Mangroves

Coastal Ecosystems Series (Volume 2)

Sriyanie Miththapala

Ecosystems and Livelihoods Group Asia, IUCN

Bundesministerium
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Contents

What are mangroves?

A mangrove is a woody plant or plant community which lives between the sea and the land, in areas which are flooded by tides for part of the time. Mangroves make up one of the world's most unique ecosystems because they thrive where no other trees can survive – in the transition zone between the ocean and land. They are also among the world's most productive ecosystems.

- The term mangrove is used to mean both plants and the habitat in which these plants are found.
- The word 'mangrove' is thought to be a combination of the Portuguese word '*mangue*' and the English word 'grove.'
- In French the word is '*manglier*', in Spanish, '*manglar*' and in Suriname, '*mangro*.'
- All these words are thought to be derived from the Malaysian word '*manggi-manggi*' meaning 'above the soil.' (Kathiresan and Bingham, 2001)

Because mangroves are found in this transition zone – where the tide rises and falls daily, where salinity changes with this rise and fall of the tide and where the content of oxygen in the soil is low – both the flora and fauna of this ecosystem have developed very distinct adaptations.

Adaptations for coping with daily changes in tides

When the tides shift daily, a) the substrate on which plants grow is not stable and b) the salinity changes. Mangroves plants have developed stilt roots for support. These roots do not penetrate deep into the soil but extend sideways providing support to the stem. A particular mangrove species in Ecuador grows up to about 60m but is supported in unstable soil by such roots (Kathiresan & Bingham, 2001).

Sessile[1] fauna adapt to this movement of tides by anchoring themselves against the tide (e.g., mussels and barnacles) and mobile fauna, by hiding from or avoiding the tide (burrowing in the mud or climbing up and down tree trunks as many species of crab do). Mudskippers are well adapted to varying tide levels and can cope with complete exposure to the air to complete submersion. This fish is able to survive out of water because its gills are housed within an enlarged cavity which contains both water and air. The tissue within the cavity can absorb oxygen from the air as long as it remains moist, so it functions like a kind of lung.

Mangrove plants cope with changes in salinity (high salt content, lack of fresh water) by evolving both xeromorphic[2] and halophytic[3] characteristics. They have leathery, wax-like leaves that reduce water loss from the plants and/or stomata[4] that are positioned in such a way as to reduce evaporation (Kathiresan & Bingham, 2001).

[1] *Sessile species* are species that do not move from one place to another.

[2] *Xeromorphic* characters are adaptations that enable plants to conserve water.

[3] *Halophytes* are plants that show adaptations for living under high salt conditions, such as plants that live near the sea shore.

[4] *Stomata* are breathing pores found on leaf surfaces.

They avoid heavy salt loads in their tissues by excluding salt (through a process of ultrafiltration by plant roots) in some species. Others take up salts but excrete them through specialised salt glands. Still others dilute salt by holding extra water in fleshy leaves (Kathiresan & Bingham, 2001).

Faunal species also have many adaptations for dealing with high salt concentrations in the environment. In the crab species *Ucides cordatus* and *Carcinus maenas,* less sodium is absorbed when the crab is immersed in sea water and more abosorbed when the salinity drops (Harris et al., 1993 in Kathiresan & Bingham, 2001). Mangrove lizards have a nasal gland that secretes salt into the nasal cavity from which it is sneezed out; crocodiles use a number of salt glands located on the tongue and sea turtles have salt glands that are modified into tear glands in their eyes; many other examples are found among reptiles such as sea snakes (Hutchings & Saenger, 1987). Other animals (such as fish) can adjust the salt concentration of their body depending on the salinity of the water around them.

Adaptations for coping with low oxygen content

Very often, mangrove soils are oxygen deficient or without oxygen (i.e., they are *anaerobic*). Therefore, both the flora and fauna of mangroves have special adaptations to counter this deficiency. The most prominent of these characteristics in flora is the presence of breathing roots or *pneumatophores* which are above-ground (aerial) roots that are filled with spongy tissue and have numerous small holes in the bark, which allow oxygen to be transferred to the root system below the ground.

