POLICY BRIEF

SECURING THE FUTURE OF MANGROVES

Hanneke Van Lavieren, Mark Spalding, Daniel M. Alongi, Mami Kainuma, Miguel Clüsener-Godt, Zafar Adeel

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Mangroves planted in and around aquaculture ponds in Java, Indonesia. *Mark Spalding*

Key Messages and Recommendations

Mangrove ecosystems, status, trends and challenges

Mangrove forests are globally rare and cover an area of only around 152,000 km² in 123 tropical and sub-tropical nations and territories; this is less than 1% of all tropical forests worldwide, and less than 0.4% of the total global forest estate.

Mangrove ecosystems are valuable both economically and ecologically, offering a considerable array of ecosystem goods and services. They are vital for the wellbeing, food security, and protection of coastal communities worldwide and are also rich in biodiversity:

- Mangrove forests serve as highly effective global carbon stores and sinks. Alongside their living biomass, mangrove soils are carbon-rich, sequestering carbon over millennial timescales.
- Nearshore fisheries among mangroves are well documented and of critical importance to numerous communities, but many large-scale fisheries, such as commercial offshore shrimp fisheries, are also highly dependent on mangroves as nursery or breeding grounds.
- Mangroves provide rot resistant, high value timber and excellent fuelwood which has been harvested in sustainable forestry programmes in some countries for over 120 years.
- In many settings, mangroves act as a form of natural coastal defence: reducing erosion, attenuating waves and even reducing the height of storm surges. Over the long-term, they can also help build or maintain elevation in the face of rising seas.

Economic valuations of mangrove ecosystem goods and services provide some of the most powerful arguments for effective mangrove management. A growing number of economic valuations reveal the considerable benefits of mangroves, even towards single services such as fisheries. When the full suite of ecosystem services is assessed, the arguments for maintaining healthy mangrove forests are compelling.

Rapid degradation or loss of mangroves is continuing in most areas. Despite declining rates of loss, mangroves are still disappearing three to five times faster than overall global forest losses. Some countries have lost more than 40% of their mangrove area over a 25 year period and many remaining areas are in a degraded state.

Mangrove nursery, India. *Shigeyuki Baba*

Overall, aquaculture has been the primary global driver for mangrove conversion, followed by urban, coastal and agricultural development.

Continued loss of mangrove forests will have serious ecological and socio-economic impacts. The impacts of loss are disproportionately felt by communities who are most heavily dependent on mangroves for food, fuel or protection, but losses will also have a wider reach, increasing vulnerability of coastal lands to natural hazards, and reducing fisheries productivity.

Considerable variation in mangrove losses between countries can be directly linked to national differences in policies, legislation and management.

Reversing the trend of mangrove loss and the growing vulnerability of coastal peoples will require a real commitment by governments to develop and implement robust high-level policies.

Management and restoration of mangrove ecosystems is achievable. We have a clear understanding of the management interventions that are required to secure the future of mangroves. These are underpinned by many successful examples from around the world, and by strong economic arguments. Trends of mangrove loss can be rapidly slowed with good management practices, laws and the establishment of clear frameworks for mangrove ownership, use and management to guide human activities. Restoration has been widely applied in many countries and offers the possibility of reversing the patterns of loss while bringing considerable benefits to coastal areas.

Key Messages and Recommendations

Improving Mangrove Management

Overarching legal and policy frameworks that support and provide the right enabling conditions for effective mangrove management should be encouraged as a precursor to good management. These frameworks should:

- Clearly define and accept the rights of ownership, access and use of mangrove forests.
- Establish framework policy and legislation for mangroves at the national level.
- Ensure that laws and regulations are enacted and enforced.
- Enhance human, technical, legal and financial capacity for mangrove management at different levels.
- Ensure that measures, including subsidies and other incentives that lead to mangrove degradation or loss, are removed.

A broad range of management measures and tools should be promoted to maximize the benefits and help secure the long-term future of mangroves and the people who rely on them. These include:

- Increase restoration efforts to recover lost mangrove forests and restore their ecosystem services.
- Ensure the involvement of local communities in mangrove management.
- Implement sustainable mangrove forestry practices which provide high value use for mangroves, ensuring long-term benefits to local communities, but are also well-planned and adapted to local conditions.
- Encourage sustainable aquaculture practices which can reduce pressure for increased mangrove conversion, and in some settings can be enhanced by mangrove restoration within or adjacent to ponds.
- Establish protected areas which are a powerful tool for ensuring the protection of mangrove biodiversity and should form part of a wider management regime. Successful protected areas require community engagement and clear legal and management structures.
- Develop cohesive management plans for entire countries and ecological units (which may be international). Such management should also be integrated into a broader spatial framework of coastal zone management.
- Promote managed realignment to (re-) establish landward expansion of mangrove habitat.
- Encourage and support mangrove ecotourism to generate income and employment for local communities and to improve outreach and education.
- Enhance existing carbon stocks and reverse CO_2 emissions by increasing protection and restoration of mangrove ecosystems, and build mangroves into emissions trading and climate change mitigation planning.
- Utilise multilateral environmental agreements, together with the establishment of national legal protection measures, to support mangrove management.

The role of mangroves in climate change adaptation and disaster risk reduction should be integrated in local and national adaptation plans. National adaptation and disaster risk reduction plans and actions should:

- Encourage the conservation and restoration of mangroves as part of "natural coastal infrastructure", recognizing their role in reducing vulnerability and increasing resilience to climate change impacts.
- Require the use of environmental impact assessment when planning and installing artificial coastal defences in or close to mangrove forests, considering the risks such structures may pose to the mangroves and to all associated ecosystem services. Consideration should also be given to using mangroves alongside built infrastructure as "hybrid engineering" where protection from mangroves alone may not suffice.

Management interventions will only be successful when backed up by sound data and a broader knowledge, understanding and awareness for the need of these interventions. We already have sufficient knowledge to justify change and precipitate action in many areas. Further information on ecosystem function, economic valuation and alternative management approaches will help build a stronger case for interventions and to refine models and management approaches. In particular, there is a need to:

- Improve public outreach and education at all levels to raise awareness of the economic and social importance of mangroves, and the potential consequences of their loss.
- Share existing knowledge on ecosystem function, ecosystem services and management interventions to support changes to mangrove policies. Success and failure stories should be widely shared to help stimulate additional effort to improve management and restoration of mangrove ecosystems.

- Investigate further and communicate the economic arguments for maintaining and restoring mangroves to assist decision makers to make more efficient and justified cost-effective choices.
- Support new research and maintenance of long-term data sets on the extent of mangrove resources, their value, and responses to a range of pressures to inform sound policy and management decisions.

Economic Policies for Sustainable Mangrove Management

To ensure that legal and policy frameworks as well as specific management interventions are successful, the right economic settings must be established. Required action includes:

- Create economic incentives that promote more environmentally responsible behavior and at the same time enhance local livelihoods.
- Ensure that the full array of mangrove ecosystem goods and services are included in national economic accounting.
- Promote Payments for Ecosystem Services (PES) schemes as a source of income for mangrove land management, restoration, conservation, and sustainable use activities.
- Fully account for all risks and all costs and benefits associated with development in mangrove areas; discouraging development in high risk settings and providing incentives for conserving and restoring mangroves as part of 'climate resilient' and integrated coastal development.

The key role of mangroves as carbon stores and sinks needs to be highlighted in national and international strategies that address climate change. This should include work on establishing mechanisms for payment through carbon markets, including credits, offsets and potential payments under the UN Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol (see International Policy section below), but also Voluntary Carbon Markets (VCM) and national or regional trading schemes.

Coordinate International Policy Agendas

Coordinated action towards the protection and restoration of mangroves needs to be embedded within the international policy arena, notably under biodiversity, wetlands, sustainable development and climate change agreements. In particular, under the UN Framework Convention on Climate Change:

- Support the implementation of mangrove projects for carbon emission reductions under the Reduction of Emissions from Deforestation and Forest Degradation (REDD+) scheme.
- Encourage the use of the Clean Development Mechanism (CDM) to support mangrove restoration and afforestation.
- Encourage accounting for ongoing sequestration and for soil carbon stocks within these mechanisms.
- Further investigate international mechanisms for mangrove carbon credits under blue carbon accounting.
- Encourage the conservation and restoration of mangroves as part of adaptation and risk reduction plans.

Management and restoration of mangrove ecosystems should be recognized as an achievable and cost effective way to help ensure food security for many coastal communities. Healthy mangrove forests contribute to the food security of millions of people around the world, through the production of numerous fishery and forest products, by supporting commercial coastal and offshore fisheries, and by providing locations for aquaculture.

Governments need to recognize the strong link between mangrove ecosystem degradation and persistence of poverty in many rural coastal communities. Integrated management of mangrove ecosystems and biodiversity within poverty reduction strategies and food security planning is critical if the Millennium Development Goal to eradicate extreme poverty and hunger (MDG 1) is to be met.

