

Mangroves for coastal defence

Guidelines for coastal managers & policy makers



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CAMBRIDGE

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About The Nature Conservancy

The mission of The Nature Conservancy is to conserve the lands and waters upon which all life depends. For general information, visit: www.nature.org. For more information about the Mapping Ocean Wealth project, visit: www.oceanwealth.org.

About Wetlands International

The mission of Wetlands International is to safeguard and restore wetlands for people and nature. Wetlands International is an independent, non-profit organisation, active in around 100 countries, which works through a network of many partners and experts to achieve its goals. For more information, visit www.wetlands.org.

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Credits

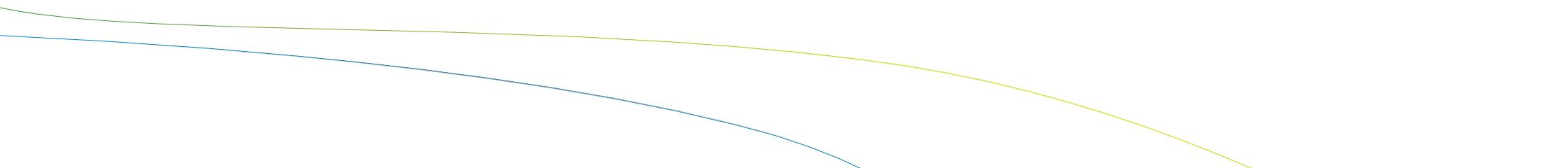
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This work forms part of the Nature Conservancy's Mapping Ocean Wealth project, a collaborative work to quantify the value of coastal and marine ecosystem services at global to local scales – www.nature.org/oceanwealth. This work is supported through a lead gift from the Lyda Hill Foundation.

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Photo front cover: Calm water amidst mangrove roots, Berau, Indonesia, by Mark Spalding

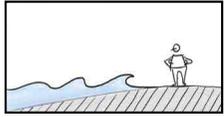
Phot back cover: People and property facing coastal hazards in Indonesia, by Stefan Verschure



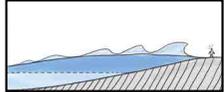
Mangroves for coastal defence

Guidelines for coastal managers & policy makers

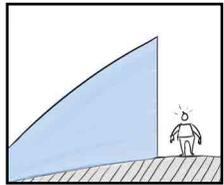
Authors: Mark Spalding, Anna McIvor, Femke Tonneijck, Susanna Tol and Pieter van Eijk



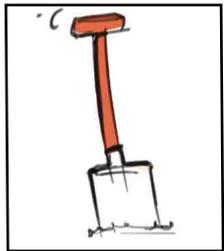
Waves



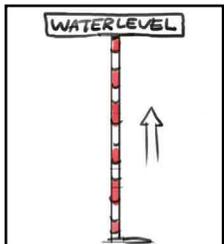
Storm Surges



Tsunamis



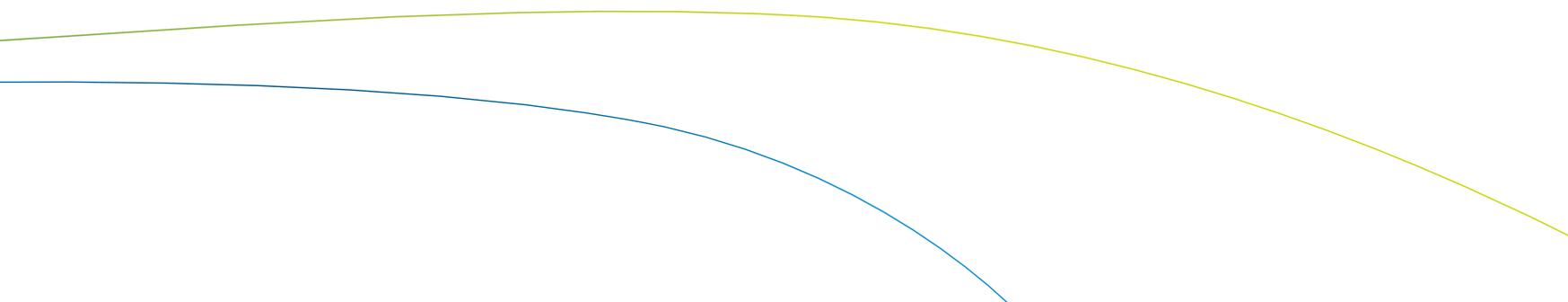
Erosion



Sea level rise

Contents

Preface	5
Executive summary	6
Section 1. Is my shore at risk?	8
Section 2. The role of mangroves in coastal risk reduction	13
2.1 Mangroves reduce wave damage	14
2.2 Mangroves reduce damage from large storms	16
2.3 Mangroves can help to reduce tsunami damage	18
2.4 Mangroves reduce erosion and bind soils together	20
2.5 Mangroves may keep up with sea level rise	22
Section 3. Managing mangroves for coastal defence	24
3.1 Integrating mangroves into coastal defence strategies	24
3.2 Mangroves as part of coastal zone management	28
3.3 Bringing the mangroves back	31
Section 4. Recognising the multiple values of mangroves	34





Asmat people entirely dependant on mangroves, Indonesia, by Wetlands International

Destruction after typhoon Haiyan in the Philippines, by Cordaid



Preface

The role of mangroves in protecting our coasts against natural hazards such as storms, tsunamis and coastal erosion has been widely acknowledged. Even so, the level of protection provided by mangroves remains subject to debate. Numerous mangrove restoration projects were instigated after the 2004 East Asian tsunami in the belief that replacing lost mangroves would reduce future risk, but others raised concerns that not all of these projects were well conceived, and that some might create greater risks by inducing a false sense of security. Can mangroves reduce waves and storm surges? How will they influence the forces of a tsunami? Do they actually contribute to stabilizing coasts and build-up of soils? Can they keep up with sea level rise? A rich scientific literature exists describing many of these processes, but careful scrutiny is needed to determine what is known or unknown, and what remains uncertain.

The Nature Conservancy and Wetlands International together with the University of Cambridge set out to map the current state of knowledge about the role of mangroves in coastal defence and put the different findings and views in perspective. An extensive review process yielded three technical reports that describe the extent to which mangroves reduce wind and swell waves, storm surges and erosion and how they build up soils in response to rising sea levels. The conclusion is that mangroves can indeed reduce risk from a large number of hazards.

This practical guidebook summarises the findings of the reviews and provides practical management recommendations to coastal zone managers and policymakers. It helps the reader to assess the risk context in a target area, to define hazard-specific mangrove management interventions and to incorporate these in risk reduction strategies, climate change adaptation protocols and broader coastal development planning. Case studies provide practical examples of mangrove management approaches and references to background information, practical tools for risk assessment and mangrove management are provided throughout the book.

restoration build and bind soils
tsunami storm surges
planning risk reduction aquaculture
sediment waves coast subsidence vulnerability
fresh water flow mangrove sea level rise
conservation wind Building with Nature
greenbelt community management
erosion resilience roots

Executive summary

The role of mangroves in protecting our coasts against natural hazards such as storms, tsunamis and coastal erosion has been widely promoted. But the supposed coastal protection services of mangroves have also been subject to debate. The Nature Conservancy and Wetlands International together with the University of Cambridge set out to map the current state of knowledge about the role of mangroves in coastal defence and put the different findings and views in perspective. The conclusion is that mangroves can indeed reduce the risk from a large number of hazards. This practical guidebook summarises the findings of the reviews and provides practical management recommendations to coastal zone managers and policymakers. These are the key messages:

Section 1. Is my shore at risk?

- Coastal managers need to understand risk in terms of hazard, exposure and vulnerability prior to determining what role mangroves can play
- The importance of mangroves in coastal defence and disaster risk reduction will depend both on the site characteristics and the local hazard context.

Section 2. The role of mangroves in coastal risk reduction

- Wind and swell waves are rapidly reduced as they pass through mangroves, lessening wave damage during storms.
- Wide mangrove belts, ideally thousands of meters across, can be effective in reducing the flooding impacts of storm surges occurring during major storms (also called cyclones, typhoons or hurricanes). This can significantly reduce flood extent in low lying areas. Narrower mangrove belts, hundreds of meters wide, will still be able to reduce wind speed, the impact of waves on top of the surge and flooding impact to some degree.
- Wide areas of mangroves can reduce tsunami heights, helping to reduce loss of life and damage to property in areas behind mangroves.
- The dense roots of mangroves help to bind and build soils. The above-ground roots slow down water flows, encourage deposition of sediments and reduce erosion.
- Over time mangroves can actively build up soils, increasing the thickness of the mangrove soil, which may be critical as sea level rise accelerates.

Section 3. Managing mangroves for coastal defence

- Mangroves don't always provide a stand-alone solution; they may need to be combined with other risk reduction measures to achieve a desired level of protection. If they are integrated appropriately, mangroves can contribute to risk reduction in almost every coastal setting, ranging from rural to urban and from natural to heavily degraded landscapes.
- For mangroves to optimally contribute to risk reduction, their conservation needs to be incorporated into broader coastal zone management planning: they need to be protected and restored, allowing wise use where possible.
- Mangroves, and their coastal risk reduction function, can recover in most places where appropriate ecological and social conditions are present or restored.