There are four types of breathing roots: a) stilt or stilt type with breathing pores as seen in *Rhizophora*, b) pencil or peg type as seen in *Avicenni*a and *Sonneratia*, c) knee type (growing upwards and then immediately downwards) as seen in *Bruguiera* and d) ribbon or plank type (curving in a snake-like fashion so that wavy, plank-like structures extend outwards from the trunk base) as seen in *Xylocarpus granatum.*

These roots also have special tissues containing air spaces between them called *aerenchyma* tissue. This allows for more gas exchange (http://cropsoil.psu.edu/sylvia/glossary.htm).

It was originally thought that the way mangroves reproduced was an adaptation to low oxygen content and/or drowning. Plant embryos need adequate oxygen to grow; because there is not enough oxygen in the soil and it is waterlogged, fertilised seeds do not drop from the tree but develop directly into seedlings while still on the parent tree. This is called *vivipary*. Once they have germinated, these seedlings grow to form a propagule that can disperse. Once these propagules fall into the water, they float until they reach a place where they can root and grow successfully (Kathiresan & Bingham, 2001). However, currently, this hypothesis is being challenged (Shi et al. 2005).

Types of mangroves

There are different kinds of mangroves. The following is extracted from Ludo and Snedaker (1974) but only describes some types.

Riverine mangroves, as their name implies, occur along rivers and streams and are flooded daily by the tides. Riverine mangroves are found in Kuraburi and Kapoe, Ranong, Thailand.

Fringe mangroves are found along protected coastlines, islands and the exposed waters of bays and lagoons. They are flooded periodically by tides. Fringe mangroves are found in Honda Bay, Palawan, Philippines.

Basin forests are located inland in depressions that channel runoff from inland to the coast. They are flooded irregularly. Basin mangroves are found in Maduganga, Galle, Sri Lanka.

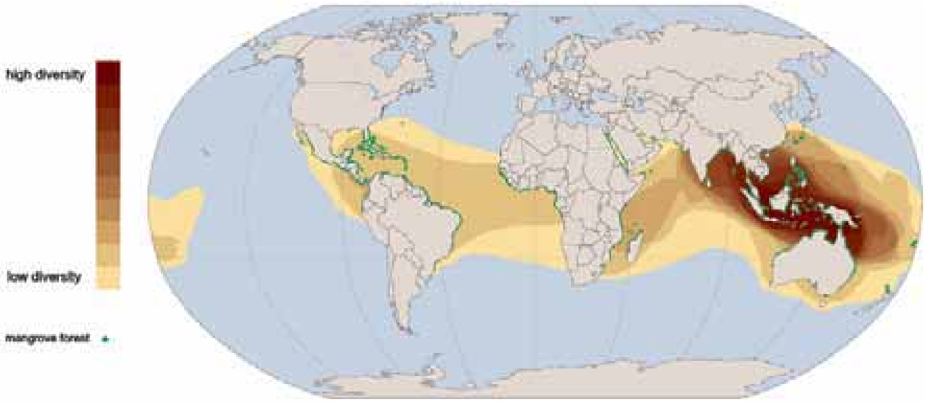
Mangrove Zonation

Each type of mangrove has not only a different composition of species but also a difference in the proportions of trees and shrubs etc.

Within a mangrove, different species are not distributed evenly. There is a distinct zonation of species within a mangrove. This zonation is dictated by the height of the tide, height of land and salinity at a given level, as well as biological factors such as the ability to outcompete another species. *Rhizophora* and *Xylocarpus* have high tolerance to both salt and flooding, so they are found close to the shoreline where conditions are harsh. *Bruguiera* and *Sonneratia* - which are less salt tolerant - are found more inland.

Where are mangroves found in the world?

Mangroves are found between the latitudes of 32ºN and 38ºS of the globe and also in the mouths of estuaries and in intertidal areas. Approximately 1/4th of the world's tropical coastline comprise mangrove ecosystems which are estimated to extend along an area of between 167,000 and 181,000km^2, in 112 countries (Spalding et al., 1997; Kathiresan & Bingham, 2001). Forty percent of mangroves occur in South and Southeast Asia regions (Spalding, 1997) and the single largest area of mangroves in the world lies in Bangladesh, in the Sunderbans, extending over 600,000ha (Bandaranayake, 1998).