Mangroves in the Republic of Djibouti. *Yves de Soye*

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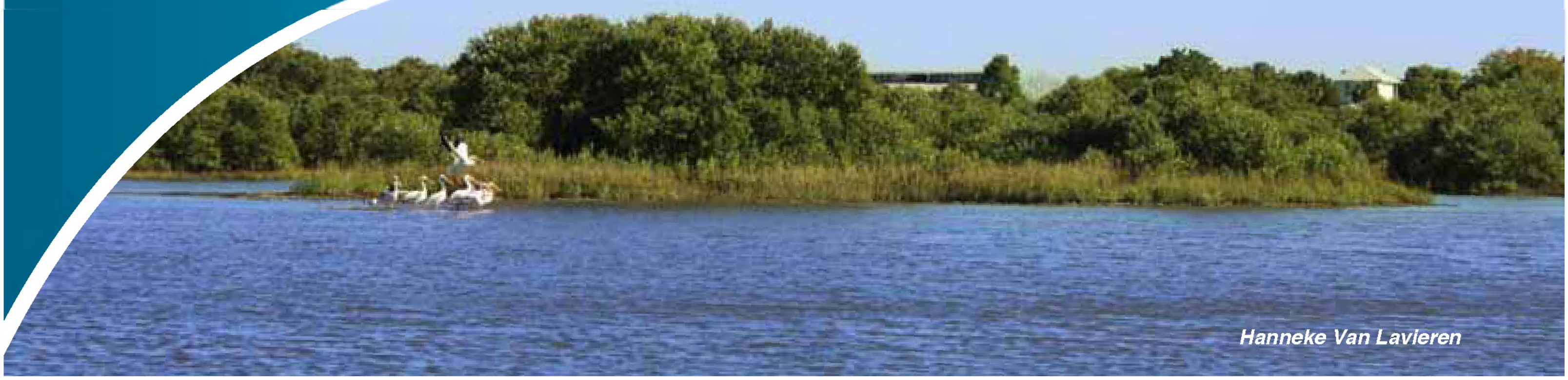
Background



Hanneke Van Lavieren

Mangroves are extraordinary ecosystems, located at the interface of land and sea, that offer a considerable array of ecosystem goods and services. They are vital for food security and protection of coastal communities; they provide a wide diversity of forest products, nurseries for aquatic species, fishing grounds, carbon sequestration, and crucial natural coastal defences that mitigate the impact of erosion and storm action. Global climate change and the associated risks of sea level rise and extreme weather events have increased their importance. Calls for conservation have also increased in recent years with growing evidence that mangroves may have an important role as natural buffers in protecting coastlines from the impacts of storms and extreme wave action.

Despite their value, nearly all mangrove nations have experienced net losses in cover in recent decades, and remaining mangrove habitats are seldom pristine. About one fifth are thought to have been lost globally since 1980 due to a suite of anthropogenic threats including over-extraction and deforestation; infilling, drainage and conversion for aquaculture; agricultural, urban and industrial runoff; oil spills; and poorly managed dredging and coastal development. These practices continue to take their toll and if left unchecked will cause significant economic and ecological decline. Rare and critically important mangrove forests continue to be lost at a rate three to five times faster than that for global forests. Set against this is a growing realisation of the social and economic value of mangroves and a remarkable array of restoration efforts in many countries around the world. These are not sufficient to reduce the overall rates of loss, but do provide a pointer to the changing attitudes in some places, and to the viability of restoration as a tool for reversing the losses associated with mangrove decline. Much of their fate is determined by high-level policy decisions and by the lack of enforcement of protection measures. Reversing this downward trend will require a real commitment by governments to develop and implement robust high-level policies that could positively affect mangroves.

This policy brief is largely based on the World Atlas of Mangroves (2010) which provides a wealth of knowledge on the ecology, biodiversity, distribution, economic value, and management status of mangroves around the world. The aim of this policy brief is to provide managers with lessons learned on the conservation and management of mangroves, and recommend policy measures that could be taken in order to protect them. We hope that this document will stimulate greater interest by policy makers in the fate of these valuable ecosystems, and promote a greater drive for their effective protection and management.

Mangroves at Pichavaram, India. *Hanneke Van Lavieren*


Ron Schaasberg

Mangroves: A Unique, Rare and Threatened Ecosystem

1

Mark Spalding

Mangrove forests are a unique and rich ecosystem found along intertidal coastlines of tropical and subtropical latitudes. These forested wetlands are home to a wide variety of flora and fauna, including mammals, birds, insects, reptiles, fish and molluscs. Birds roost in the canopy, shellfish attach themselves to roots, and snakes and crocodiles use them as hunting grounds. Mangroves provide a valuable nursery habitat for fish and crustaceans; a food source for monkeys, deer, birds, even kangaroos; and a source of nectar for bats and honeybees. Typically, there are tight ecological linkages and energy flows between mangroves and adjacent ecosystems such as mudflats, coral reefs, seagrass beds and salt marshes. Mangrove forests are highly productive and support complex communities; linked to mangroves are thousands of other species which interact in a myriad of ways and with complex interdependencies.

Mangroves are ecosystem engineers that shape, build and maintain the integrity of their surrounding physical environment. Seventy-three mangrove species and hybrids defined by the World Atlas of Mangroves (2010) have adapted to intertidal zones, growing in environments characterized by harsh saline conditions and inundation on one side, and aridity or highly competitive conditions typical of tropical lowland vegetation on the other. Sediments within which mangroves grow are soft, waterlogged and unstable. Physical properties, chemical composition, salinity, soil acidity, and substratum type as well as climate are other factors which determine development, growth and productivity. Considerable variability exists among mangrove species with respect to ability to survive in different conditions. Where conditions are optimal, mangroves can form extensive and diverse forests that reach canopy heights of 30 m or more. At the other extreme, where conditions are more arid or saline, fewer species survive, rarely reaching 3 m in height.

Mangrove forests are found in 123 tropical and subtropical nations and territories. They are globally rare and only cover an area of about 152,000 km^2, which is <1% of all tropical forests worldwide, and <0.4% of the total global forest estate (39,520,000 km^2; FAO, 2006). Mangroves are distributed as two biogeographic floras, a diverse Indo-West Pacific flora extending from East Africa to Polynesia and a less speciose Atlantic East Pacific flora in the Americas and West and Central Africa. With the exception of the fern *Acrostichum aureum*, there is virtually no overlap in species distribution between these two realms. Four countries (Indonesia, Brazil, Australia, and Mexico) account for >40% of the total global mangrove coverage, with Indonesia leading the way with >20%.

Mangroves are home to a wide variety of flora and fauna. *Ron Schaasberg*

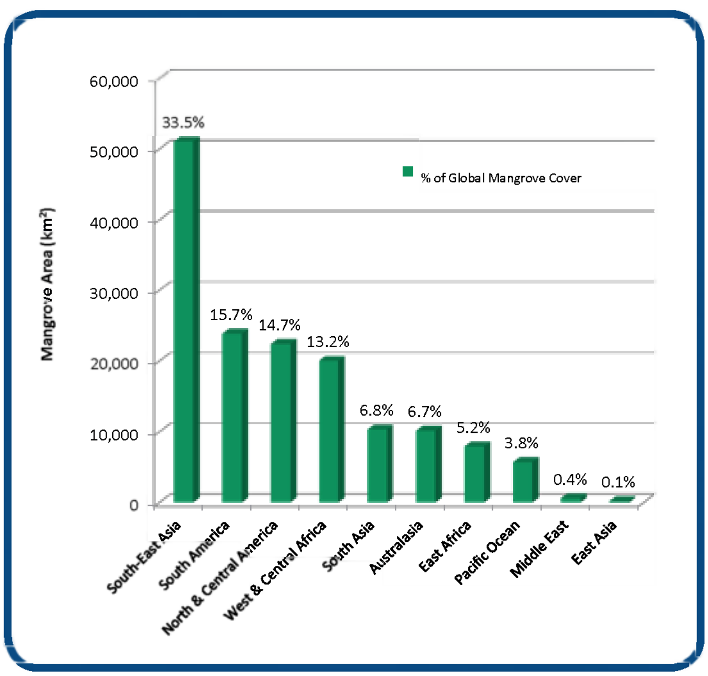
Mangroves: A Unique, Rare and Threatened Ecosystem

Global distribution of mangroves (adapted from the 2010 World Atlas of Mangroves)

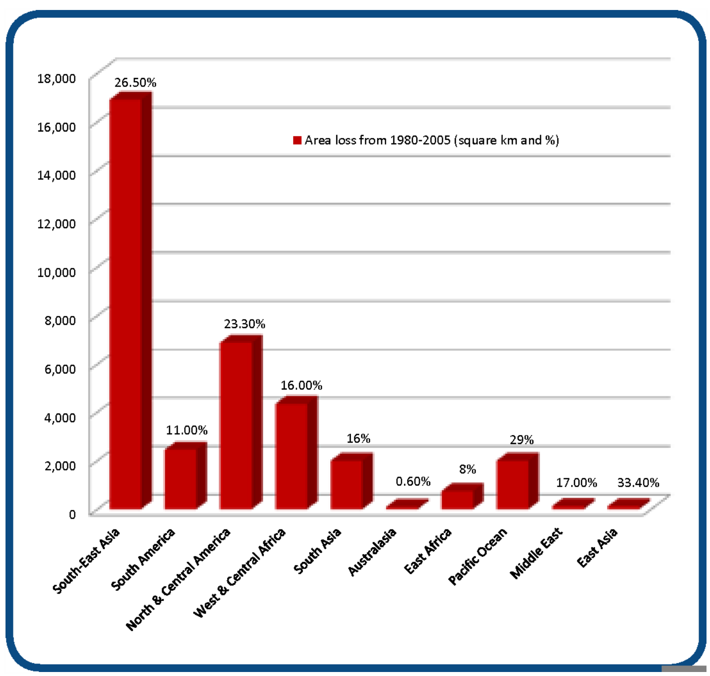
Since 1980, nearly all regions have experienced extensive losses of mangrove area. The most detailed historical records indicate that in 1980 there was a total of 188,000 km^2 of mangroves (FAO, 2007), and while we have no accurate means of determining the global cover prior to 1980, it is thought to have been greater than 200,000 km^2 (Spalding et al., 1997). It is estimated that about one fifth of all mangroves have been lost since this time and today, many remaining mangrove forests are considered degraded. Most pronounced losses (>20%) have occurred in the Asian and Pacific regions, followed by Central America. Limited losses have occurred in East Africa, with only an 8% decline between 1980 and 2005. In some countries, the extent of loss has been much higher than the regional norm; for example, Pakistan, Honduras, the Democratic Republic of Congo, Vietnam, Sierra Leone and El Salvador each lost >40% of their 1980 coverage by 2005 (FAO, 2007). However, in Australia, Bangladesh, Cuba, Suriname, and the French Guiana, the extent of loss has been <1% over the same period.