Section 4. Recognizing the multiple values of mangroves

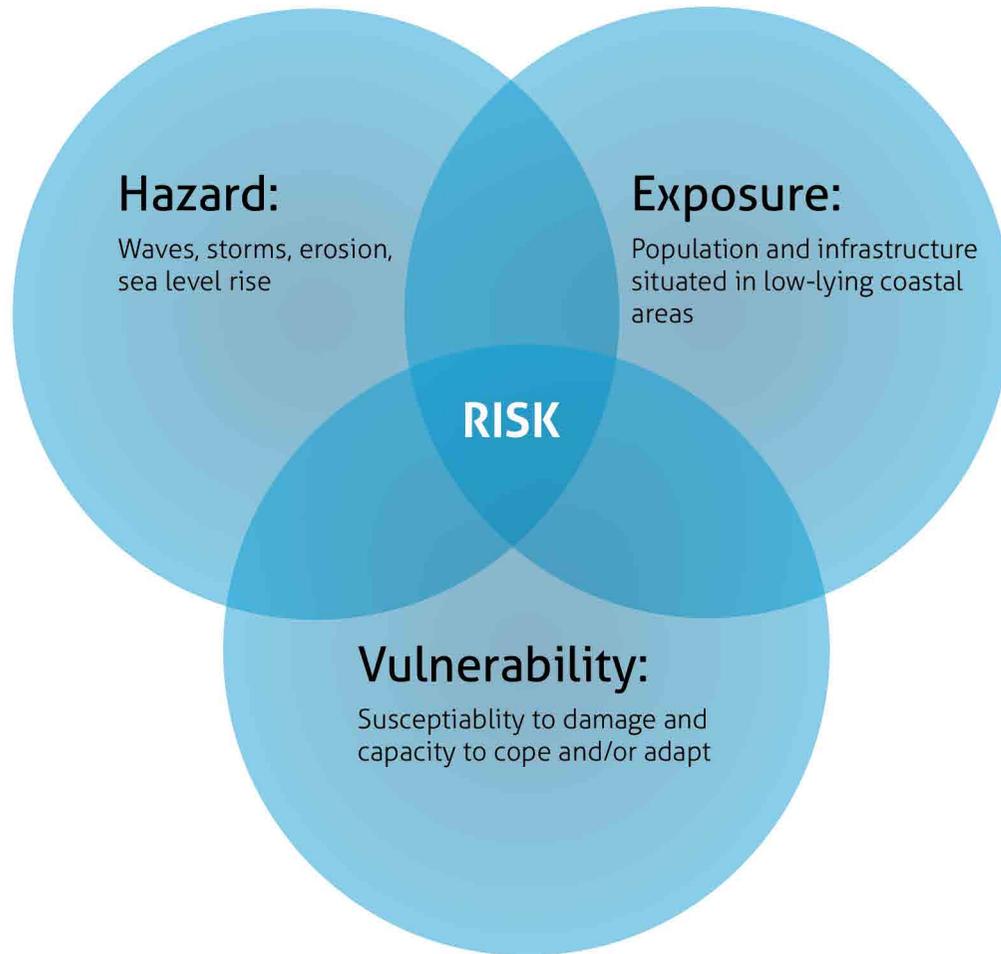
- Mangroves are among the most valuable ecosystems in the world. Decision makers, and the public, need to take full account of the many benefits that mangroves provide, and consider the true costs that may incur from mangrove loss.

Natural mangrove in Senegal, by Wetlands International



Section 1. Is my shore at risk?

To understand whether mangroves can help to reduce risk on a particular stretch of coast, it is first necessary to assess the risk context in the target area.

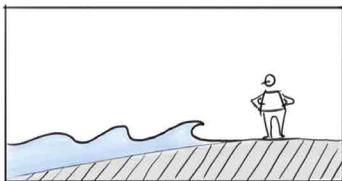


Risk is a combination of the occurrence of given hazards (frequency, intensity) and the exposure and vulnerability of people to those hazards. Coastal lands are subject to multiple natural hazards such as erosion, wave damage, tsunamis, storms and flooding, and over the long-term, rising sea levels. Such hazards may threaten lives, livelihoods, property, health and economic development. Exposure refers to the extent to which people and their property are situated in hazard zones and therefore face potential losses from extreme events. Vulnerability can be defined as the characteristics of a community, system or asset that make it susceptible to the damaging effects of a hazard. Disaster Risk Reduction aims to reduce the damage caused by natural hazards like earthquakes, floods, droughts and cyclones, by taking preventive actions. Figure adapted from the National Institute of Water and Atmospheric Research New Zealand www.niwa.co.nz

How can I tell which hazards affect my area?

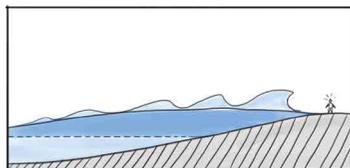
To understand the local threats from the sea it is important to consider the everyday conditions that may cause gradual "slow-onset" events, as well as the rare high impact events that cause massive damage. As every coastline is different, this assessment needs to be undertaken on a case by case basis. Often local communities have good insights into the local risk profile and any changes that have occurred over time. Other sources of information include coastal engineering reports, government records of past events and their effects, and historical media reports or other historical accounts. Various risk assessment tools may help to organize this assessment process in a structured manner (examples included under 'more information').

Sources of information for the main coastal hazards covered in this guide include:



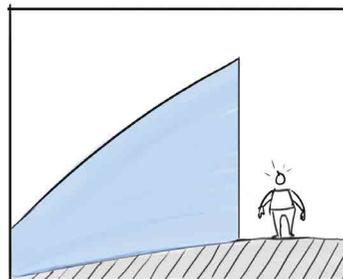
Wind and swell waves

The shape of the coastline and the depth of near shore waters both exert a strong influence over the patterns of waves reaching the shore. Some mangrove coasts are relatively exposed to wind and swell waves, but in more sheltered areas in estuaries and behind barrier islands such waves may only occur during major storms. Alongside local knowledge, useful information on the local patterns and behaviour of wind and swell waves near the shore can be gained from meteorological records of wind speeds and topographical maps showing the slope of the seabed.



Storm surges

Global and regional storm track records can both help improve understanding of the potential likelihood and intensity of storms, while local knowledge and expert assessment can help build up an understanding of local conditions during storms, including natural amplification or amelioration by the landscape. It should be noted that storms are rare, high impact, events and a historic lack of storms is still no guarantee of safety especially in view of climate change.



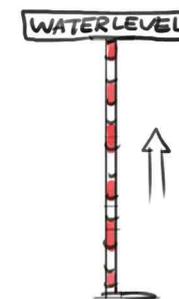
Tsunamis

These are rare events and local knowledge or memory may be misleading. Data on seismic activity and proximity to seismically active regions, along with long-term historical data and geomorphological data (seabed, coastal profile), can help to assess the risk and potential intensity of tsunami waves.



Erosion

An understanding of recent changes along a coastline will give an indication of the rate of erosion. Older residents may well remember a time when the coastline was different. Comparing historical maps and satellite images to current ones will give an indication of erosion rates. In areas where erosion is a problem, there may be dead mangrove trees at the seaward edge or a steep drop between the mangrove surface and adjacent mudflat. Experts may judge the dynamics of the coastline on the basis of a number of parameters including size and frequency of waves, tidal range, long-shore currents and sediment supply.



Local sea level rise

Global and regional models of sea level rise provide a crude indication of risk from future sea level rise, but local changes in the land level are often also important. In some places land is naturally sinking or rising which will exacerbate or reduce the relative impact of sea level rise. Local tide gauge information can help to understand recent local change which may also give an indication of the future threats. In considering sea level rise it is important to also consider the adjacent land area which could be inundated and other related changes such as intrusion of saltwater. Particularly vulnerable are low-lying coastal plains or coralline platforms. Among the most vulnerable of all are low-lying areas of peat lands and other wetlands that have been drained – such areas will subside dramatically as their soils dry out and are broken down: this could create large areas of coastal lowlands that are actually below sea level.

Assessing exposure and vulnerability

Disasters, involving great damage or loss of life, are often linked to natural hazards. The size or scale of a disaster arising from any hazard is related both to the exposure and the vulnerability of humans and infrastructure. Exposure is a measure of where people and property are located – low-lying areas with no sea defences are clearly more exposed than those higher up or further from the shore. Vulnerability is distinct from exposure and is a measure of the ability of people and infrastructure to deal with a hazard, either during or after the event. For example, if an early warning system is in place and people are trained in using it, then the vulnerability is lower. Likewise if the community have effective resources and finances to support recovery, clean-up and rebuilding following storm surge flooding, they can be considered less vulnerable. The tools mentioned below help to identify a broad variety of vulnerabilities, including those related to resources, capacities and behaviours.

Hazards, vulnerabilities and exposure need to be assessed at multiple scales: within communities, at the level of multiple communities and infrastructure networks and across the wider landscape. These dimensions interact, and changes at each level might contribute to either an increase or a decrease in risk. Construction of a seawall for example may in some case offer increased protection. In other cases it may increase vulnerability in other locations, e.g. when it triggers erosion further down the

coast and makes that area more susceptible to storms. Likewise the degradation of coastal ecosystems may exacerbate hazards such as flooding, thus increasing people's exposure. Understanding these interrelationships helps to assess the risk context and design truly integrated approaches to risk reduction and coastal zone management.

How do mangroves fit in?

Mangroves are found on the front line in terms of their position relative to many coastal hazards. The fact that they thrive in many coastal settings give some indication of their ability to cope with such hazards, or at least to recover from major impacts. Mangroves often modify coastlines through their ability to attenuate waves, capture sediments and build soils and it is these same properties which make them important in terms of reducing hazard intensity on landward margins and of decreasing exposure. They also provide many associated benefits that can help reduce the vulnerability of coastal communities and support recovery following hazard impacts. Such benefits are not universal, and every coastline and mangrove forest has unique properties and so it is critical to understand both the local mangroves and the many environmental, social and economic settings of the individual locations where mangroves are found.



Guidance for coastal managers

- Coastal managers need to understand risk in terms of hazard, exposure and vulnerability prior to determining what role mangroves can play
- The importance of mangroves in coastal defence and disaster risk reduction will depend both on the site characteristics and the local hazard context.

More information

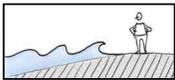
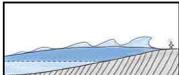
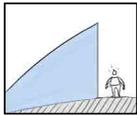
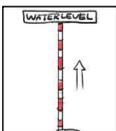
- [CARE International \(2009\) Climate Vulnerability and Capacity Analysis \(CVCA\) Handbook.](#)
- [IISD \(2012\) CRiSTAL – Community-based Risk Screening Tool. The International Institute for Sustainable Development, Winnipeg, Canada.](#)
- [UNISDR \(2009\) Terminology: Basic terms of disaster risk reduction.](#)
- [Wetlands International \(2013\) Integrating ecosystems in resilience practice. Criteria for Ecosystem-Smart Disaster Risk Reduction and Climate Change Adaptation.](#)

Natural mangrove forest in the Philippines, by Wetlands International



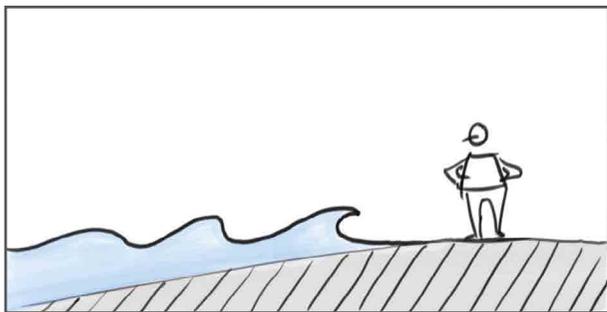
Section 2. The role of mangroves in coastal risk reduction

This section summarizes our current understanding of how and to what extent mangroves reduce coastal hazards that put us at risk. It provides practical guidance for coastal zone managers in terms of the mangrove characteristics that are needed to optimize protection against these hazards. A mangrove greenbelt should always be part of a wider risk reduction approach (see section 3).