Groombridge and Jenkins (2002)

What is the importance of mangroves?

Mangroves are one of the most productive ecosystems in the world and provide humans with many services.

Provisioning services:

The flora of the mangroves provides many goods to humans.

- All over the world, the timber of mangrove flora is used to build and make houses, furniture, rafters, fences and boats. About 300,000m^3 of mangrove wood is extracted annually from the Sunderbans.
- Mangrove wood is also used as fuelwood and still provides 90% of the fuel used in Viet Nam.
- The leaves of species such as the Mangrove Palm (*Nypa)* and Screw Pine (*Pandanus*) are used for thatching and weaving. Because it is light, the wood of *Cerbera manghas* is used in Sri Lanka to carve masks and puppets.
- The breathing roots of various *Sonneratia* spp – with their aerenchyma tissue – are used to make corks and fish floats.
- Because of their salt glands, mangrove plants are a source of sodium and the ash of some species such as *Avicennia* is used as soap.
- The bark of many species produces gums and tannins, which are still used in the Indian subcontinent for curing leather and fish nets.
- In the Bangladesh and India, honey from mangroves is an important local industry, producing 20 tonnes of honey every year from 200,000ha of mangroves.
- Mangrove leaves, fruits, shoots and roots serve as vegetables and edible fruits in many parts of the region and other non-timber forest products such as sugars and drinks are extracted from different species such as *Sonneratia*.
- About 70 different mangrove plants are listed as having traditional medicinal uses for treatment of various ailments and diseases. (All sources above: Bandaranayake, 1998.) A study in Indonesia estimated that mangroves provide a potential net benefit of 1,500 per km^2 for medicinal plants (Ruitenbeek, 1992). For example, *Bruguiera, Rhizophora, Lumnitzera* are used for various ailments such as diarrhoea, blood pressure and angina (Upadhyay et al., 2002).
- In parts of Indonesia, traditional use of mangrove products contributes up to a half of the income for the poorest households, and in southern Thailand, is thought to generate products worth almost a quarter of per capita GDP among coastal villages (Ruitenbeek, 1992; Sathirathai, 1998).

Mangrove fauna are as important. While mangroves are permanent or temporary habitats for many aquatic animals, they are also hatcheries and nurseries for many marine fish. Juveniles remain in the mangrove habitat until they are less vulnerable to predators and then move into the open seas. In addition, the floor of mangroves holds crustaceans and molluscs, many of which are commercially important.

- It is estimated that up to 80% of global fish catches are directly or indirectly dependant on mangroves (Sullivan, 2005).
- Annual commercial fish harvests from mangroves have been valued at 6,200 USD per km^2 in the United States to 60,000 USD per km^2 in Indonesia (Bann, 1997).
- The annual market value of seafood from mangroves is estimated at 7,500-167,500 USD per km^2 (Millennium Ecosystem Assessment, 2005).

Regulating services:

Mangroves protect the shoreline.

Mangrove plants, which are adapted uniquely to regular movement of tides (i.e., to withstand the force of the tides) are, therefore, also able to withstand stronger forces of waves and wind energy that occur with extreme weather events. Depending on their ecological condition, they absorb at least 70-90% of the energy of the waves, acting as physical buffers between the elements and the shore (UNEP-WCMC, 2006). It has been estimated that a 1.5km belt of mangrove plants may be able to reduce entirely the force from a wave that is one metre high (Mazda et al., 1997). Mangroves provide physical protection from storm surges, cyclones and other such extreme weather events (UNEP-WCMC, 2006). Traditionally, fishermen have used mangrove areas for anchoring boats during monsoons.