The global rate of loss of mangrove area has been declining over the past two decades; although it remains 3-5 times faster than the overall global rate of deforestation, there is considerable variation in the rate of decline among countries. Mangrove loss was estimated at 0.72%/annum versus 0.22%/annum for total forest loss in the 1990s, dropping to 0.66% versus 0.18%/annum during the five years up to 2005 (FAO, 2007). The variation between countries can be mostly attributed to national policies and legal protection. For example, FAO data show that since 1980, Indonesia has lost some 31% of its mangroves, whereas Malaysia has lost only 16%. This may be largely due to the fact that the majority of Malaysia's forests fall within a national forest reserve network and many mangroves are actively managed, whereas in Indonesia, mangroves are under extreme pressure from conversion to agriculture, aquaculture and coastal development.

Region	Most Common Threats
North & Central America	Development (coastal, tourism, urban), hurricanes, land conversion to agri/aquaculture, pollution
South America	Land conversion to agri/aquaculture
West & Central Africa	Development (urban), degradation, land conversion to agriculture, oil/gas extraction, pollution
East Africa	Clearing, degradation, land conversion to agri/aquaculture, overharvesting, pollution, sedimentation
Middle East	Degradation, development (coastal, tourism, urban), land reclamation, poor planning, oil spills, overharvesting, sedimentation
South Asia	Disease (top-dying), erosion, encroachment, land conversion to agri/aquaculture, reduced freshwater flow, plantations, poor planning, storms
South-East Asia	Land conversion to agri/aquaculture, development (coastal, urban), disease, industrial overharvesting, overfishing, gas extraction, poor planning and enforcement, pollution, sedimentation
East Asia	Development (coastal), land conversion to agri/aquaculture, overharvesting, pollution, unsustainable timber harvest
Australasia	Development (coastal, urban), land reclamation, oil spills, pollutants (agricultural), storms
Pacific Ocean	Development (coastal, tourism, urban), overharvesting, overfishing, pollution, sedimentation (from mining)



Mangrove coverage per region and proportion of global share in 2010 (from the World Atlas of Mangroves, 2010).



Mangrove area loss in km^2 and % between 1980 and 2005 (FAO, 2007).

Mark Spalding

Living on the Edge: Human Impacts on Mangrove Ecosystems

2


Katey Savage

Continued loss of mangrove forests will have serious ecological and socio-economic impacts, especially on coastal communities that rely directly on mangrove products and services for their livelihoods. The effects of human activities on mangroves have far exceeded those of natural events over the past few decades. Economic development, rapid population growth and high population densities in coastal areas are the main drivers for mangrove degradation and loss. Although causes for loss can differ substantially amongst regions and countries, aquaculture has been the major global driver for mangrove conversion, and still represents one of the greatest global threats. Already the environmental toll on mangroves and other coastal ecosystems from aquaculture has been severe. A 2001 study estimated that about 38% of global mangrove loss can be attributed to the clearing of mangroves for shrimp culture, while another 14% can be blamed on other forms of aquaculture (Valiela et al., 2001). With almost half (~44%) of the world's population living within 150 km of a coastline, it is not surprising that there has been widespread clearing and degradation of mangroves for coastal development, conversion to aquaculture or other resource use, as well as pollution. Climate change will exacerbate existing pressures; future coastal wetland (including mangroves) loss through sea level rise is predicted to reach 5–20% by 2080 (Crooks et al., 2011) and this 'coastal squeeze' may cause coastal wetland systems to be lost entirely locally (CBD, 2010). Armed with this knowledge, policies must change in order to halt, or reverse, the rate of mangroves loss.

Land reclamation for tourist infrastructure development, the Philippines. *Mark Spalding*

MAIN THREATS TO MANGROVES

A. CONVERSION

Many mangrove habitats have been lost globally because of direct conversion to urban and industrial spaces, aquaculture ponds, residential areas, ports, marinas, tourist resorts, and agricultural land. The magnitude of impact varies from region to region but a common denominator is that planners typically view mangrove forests as a low-value space and most decisions are made without sound knowledge of the value of keeping mangrove habitat intact versus converting it to other uses.

i) Urban, infrastructure and tourism development: Extensive areas of mangrove forest have been lost to urban expansion, tourism development, and other infrastructure needs. This is probably best demonstrated in Central America, the Caribbean, and some parts of Southeast Asia and the Middle East where extensive mangrove areas have been converted to waterfront property, tourism resorts and golf courses. With substantial sea level rise now anticipated before 2050, development of such low-lying land seems unwise.

ii) Aquaculture: Over the last few decades a major driver of mangrove conversion has been continuous growth in aquaculture activities, particularly shrimp farming in Southeast Asia. With intensive aquaculture, productivity can only be maintained via heavy application of fungicides, pesticides and antibiotics. This shortens the effective lifespan of ponds, which are abandoned in favor of new ponds when incidence of disease or pollution becomes too great. Abandoned ponds do not return quickly to mangrove habitat unless actively restored.

iii) Agriculture: The flat and rich organic soils of mangrove forests have made them prime locations for conversion into agricultural land, especially rice paddies and palm oil plantations. However, conversion for agriculture can lead to drying and rapid and irreversible acidification of soils which results in unusable land. Such conversion can also lead to loss in soil elevation and costly engineering interventions to prevent flooding. Economic arguments for this conversion are often weak; nonetheless, where population pressures are high and space is limited, wide areas of mangroves have been converted for agriculture.

B. DEGRADATION

i) Grazing by animals: In some arid regions, notably in India and the Middle East, heavy browsing by goats and camels can cause severe degradation and sometimes death of mangrove trees.

ii) Pollution: Pollutants from agricultural and urban runoff, sewage, industrial waste and oil spills, often end up in mangrove forests either directly or indirectly. Mangroves can survive significant levels of pollution that would be detrimental to more sensitive ecosystems like coral reefs, but high nutrient levels, pesticides, and other toxic man-made chemicals can kill animals living in mangrove forests, while oil pollution can smother mangrove roots and suffocate trees.

MAIN THREATS TO MANGROVES CONTINUED

iii) Altered water flow: Human alteration of natural tidal flow near mangrove forests, via construction of roads, drainage canals, sea defences or other infrastructure, has had dramatic impacts on natural hydrological flow. Roads, for example, are often built across tidal flats in arid countries, acting as a barrier to natural water flow and causing drying and hyper-salinization of soils. Changes to freshwater inputs, arising from upstream dams and irrigation also impact mangroves, altering salinity and often leading to mangrove losses; for example, in the Indus Delta in Pakistan, there has been a 90% reduction in freshwater inflow, leading to increases in coastal erosion due to the lack of new sediment input.

iv) Overharvesting: While harvesting of mangroves products (e.g., for firewood, construction material, animal fodder, wood chip, and charcoal) has taken place for centuries, in some parts of the world it is no longer sustainable. As communities have grown and became more structured, uses of mangroves have become larger scale and even industrial. Often mangrove products are harvested without any clear management framework or quota, leading to unsustainable harvesting levels and diminished yields.

v) Overfishing: Mangroves are of considerable importance to artisanal, commercial and export fisheries because of their importance as nursery grounds for many exploited fish and crustacean species. Mangroves support a complex community of species and fish play a vital part as they consume large deposits of decomposed leaf, bark and twig litter produced by mangrove trees. Overfishing is a serious problem both within mangroves and in some offshore fisheries; the removal of fish can lead to an imbalance in the natural food web.

vi) Natural impacts: Extreme weather events (e.g., hurricanes) and wave action: Although mangroves can absorb and reduce the impact of strong winds, storm surges, and floods that accompany tropical storms, as well as tidal waves, they are sometimes severely damaged. For example, a sequence of hurricanes have permanently changed and shaped the structure of mangrove forests in the Florida Everglades. Studies indicate that some sites were able to recover naturally while other sites have been permanently transformed into other ecosystems. Tsunami waves can also be highly destructive and in extreme cases, such as the 15 m high waves that occurred near the epicentre of the 2004 Indian Ocean Tsunami, mangroves were overwhelmed and lost.

Disease: Disease can cause severe damage to mangroves. In one specific case, the 'top dying' disease damaged about 20% of the entire mangrove area in Bangladesh. This disease is believed to be caused by an array of factors including increased soil salinity resulting from reduced water flow.

vii) Sedimentation: The aerial roots of mangroves allow root respiration within the anaerobic substrate. Mangroves can thrive in areas with shifting sediments, such as deltaic systems; they are also active colonizers of new sediments, as exemplified in the shifting mudflats found along the coastline of the French Guyana. Still, it has been shown that excess input of sediment to mangroves can cause death of trees due to root smothering.

MANGROVE PLANTING: THE REPUBLIC OF KIRIBATI

The fate of the many small and low-lying islands in the Pacific is in question as they are especially vulnerable to the impacts of rising sea levels, storm surges and coastal erosion. Tide gauge records show a mean sea level rise (SLR) of almost 2 mm per year for the 55 years up to 2004, and investigations of seaward mangrove margins suggest detectable retreats of 25 to 72 mm per year over a ten-year period (Gilman and Ellison, 2007). Research shows that healthy mangroves can protect shorelines against SLR, storm waves and surges and coastal erosion. The Republic of Kiribati, a small island nation in the Central Pacific has elevations ranging from sea level to only 3 m and in an effort to reduce coastal erosion a mangrove plantation project has been implemented by the Kiribati government and the International Society for Mangrove Ecosystems (ISME), together with environmental youth groups and school children in the Tarawa atoll, and financial support from the Japanese Cosmo Oil Company Ltd. (Baba, et al. 2009). This project has led to the development of a unique and effective close group planting method where three propagules per group of *Rhizophora stylosa* are planted close together (25x25 cm or 50x50 cm) along the shoreline between the mean water level and the mean high water level (Baba, 2011). At one site, Ananau Causeway, survival was 90% just one year following planting and over 50% after 3 years (Suzuki et al., 2009). Within 4 years, increases in sediments were observed and the mangroves had formed a distinct barrier with trees bearing flowers and fruits. During a special visit in September 2011, Mr. Ban Ki-moon, the Secretary General of the United Nations, planted mangroves alongside Mr. Anote Tong, President of Kiribati, using this method. There is great optimism that this effort will help further mitigate coastal erosion and protect against projected sea level rise.