		HAZARD				
		 Waves	 Storm surges	 Tsunami	 Erosion	 Sea level rise
MANGROVE FOREST PROPERTIES	Width	Hundreds of meters needed to significantly reduce waves (wave height is reduced by 13-66% per 100m of mangroves)	Hundreds of meters needed to significantly reduce wind and waves on top of surge Thousands of meters needed to reduce flooding impact (storm surge height is reduced 5 - 50 cm/km)	Hundreds of meters needed to reduce tsunami flood depth by 5 to 30% Mangroves do not provide a secure defence (nor do many engineered defences)	Sufficient mangrove forest width needs to be present to maintain sediment balance. This can help to prevent erosion and may encourage active soil build-up.	
	Structure	The more obstacles the better: dense aerial root systems and branches help attenuate waves	Open channels and lagoons allow free passage, while dense aerial root systems and canopies obstruct flow		Complex aerial root systems help slow water flows, allowing sediment to settle and causing sediment to accrete rather than erode.	
	Tree Size	Young & small mangroves can already be effective	Smaller trees and shrubs may be overtopped by tsunamis and the very largest storm surges		Young trees already enable soils to build up. The more biomass input into the soil the better.	
	Link to other ecosystems	Sand dunes, barrier islands, saltmarshes, seagrasses and coral reefs can all play an additional role in reducing waves				Allow room for landward retreat of the mangrove
	Underpinning factors	Healthy mangroves are a prerequisite for all aspects of coastal protection. Healthy mangroves require: sufficient sediment and fresh water supply and connections with other ecosystems. Conversely, pollution, subsidence (due to deep groundwater/oil extraction or oxidation upon conversion) and unsustainable use jeopardizes mangroves.				

2.1 MANGROVES REDUCE WAVE DAMAGE

Wind and swell waves are rapidly reduced as they pass through mangroves, lessening wave damage during storms.

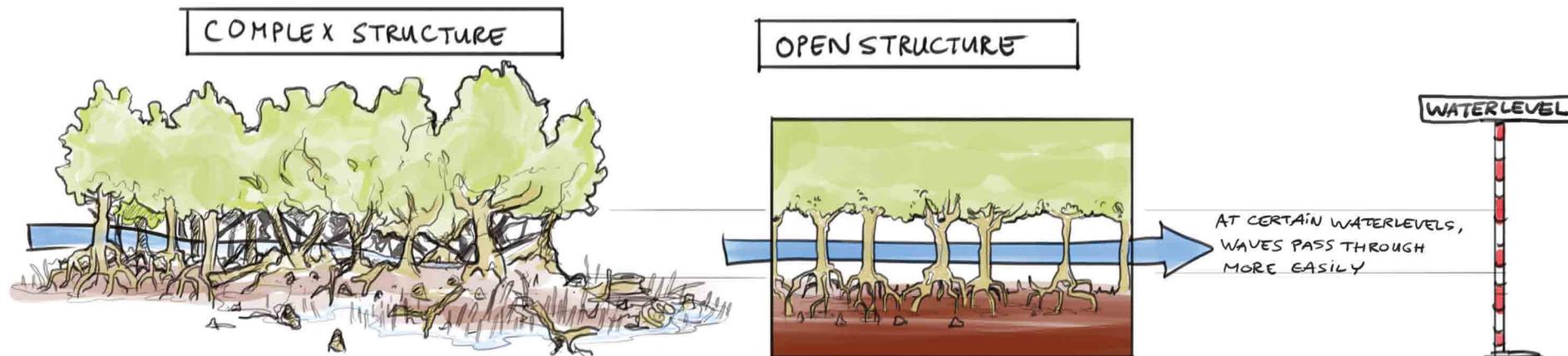


Wind and swell waves are commonly seen at the sea shore, as they break on the beach or smash against rocks. They are created by wind, sometimes far out to sea, sometimes close to the shore. They vary in height, from almost imperceptible ripples to large waves, reaching several metres in height, which can pound the shore relentlessly during storms. During flooding, waves can reach further inland, causing damage to houses and infrastructure.

The role of mangroves

Mangroves reduce the height and energy of wind and swell waves passing through them, reducing their ability to erode sediments and to cause damage to structures such as dikes and sea walls. During rising tides, as the sea comes in, waves enter the mangrove forests. They lose energy as they pass through the tangled above-ground roots and branches and their height is rapidly diminished, by between 13 and 66% over 100 m of mangroves. As this happens, waves lose their ability to scour the sea bed and carry away sediments. Mangroves also reduce winds across the surface of the water and this prevents the propagation or re-formation of waves.

Waves are most rapidly reduced when they pass through a greater density of obstacles. This means that mangroves with aerial roots attenuate waves in shallow water more rapidly than those without. Tightly packed arching prop roots and low branches clearly present a more solid obstacle to waves than sparse areas with few or no aerial roots. When the water gets deeper, waves may pass above aerial roots, but then the lower branches or the dense fronds of the Asian Nypa palm can perform a similar function in obstructing waves. Mangroves with a complex structure of dense aerial roots and low branches, with various species of different age and size, are most likely to be effective at reducing wave heights.





Guidance for coastal managers

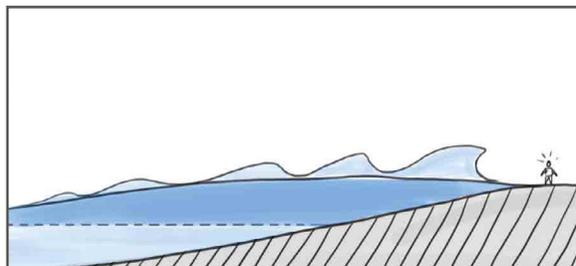
- Maintain wide mangrove belts. To significantly reduce everyday waves you need a belt of hundreds of meters wide – the more the better. A few trees won't help very much.
- The more obstacles the better, so mangroves of various species of different age and size are most valuable in reducing wave heights. In a dense mangrove forest packed with aerial roots and low branches, a wave may be reduced to half its height after 100m passage through the mangroves, while in a more open forest, it might take 500m of mangroves to reduce such a wave.
- Even relatively young or small mangrove forests can reduce the height of common wind and swell waves. Hence, reforested areas become effective at reducing waves in just a few years.
- Protection of adjacent ecosystems is important as these can also help attenuate waves. They include sandbanks, seagrasses and coral reefs, as well as landward dunes and saltmarshes.

More information

- [McIvor AL, Möller I, Spencer T & Spalding M \(2012a\) Reduction of wind and swell waves by mangroves. Natural Coastal Protection Series: Report 1. Published by The Nature Conservancy and Wetlands International.](#)

2.2 MANGROVES REDUCE DAMAGE FROM LARGE STORMS

Wide areas of mangroves can reduce storm surge flood levels, while narrower belts can still reduce the impacts of large waves and high wind speeds occurring during major storms (also called cyclones, typhoons or hurricanes).



Tropical storms, the largest of which are termed cyclones, hurricanes or typhoons, are widespread in many tropical and subtropical areas. Large waves, raised sea levels (the storm surge), strong winds and torrential rainfall, can cause widespread flooding, extensive damage and deaths. These storms form during the warmest parts of the year. The surges are caused by high winds and low atmospheric pressure allowing sea water to pile up as it approaches land. Such storms take several hours or longer to pass over any place. Their surges can carry a lot of debris, which can cause further damage. The largest storms typically affect any particular area every few years or decades.

The role of mangroves

Mangroves may contribute to reducing loss of life and damage to property from storms and cyclones as they reduce the impacts of waves, storm surges and high winds.

Waves: Mangroves can rapidly diminish the height of wind and swell waves as discussed in Section 2.1. Even during relatively large storm surges the leaves and branches of the forest canopy will help to reduce wave energy providing the trees are tall enough.

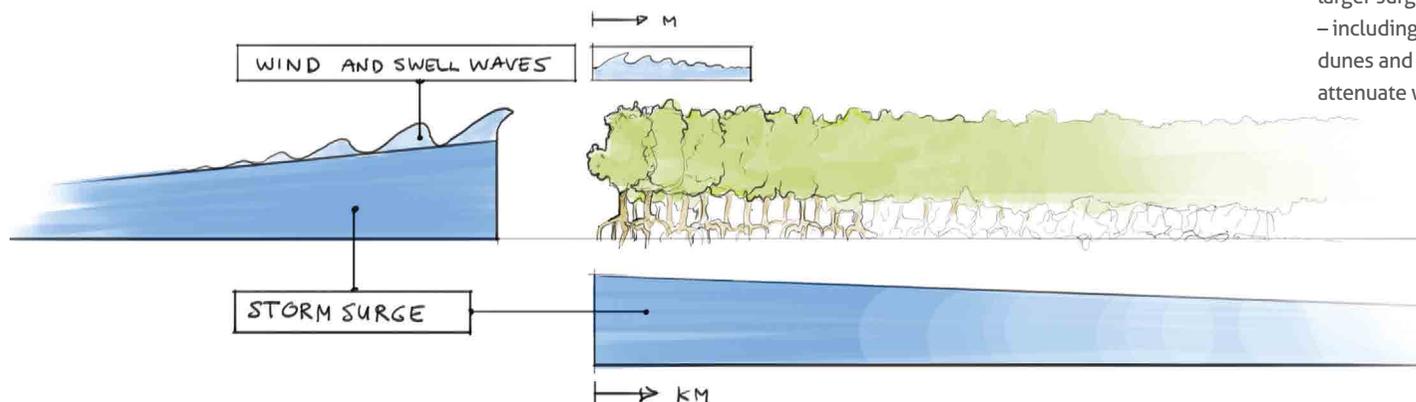
Storm surges: Where mangroves are extensive they are able to reduce storm surge water depths as the surge flows inland. While storm surge depths may only be reduced by 5-50 cm per kilometre width of mangroves, nevertheless a small reduction in water level can already greatly reduce the extent of flooding in low lying areas behind the mangroves. Debris movement can also be reduced by mangroves: the complex network of roots and branches can serve to trap even large moving objects.

High wind speeds: The dense mangrove forest canopies also reduce wind speeds locally. This prevents further development of wind and swell waves in and immediately behind the mangroves, potentially reducing damage to nearby infrastructure. In the most severe storms, mangroves may themselves be damaged or torn up

by the high winds and waves, although breakage or uprooting of mangrove trees is relatively rare.