The role that mangroves played in protecting communities during the December 2004 Indian Ocean tsunami has been argued hotly and has led to a great deal of controversy. This is because the protective function of a mangrove to a community can only be measured given that all other factors – wind speed and direction, wave energy, height and direction, the geography of the shoreline etc. – remain equal. A study carried out in the tsunami affected districts of Sri Lanka shows clearly that mangroves did play an important role in storm protection, but that this protection depended on the quality of the mangrove habitat. Degraded habitats or habitats with mangrove associate species instead of true mangrove species did not provide adequate protection (Dahdouh-Guebas et al., 2005).

Mangroves serve to reduce the effects of flooding.

Mangrove roots and organic matter in mangroves function to trap sediment, and also act like a sponge to absorb flood water.

Mangroves trap pollutants.

Mangrove roots also function as filters to sift out pollutants that reach the sea from inland waters. Therefore, they help improve the quality of water reaching ecosystems in the sea, in particular, sensitive ecosystems such as coral reefs.

Supporting services:

Mangroves are important in carbon sequestration.·

Carbon sequestration is the process through which plant life removes carbon dioxide (CO_2) from the atmosphere and stores it as biomass. Plants and oceans are, therefore, called carbon sinks. It is estimated that mangroves sequester large amounts of carbon, approximately 25.5 million tonnes of carbon every year (Ong, 1993) and also that mangroves provide more than 10% of essential dissolved organic carbon that is supplied to the global oceans from land (Dittmar et al., 2006).

Mangroves promote land accretion.[5]

Because of their extensive and tangled supporting root systems, mangroves trap sediments and prevent them from washing into the sea. They function much like a living groyne to build up sediment, stabilising the ground and fixing mud banks (Broom et al., 1981). Therefore, they prevent erosion. They also protect coral reefs from sedimentation.

Mangroves support the sustainance of coastal biodiversity.

Mangroves are diverse ecosystems that support unique wetland communities of plants and animals.

> The Maduganga mangrove in south western Sri Lanka has 303 species of plants and 248 vertebrate species (70 fish, 12 amphibians, 31 reptiles, 124 birds, 24 mammals) as well as nesting and roosting sites of water birds, crocodiles and bats (Bambaradeniya et al., 2002).

Mangroves are primary producers.

Like all green plants, mangroves manufacture their own food (organic material) from inorganic materials such as sunlight, carbon dioxide and water. This basic service that is provided by this ecosystem contributes to supporting life on earth.

Mangroves enrich nutrients in coastal waters.

Decaying organic matter from mangroves is broken down into free nutrients that are washed away to the sea. This serves to enirch coastal food webs, and with it, coastal fishery production.

[5] Accretion is the slow addition to land by the deposition of sediment carried in water.

Cultural services:

Mangroves provide aesthetic services

In recent decades, visitors to mangroves have increased, as they learn to appreciate the value and uniqueness of mangrove ecosystems.

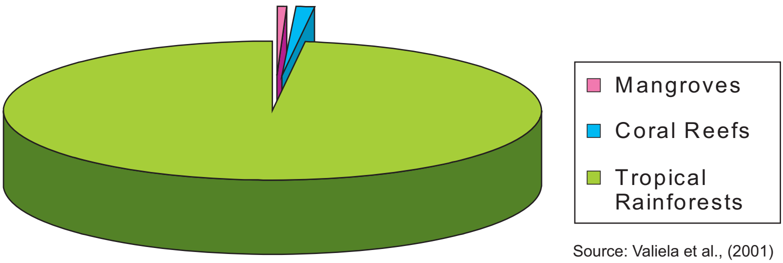
Mangroves sustain traditional fishing practices.

Brush pile fisheries (traditional fishing methods in Bangladesh and Sri Lanka) and other traditional fisheries in South Asia are being sustained because of mangroves.

What are the threats to mangroves?

Although the Indian Ocean has the largest mangrove tracts in the world and the Indo-Malayan region is the global centre for mangrove diversity, this is also the area in which the rate of loss of mangroves have been the highest in the last ten years. Less than half the original extent of mangroves remain in the world today and half of the remaining habitats are degraded. Globally, the rate of mangrove deforestation is between 2-8% per year. As a result, mangroves are among the world's rarest and most threatened ecosystems. (Globally, coral reefs cover nearly twice the area of mangroves, and tropical and subtropical forests more than 125 times as much.) (EJF, 2005).

