

- Burrowing habits. Burrows serve as places, in which various faunal species live, eat, breathe, hide and mate:

  The Common Grapsid Crab (Chiromantes sp.) burrows between Mangrove roots and in small water holes.

  The Fiddler Crab (Uca sp.) has a single burrow, which normally ends up below the water table.

  Neosermatium malbaricum has a T-shaped burrow on firm soil, which forms 2 arms immediately after the entrance.

  Neosermatium smithi has a complex burrow with a number of side arms. It builds “castles” above the ground during the rainy season.

  The Mud Lobster (Thalassina singularis) has a very complex burrow which it usually never leaves and it keeps moving soil to the surface during the nights of the rainy season.

  Polychaetes such as Branchiocapitella singularis and Marphysa boradellei reside on top soils in the rainy season and penetrate deep down in dry weather.

- Living attached to Mangrove plants:

  Crassostrea sp. live attached to the roots of Rhizophora sp. and Bruguiera sp. along with other gastropods, bivalves, crabs, shrimps, barnacles, isopods, amphipods, polychaetes, sponges and fish.

  Littorina scabra and Cassidula musterina occur on Mangrove leaves and stems.

  Metapograpsus messor is a Grapsid Crab capable of climbing Mangrove roots.

Mangrove species are composed of two types of plant communities as follows:

1. True Mangroves: Trees and plants, which are seen predominantly in the amphibious Mangrove ecosystem. 14 species have been identified in Sri Lanka.

   e.g. Rhizophora sp., Bruguiera sp., Sonneratia sp., etc.

2. Mangrove Associates: Trees and plants, which are more terrestrial but form a part of the Mangrove ecosystem. 12 species have been identified in Sri Lanka.

   e.g. Cerbera sp., Nypa sp., Dolichandrone sp.

Genus	Species	Sinhala	Tamil	Description	Leaves	Flower	Fruit
Family: Rhizophoraceae							
Rhizophora	*R. mucronata* *R. apiculata*	Kadol, Maha	Kandal	Fringing species with prop roots and stilt roots.	Thick, leathery, light coloured leaves with red spot-like tannin glands.	4 Persistent sepals, 4 white petals.	Green or brown viviparous fruits. Contains one seed.
Bruguiera	*B. gymnorhiza,* *B. cylindrica* *B. sexangula*	Malkadol	Sirikanda	Knee roots instead of prop roots.	Leathery leaves. Underside light coloured. Interpetiolar leaflets	red yellow, orange or green calyx 7 – 16 sepals	
Ceriops	*C. tagal* *C. roxburghiana*	Punkanda, Rathugas	Chirukandal	Occur in Sri Lanka as short shrubs with stilt roots.	Leathery, opposite, wider towards the apex.	Small and greenish yellow in colour. Arise in clusters. 5 – 6 Sepals and petals.	Viviparous with thin, long hypocotyls.
Family: Sonneratiaceae, Lythraceae							
Sonneratia	*S. alba,* *S. apetala,* *S. caseolaris*	Kirala, Kirilla	Kinna	Small trees with pendulous branches. Stumpy pneumatophores.	Dull green foliage	Persistant calyx and style, 6 – 9 green sepals and 6 petals. *S. apetala* - no petals	Spherical berry with numerous seeds.
Family: Avicenniaceae, Verbenaceae							
Avicennia	*A. marina,* *A. officinalis*	Manda, Madagas	Kanna	Prefers dry climate. White Bark.	Underside is whitish	Panicle inflorescence with yellow sessile flowers. Odour of bee's honey.	Greyish green capsule of about 1 inch length. Contains 1 seed.
Family: Myrsinaceae							
Aegiceras	*A. corniculatum*	Heen Kadol Kehelakan gas Modarakan na	Vethilikanna Modarakann a	The bark is white or brown in colour. Much branched bush.	Leathery, smooth, rounded. Sometimes notched at the apex.	Umbel inflorescence bears white cylindrical, curved flowers. 5 Sepals twisted to the left and overlapping to the right.	Curved, viviparous. Pericarp splits vertically.
Family: Acanthaceae							
Acanthus	*A. ilicifolius*	Katu Ikili Mulli	Mulli	A 2 to 4 foot long shrub with small prop roots.	Large, thorny, opposite, very short petioles.	Large, sessile, borne on spikes, surrounded by 2 bracts and a bracteole. Calyx has 4 sepals.	1 inch long capsule which occurs rarely.