Other determining factors

Mangrove forest structure is important in determining potential risk reduction by mangroves. Open channels and lagoons allow surges to travel freely landwards, and this should be taken into account in spatial planning. Dense forest vegetation helps to reduce surge depths and also reduces the height of wind waves riding on the surface. Sparse or low-canopy shrub mangroves may be less effective at reducing both surge and wave height. Dense mangroves are also a highly effective debris trap, protecting people and infrastructure from the potential damage that might be caused by the physical pounding of solid debris carried by storm waters. In the aftermath of a storm, mangroves enhance recovery by providing food, fuel wood and construction wood. The capacity of mangroves to reduce storm surge peak water levels also depends on the size and forward speed of the storm, as well as the characteristics of the coast. Storms can be 100 km or more across, and larger storms tend to generate higher water levels and greater flooded areas. Mangroves are more effective at reducing surge levels if storms pass over relatively quickly. Extensive areas of shallow water near the coast produce larger surges than steep off-shore slopes. Adjacent ecosystems – including offshore sandbanks, sea grasses and coral reefs, and dunes and saltmarshes on landward margins – can also help attenuate waves and reduce storm impacts.



Guidance for coastal managers

- Maintain wide mangrove belts, ideally thousands of meters across, as these can be effective in reducing the flooding impacts of storm surges, typically reducing water heights by 5 to 50 centimetres per kilometre of mangroves. This can significantly reduce flood extent in low lying areas. Narrower mangrove belts, hundreds of meters wide, will be able to reduce the impacts of wind waves during storms.
- Ensure structural diversity, the more obstacles the better. Mangrove trunks, branches and leaves all help reduce wave energy in times of very high seas, so diverse mangroves with various species of different age and size are most valuable.
- Open channels and lagoons allow free passage of floods, which should be taken into account in spatial planning.
- Since storm surges reach high up into the forest, trees need to be tall to act as an obstacle to the flow. Hence, mature and tall forests will perform better than young and small forests.

More information

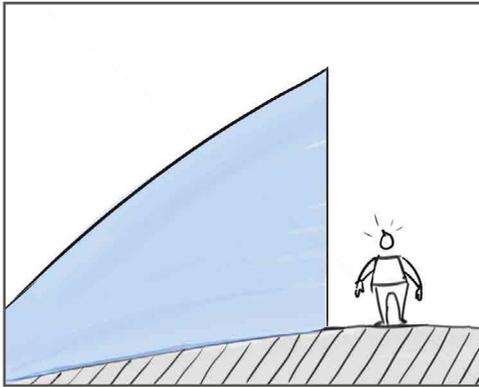
- [McIvor AL, Spencer T, Möller I & Spalding M \(2012b\) Storm surge reduction by mangroves. Natural Coastal Protection Series: Report 2. The Nature Conservancy and Wetlands International.](#)

Destruction after typhoon Philippines by Cordaid



2.3 MANGROVES CAN HELP TO REDUCE TSUNAMI DAMAGE

Wide areas of mangroves can reduce tsunami heights, helping to reduce loss of life and damage to property in areas behind mangroves.



Tsunamis are caused by earthquakes and landslides disturbing large masses of water. The resulting tsunami waves can travel rapidly over very long distances across the ocean. When tsunami waves approach land, they increase in height, sometimes becoming several metres high at the shore. Tsunamis can result in massive destruction and loss of life, as seen during the 2004 Asian tsunami. While the water depths in both storm surges and tsunamis can be similar, tsunamis arrive more quickly as one or a series of waves that may appear and flood an area in a matter of seconds or minutes.

The role of mangroves

There is growing evidence, particularly from the devastating Indian Ocean tsunami of 2004 that mangroves reduced tsunami impacts by reducing the destructive energy of water flowing inland. Mangrove belts several hundred meters wide have been shown to reduce tsunami height by between 5 and 30%. Wider mangrove forests are more effective at reducing tsunami height, as well as speed of the water and the area flooded by the tsunami. Dense forest vegetation also helps to reduce tsunami depth and area of flooding. However, large tsunamis (more than 4 m in depth) can damage mangroves, eventually destroying them and making them less effective at reducing tsunami flows. The highest tsunami waves may be taller than mangrove trees, so that the incoming water flows over them. Of course the same is true for engineered structures, which are rarely built to the height of mangroves.

Despite these limitations, mangroves can still be an important asset in many settings. Even a modest reduction in the total area of inundation can already reduce loss of lives and economic damage. Equally importantly, mangroves trap floating debris, and provide a safety net for human victims caught up in the incoming flood or the returning waters. Mangroves also enhance recovery by providing food, fuel wood and construction wood directly after the event, when these resources may be scarce.

Clearly the size of the tsunami is a major control on the ability of mangroves to protect communities living behind the mangrove. A very large tsunami, arriving with little or no warning, will be highly destructive. As with storm surges, extensive areas of shallow-water near the coast produce larger tsunami waves than steep off-shore slopes.

Guidance for coastal managers

- Maintain wide mangrove belts, ideally several hundred meters wide, as these will be more effective than narrow strips in reducing impacts from tsunamis.
- Mangrove trunks and branches are expected to reduce the energy and force of incoming tsunami waves. Taller trees are less easily overtopped by a tsunami than small ones. Mature forests with thicker trees can withstand greater wave energy.
- Open channels and lagoons allow free passage to floods, which needs to be taken into account in spatial planning.

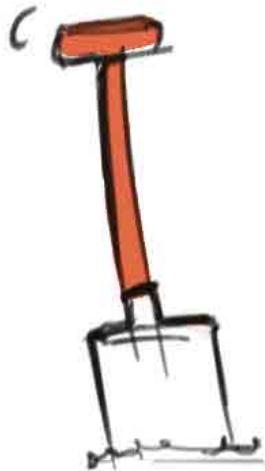
Mangrove restoration by Wetlands International

BOX 1. MANGROVE RESTORATION POST-TSUNAMI

In 2004 a massive tsunami hit the coastlines of South East Asia. It killed 230,000 people and caused enormous damage. In response to this tragedy, Wetlands International, together with IUCN, WWF and Both Ends initiated the Green Coast project (2005-2008). Funded by Oxfam Novib, this project supported disaster-recovery in 6 countries by restoring mangroves and developing sustainable livelihoods. In Indonesia alone 70 community groups restored no less than 2000 hectares of mangroves. In return they received support to develop new livelihoods such as crab farming, small-scale fisheries and sustainable aquaculture. Currently these communities live in mangrove landscapes, with patches of mangroves alternating with agriculture and aquaculture. These resilient landscapes, along with a well-educated local population and robust infrastructure ensure that the people are much better prepared for and equipped to deal with natural hazards that may occur in years to come.

2.4 MANGROVES REDUCE EROSION AND BIND SOILS TOGETHER

The dense roots of mangroves help to bind and build soils. The above-ground roots slow down water flows, encourage deposition of sediments and reduce erosion.



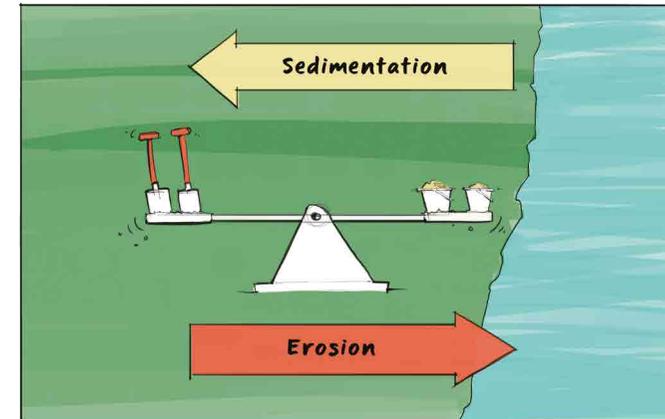
Erosion refers to the removal of sediments from the shore, resulting in the loss of land and a retreating shoreline. Erosion can be caused both by the small waves that lap against the shore on a daily basis, and by infrequent large waves, storm surges or tsunamis. Erosion can occur from the sediment surface, resulting in a lowering of the surface (leading to more frequent flooding by waves and tides). It can also occur at the mangrove edge, e.g. through the formation of an erosive cliff (a step change in surface height) at the seaward edge of the mangroves.

The role of mangroves

On every coastline waves and currents create change, sometimes bringing sediments to the coast, but sometimes causing erosion and the loss of land. Where mangroves occur they generally reduce erosion and enhance sedimentation. The mangrove vegetation reduces wave energy and slows the flow of water over the soil surface, reducing the water's capacity to dislodge sediments and carry them out of the mangrove area. At the same time the slower water flows can allow already suspended sediments to settle out from the water, resulting in increased deposition of sediment.

Typical mangrove soils are rich in organic matter produced by the mangroves themselves, including living roots but also dead leaves and woody materials. The dense network of fine roots helps to armour the soil from erosive forces and to trap and bind soil particles together. Because mangrove soils are often waterlogged and so have very low oxygen content (anaerobic conditions), much of this organic matter accumulates, forming a layer of peat that increases in thickness over time.

When mangroves are lost, the patterns of sediment movements can change dramatically – where mud and soil were stable or even gradually building up, they may begin to erode so that land disappears into the sea. Further, drainage and conversion of mangrove areas to other uses leads to the rapid breakdown of organic matter as oxygen becomes available in the soil, which in turn causes subsidence. This is very clearly seen in a number of coastal areas where mangroves have been converted to aquaculture or agriculture, such as along the coasts of the Gulf of Thailand, in northern Java, and in Guyana. These formerly stable or even advancing coasts are now retreating at rates of many meters every year.



Other determining factors

Besides mangrove deforestation or degradation, other drivers of land loss include subsidence caused by extraction of deep groundwater or oil, sea level rise and the construction of hard infrastructure (see also box 2, page 25). Adequate sediment supplies are vital to allow mangroves to build up soils. Sediment supplies can be affected when infrastructure along the coast alters long shore currents or when upstream dams block sediment supplies to the rivers which then bring them to the coast. Coastal engineering works should be planned to maintain sediment flows, so that mangroves receive a healthy sediment supply. In some cases active interventions may be needed to trap sediments and restore sediment supplies, by placing permeable dams to trap sediment or through mud nourishment or agitation dredging.

Guidance for coastal managers

- Maintain wide mangrove belts. Wider mangrove belts are better able to maintain sediment flows, reducing sediment losses and erosion. Conversion of even parts of the mangrove belt can lead to reductions in sediment flows, reductions of deposition and increasing erosion.
- Ensure healthy mangrove growth. In most places healthy natural mangroves are likely to be relatively stable habitats with little erosion: complex root systems help slow water flows, allowing sediment to settle and causing sediment to accrete rather than erode; while productive root growth and leaf litter supply are critical to build and bind soils.
- Maintain or restore sediment supply and avoid sediment starvation caused by certain coastal and inland engineering works that block the flow of sediments from rivers or along the coast.
- Processes that lead to subsidence, such as oxidation caused by drainage and deforestation or extraction of deep groundwater and oil should be prevented.