Mangrove planting in the Republic of Kiribati. *Shigeyuki Baba*

There are some positive changes taking place in people's perceptions of the importance of mangrove forests, but improved management still lags. A growing number of economic valuations reveal the benefits to society of healthy mangrove forests. Awareness of this value has been heightened by failures of aquaculture operations, falling shrimp prices, collapsing offshore fish stocks, and coastal erosion, often clearly linked to mangrove losses. In some cases, this increased awareness has led to new legislation, better protection, and improved management. There has also been an increasing effort to rehabilitate and restore mangrove habitats that have been lost and afforestation techniques have been used to increase the extent of mangrove area. The World Atlas of Mangroves (2010) documents over 3840 km^2 worth of restoration projects worldwide and there are doubtless many more.

Shrimp aquaculture has been the major driver for mangrove conversion worldwide. *Mark Spalding*

Impacts of climate change on mangrove ecosystems

It is highly likely that climate change will have strong impacts and exacerbate existing pressures on coastal ecosystems, including mangroves. Anthropogenic climate change is now widely regarded as one of the greatest threats to natural ecosystems worldwide. Effects include a rise in relative sea level and sea water temperature, with a possible increase in the frequency and magnitude of extreme weather events and associated elevated storm surges and wave height (IPCC, 2007).

SHRIMP AQUACULTURE: SOUTHEAST ASIA

Southeast Asia is the global centre of mangrove diversity and hosts one third of the world's mangroves by area. Aquaculture has been the single largest driver of mangrove losses. Since the 1970s, aquaculture development, primarily for shrimp farms, has decimated vast areas of mangrove forest especially in the Gulf of Thailand, Vietnam, Java, Kalimantan, the Philippines, and elsewhere. In Java, Indonesia, some 90% of the once extensive mangroves have been converted to agriculture and aquaculture since 1980 (Tomascik et al., 1997). This trend was pushed by rising demand for shrimp in international markets in the 1980s, which drove up the price, and encouraged growth in supply, and resulted in a push to fund aquaculture development. In the Philippines, for example, Government support in the form of loans was a major incentive for aquaculture development through the 1950s and 1960s. Further expansion during the 1980s was partly encouraged by a 1975 Fisheries Decree mandating a policy of fish-pond development and extending ten-year aquaculture permits to 25 years (Primavera, 2004). At the same time there was a failure by national and local governments to adequately regulate the shrimp industry and enforce mangrove protection. World shrimp aquaculture production increased from about 500,000 tonnes in 1988 to over 2.8 million tonnes in 2008 (FAO, 2012). Over 80% of the production in 2008 was concentrated in Asia; China, Thailand, and Indonesia. The benefits of this industry have too often been short lived due to poor planning, with ponds being abandoned when pollution or disease take hold, leaving unproductive saline pools and depleted coastal fisheries. Such large-scale conversion has had major negative environmental impacts, including collapses in wild fisheries. In a region where fishing in and around mangroves is a critical activity providing food and income for millions of people, the socio-economic impacts of this conversion have been tremendous. There is now a growing awareness of the importance of mangroves, and government and community led efforts are underway to restore or replant mangroves, and to improve legal systems to regulate their future use.

The Impacts of Global Change on Mangrove Ecosystems

Physical Parameter	Predicted Change	Expected Impact on Mangroves
Sea Level Rise (SLR)	Projected to rise 18-79 cm between 1999-2099*	This could be the greatest threat facing the future of mangroves (Field, 1995; Gilman et al., 2008). Predictions of mangrove loss range from 30% to extinction (IPCC, 2007; Duke et al., 2007). Extent of loss will depend on many physical and biological factors. Mangroves may migrate landwards according to rates of SLR and vertical accretion, both also interlinked to slope and available space at the landward edge. Adaptation to local factors, such as changes in tidal range and sediment supply, will likely be species dependent (Alongi 2002, 2008). Zonation patterns and species composition of plants and animals will change as erosion and flooding at the seaward front begins. These effects are likely to be magnified in areas with low lying coasts (especially small islands) and where available upland space are limited, and in the arid tropics where rates of sediment supply and mangrove growth are low.
Temperature	Global temperatures have increased by 0.74°C (+/–0.18°C) between 1906 and 2005 and most models predict rises of 2°C to 4°C within the next 100 years*	Projected changes in atmospheric and sea surface temperatures may result in expanded latitudinal limits for some species, alteration of community composition and increases in photosynthesis, respiration, litter, microbial decomposition, floral and faunal diversity, growth and reproduction, but declining rates of sediment accretion (Field, 1995; Alongi, 2008). At local and regional scales, changes in weather patterns may induce changes in the salinity regime and community composition as a result of salinity changes, and a change in primary production if the ratio of precipitation to evaporation is altered (IPCC, 2007).
Atmospheric Carbon Dioxide (CO_2)	CO_2 levels have increased from 280 ppm by volume (ppv) in 1880 to nearly 370 ppv in 2000 (Houghton et al., 2002) with the pH level of the oceans increasing in acidity by 25%. Despite large variation, all models predict a further increase in CO_2 levels by the end of the century, with some predicting a doubling or even tripling of today's level	Responses will be difficult to predict but rates of photosynthesis, and salinity, nutrient availability and water-use efficiency will likely change (Ball et al., 1997). There will likely be no or little change in canopy production, but species patterns within estuaries are likely to change based on species-specific responses to the interactive effects of rising CO_2, sea level, temperature, and changes in local weather patterns (Alongi 2002, 2008). Elevated CO_2 concentration could alter competitive abilities, thus altering community composition along salinity-humidity gradients (Ball et al., 1997).
Intensity and Frequency of Storms	Intensity and frequency will increase*	The level of impact will be proportional to the strength, frequency, size and duration of storms. Impacts include defoliation, up-rooting, tree mortality, and increased stress from altering mangrove sediment elevation due to soil erosion, deposition, and compression (Smith et al., 1994; Cahoon et al., 2003). Recovery from storm damage can be very slow.
Precipitation patterns	**Globally**, rainfall is predicted to increase nearly 25% by 2050 and the intensity of rainfall events will also increase* **Regionally**, changes in rainfall are predicted to be uneven (Houghton et al., 2002); significant increases in precipitation at higher latitudes (eastern parts of North and South America, North Europe and North and Central Asia) and decreased precipitation in most subtropical regions (Sahel, South Africa, the Mediterranean and parts of South Asia)*	Regional and local patterns of growth and distribution may be affected (Field, 1995; Ellison, 2000). Increased intensity of rainfall events is likely to influence erosion and other physical processes in catchments and tidal wetlands. Increased rainfall may increase diversity and enhance growth and coverage via colonization of previously un-vegetated areas. Reduced rainfall may lead to reduced diversity and productivity of mangroves and increases in salt marsh and salt flat areas (Smith and Duke, 1987).

* IPCC, 2007

COASTAL DEVELOPMENT: MEXICO

With over 7700 km^2, Mexico has the most extensive area of mangroves in the Central American region. The north-western and northern coasts of the Yucatán Peninsula, as well as the Caribbean east facing shores of Mexico, were originally almost entirely lined by lagoons and barrier islands rich with mangroves. These habitats are host to spectacular birdlife, including over 20,000 flamingos. As in many other parts of this region, coastal tourism is a large and ever expanding industry. Although there is considerable low impact ecotourism, it is dwarfed by the very large-scale resorts that have transformed the original landscape. Cancún presents one of the most extraordinary examples where a mangrove-fringed lagoon was replaced in just a few decades by high rise hotels and some of the most expensive real estate in the country. New coastal roads that were built to provide access to these hotels have cut off the natural hydrological connections between habitats. Without mangroves, coastal erosion is widespread and beaches are continuously being replenished artificially, a very expensive venture. The legal protection that once safeguarded mangroves was rescinded in 2004 due to pressure from coastal developers, but was reinstated in early 2007 to absolute protection. However, there remains significant pressure from tourism developers to return to lower levels of protection and so far, national, regional, and local governments have failed to adequately regulate the fast growing coastal tourism industry. It is clear that integrated and stringent management action is needed to protect remaining mangroves.