Genus	Species	Sinhala	Tamil	Description	Leaves	Flower	Fruit
Family: Combretaceae							
Lumnitzera	*L. racemosa, L. littorea* (very rare)	Bariya	Tipparethai	An evergreen, large shrub with a smooth, purplish bark.	Spiral, fleshy, apex rounded and notched. Leaf base pointed. Very short petiole.	Small, sessile, white coloured, arranged on a spike. Green persistent calyx with 5 sepals, 5 white petals.	Woody, green, small, oblong and narrow at both ends, single seed.
Family: Euphorbiaceae							
Excoecaria	*E. aggalocha* (common)	Thela Thelakiriya	Thilla	Small tree. Grows on mud or sand. Bark is light grey. Latex poisonous.	Oval, acute at base, acuminate, crenate, alternate. Mature leaves are red in colour.	Small, 3 sepals, 3 stamens, no petals.	
Family: Meliaceae							
Xylocarpus	*X. granatum, X. molluccensis*	Mutti Kadol	Somuntheri Kadal Manga	Small tree with dark brown petiole and bark.	Alternate, compound, large with 1 – 3 pairs of leaflets.	Borne on long flowering branches. Calyx has 4 sepals. 4 Rounded petals with overlapping edges.	Large, spherical, corky leathery. Splits into 4 when dry.
Family: Verbenaceae							
Clerodendron	*C. inerme*	Wal gurenda Gowinda	Pinchi Pinari Pichuvilathi	Small, much branched shrub with dark brown bark.	Small, oval in shape.	Cymose inflorescence, exerted stamen and style.	
Family: Palmae							
Nypa	*N. fruticans*	Gin Pol		The only mangrove palm. Occurs along tidal rivers. Short, stout subterranean rhizome.	Erect with long petioles.	Characteristic inflorescence.	Large fruiting head.
Family: Pteridaceae, Polypodiaceae							
Acrostichum	*A. aureum*	Karan Koku	Minni	The only mangrove fern. Erect, stout, strong rhizome.	Pinnate, leathery, venation reticulate and ex-indusiate.		

Genus	Species	Sinhala	Tamil	Description	Leaves	Flower	Fruit
Family: Sterculiaceae							
Heretiera	*H. littoralis*	Etuna Homadiriya	Chomuntiri	Found away from the shore, also around freshwater streams. The bark is longitudinally furrowed.	Green upper surface with silvery under surface.	Flowering branches are hairy No petals, 5 sepals.	2 – 3 inches long, hard and woody fruits
Family: Bignoniaceae							
Dolichandrone	*D. spathaceae*	Diya Danga	Mankulanchi Vilpadri	A tree with high branches.	Leaf scars are prominent on stem. 7 – 13 glossy leaflets with short stalks.	3 – 4 white flowers in a cluster. Long corolla tube.	1 inch long follicle with a corky testa and many seeds
Family: Apocynaceae							
Cerbera	*C. mangha*	Gon Kaduru	Nachchukkai	Trees with prominent leaf scars.	Linear, lanceolate, alternate.	Large, white flowers with 5 petals. Calyx tube has 5 sepals.	Smooth, rounded, fibrous drupe.
Family: Leguminoseae							
Derris	*D. scandens, D. uliginosa*	Kala Wel	Tekil	Common mangrove creeper.	Oblong, lanceolate, acute at base and emarginated at apex.	White flowers on a slender peduncle.	

References and Links

Information on ecological hydrological mangrove restoration: www.mangroveactionproject.org and www.mangroverestoration.com

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