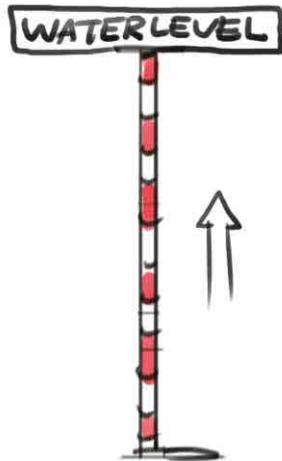
More information

- [McIvor AL, Spencer T, Möller I & Spalding M \(2013\) The response of mangrove soil surface elevation to sea level rise. Natural Coastal Protection Series: Report 3. Cambridge Coastal Research Unit Working Paper 42. Published by The Nature Conservancy and Wetlands International.](#)

Mangrove roots protecting the upper banks of the Daly Estuary in Australia, by E. Wolanski

2.5 MANGROVES MAY KEEP UP WITH SEA LEVEL RISE

Over time mangroves can actively build up soils, increasing the height of the mangrove soil surface, which may be critical as sea level rise accelerates.



Globally, sea levels are rising as a result of the melting of ice sheets and glaciers, and the expansion of the oceans as they warm with climate change. At more local scales the height of the land itself may be slowly rising or sinking as a result of geological changes, the compaction of the soil or extraction of water or oil from deep within the ground. Recent sea level rise has averaged 3.2mm per year. Sea level rise rates are accelerating, but they are also variable across the oceans due to patterns in ocean currents and differences in ocean temperatures. Wherever sea levels are rising or the land is subsiding, the impacts of waves, storm surges and erosion will reach further inland.

The role of mangroves

Mangrove soils are actively growing in many places. Mangroves contribute to an increase in soil volume by capturing riverine or coastal sediments that pass through, as well as adding their own organic matter in the form of roots, leaves and woody material. The fine mangrove roots also help to trap and bind the particles. Due to a lack of oxygen in the waterlogged soil, organic matter is not broken down by soil organisms. This allows the organic matter to build up over time, producing the deep peaty soils that underlie mangroves in some areas. Mangrove root growth also pushes the soil upward, resulting in a higher soil level.

These processes can allow mangroves to keep pace with rising sea levels. Some mangroves sit on top of deep layers of mangrove peat that may be 6 meters deep or more, that were built up over thousands of years as sea levels rose. These mangrove soils grew vertically at rates of up to 10 mm per year in sites from Australia to Belize, suggesting that mangroves may be able to keep up with similar rates of sea level rise into the future, where local conditions allow. While not all mangroves may be able to fully “keep up” with rising seas, even a small increase in soil surface height over time may help to reduce the impact of sea level rise on coastal areas. Mangroves may be able to colonise landward areas if space is available, and thus continue to provide coastal defence services against waves and storms.

Other determining factors

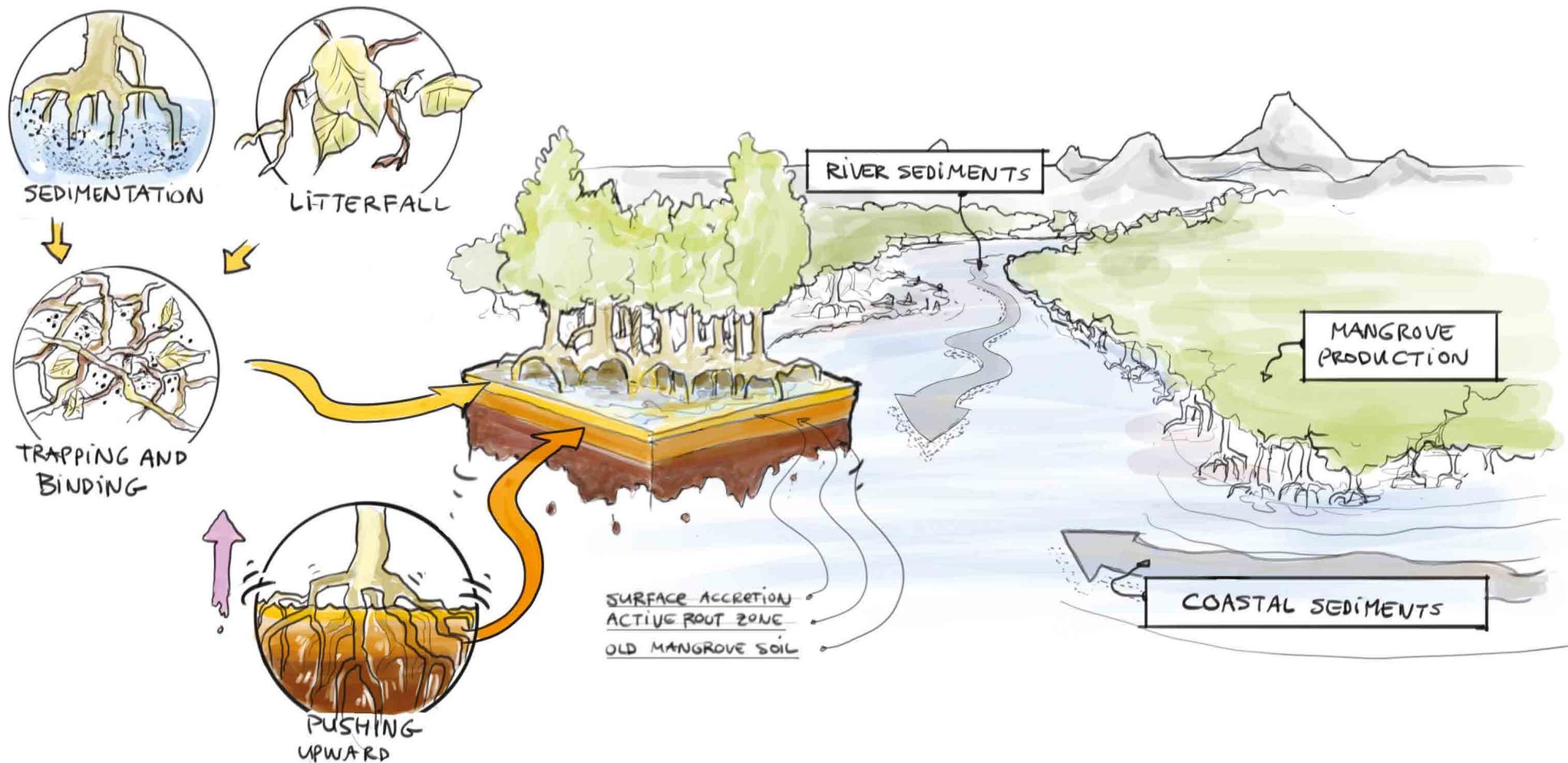
Mangroves are more able to keep up with sea level rise in areas with high rates of sediment input. Supplies of sediments can be rapidly reduced through inappropriate coastal engineering projects or the damming of rivers. Hence, shore structures should be designed such that they allow long shore sediment transport, and dams on rivers should be carefully planned to reduce impacts on sediment flows to coastal mangrove areas. In cases of sediment starvation it may be necessary to artificially enhance sediment retention and supply through the placement of permeable dams to trap sediment, or the use of mud nourishment or agitation dredging.

Further, mangroves thrive in brackish water, a mix of salty sea water and fresh water. If fresh water supplies are disturbed due to dams upstream, conditions may become too saline and mangrove growth rates and diversity will be reduced, which may affect their production of organic matter and ability to bind and build soils.

Subsidence counteracts the ability of mangroves to keep up with sea level rise. Processes that lead to subsidence such as oxidation caused by drainage and deforestation and extraction of deep groundwater and oil should be prevented.

Guidance for coastal managers

- Ensure healthy mangrove growth. Healthy root growth and leaf litter supply are critical to build and bind soils. If mangroves are to keep up with sea level rise, activities that decrease organic matter input into the soil (such as harvesting) should be minimised. It is important to maintain or restore fresh water supply to keep mangroves healthy.
- Maintain or restore sediment supply and avoid sediment starvation caused by certain coastal and inland engineering works that block the flow of sediments from rivers or along the coast.
- Allowing mangroves space to retreat landwards will help to ensure their survival so that they can continue to act as a first line of defence against waves and surges.
- Avoid drainage and conversion of mangrove areas as subsequent oxidation causes a severe loss in soil surface height. Extraction of deep ground-water and fossil fuels can similarly lead to subsidence leaving mangroves and adjacent lands prone to flooding as sea levels rise



More information

- [McIvor AL, Spencer T, Möller I & Spalding M \(2013\). The response of mangrove soil surface elevation to sea level rise. Natural Coastal Protection Series: Report 3. Cambridge Coastal Research Unit Working Paper 42. Published by The Nature Conservancy and Wetlands International.](#)
- [Ellison JC \(2012\) Climate Change Vulnerability Assessment and Adaptation Planning for Mangrove Systems. WWF, Washington D.C.](#)



Mangrove flower, by Wetlands International

Section 3. Managing mangroves for coastal defence

Mangroves can contribute to risk reduction in many coastal settings. In some places this role of mangroves can be enhanced by combining such benefits with other risk reduction measures, making them part of a wider coastal defence and disaster risk reduction strategy (section 3.1). Mangroves also contribute to societal resilience. They generate valuable fish, timber, fuel and fibre which help recovery after disasters. To ensure maintenance of these valuable services, it is critical to engage the many sectors and stakeholders involved in coastal areas through integrated management (section 3.2). Mangroves even play a role in severely degraded settings, where their restoration can bring back their many valuable functions (section 3.3).

3.1 INTEGRATING MANGROVES INTO COASTAL DEFENCE STRATEGIES

Mangroves don't always provide a stand-alone solution; they may need to be combined with other risk reduction measures to achieve a desired level of protection. If they are integrated appropriately, mangroves can contribute to risk reduction in almost every coastal setting, ranging from rural to urban and from natural to heavily degraded landscapes.

Disaster risk reduction is the practice of reducing disaster risks through systematic analysis and management of the causal factors of disasters. This includes reducing exposure to hazards, lessening vulnerability of people and property, improving preparedness for adverse events and wise management of land and the environment. Healthy and well managed mangroves can reduce disaster risk.

As demonstrated in the previous section, mangroves can reduce the risks associated with waves, storms and erosion and over the long term can even contribute to maintaining land as sea levels rise. Every coastline around the world is different though, with a unique combination of hazards and associated exposure and vulnerability. Mangroves too are highly variable from place to place. It is critical to consider these different factors to understand if, how and to what extent mangrove management can play a role in risk reduction planning. Modelling, measuring and monitoring is needed to ensure a predefined level of risk reduction is achieved.