Mangroves are threatened by coastal development, Cancun, Mexico. *Hanneke Van Lavieren*

Shigeyuki Baba

Valuing Mangrove Ecosystem Goods and Services

3

Mark Spalding

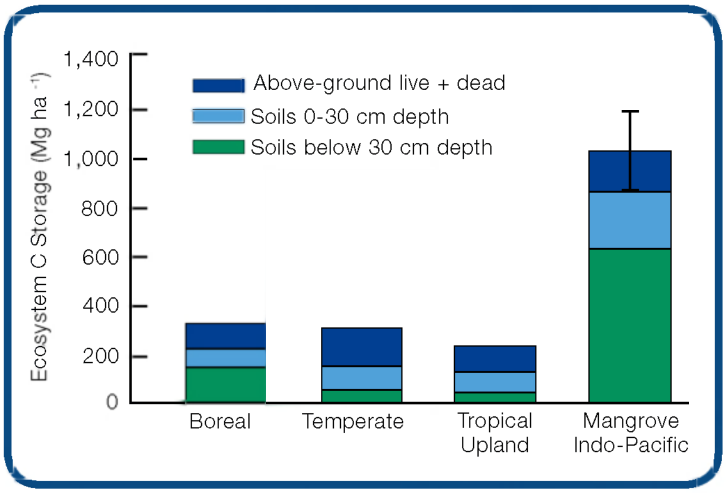
For thousands of years, indigenous communities have depended upon mangroves for traditional and commercial uses. For many of those that live within or near mangroves, these forests provide critical ecosystem goods and services: provision of timber and non-timber resources, support to fisheries, and protection of coastlines from storms and erosion. Mangroves also contribute towards a broad range of other important socio-economic benefits to coastal communities. In a number of areas, traditional communities living near or even within mangrove habitats have maintained a symbiotic relationship that is often sustainable and even integral to the ecology and functioning of both the mangrove ecosystem and the community. In most places, however, commercial and high-intensity uses have changed the nature of this relationship. Unfortunately, many of these societies, once dependent on mangroves for valuable services, have chosen to overlook the long-term benefits that mangroves provide, allowing rapid degradation or entire loss of mangroves.

Mangroves support many coastal and offshore fisheries. *Hanneke Van Lavieren*

Valuing Mangrove Ecosystem Goods and Services

Mangrove Goods and Ecosystem Services							
Provisioning		**Regulating**		**Supporting**		**Cultural**	
Goods and products		Natural processes		Natural processes that maintain other ecosystem services		Non-material benefits	
Services	**Examples**	**Services**	**Examples**	**Services**	**Examples**	**Services**	**Examples**
Forest Resources	*Construction material, food, fuel, tannins and resins, ornamentals, fodder*	**Carbon Storage and Sequestration ('Blue Carbon')**	*Provide high rates of carbon sequestration and storage*	**Nutrient Cycling**	*Maintain nutrient flows in surrounding air, soil, and vegetation*	**Aesthetic**	*Beautiful scenery and landscapes*
Fisheries	*Fish, shrimp, crustaceans, and other marine species*		**Flood Regulation:** *Protects against storms, floods, and tsunamis*	**Soil Stabilization**	*Roots constrain water movement and trap sediments*	**Educational**	*Research/ education/ training opportunities*
Genetic Resources	*Wild species & genes used for animal/plant breeding/ biotechnology derived from mangrove species products*	**Coastal Protection**	**Erosion Control:** *Contributes to wave attenuation and stabilization of soils*	**Primary Production**	*Organic matter produced through photosynthesis*	**Recreational**	*(Eco)-tourism (boat tours, boardwalks, bird watching, sport fishing, kayaking etc.)*
Biochemicals/ Medicines	*Commercial and traditional medicines from leaves, fruits, barks and other materials*	**Water Regulation**	*Water catchment and groundwater recharge*	**Oxygen Production**	*Oxygen release during photosynthesis*	**Heritage and Spiritual**	*Local communities place cultural and spiritual values on mangroves—e.g. mangroves are worshipped in Shri Shiva Nataraja temple in India*
		Biofiltration	*Extraction of excess nutrients and removal of pollutants from surrounding water/soil*	**Provision of Habitat**	*Critical habitats (e.g., nursery grounds) for a wide array of flora and fauna*		

The organic carbon stored in mangrove soils can remain sequestered for thousands of years; these forests serve as highly effective carbon sinks. If this carbon-storage asset was better recognized, it could radically alter the way these forests are valued. Recently, there has been an increasing interest in the important role that mangroves play in the global carbon cycle (Laffoley and Grimsditch, 2009). Mangrove primary production averages 11.1 t dry weight ha^{-1} yr^{-1}, which is roughly equivalent to rates of tropical rainforest productivity. Most carbon in mangroves is stored as large pools of soil carbon and within roots below ground, with storage averaging 937 tC ha^{-1} (Alongi, 2012). Mangroves may account for only 3% of carbon sequestered by the world's tropical forests, but an impressive 14% of the total carbon sequestered in the coastal oceans (intertidal to shelf edge) considering they account for only ~0.5% of the total coastal ocean area. Mangrove forests store over three times more carbon per unit of surface area compared to other forest types, especially below-ground. Carbon storage is of growing interest to policy makers as many governments around the world are considering carbon offset investment as a method to reduce overall greenhouse gas emissions.



Comparison of mangrove carbon storage with that of major global forest domains (data from Donato et al., 2011)

Mangroves provide many communities with timber and forest products.
Shigeyuki Baba

Contribution of Habitats to Carbon Sequestration in the Global Coastal Ocean (data from Alongi, 2012)

Habitat	Area (10^{12} m^2) and Percentage of Total (%)	Sequestration Rate (gC m^{-2} yr^{-1})	Global C Sequestration (Tg yr^{-1}) and Percentage of Total (%)
Mangroves	0.14 (0.5%)	174	24 (14.0%)
Salt Marshes	0.22 (0.8%)	150	33 (20.0%)
Seagrasses	0.3 (1.1%)	54	16 (10.0%)
Estuaries	1.1 (4.0%)	45	50 (30.0%)
Shelves	26 (93.6%)	17	44 (26.0%)[a]
Total Coastal Ocean			**167**

[a] = assumes that depositional areas cover 10% of the total shelf area

Valuing Mangrove Ecosystem Goods and Services

MANGROVES AND FISHERIES: AUSTRALIA

With 6.6% of the total global mangrove area, Australia is one of the world's major mangrove nations and some 40 mangrove species have been recorded here. The value of mangroves in supporting coastal and offshore fisheries in Australia is substantial. Trawling for prawns across the wide shallow shelf areas off the coasts of both the Northern Territories and Queensland is a major industry and one of this country's most valuable export fisheries, bringing in over AU$70 million annually. Although mature prawns are captured far offshore, most commercial species spend their early life stages in mangrove habitats. For example, banana prawns, which make up 50-80% of the total prawn catch, depend on mangroves as critical nursery grounds. Also, the highly prized tiger prawn utilizes seagrass beds which are often found growing adjacent to mangroves (CSIRO, 1998; AFMA, 2009). Protection of these important nursery habitats is therefore crucial for the longterm sustainability of these fisheries.

For many communities, mangroves constitute a vital food source. *Hanneke Van Lavieren*

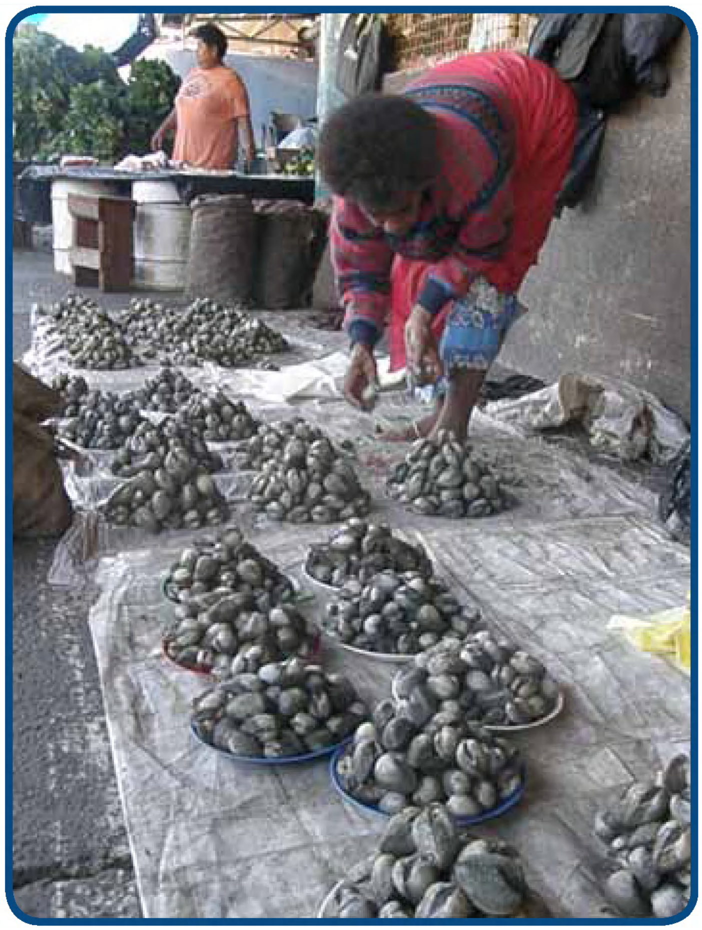
Economic valuations of mangrove ecosystem goods and services can entice financial investment and provide some of the most powerful arguments for effective mangrove management. Too often the benefits that ecosystems deliver to humans are only appreciated once they are lost. If mangrove forests are not seen as a fundamental economic and ecological resource to be treasured, they will continue to be over-exploited, degraded and lost. The value of healthy mangrove forests needs to be more widely communicated both to the public and to those policy makers with the capacity to make a difference. In some cases, valuation studies are already providing powerful arguments for investment in sustainable utilisation, protection and restoration of mangrove ecosystems. These successful examples should be better captured and shared to help stimulate such actions.

Decision-makers with access to information on the full range of ecosystem service values that mangroves provide will be better positioned to make more efficient and justified cost-effective choices. There is ample evidence that highlights the economic value of mangrove ecosystem services in different regions and under different socio-economic conditions[1]. Still, considerable variance exists in the estimated values among studies because of discrepancies between valuation methods and among locations with differing socio-economic circumstances. Where they are extensive and close to human populations, mangroves have been found to be worth US$2000 - US$9000 per hectare per year (Wells et al., 2006) but estimates can be much lower for more remote mangrove areas, for low-diversity and more arid systems, or for those utilized primarily for subsistence in poorer countries. Many of those who depend on mangroves live largely outside regular cash economies and are often ignored in economic valuations, centralised planning and policy formulation. At the present time, some of the most compelling arguments for sustainable management, use and restoration of mangroves, arise from valuations from individual field studies, such as the Matang Mangrove Forest Reserve in Malaysia and Mexico's Gulf of California, where it is estimated that one hectare of mangroves contributes ~US$37,500 per year to fisheries (Aburto-Oropeza et al., 2008).