Extent of mangroves remaining, compared to coral reefs and tropical rainforests



Source: Valiela et al., (2001)

There are many threats to mangroves, as detailed below.

Overexploitation of mangrove products:

It is estimated that 26% of mangrove habitats are degraded because of over-exploitation for fuelwood and timber production (Valiela et al., 2001).

Tannins, extracted from several mangrove species (such as *Rhizophora*), are used in the leather industry in many countries in Asia. It is reported that over-harvesting of wood for tannins, as well as for charcoal production, is destroying mangrove habitats in Viet Nam (http://www.fao.org/docrep/v0782e/v0782e06.htm).

Habitat destruction:

a) Shrimp farming and aquaculture:
According to a recent study, shrimp culture is the greatest threat to mangroves, contributing to 38% of mangrove habitat loss, with other aquaculture accounting for another 14% (EJF, 2005). Once mangroves are cleared, the coast is made vulnerable to erosion and coral reefs and seagrass beds become vulnerable to sedimentation. In order to grow as much shrimp as possible, shrimp farmers add artificial feeds with chemical additives (including chlorine) and insecticides (such as malathion and parathion - which persist in the environment) as well as antibiotics to prevent disease. This chemical soup is often dumped into surrounding land or waterways, harming aquatic life, as well as people, who depend on these waterways. In addition, land that is adapted to the ebb and flow of the tide is now flooded permanently, and this damages the soil. Often, in about five years, shrimp farms are abandoned as they are no longer viable (http://oceans.greenpeace.org).

- Worldwide, shrimp farming has grown at an annual average of over 18% since 1970 (EJF, 2005).
- Shrimps are a valuable, internationally traded seafood product, valued at an estimated 50-60 billion USD (EJF, 2005).

b) Coastal development and land reclamation:
Coastal development, conversion to agriculture and land reclamation remain major causes of mangrove destruction. Historically, mangroves and wetlands have been considered wastelands which needed draining, filling and development (Conde & Alarcón, 1993).

In India, in the last three decades, 40% of mangrove habitats on the western coast have been converted to agriculture and for urban development (Upadhyay et al., 2002).

Habitat degradation: diversion of inland freshwater

Mangroves are affected seriously by inland freshwater diversion schemes: it is estimated that 11% of mangrove habitats are degraded globally by inland water extraction (EJF, 2005).

The Indus river, which flows through Pakistan, supports some 129,000ha of mangrove forests. Over the last 60 years, a series of dams, barrages and irrigations schemes have been built in upstream parts of the Indus river. As a result, only 15% of Indus river mangroves are considered healthy and the rate of degradation of mangrove forests in the Indus Delta has been estimated at 6% between 1980 and 1995 (Stedman-Edwards, 2000).

Pollution

Inland farming, housing and development result in chemical and sewage pollution, which can over-fertilise coastal waters, causing the growth of 'tides' of algae which rapidly reduce productivity by blocking sunlight from reaching below water surfaces. These algal tides can also turn toxic.

A toxic algal tide was observed in the South China coast, destroying fish farms and causing food poisoning (Farnsworth & Elison, 1997). These algal outbreaks have also caused mass deaths of sea mammals – for example, 100 critically endangered Mediterranean monk seals (*Monachus monachus*) died on the Mauritian coast in 1997 as a result of algal tides (Spalding, 1998).

Invasive Alien Species (IAS)

IAS do not remain confined to the area into which they were introduced; they become established in natural ecosystems and threaten native species. IAS pose a threat to the provisioning services of mangrove species.

Common cordgrass (*Spartina anglica*) introduced intentionally in 1960 and 1980 to protect tidal banks in coastal China is now causing the death of mangroves - which have died through competition with Common cordgrass (Xia et al, 2006).

Climate Change

Changes in precipitation as a result of climate change will retard growth, productivity and seedling survival in mangroves. Decreased precipitation and increased salinity could favour more salt-tolerant species and change species composition, affecting mangrove provisioning services. Increased natural disasters will increase physical damage to mangroves. Sea level rise will result in the loss of land occupied by mangroves. Changing wave climates increase coastal erosion and damage mangrove habitats. Salt water intrusion will also alter the salinity regime in mangroves, changing the species composition. Climate change, in short, will have serious impacts on mangroves, affecting their provisioning, supporting and regulatory services.