Mangroves and coastal engineering

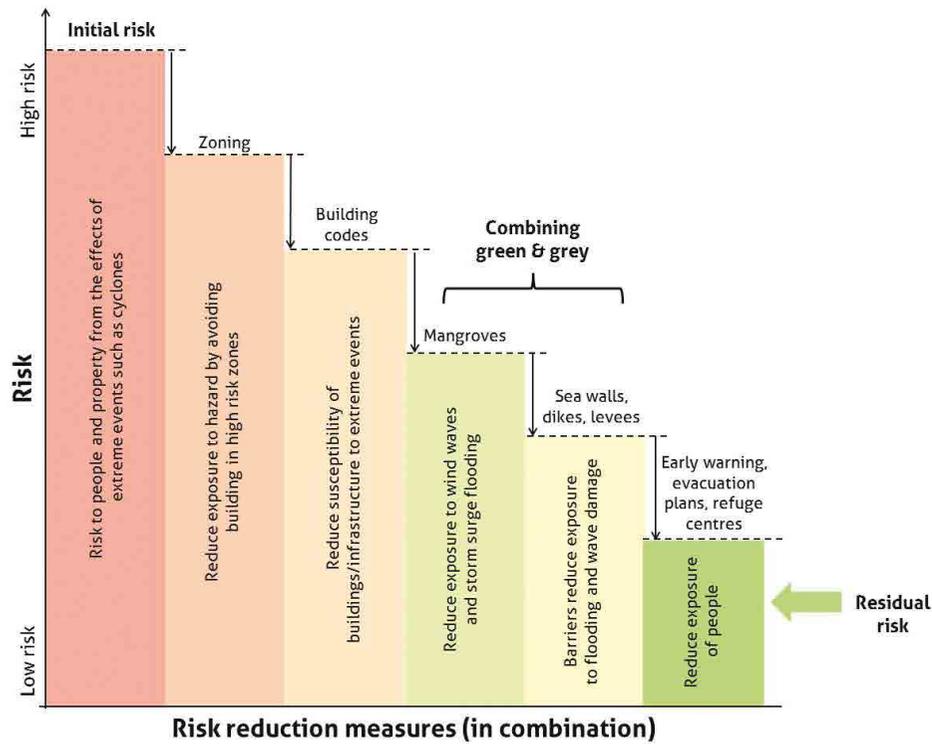
Mangroves as a stand-alone solution may not always offer full protection against large magnitude hazards like tsunamis or cyclones. The same also holds for hard defence structures. In addition, hard infrastructure might have various adverse impacts, for example interrupting sediment flows and exacerbating

erosion (see box 2, opposite). In recent years, some coastal zone managers have begun to approach these challenges by combining green (nature-based) with grey (engineered) solutions. This 'Building with Nature' approach has shown promising results, representing a remarkable shift in paradigm: from fighting against nature, to working with and alongside natural processes. The more coastal defence relies on mangroves, the more important it is that this is integrated within coastal engineering approaches (Section 2). Where there is a lot of space, mangroves can play a larger role than where there is little space.

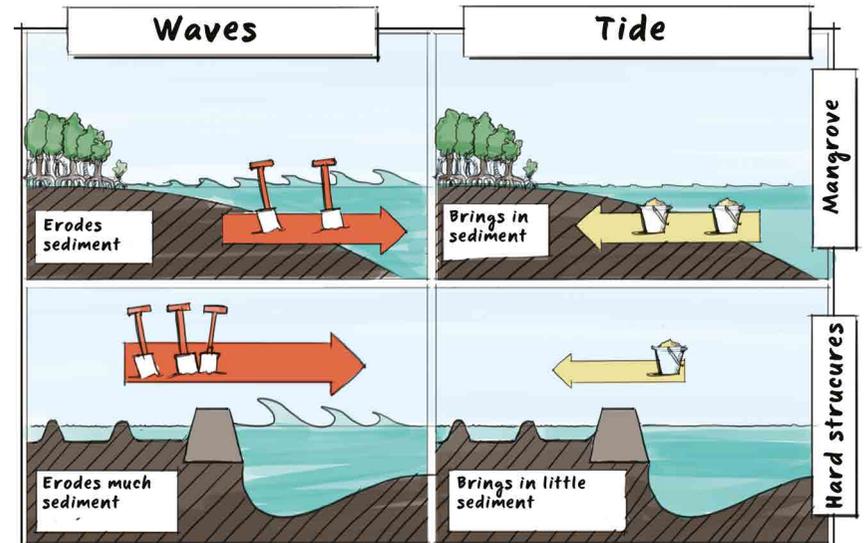
Mangroves and risk reduction

Engineered and ecosystem-based coastal defence measures also need to be implemented alongside a suite of other risk reduction measures. This includes avoidance of human activities in high risk zones, improved building standards, increased preparedness, early warning systems and evacuation procedures.

Risk reduction measures diagram. Adapted from diagram presented by Ty Wamsley, US Army Corps of Engineers



BOX 2. WHY HARD-ENGINEERING STRUCTURES CAN FAIL IN MUDDY COASTS



In a healthy mangrove ecosystem, waves take sediment away and the tides bring sediment in. The mangroves' aerial root systems help to dissipate the waves and to capture and stabilize the sediment. By contrast, hard structures, such as breakwaters and also the earthen or concrete dykes surrounding aquaculture ponds, only protect against wave impacts in the short term, and may need rebuilding frequently as they are undercut by erosion. This occurs because waves can get 2 – 4 times bigger when they reflect off a hard structure. These bigger waves increase erosion in front of the structure, and can eventually lead to its collapse. Such collapsed sea walls are then useless in reducing waves or preventing erosion. Moreover, hard structures disturb the balance of incoming and outgoing sediment because they block the flow of water and sediment into areas that were previously flooded by the tides.



Failed coastal defence structure in Guyana, by Han Winterwerp



Mangroves contribute to risk reduction in different settings

In **natural** settings, where the mangrove belt is still very wide, mangroves are capable of lowering storm surge height and of dampening the waves on top of the surge within the first few hundreds of meters of mangrove. **Wise use** of mangroves, in rural settings, ensures that a mangrove belt of hundreds of meters wide is maintained and continues to play a critical role in reducing wind or swell waves, thus reducing erosion. **Restoration** remains an important option in areas where mangroves have been lost – interventions to enhance sediment supplies, or using permeable barriers to reduce erosion, may help mangroves to become re-established. In all settings, mangroves may be able to keep up with sea level rise, provided that the sediment and fresh water balance enable mangroves to thrive. Therefore they are an adaptive solution that may help to cope with climate change impacts.

Depending on the hazard, vulnerability and mangrove condition, combinations of green and grey solutions may be needed to provide optimal risk reduction. In **urban** settings, where space is limited, even small areas of mangroves offer some protection from waves, reducing construction and maintenance costs for hard infrastructure behind them that in those settings are the primary defence. In all these settings, mangroves add additional value in the form of enhanced fisheries, carbon storage, forest products and recreation. Mangroves thus support food security, climate change mitigation and human wellbeing and can enhance recovery after major hazards.

Guidance for coastal managers

- Mangroves can play a role in reducing risk in natural, rural, urban and even degraded settings.
- Mangroves are rarely a stand-alone solution and need to be appropriately combined with other risk reduction measures. This includes integrating mangroves in the design of coastal infrastructure.
- Modelling, measuring and monitoring the role of mangroves in coastal defence is needed to inform how to achieve a desired level of risk reduction.
- Mangroves should be embedded in coastal defence and disaster risk reduction strategies and in multi-sector integrated management planning for large coastal areas.
- Long-term provisions for coastal realignment may be needed to give space for the landward migration of mangroves for the eventuality that sea level rise might lead to losses of mangroves at the seaward margins.

More information

- [Wetlands International \(2013\) Integrating ecosystems in resilience practice. Criteria for Ecosystem-Smart Disaster Risk Reduction and Climate Change Adaptation.](#)
- [Partnership for Environment and Disaster Risk Reduction \(PEDRR\) website.](#)
- [De Vriend HJ & Van Koningsveld M \(2012\) Building with Nature: Thinking, acting and interacting differently. EcoShape, Building with Nature, Dordrecht, the Netherlands.](#)



3.2 MANGROVES AS PART OF COASTAL ZONE MANAGEMENT

For mangroves to optimally contribute to risk reduction, their conservation needs to be incorporated into broader coastal zone management planning: they need to be protected and restored, allowing wise use where possible.

Sustainable development is the management and conservation of the natural resource base to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable (FAO 1989).

Managing mangroves in the landscape

Mangroves are under threat from many development pressures. This includes overharvesting, conversion for alternative uses (urban, agriculture, aquaculture) and on- and off-site development of infrastructure. Integrated coastal management and development plans are required to safeguard the risk reduction values of mangroves. These plans should prevent further degradation of existing mangrove forests and support rehabilitation of mangroves where possible, and most importantly should consider mangroves as being a fundamental part of the local economy. One vision for the integration of mangroves into coastal landscapes and seascapes would be the promotion of tiered protection, with strictly protected mangrove areas alternating with wise use zones as well as more intensively used production systems.

Since mangroves can be impacted by measures taken quite far from them, and since coastal systems tend to include a great variety of sectors and stakeholders, it is important to consider mangrove management from a broad geographic perspective, and to place use and development needs in a wider framework of planning and management. Such **integrated coastal zone management** will help address the root causes of coastal vulnerability. This may include ensuring sustainable use of adjacent land, rivers and marine ecosystems to avoid impacts to soil surface height, freshwater, nutrient and sediment supplies and to ensure the ecological and physical conditions remain in place for mangroves to flourish.

Key to this process is the **involvement of local communities** and other stakeholder groups in both the design and implementation of spatial plans and management plans. Further, successful mangrove management requires an effective system of ownership, use and

access. Some countries have framework legislation which establishes who owns mangroves, or who has the right to use mangroves. Clear ownership, by state, local communities or individuals, provides a setting for wise use and management. There is also a need to understand existing legal and policy systems that may have relevance for mangroves. Many countries have unwittingly encouraged mangrove degradation or loss through policies that provide incentives for aquaculture or coastal development. Others have ensured long term coastal protection by legally requiring mangrove belts of a certain width to be left in front of developments.

Sustainable financing mechanisms can help to ensure the long-term maintenance of appropriate management interventions. When wisely used, mangroves can support aquaculture and fisheries while simultaneously reducing coastal risk. Map-based tools are becoming increasingly available, and this may help with deciding on best practices for coastal land-uses to maximize benefits and to minimize costs (box 3, page 30).

Mangrove management options

Protected areas cover some 36% of the world's remaining mangrove areas. Defined as areas set aside primarily for conservation purposes, protected areas such as national parks and nature reserves typically forbid many extractive activities such as timber harvesting. In reality, however, most mangrove protected areas still allow some levels of sustainable fishing, harvesting of non-timber forest products and tourism.