1 For a detailed list of studies please refer to Table 2.1 (p. 30) in the 2010 World Atlas of Mangroves.

THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY (TEEB)

The Economics of Ecosystems and Biodiversity (TEEB) initiative helps draw attention to some of the economic benefits of mangrove ecosystems and confirms that the cost of sustaining ecosystem services is lower than the cost of allowing them to dwindle. One study shows that planting and protecting nearly 12,000 hectares of mangroves in Vietnam cost just over US$1 million but saved annual expenditures on dyke maintenance of well over US$7 million (World Disasters Report, 2002). TEEB draws together expertise from the fields of science, economics and policy to highlight costs of biodiversity loss and ecosystem degradation. It calls on policy makers to accelerate, scale-up and embed investments in the management and restoration of mangrove ecosystems and for more sophisticated cost-benefit analysis before policy decisions are made.



Mangrove cockles are harvested around the world, both for local consumption and commercial markets. *Mark Spalding*


Mami Kainuma

Improving Mangrove Management

4

The importance of mangroves is now widely recognized, including their direct provisioning of food, timber and other products, and their role in regulating services such as coastal protection and carbon sequestration. This importance is heightened in many countries and coastal settings where there is a high degree of dependence on mangroves and lack of alternative livelihoods. Without mangroves, many communities would lose their primary source of food and fuelwood, and be placed at higher risk from storms and coastal erosion.

Against this background, and in many cases strongly supported by international agreements and commitments, efforts are underway to manage mangroves in a way that restores, improves, or simply maintains the many benefits they provide. Here we list the main interventions that are being applied to improve and steer mangrove management as well as policy and legal frameworks which can steer such management in a direction that maintains a healthy balance between the needs of people and mangroves.

Frameworks for Management

In order for mangroves to be managed effectively, critical frameworks or enabling conditions must be established. These include a clear and accepted understanding of ownership and use rights and a solid legal infrastructure that supports and incorporates mangrove management strategies into a wider planning and policy framework. Such frameworks need to involve all relevant agencies and stakeholders and extend across all adjacent and connected ecosystems, watersheds and adjacent waters.

Tenure, access and use

Rights of ownership, access and use of mangrove forests and land must be explicitly defined, and widely accepted if management plans are to have any chance of success. Ill-defined property rights or overlapping authority over mangrove ecosystems by multiple state agencies, communities or individuals, can lead to conflicts among stakeholders in any location, and can exacerbate the deterioration of mangroves. Many original (indigenous) communities living in tropical coastal zones across the world have traditional rights to mangrove land and depend on mangroves for subsistence. Traditional customary rules and regulations regarding forest resource use evolve and are embedded within their social structure. However, when these rules and regulations are not recognized by the governing state, the result is tension between local communities and official institutions. Where they do not have any legal title to the land other than traditional de facto rights, local people are often displaced by centralized decisions that lead to the development, reclamation and clearing of mangrove habitats. Equitable use, access and tenure should support benefit-sharing, and should provide a secure and stable setting for the development of ecosystem service payments.

Framework policies

Framework policy and legislation established at national levels can prevent piecemeal loss and degradation. A number of countries have placed mangrove protection firmly into policy guidelines or framework legis-

Improving Mangrove Management

Community consultation. *Kandasamy Kathiresan*

lation, which forces a holistic vision of mangrove management which can be critical in preventing gradual losses of mangrove resources through numerous site-level decisions. The primary laws that govern land use and management of mangroves vary greatly across nations. Countries such as Tanzania and Malaysia have placed all mangroves in forest reserves under state ownership. A number of smaller countries have blanket regulations preventing damage to mangroves, while others permit licensed exploitation which can potentially allow for broader holistic management. In some locations (e.g., Australia and the US), local policies of 'no net loss' have placed specific limitations on future mangrove clearance, and developers are required to 'replace' areas proposed for conversion by investing in afforestation or restoration projects elsewhere.

Removing perverse incentives

Alongside 'enabling' policies and legislation, a number of countries should remove those measures that harm mangroves. There are too many subsidies or incentives that contribute to mangrove loss and conversion, e.g., low cost sale of mangrove areas for development purposes, tax breaks for the establishment of new aquaculture, and subsidies for shrimp farmers. These need to be eliminated or counterbalanced by introducing positive incentives for restoration and maintenance of mangrove habitat, and legislation to encourage more sustainable low impact aquaculture, including the rehabilitation of abandoned ponds. Another growing threat to mangroves in some areas is the upstream utilisation of freshwater and the reduction or removal of estuarine flows. Holistic thinking needs to be applied, also in the management of such watershed-scale impacts.

Management Tools

With the establishment of clear frameworks for mangrove ownership, use and management to underpin human activities that relate to mangroves, a broad range of management tools can be utilized to maximize benefits and secure the long-term future for mangroves and the people who rely on them.

Local involvement

Involvement of local communities in mangrove conservation efforts is critical to the success of any management intervention. This can be achieved with rigorous stakeholder identification and analysis, the design of collaborative agreements, and the facilitation of equitable participation in policy formulation and management. Frequently, communities living adjacent to mangrove forests are the key beneficiaries of the many goods and services they provide, even when they do not have formal legal ownership. These are the people who rely on mangroves the most and they suffer or gain the most from changes in mangrove management. Local involvement, profit sharing, or payments for ecosystem services can all improve the chances of successful management and long-term viability of interventions. In contrast, problems can arise when local communities are not involved, and when mangroves are lost or converted, or when access is denied through the establishment of protected areas. Encouraging local communities to develop alternative livelihoods that are less destructive than (over-) harvesting is a crucial step to mitigating mangrove deforestation. Examples of alternative livelihoods include oyster harvesting, channel-based fisheries and aquaculture, non-timber forest products, and apiculture (honey production) which encourages agroforestry and the conservation of mangrove forests.

OYSTER HARVESTING: THE GAMBIA

The Gambia is a small coastal nation in West Africa with extensive mangrove forests. The roots of mangroves in this area are covered with the oyster (*Crassostrea tulipa*) and harvesting of this species is an important income source for Gambian women in particular. One tin full of oysters (~50-60) sells for approx. US 55 cents (Crow and Carney, 2012) which is considerable considering that the Gross National Income (GNI) per capita in the Gambia was US$ 440.00 that year (UNICEF, 2012). There is much local and national support to promote this underdeveloped industry. In 2007, a group called 'TRY Women's Oyster Harvesting Association' was born and has grown from a handful of women in one village to more than 500 female oyster harvesters from fifteen different communities. The Gambian government has also made it a stated policy to encourage such small-scale subsistence aquaculture. A more sustainable method for collection is being tested which involves a simple rack system (hanging method) for culture and harvest. This has proven to be a more efficient method than traditional means which are more difficult and often involve the cutting of mangrove roots which can seriously harm trees. This method places less pressure on natural oyster populations while contributing to national fish production. The Gambia provides an excellent example where when active participation of local communities occurs, wise use of mangroves can provide considerable economic returns and contribute to the livelihoods, food security and wellbeing of local communities.

Oyster farming, The Gambia. *Yves de Soye*

Improving Mangrove Management

Sustainable silviculture

The establishment of formal forestry practices (silviculture) is one of the best means of ensuring that harvest of mangrove resources remains sustainable, even at high levels. The Matang Mangrove Forest Reserve in Malaysia provides what may be the best example of sustainable tropical forestry (i.e., silviculture) in the world, where sustainable harvesting under a formal management regime has been in operation for over a century. Such well managed systems have high commercial value and remain firmly embedded as a local industry, providing secure long-term employment and wealth generation. At commercial scales, it is necessary that such relatively large areas of mangroves are properly managed in order to allow for harvest cycles that are typically 30 years or longer. Fortunately, different planting and harvesting regimes exist and can be adopted according to local conditions and in many cases regeneration is at least partly natural, with no need for nurseries or planting.

Sustainable aquaculture

Mangroves and aquaculture can coexist if well planned and well managed. Aquaculture provides economic benefits and food security in many mangrove regions. To achieve sustainable aquaculture, it is helpful to apply a full accounting of the costs and benefits of the forest itself, its removal and replacement by ponds, and the benefits derived from aquaculture during the life of those ponds. The cost of reforesting ponds once they are no longer useful for aquaculture should also be determined. Armed with such relative values, managers are able to make well-informed management decisions. Among sustainable management methods, the planting of mangroves near and within ponds well before they reach the end of their aquaculture lives can be very effective. A good example is the so called 'Tambak Tumpangsari' in Indonesia (Inoue et al., 1999), where mangroves not only provide nutrition to nourish plankton in the ponds, but mangroves also reduce vulnerability to strong winds, tidal floods, and abrasion during at least part of the life of the aquaculture venture. This also allows for sustained

SUCCESSFUL MANAGEMENT: THE MATANG MANGROVE FOREST RESERVE

The Matang Mangrove Forest Reserve in the State of Perak, Malaysia, is arguably the best example of a sustainably managed mangrove ecosystem and demonstrates that an effective balance can exist between the harvest of natural resources and conservation. This reserve, established in 1902, covers an area of about 500 km^2 making it the largest area of mangroves in Peninsular Malaysia. Approximately 73% is considered productive forest while the remaining portion is classified as non-productive or protected. The existing management plan regulates forestry, fishing, and aquaculture activities and only non-destructive practices are permitted. Harvesting of mangrove timber for poles, firewood, and charcoal production, occurs on a 30 year rotation cycle (Chong, 2006). Selective felling is carried during year 15 and year 20 and then a final clear-felling occurs during year 30. When necessary, re-vegetation programmes are implemented two years after the final felling. The annual value of charcoal between 2000 and 2009 was estimated to be RM 27.2 million (equivalent to approx. US$ 8.9 million) while the annual value of poles was estimated at RM 2.6 million (equivalent to approx. US$ 847 thousand). Fisheries in the Matang Mangroves are also an important contributor to the Malaysian economy. Fish cage and cockle aquaculture are allowed, and cockle farming is estimated to have an annual market value of RM 32.45 million (equivalent to approx. US$ 10.7 million). Most of the natural resources obtained from the forest are exported to markets in the states of Selangor, Penang, and Kedah. This case provides evidence that mangrove forests can be conserved and enjoyed while still providing reliable long-term but reasonably high economic return for local and larger communities. It shows that when well-managed, mangroves can ensure sustainable yields of products (numbers are from the Malaysian Timber Council, 2009).