In 1997, Typhoon Linda destroyed both large natural mangrove trees and plantations of *Rhizophora* trees in southern Viet Nam (AIMS, 1999).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At a glance: services provided by, and threats to mangroves

(References as in text.)

Mangrove Services	Description	Threats
Provisioning (Goods)		
Food (finfish, shellfish, vegetables and other plant parts)	Mangroves are permanent or temporary habitats for many aquatic animals and are also hatching and nursery grounds for many marine fish. It is estimated that up to 80% of global fish catches are directly or indirectly dependant on mangroves.	Over-exploitation (shrimp and other aquaculture, unsustainable fishing practices, over-harvesting); coastal development and land reclamation; and inland freshwater extraction.
Timber and fuelwood	All over the world, the timber of mangrove flora is used to build houses, make furniture, rafters, fences, bridges, poles and boats. Mangrove wood is also used as fuelwood and still provides 90% of the fuel used in Viet Nam.	Over-exploitation (shrimp and other aquaculture, unsustainable fishing practices, over-harvesting); coastal development and land reclamation; and inland freshwater extraction.
Medicines	About 70 different mangrove flora are listed as having traditional medicinal uses for treatment of various ailments and diseases. In parts of Indonesia, traditional use of mangrove products contributes up to a half of income among the poorest households, and in southern Thailand is thought to generate products worth almost a quarter of per capita GDP among coastal villages.	Over-exploitation (shrimp and other aquaculture, unsustainable fishing practices, over-harvesting); coastal development and land reclamation; and inland freshwater extraction.

Mangrove Services	Description	Threats
Provisioning contd.		
Other Non Timber Forest Products (NTFP)	The leaves of species such as *Nypa* and *Pandanus* are used for thatching and weaving and light woods such as *Cerbera manghas* used to carve masks and puppets. The breathing roots of various *Sonneratia* spp are used to make corks and fish floats. Mangrove plants are sources of sodium and the ash of some species such as *Avicennia* is used as soap. The barks of many species produce gums and tannins, which are still used in the Indian subcontinent for curing leather and fish nets. In the Bangladesh and India, honey from mangroves is an important local industry. Mangrove leaves, fruits, shoots and roots serve as vegetables and edible fruits in many parts of the region and other non-timber forest products such as sugars and drinks are extracted from different species.	Over-exploitation (shrimp and other aquaculture, unsustainable fishing practices, over-harvesting); coastal development and land reclamation; and inland freshwater extraction. It is reported that over-harvesting of the wood for tannins as well as for charcoal production is destroying mangrove habitats in Viet Nam.
Supporting services		
Biodiversity	Because mangroves grow between the land and the sea, mangrove species are uniquely adapted to live in extreme and variable conditions. Mangroves, therefore, carry an unique assemblage of flora and fauna found in no other ecosystem.	Mangrove deforestation for shrimp and other aquaculture; over-exploitation (unsustainable fishing practices, over-harvesting); coastal development and land reclamation; inland freshwater extraction; pollution; and spread of IAS. Mangroves in the southwestern Sri Lanka are being affected by the spread of *Annona glabra* and *Wormia suffruticosa.*