Sustainable silviculture has been developed in many mangrove forests. In both Matang forest in Malaysia and in the Bangladesh Sundarbans, the mangroves have been harvested for over 120 years.

Such long-term management is so well developed that it gives valuable security in terms of production, income and job-creation. Standards for sustainable forestry can help determine management that sustains social, ecological and economic benefits over the longer term. Care should be taken to ensure that harvesting does not jeopardize the coastal protection function.

Sustainable aquaculture in some cases needs to be developed in the vicinity of mangrove areas to address food security concerns and to redirect one of the most important drivers of mangrove conversion. It is essential to avoid siting of new aquaculture ponds in mangrove areas. Mangroves play a role in coastal risk reduction, water quality improvement and fisheries enhancement which can be of critical value even to the aquaculture sector itself. Even where ponds are already located in mangrove areas, further mangrove loss should be minimised and wide margins of mangroves should be restored where possible in front of ponds. Mangroves can also be planted within aquaculture ponds and on the pond margins where they can help to maintain water quality, reduce erosion and support nutrition, but this will have minimal benefits in terms of coastal defence. Standards for sustainable aquaculture increasingly take mangroves into account, prohibiting siting in mangrove areas and requiring mangrove rehabilitation.

Community based management can be highly effective. Local communities can be stewards for mangrove management, and their support for any management is likely to increase a project's chances of success. Such communities can help in projects for restoration; they can help to regulate use and access, and are the direct beneficiaries of sustainable management.

Mangroves at the coast of Panama City,
by Wetlands International



Keeping mangroves healthy and avoiding threats

Healthy mangroves are a prerequisite for all aspects of coastal protection. Robust growth should be encouraged by avoiding degradation through pollution, waste dumping, drainage or unmanaged timber extraction. Mangrove health can be impacted by measures taken quite far from the mangroves. The building of dams for hydropower, and the use of freshwater for crop irrigation has led to profound changes in many estuaries and deltas, reducing freshwater supplies and changing sediment loads in rivers. Increased salinities in deltas and estuaries can greatly affect survival of some mangrove trees, while reduced sediments can lead to erosion.

Climate change could also have implications for mangroves. Typically mangroves are opportunistic, growing well in many conditions. Thus far it would appear that no species are negatively affected by heat, but some may be able to expand their ranges as warm conditions expand around the world. Indeed warming temperatures are probably already contributing to the colonization of mangroves in salt-marsh communities in Australia, New Zealand and the USA. Alongside warming of course, there are likely to be significant changes in patterns of rainfall, and possibly storms, which may influence some areas in the longer term. Sea level rise has been implicated as a threat to mangroves. In reality current rates of change are still relatively low and unlikely to be driving any large-scale losses just yet. Indeed there is a chance that some mangrove areas may be able to mitigate, or at least reduce the rate of change as they capture and build sediments to raise the elevation of the mangrove soils.

BOX 3. MANAGING COMPLEX TRADE-OFFS ALONG BELIZE'S COASTAL ZONE

Belize's barrier reefs, mangrove forests, and wetlands all provide buffers against erosion and storm surges, thus helping to protect 40% of Belizeans that live in the coastal zone. Stakeholders in Belize recently formulated an Integrated Coastal Zone Management Plan that designates areas for preservation, restoration, development, and other uses. This plan was based on mapping and valuation of ecosystem services, including their value for coastal protection, but also other benefits such as tourism and fisheries. These were modelled both for present conditions and under alternative zoning schemes in the future, enabling stakeholders and planners to take nature's values into account when taking management decisions. More information: <http://www.naturalcapitalproject.org/>

Natural mangrove regeneration in South Africa, by Wetlands International

Guidance for coastal managers

- Prevent mangrove conversion, and in all cases maintain wide seaward greenbelts. Allow wise use (forestry, fisheries) to the extent that it does not jeopardize the coastal risk reduction function or mangrove health in general.
- Healthy mangroves are a prerequisite for coastal protection. Encourage robust growth by avoiding degradation through pollution, waste dumping, drainage or unmanaged timber extraction and by maintaining or restoring fresh water supplies.
- Protected areas, sustainable silviculture, sustainable aquaculture and community based management can be effective mangrove management measures.
- Integrated coastal zone management that places such measures into a wider framework of planning and management and involves multiple stakeholders is needed to ensure long-term security and broad support.

More information

- UNEP (2014) *The Importance of Mangroves to People: A Call to Action*. Cambridge, UK, United Nations Environment Programme World Conservation Monitoring Centre and Wetlands International.

3.3 BRINGING THE MANGROVES BACK

Mangroves, and their coastal risk reduction function, can recover in most places where appropriate ecological and social conditions are present or restored.

Restoration can be defined rather broadly as 'a return from a disturbed or totally altered condition to a previously existing natural or altered condition by some action of humans'. Rehabilitation is similar to restoration but the goal is not to return to some previous condition as defined by measurable reference criteria, but instead the conversion of an altered wetland to some beneficial use as defined by locally agreed upon goals and criteria.

Mangrove recovery

Mangroves are remarkably robust and opportunistic species, which means that, while mangroves have been lost or degraded in many areas, they can also recover, and indeed such recovery can be enhanced with a variety of interventions. Generally speaking it is still more cost-effective to prevent mangrove loss than to allow loss and then have to invest in rehabilitation or restoration, but this is not always an option. Around the world hundreds of thousands of hectares of mangroves have been actively planted in mangrove restoration projects from Bangladesh to Cuba, and from Florida to Australia. Many of these have highlighted the role of mangroves in coastal defence as a key motivating factor. Not all restoration projects have been successful, but then again many areas of mangroves have re-established themselves without active planting or management. Clearly, recovering and restored mangroves begin to bring back many of the ecosystem services that were lost or degraded when the mangroves were absent, but this will not be instant. Before any efforts are made towards restoration it is critical to understand two things: firstly, why the mangroves are gone, and secondly, who owns and/or uses the place where they were.

Principles for mangrove restoration

Ensure ecological conditions are appropriate for mangrove recovery. Mangroves may have been lost through local changes in hydrology, changes in freshwater supply, or loss of sediments. These in turn might be linked to local infrastructure developments, building of aquaculture ponds, coastal engineering works preventing the long-shore transport of sediments, or to dams on rivers far inland. There is no point investing money in mangrove restoration if they will simply be lost again.

Ensure that social conditions will allow mangrove recovery. If mangroves have been removed by local people this could easily happen again. The ownership and use rights of potential restoration areas need to be clearly established, and there must be both a desire for recovery and a possibility for management. Many restoration projects have failed because local people did not support or understand the need for mangroves.

Follow nature. Some of the worst failures in mangrove restoration occurred because people attempted to plant the wrong species, often in the wrong places. Mangroves are intertidal species which grow best above mid-tide levels. Different species have more specific needs: many

restoration efforts have focused on the easiest species to plant, such as *Rhizophora* species with their large seedling-like propagules, but these will not always grow on exposed outer margins, and such efforts can easily fail. All mangroves need to be in shallow intertidal areas: planting them in deeper water areas may seem an easier proposition if such areas are state owned, but mangroves cannot grow out of their depth. Furthermore planting of mangroves in the wrong places may destroy valuable ecosystems such as seagrass meadows and mudflats.

Mimic nature. Natural mangrove forests are not monocultures and new forests will be more resilient and provide greater benefits if they can replicate the density, structural complexity, and natural restocking of natural mangroves, using multiple native species with natural zonation.

In many places it is not necessary to plant mangroves at all. Restoring the natural patterns of water flow, preventing human disturbance and perhaps removing choking weed species may be enough to allow natural regeneration. This is already a widespread practise in many mangrove "plantations" (production mangrove forests).

Mangrove recovery may require more active intervention. Where there is small scale erosion it may be possible to reduce erosive impacts through protecting individual seedlings until they become more established. In disturbed areas such as former aquaculture ponds active levelling and the restoration of hydrological flows may be needed. The restoration of sediment supplies may also require the alteration of coastal engineering structures or even water flows from inland dams, to allow sufficient sediment to flow back into coastal areas.

Building with Nature. On rapidly eroding muddy coasts in Indonesia and Vietnam, new techniques are being developed to stabilise or enhance sediments to allow mangrove recovery, using permeable structures to trap sediments, or sediment-agitation dredging and nourishment to enhance sediment supply (see bpx 4, page 33).

Afforestation may be appropriate in some places. Planting mangroves in places where they have not occurred before is known as afforestation, rather than restoration. This may be an appropriate intervention in places where there has been major coastal engineering, and where mangrove appropriate intertidal substrates have been created.



Guidance for coastal managers

- Mangroves can recover in most areas, as long as ecological and social conditions are appropriate for mangrove recovery.
- Follow and mimic nature: mangroves are intertidal species which grow best above mid-tide levels. Natural mangrove forests are diverse in terms of species, structure and age.
- In many places it is not necessary to plant mangroves at all and mangroves may naturally recover.
- In areas with erosion, mangrove restoration may require more active intervention such as protecting individual seedlings or restoring the sediment balance and hydrology.
- Ensure that mangroves can be restored, following termination or abandonment of aquaculture or aquaculture development. Trust funds, built up through payments by original developers, could be established to support this.

More information

- [Lewis III R. & Brown B \(2014\). Ecological Mangrove Rehabilitation - a field manual for practitioners. Mangrove Action Project, USA.](#)
- [Primavera JH, Savaris JP, Bajoyo BE, Coching JD, Curnick DJ, Golbeque RL, Guzman AT, Henderin JO, Joven, RV, Loma RA & Koldewey HJ \(2012\) Manual on community-based mangrove rehabilitation. Mangrove Manual Series no. 1 London, UK: ZSL viii +240p.](#)
- [Primavera JH, Yap WG, Savaris JP, Loma RA, Moscoso ADE, Coching JD, Montilijao CL, Poignan RP & Tayo ID \(2013\) Manual on Mangrove Reversion of Abandoned and Illegal Brackishwater Fishponds – Mangrove Manual Series No. 2. London, UK: ZSL. xii + 108 p.](#)
- [Green Coast \(2009\) Best Practice Guidelines on Restoration of Mangroves in Tsunami Affected Areas.](#)

BOX 4. RESTORING SEVERELY ERODING COASTLINES THROUGH BUILDING WITH NATURE

Northern Java's coasts suffer from severe erosion. In one decade, some coastal areas have retreated by three kilometres. Development of coastal infrastructure and aquaculture went hand in hand with the removal of protective mangrove forests and the disturbance of sediment flows towards the coast and floodplains. Previous replanting efforts have not been successful, as the sediment balance is currently too disturbed to enable mangroves to survive. To counter this destructive erosion, a "Building with Nature" approach was tested in Timbul Sloko village in Central Java. The approach entails the placement of permeable dams that break the waves and trap sediment thus reclaiming land. Once the land is back, mangroves can recolonize the area and help protect the coastline against erosion. The waves are clearly much lower inside the grid of permeable dams than outside. In some cases, pioneering mangrove trees are already becoming established. In a direct response to these initial tests, the village signed a decree in 2014, demarcating 100 hectares of the recently lost land as protected area, ensuring that, upon recovery, it will not be damaged or destroyed again.