Matang Mangrove Forest Reserve, Malaysia. *ISME*

regional biodiversity and an ameliorated local microclimate, and prepares a pond for rapid return to forest at the end of its lifespan.

Protected Areas

Protected areas are a widely used management tool that can help prevent mangrove loss and degradation in specific locations. Protected areas can provide social, economic and environmental benefits, both directly through more sustainable management of resources, or indirectly thorough protection of ecosystem services. Approximately 1200 protected areas across the world cover approximately 25% of the remaining mangrove habitat. This is greater than the global forest average (16% for all terrestrial forests, or 20% for only tropical forests (Chape et al., 2008)). These sites, which by definition are established for conservation benefits, fall under various levels of protection, from forest management for sustainable harvest to strict nature reserves. Unfortunately, many of these protected areas are poorly designed or poorly enforced and some fail to prevent mangrove loss and degradation within their boundaries. Also, there are still large gaps in protected area coverage – notably in much of the Red Sea, Myanmar, the Solomon Islands, Fiji, and West and Central Africa. To be effective, systems or networks of protected areas need to incorporate the full representation of species and ecosystems, and should take into account representation, replication, and connectivity of coastal areas (McLeod and Salm, 2006). Management approaches also need to incorporate wider areas - protected areas alone will not be enough to secure the future of mangroves, and they need to be built into wider planning regimes. Better recognition of the values of the full range of goods and ecosystem services derived from mangroves may provide the needed impetus for further implementation or improvement of protected areas that incorporate mangrove habitats.

Wider management regimes

Mangrove management should be integrated into a broader spatial framework of coastal zone management. These efforts should also cross all sectors and involve all stakeholders. Without a holistic approach, implementation of management strategies can be ineffective. Coordination and clear distribution of responsibilities among the various concerned government authorities (national and local) responsible for mangrove ecosystems is critical to ensure sustainable management. This could be achieved by establishing formal Mangrove Action Plans within a country (already established in several countries) to help coordinate national plans and strategies. The other critically important element in any management approach is the involvement of all stakeholders, including local communities and indigenous peoples, as well as the various affected economic sectors (aquaculture, fisheries, forestry, agriculture, industry, transportation, tourism), at all stages of the process.

A UNESCO MAN AND BIOSPHERE RESERVE: RANONG, THAILAND

The UNESCO Man and the Biosphere (MAB) Programme is an Intergovernmental Scientific Programme, launched in the early 1970s, aimed at setting a scientific basis for the improvement of the relationships between people and their environment. It is not a legally binding convention, but simply a cooperative venture between nations and UN agencies. Sites are identified in which sustainable development and conservation goals can both be aided by use of appropriate science. They are often seen as a means of empowering local communities to better manage their natural resources. Designation gives an international profile to a site, which also means it receives closer scrutiny and greater pressure for wise management. A good example is the Ranong Biosphere Reserve, located in Ranong Province, southern Thailand. It was declared on December 1997, covers an area of 30,309 ha, is administered by the Ranong Mangrove Research Center, and is protected by the National Reserve Forest Act. Various departments are responsible for managing different resources, e.g., the Department of Marine and Coastal Resources is responsible for mangroves. The reserve comprises mangrove, tropical rain forest and seagrass ecosystems. Mangroves are the predominant ecosystem and not only represent the largest concentration remaining in Thailand, but also one of the most extensive in the Indo-Pacific. There are 24 species of mangroves, as well as shrubs, and vines, and more than 300 animal species have been identified. As of 2000, some 4,000 people have been living within this reserve, mainly subsiding on a fish and shrimp farm. Villagers living landward of the mangroves edge predominantly derive their incomes from a fruit orchard, rubber plantation, cashew nut plantation and shrimp farming. Tourism has barely been developed, and there is a good potential for growth in this sector. The Ranong Mangrove Research Center has a long history of scientific research in this area, and focuses on topics such as mangrove reforestation and rehabilitation, and human health and sanitation. This reserve is a good example where research is conducted to promote effective management that is sensitive and responsive to the traditional ways of life of local communities.

Local community living in the Ranong UNESCO MAB Reserve, Thailand.
Mami Kainuma

Restoration and afforestation

Restoration and afforestation are viable and widely used management options to recover lost or establish new mangrove forest. While avoiding loss remains the lowest cost and highest benefit route to mangrove conservation and sustainable use, mangrove restoration has been widely practiced around the world[2]. The term restoration (or rehabilitation) is used where mangroves are returned to areas where they previously existed, or where they remain, but are in a degraded state. The term afforestation is used when mangroves are planted in areas where there is no evidence of prior existence. Arguments for restoration vary, but most center on the restoration of ecosystem services, including coastal protection, fisheries enhancement and the provi-

2 For a detailed list of mangrove restoration studies from around the world please refer to Table 2.4 (p. 39) in the 2010 World Atlas of Mangroves.

sion of timber and fuelwood. By contrast, restoration solely for biodiversity enhancement remains rare. A wide variety of restoration techniques have been developed, but the most critical point is to fit restoration efforts with the local physical and ecological settings, selecting the right species and right locations, and ensuring that land tenure is secure. While there have been failures (Primavera and Esteban, 2008; Samson and Rollon, 2008), mangrove restoration represents the most successful and widely practised form of ecological restoration in any coastal or marine setting (Field, 1996; Lewis III, 2005; Twilley and Rivera-Monroy, 2005; Lewis III and Perillo, 2009). Afforestation has taken place quite widely (Southeast Asia, Florida, the Middle East), and in some cases the results of such afforestation have been dramatic, with large increases in mangrove-associated species, including birds and commercially important fish (Hong, 2004).

Managed realignment

Managed realignment allows for the creation and maintenance of mangrove habitat which in turn ensures a continuous supply of ecosystem service benefits. Managed realignment (or managed retreat) is the deliberate and controlled removal or realignment of sea defences to re-establish landward expansion of tidal wetlands such as mangroves. In natural settings mangroves are active colonisers of new sediments, and are also able to migrate landwards as land subsides or sea levels rise. However, where mangroves border onto land used by people, this migration is often blocked by man-made sea defences. Although there may be substantial costs to individual landowners associated with realignment efforts, these costs are often

Sustainable mangrove aquaculture practices should be promoted. *Hanneke Van Lavieren*

MANGROVE RESTORATION: CUBA

After Mexico, Cuba is the most mangrove-rich nation in North and Central America, with mangrove forests encircling much of the main island and offshore barrier islands. Mangroves here have not been immune to human impacts and an estimated 30% have been degraded or lost because of pollution, conversion to agriculture, and illegal deforestation. With 2.3 million visitors in 2005, and hotels and associated infrastructure increasing steadily, there have also been losses due to coastal development, and impacts caused by changes to the hydrology following the building of causeways and roads. In response, restoration and reforestation projects, totaling some 440 km^2, were conducted between 1984 and 1994 (Suman, 2003), most notably along the south coast where some 100 km^2 of coastline were restored. In this particular project, appropriate hydrology was restored and both natural and artificial regeneration methods were used. Further conservation efforts included creation of a broad and consistent body of legislation over environment, forestry, protected areas, and coastal zone management, that have provided protection to mangroves since 2000. These approaches are all prerequisites for successful and cost-effective mangrove restoration.

outweighed by benefits such as improved coastal protection and fisheries enhancement. In some areas, there is evidence that the presence of mangroves in front of engineered sea defence structures improves protection of those structures from wind, wave and storm surges, and greatly reduces the cost of building and maintaining them.

Recreation and tourism

Case studies from around the world have confirmed that ecotourism can be effectively applied to mangrove ecosystems to generate income and employment for local communities and for outreach and education purposes. Mangrove ecotourism activities include boat tours, board walks, kayaking, bird watching and fishing. Other activities include wildlife watching tours of species found in and around mangrove habitat such as the scarlet ibis, proboscis monkeys, crocodiles, manatees, and hippos. Some tourism attractions can be inventive. For example, in Malaysia, tourists come to witness spectacular evening fire fly displays, in Japan to see the one-off night time summer bloom of the flower *Barringtonia racemosa*, and in Puerto Rico people come to watch displays of bioluminescent plankton. A number of mangrove reserves are receiving tens of thousands of visitors per year, and generating significant income.