Mangrove Services	Description	Threats
Supporting services contd.		
Protecting the shoreline	Mangroves act as physical buffers between the elements and the shore, and can absorb at least 70-90% of the energy of the waves, depending on their ecological condition.	Mangrove deforestation for shrimp and other aquaculture; over-exploitation (unsustainable fishing practices, over-harvesting); coastal development and land reclamation.
Promoting accretion	Mangroves function much like a living groyne to build up sediment, stabilising the ground and fixing mud banks. Therefore, they prevent erosion. They also protect coral reefs from sedimentation.	Mangrove deforestation for shrimp and other aquaculture; over-exploitation (unsustainable fishing practices, over-harvesting); coastal development and land reclamation.
Primary production	Estimated net primary productivity values of up to 7.5g C/m/day for mangrove forests in Florida, USA. In comparison, a heavily fertilised and managed sugarcane field has a maximum net productivity of 10g C/m/day.	Mangrove deforestation for shrimp and other aquaculture; coastal development; land reclamation and extraction of river sand.
Enriching nutrients	It is estimated that every time the tide goes out, it takes with it as much as 12,500 tonnes of food for marine life each year.	Mangrove deforestation for shrimp and other aquaculture; coastal development and land reclamation; inland freshwater extraction; and pollution.
Regulating services		
Sequestering carbon	Mangroves are important carbon sinks, and sequester approximately 25.5 million tonnes of carbon every year. They also provide more than 10% of essential dissolved organic carbon that is supplied to the global ocean from land.	Mangrove deforestation for shrimp and other aquaculture; over-exploitation (unsustainable fishing practices, over-harvesting); coastal development and land reclamation.
Trapping pollutants	Mangrove roots that help trap sediments also function as filters to sift out pollutants reaching the sea from inland waters.	Mangrove deforestation for shrimp and other aquaculture; coastal development and land reclamation; inland freshwater extraction; and pollution.

Mangrove Services	Description	Threats
Regulating services contd.		
Reducing floods	Mangroves provide physical buffering to prevent floods.	Mangrove deforestation for shrimp and other aquaculture, overexploitation, coastal development and land reclamation.
Aesthetic services		
Mangroves provide a recreational habitat for visitors	The foreign visitor recreational value of a mangrove in the western coast of Sri Lanka is estimated at 1196 USD/ha/year.	Over-visitation; user conflicts with traditional fishing practices (i.e, damage to by motor boats): irresponsible trash disposal

What is being done to conserve mangroves?

Setting aside protected areas.

One of the surest methods of ensuring the protection of habitats is to set aside protected areas where human use is restricted to varying degrees.

Worldwide, there are over 700 protected areas containing mangroves (UNEP, 2006).

Prevention of habitat destruction/ degradation through legislation

There is a great deal of variation in the national laws for Integrated Coastal Management in Asian countries and in their enforcement. There is unclear definition of the coastal zone in some countries; unclear property rights in the coastal zone in others; little local level participation in decision-making and inadequate sharing of benefits of the use of mangroves and other coastal resources with coastal communities; and inadequate zoning and other land use controls (IUCN, 2006). Mangrove ecosystems, therefore, tend to 'fall through the cracks' (IUCN, 2006).

In Sri Lanka, the Coast Conservation Act governs the coastal zone, but mangroves are governed by the Forest Act. This causes conflicts related to jurisdiction and poor enforcement of both laws (IUCN, 2006).

The most extensive treaty for the protection of mangroves all over the world is The Convention on Wetlands (popularly known as the Ramsar Convention), signed in Ramsar, Iran, in 1971. This is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.

- There are presently 155 Contracting Parties to the Convention, with 1675 wetland sites, totalling 150 million ha, designated for inclusion in the Ramsar List of Wetlands of International Importance.
- There are 182 Ramsar sites in south, southeast and far eastern Asia.

(Source: http://www.ramsar.org/)

Mangrove restoration

After the tsunami of December 2004, there was a rush to replant mangroves where damage had been severe, given that, in many cases, mangroves had provided some protection from the waves. Although mangrove restoration is ongoing in most tsunami affected countries and it appears to be simple and cheap, it is, in fact, complex and difficult. What is needed is the correct mix of species, 'not a collection of branches, roots and mud ' (IUCN, 2006). Monocultures will not provide this. Because of this, many post tsunami mangrove restoration projects have failed.

Also, the selection of sites was unsuitable in many cases, and mangroves were planted in areas that never had mangroves before. Further if there were human stresses – such as shrimp farming and pollution – prior to the tsunami and those stresses still continued after restoration, then the process will fail (IUCN, 2006).

However, there are also several success stories of mangrove restoration in the region.