Harvesting from the mangroves in Indonesia,
by Nanang Sujana

Section 4. Recognising the multiple values of mangroves

Mangroves are among the most valuable ecosystems in the world. Decision makers, and the public, need to take full account of the many benefits that mangroves provide, and consider the true costs that may incur from mangrove loss.

Ecosystem services are the benefits people obtain from ecosystems. Ecosystem services can be grouped in four broad categories: provisioning, such as the production of food and water; regulating, such as coastal risk reduction and control of disease; supporting, such as nutrient cycling and water purification; and cultural, such as spiritual and recreational benefits. To help inform decision-makers, many ecosystem services are being assigned economic values.

In many parts of the world mangroves have been lost as people have cleared them to build aquaculture ponds or to make space for agriculture or urban developments. Although rates of loss have slowed in many areas, elsewhere they are continuing, with rapid expansion of aquaculture in many parts of Indonesia and South America. Mangrove removal is frequently justified on economic grounds, but this is often based on an incomplete analysis. Typically the initial value of the mangrove is under-estimated, as fisheries, employment, carbon, water purification and other benefits are ignored. Meanwhile profits from conversion are typically short-term, with initial profits from aquaculture or agriculture rapidly falling

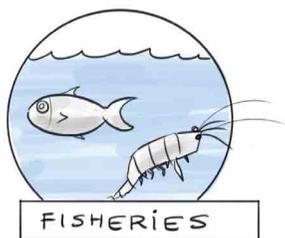
away as ponds become polluted or degraded, or soils become acidified or saline. Few will consider the heightened risk of erosion or flooding.

Communities, managers and planners need to take full account of all the services and functions of mangroves. Alongside protecting coasts from wave damage and erosion and building up sediments, mangroves are breeding grounds for fish, and rich sources of timber and fuel wood. They can help to filter pollution from estuaries, and in some places generate rich revenues from tourism and recreation. They are valuable to coastal villagers, for whom they supply jobs, income, a stable food supply

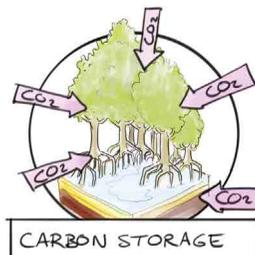
and support their recovery after coastal disasters, providing food, fuel wood and construction materials. They are also valuable beyond the local villages, supplying luxury foods such as crabs and shrimp to national and international markets. At the global level mangroves are some of the richest stores of carbon. In taking decisions about managing coastal resources it is important that communities, managers and planners take full account of all these values, and consider the true costs that may incur from mangrove loss by conducting a socio-economic cost benefit analysis.



Forest products. Mangrove trees produce dense, valuable wood, which is resistant to decay and to the impact of termites. Mangrove timber and poles have been used for centuries in house-building, while thinner “pole wood” is also valued for the building of fish-traps in mangrove waters. The same wood is important as fuel and for production of charcoal. The mangrove palm, or *Nypa*, is another highly valued species. Its enormous frond-leaves are widely used for making roofs, while this species also produces considerable volumes of sugary sap, used to make sugar, and alcohol. Fruits of some other species are also harvested in some countries. Mangroves have been sustainably harvested for over 120 years in parts of Malaysia and Bangladesh, but any harvesting needs to be managed to ensure the mangroves are not degraded or lost. Commercial-scale mangrove forestry requires extensive areas of mangrove, but can be sustainable and provide essential jobs and income.



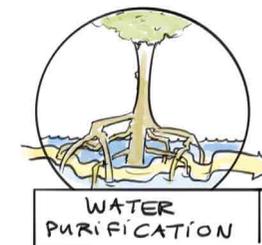
Fisheries. Mangroves are among the world’s most productive fishing grounds, yielding vast numbers of fish, crabs, shrimps and molluscs. Oysters cling to mangrove roots, crabs and cockles are collected from the mangrove mud, while many other species move with the tides. Fish and shrimp forage among the trees when the tide is high, but congregate in the channels as the water falls. It can be hard to put a value on such fisheries as much goes straight to local communities, and does not pass through conventional markets. Tens of millions of people rely on such fisheries, and without them would lose their primary source of protein, work or income. In a few cases the value of mangroves also converts directly to macro-economic outputs. This can include rich fisheries located quite far from the mangroves. Many fish and shrimp species use mangroves for just a short part of their life-history – adult fish may come into the mangroves to breed, and many larvae or young fish use mangroves as their home in early life. As they mature, such fish and shrimp move out into surrounding waters, to seagrasses, coral reefs and the wider expanses of offshore waters. The large and highly profitable commercial shrimp fishers from as far afield as Guyana, eastern Malaysia or northern Australia all depend on shrimps that in turn depend on mangroves.



Carbon. Vast quantities of carbon are tied up both in the living trees of the mangrove forests and in their rich soils. Unlike many other tropical forests, they sequester carbon and store it away in the soils where it can remain for millennia, as the saline, waterlogged conditions prevent the breakdown of organic material by fungi or bacteria. Mangroves are thus often seen as critical for long-term storage and sequestration of carbon – removing carbon dioxide from the atmosphere and storing it in their biomass and soil. Conversely, mangrove destruction can lead to massive releases of carbon dioxide, driven not only by the loss of trees, but by the breakdown of the soil carbon as well.



Tourism and recreation. Recreational fishing in mangrove areas can be big business – certain species such as bonefish, tarpon and snapper are considered top “game” fish. These recreational fisheries are thought to contribute US\$1 billion each year to Florida’s economy, and \$57 million and \$141 million respectively to Belize and the Bahamas. Such benefits are enjoyed by relatively few fishers, but if access can be facilitated, mangroves can be popular for a much wider group of visitors to explore, by boat or on foot. Boat trips take visitors to see birds, monkeys and other wildlife, and in a few places visitors are encouraged to explore alone or in guided canoe trips. Visitors on foot are encouraged by trails along board-walks that wind through mangroves and enable access at low and high tides. The success of such ventures probably still depends on accessibility and proximity to other tourism attractions, but numbers in some locations are now very high indeed, with tens of thousands of visitors each year to many sites, from Venezuela to China. Tourism and recreation in mangroves requires up-front investment, but can yield high economic returns to local communities.



Water purification. Mangroves, and associated biota such as algae, bacteria, and filter-feeding animals, play an important role in removing excess nutrients from the water. Some of these are bound into the soils; others may be broken down and, in the case of nitrogenous waste, may be released into the water as inert nitrogen. Mangroves can also help to trap sediment passing through their complex aerial root structure. Such services are not limitless, and excessive nutrients can remain and threaten marine life, but in many cases the role in removing toxins and nutrients is highly important. This may be particularly important where mangroves are found near coral reefs, which are highly sensitive both to excess sediments and to nutrient pollution. Water purification can also be a service of importance for aquaculture.



Using mangrove leaves,
by Wetlands International

Unfortunately many of these values are overlooked, for three reasons:

1. The value may be high in social terms, but low in conventional economic terms – many mangrove areas are critical for food supply or jobs, but generate little income.
2. Values from mangroves may be generated elsewhere. Nowhere is this clearer than with offshore shrimp fisheries where the mangroves provide critical nursery areas to commercially valuable species.
3. Mangroves provide long-term stable income or intermittent high value benefits, which are typically overlooked at the short-term time-scales of many planning bodies. Hence rapid profits made from conversion to agriculture or aquaculture seem more appealing, although these often have a limited lifetime beyond which they provide few additional benefits. Over decadal timeframes mangroves would outperform these short-term investments.

Mangrove value can be expressed in terms of monetary value, jobs and security. The growing awareness of the value of mangroves is leading to a positive trend. Mangrove planting, as well as natural recovery, has led to growing mangrove extents in many communities. Such trends, although insufficient to counter losses in other areas, look set to rise in the future.

Guidance for coastal managers:

- Get a full picture of mangrove values and the true costs of mangrove conversion over decadal time scales – using a socio-economic cost benefit analysis - in order to inform coastal planning and development.
- Note that some values are often overlooked, not only by policy-makers but even by the direct beneficiaries. Notable examples are offshore prawn fisheries and coral reef fisheries, which often benefit from mangroves.
- Many of the mangrove values need to be considered not only for their direct monetary benefits, but also in terms of providing jobs and food security in places where there may be few alternatives.

More information

- [TEEB website](#): The Economics of Ecosystems and Biodiversity (TEEB) is a global initiative focused on drawing attention to the economic benefits of biodiversity including the growing cost of biodiversity loss and ecosystem degradation. TEEB presents an approach that can help decision-makers recognize, demonstrate and capture the values of ecosystem services and biodiversity.
- [Ecosystem Services Partnership](#): a worldwide network to enhance the science and practical application of ecosystem services assessment.
- [Marine Ecosystem Services Partnership](#): a virtual centre for information and communication on the human uses of marine ecosystems around the world.
- [TESSA toolkit](#): providing practical guidance on how to identify which services may be significant at a site of interest, what data are needed to measure them, what methods or sources can be used to obtain the data and how to communicate the results.
- [INVEST tools](#): InVEST (Integrated Valuation of Environmental Services and Tradeoffs) is a suite of software models used to map and value the goods and services from nature that sustain and fulfill human life.
- Hutchison J, Spalding M & zu Ermgassen P (2014) The Role of Mangroves in Fisheries Enhancement. The Nature Conservancy and Wetlands International. 56 pages.
- UNEP (2014) The Importance of Mangroves to People: A Call to Action. Cambridge, UK, United Nations Environment Programme World Conservation Monitoring Centre.



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These guidelines are mainly based on 3 reviews, together summarizing hundreds of scientific papers on the role of mangroves in coastal risk reduction:

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- [Mclvor AL., Spencer, T., Möller, I. and Spalding, M. 2012b. Storm surge reduction by mangroves. Natural Coastal Protection Series: Report 2. Cambridge Coastal Research Unit Working Paper 41. Published by The Nature Conservancy and Wetlands International.](#)
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Join our efforts

Join us and support our on-going initiatives by advocating for integrated coastal zone management, helping us with research, contributing to community-based mangrove conservation and restoration, and funding our activities on mangroves and coastal resilience.

Stay in touch

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