Creating awareness:

In the past, mangroves areas were considered to be swamps with no value to humans, so that development was made easy through acquisition of mangrove habitats. However, in the last decade, a concerted effort has been made to create awareness among the public that 'wetlands are not wastelands' (Spray & McGlothin, 2004). Since 1997, February 2nd of each year has been designated as World Wetlands day.

Awareness among the public has led to increased tourism to mangrove areas.

- The Xixi National Wetland Park, China has had over 977,000 visitors since its opening in 2005 (Wetlands Link International, 2007).
- The Osaka Nankou Bird Sanctuary (ONBS), opened in 1983, was created from a landfill and wetland habitats have been regenerated for key water bird species. The sanctuary has about 100,000 visitors per year, including many schools (Wetlands Link International, 2007).

There are many databases on the Internet that have a wealth of information about mangrove ecosystems worldwide. Some of these are listed below.

- The Global Mangrove Database and Information Center GLOMIS (http://www.glomis.com/) is a worldwide database on mangroves, satellite images and articles.
- The World Atlas of Mangroves (http://www.fao.org/forestry/site/mangroveatlas/en/) provides information per country of mangrove distribution, areas estimates, status and trends and species checklists.
- Wetlands International (http://www.wetlands.org/) gives access to publications, newsletters, projects and photographs.
- The Ramsar Convention site (http://www.ramsar.org/) describes wetlands and discusses wise use and has many manuals for practitioners.
- EarthTrends - the Environmental Information Portal (http://earthtrends.wri.org/) has country profiles and maps for coastal ecosystems.

Mangrove valuation:

While much time and effort is invested in infrastructure such as roads, bridges, ports, and water treatment plants, investment in natural infrastructure is often neglected. Despite the direct link between ecosystem well-being and human well-being, ecosystem under-valuation is a continuing problem in development planning.

Although economic models traditionally have only dealt with the provisioning services (i.e, goods) of ecosystems and have ignored indirect values, there have been many recent valuation studies of mangroves that explicitly cost their various services and highlight their varied importance to human well-being.

Ecosystem service	Location of study	Value
Provisioning – food (fish)	Mangroves on the Baluchistan coast of Pakistan	One thousand three hundred USD/ha/year (95% of local income) are obtained from inshore fisheries. Mangroves provide the nursery and breeding habitat upon which up to a half of offshore commercial fish stocks (valued at around USD 900/ha) depend (Baig & Ifthikar, 2005).
	Indus River Delta, Pakistan	The annual value of catch from mangrove dependent fish species in the Indus Delta is estimated at around 20 million USD. Shrimps are particularly important, with a domestic value of 70 million USD and an export value of about 1.5 times this figure. The export of mud crabs contributes an additional 3 million USD to the regional economy (Ifthikar, 2002).
Provisioning – traditional use of mangrove products	Indonesia	Traditional use is valued at 3,000USD/ha/year, contributing up to a half of the income of the poorest households (Ruitenbeek, 1992).
	Southern Thailand	Mangroves contribute more than a quarter of per capita GDP (Sathirathai, 1998).
Protection against storms	Hambantota, Sri Lanka	2,196–9,884,000 USD per ha coastal protection in three villages (Ranasinghe & Kallesoe, 2006).

Ecosystem service	Location of study	Value
Flood protection	Muthurajawela marsh, Sri Lanka	Protective services (from floods) of the Marsh is valued at 5,394,556 USD per year (2,500 USD per ha) (Emerton & Kekulandala, 2002).
Water purification	Muthurajawela marsh, Sri Lanka	Water purification services provided by the Marsh are valued 1,803,444 USD per year (Emerton & Kekulandala, 2002).
Carbon sequestration	Ream National Park, Viet Nam	The value of carbon sequestration is the national park is valued at 3.6 million USD per year (Emerton et al., 2002).
Recreation (coastal tourism)	Maldives	Coastal tourism produces 74% of national income (Emerton, 2006).
Cost of damage to mangroves and their services (siltation and salinisation)	Indus River Delta, Pakistan	Thirty thousand households incurred average annual losses of 70,000 USD in crop damage and 45,000 USD from reduction in fish catches as a result of saltwater intrusion (Ifthikar, 2002).

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