Carbon storage and sequestration in mangroves

Healthy mangrove forests have potential economic value both as carbon stores and as important locations for carbon sequestration. When mangrove forests are cleared and the land drained for other uses there is substantial release of carbon from rich organic sediments and decaying roots. Crooks et al. (2011) estimated that the 35,631 km^2 of mangroves reported by FAO (2007) which were cleared and drained worldwide between 1980 and 2005 would have released emissions totaling 0.02-0.12 $PgCyr^{-1}$ during that time, or between 2% and 10% of all emissions from deforestation. It follows that a nation that protects or expands its mangrove forests can both reduce emissions, and indeed facilitate carbon sequestration and such measures should be of considerable interest in growing carbon markets. The IPCC (2007) reported that reducing and/or preventing deforestation is the mitigation option with the largest and most immediate carbon stock impact in the short term. Furthermore, a recent report released by UNEP, IOC-UNESCO, IUCN and FAO (Nellemann et al., 2009) has shown that as much as 7% of the CO_2 reductions required to keep atmospheric concentrations below 450 ppm could be achieved simply by protecting and restoring mangroves, salt marshes and seagrass communities. The value of this

Board walks provide an excellent way to view mangrove ecosystems while minimizing human impact. *Hanneke Van Lavieren*

INVESTING IN MANGROVE CARBON

The Livelihoods Fund (www.livelihoods.eu) is an innovative new fund which aims to use corporate investments to deliver carbon credits while restoring mangroves and supporting local economies. Corporate investors had invested over €26 million by early 2012 and projects included 14,000 hectares of mangroves planted in four countries. If such projects meet their ecological and social performance objectives over time, they may offer a significant opportunity for reversing long-term losses of mangrove forests.

MANGROVE ECOTOURISM: IRIOMOTE ISLAND, JAPAN

Mangrove forests in Japan cover a mere 700 ha, the majority occurring in the subtropical Nansei Islands, including Okinawa and Yaeyama. Many years ago, mangroves were harvested in these locations but are now protected to help sustain fishery resources, protect coastlines against erosion and to provide a natural venue for ecotourism. For instance, at the Nakama river of Iriomote island, more than 2,000 tourists/day use motorized boats to visit the *Heritiera littoralis* trees. In an effort to prevent treading stress by tourists, the Forestry Agency and Ministry of Environment constructed a boardwalk and wood deck around the trees. To control other impacts, private companies have committed to limiting the number of tour boats per hour. For example, kayak guiding companies that offer tours up the Hinai river have come to an official agreement: each day, a single company can only send in 2 guides, each bringing a maximum of 7 tourists. One notable tour is a very early morning outing that allows kayakers to observe the extraordinary flowers of the *Barringtonia racemosa* in Iriomote Island. These flowers bloom only once a night during summer and tourists come by kayak to watch the blooms fall onto the rivers calm surface at sunrise. However, even with private sector agreement, many tourists cause disturbances to the ecosystem by catching many fishes, mollusks, butterflies and insects. The lesson here is that although mangrove ecosystems can provide suitable places for ecotourism, tour companies and tourists must be educated to minimize the potential negative impacts on these natural ecosystems.

approach is now being realised and a small number of restoration efforts are now being funded by the private sector for the value of their carbon credits alone. It is important to note that the rate at which carbon is lost from disturbed mangrove areas is typically much greater than the rate at which it can be restored; there is a considerable time lag following the initiation of restoration and the time at which carbon sequestration in the mangrove forest matches natural reference sites (Lovelock et al., 2011).

Mangroves in disaster risk planning and climate change adaptation

Conservation and restoration of mangroves and associated coastal ecosystems are important climate change adaptation strategies. Mangroves are not only valuable in climate change mitigation efforts but also play an important role in adapting to changing climates. In many settings, mangroves have the ability to attenuate waves, reduce storm surges and maintain their elevation in response to rising seas or land subsidence and can form a critical part of coastal defence planning (Krauss et al., 2009; McKee, 2011; McIvor et al., 2012). Wind and wave action can be rapidly attenuated as they pass through mangroves, while wide mangrove barriers can even have some effect against storm surges by slowing the flow of water and reducing inland flooding. Over longer time frames, mangroves can also maintain or increase their elevation by capturing sediments and adding organic matter to soils which enables them to keep pace with rising sea levels. These important roles are variable and hence the inclusion of such functions in management and planning requires detailed site level assessment, but in many settings mangroves can be of immense value. There is also growing cognisance of the possibility of using mangroves alongside hard engineering as a form of hybrid engineering for coastal defence. As climate change adaptation is becoming an increasingly important part of the international development agenda (World Bank, 2010), it will require much more investment than is currently planned (TEEB, 2009).

Detailed vulnerability and risk assessments for long-term anthropogenic impacts should be an integral part of coastal management strategies. Presently, the assessment of mangrove decline and of ongoing threats is piecemeal, with no clear understanding of large-scale patterns, trends in loss and degradation and a limited ability to

Improving Mangrove Management

Awareness of the unique nature of mangroves needs to be improved. *Mark Spalding*

forecast future change. Vulnerability and risk assessments consist of a combination of remote sensing, reconstruction of past sea level trends, site-based monitoring, community-based approaches and ecosystem valuations and are useful in the formulation of specific management options and adaptation strategies.

Protection through environmental agreements

Well-established conventions and treaties relevant to mangrove conservation offer an opportunity to strengthen management. At the international level, a common approach to major environmental policy issues has been to formulate conventions, treaties and agreements. There are more than half a dozen regional and international agreements that are relevant to mangroves and afford them some level of protection, at least on paper (see page 38-39). A number of these have even been in force for over 50 years. The designation of sites under any of these international mechanisms offers considerable prestige and comes with some degree of support and collaboration; it also provides an international profile, which means that they receive closer scrutiny, which prompts wise management. Despite their existence, the current trend of global decline in mangroves indicates that these measures have not been very successful. Inadequate implementation of these treaties and instruments often means that legal protection is not established by the countries, while the treaties themselves have insufficient penalties for noncompliance. Governments need to come together to create synergies and streamline agreements so that their effectiveness is strengthened.

Information, Awareness and Capacity

Improving the mangrove knowledge base

New research and maintenance of accessible, long-term data sets on the extent of mangrove resources, their value, and their responses to a range of pressures are essential to making sound policy and management decisions. Despite an increasing trend in available data and knowledge, many countries still have insufficient information on their respective mangrove resources, extent, status and connections to other ecosystems. This hampers robust policy-making, planning and resource management. Improved quantification of ecosystem service values is urgently needed, including those relating to carbon storage and sequestration, coastal risk reduction, and fisheries enhancement via mangroves. Such information will help make a more compelling case for conservation and restoration, and will enable the inclusion of mangroves into economic frameworks for planning and coastal management. These partly reflect a need for more primary data, but also a need to synthesize and share existing information. The Millennium Ecosystem Assessment (MEA), Global Environment Outlook (GEO) and the Global Biodiversity Outlook (GBO) are some existing platforms at the global level which provide ecosystem status assessments aimed at developing guidance for policy makers at international, regional and local levels. Other databases, such as the Global Mangrove Database and Information System (GLOMIS) also provide and encourage free and open access to biodiversity data via the internet. The establishment of an Intergovernmental Sci-

GLOBAL MANGROVE INFORMATION AND DATABASE SYSTEM (GLOMIS)

The Global Mangrove Information and Database System (GLOMIS), is a searchable on-line database that was developed by the International Society for Mangrove Ecosystems (ISME). It serves as the very first tool of its kind that allows for easy access to mangrove-related information from around the world. This venture, which was funded by the International Tropical Timber Organization (ITTO), began in 1997 and although completed in 2004, is continually being updated by ISME as new information arrives. The initial data were collected by regional centers (India/Malaysia, Fiji, Ghana, and Brazil), as well as the Headquarters in Okinawa. The information within the database relates to mangroves and associated ecosystems, and falls under the following categories: People, Institutions, Projects and References. GLOMIS contains 8400 records and provides end users easy retrieval of abstracts from numerous journal sources. This database is not only accessible online (http://www.glomis.com) but also comes in a stand-alone CD-ROM form for those who do not have internet readily available (Baba, 2004). Currently, this valuable tool is utilized by researchers, students and decision-makers who need to retrieve information relevant to mangroves for educational or professional purposes.

ence-Policy Platform for Biodiversity and Ecosystem Services (IPBES) would be an important step forward to bridge science with policy as the IPPC platform has achieved for climate change issues.

Improving outreach

A major challenge for many working in the fields of mangrove management is to ensure that the public is fully informed of the unique features and value of mangroves as well as the potential consequences of their loss. There are many ways that public outreach could be improved. For example, the 2010 World Atlas of Mangroves is one useful source of current information that greatly contributes to improved global understanding and awareness, but such detailed information also needs to be translated into shorter, simpler and more targeted communications. General awareness can be enhanced through public media campaigns and educational programmes. Where opportunities exist, demonstration sites, boardwalks, interpretive centres, and other activities that bring people into direct contact with mangroves, should be created to encourage local community involvement and increase awareness. The UN Decade on Biodiversity is upon us and there is no better time than now to highlight the unique nature of mangroves; perhaps it is time for countries around the world to come together and call for an International Year of Mangroves under the UN system.

Strengthening capacity

It is essential that technical, legal and financial capacity for mangrove management is strengthened at various levels. Training and education programs need to be targeted specifically at either mangrove managers or professionals, local communities or at central and local government bodies. Priorities for training should be based on local needs and appropriate institutions and courses should be identified on a country-by-country basis. Besides training on specific management tools and techniques, there is also a need to develop capacity to assess mangrove vulnerability and responses to climate change, and to measure mangrove carbon fluxes so that adequate adaptation strategies can be developed.

Improving capacity through training, India. *Kandasamy Kathiresan*

Improving Mangrove Management

Agreement	Year of Entry Into Force	Number of Parties*	Description
Convention on Biological Diversity (CBD)	1993	193	CBD`s objectives include: conservation of diversity, sustainable use of components associated with biodiversity, and equitable distribution of benefits arising from the utilization of genetic resources. It relates to mangrove protection in some of its seven thematic programmes including: Forest Biodiversity and Marine and Coastal Biodiversity as well as through cross cutting themes such as Protected Areas, Sustainable Use, Biodiversity for Development and Climate Change and Biodiversity. Furthermore, nearly all the Aichi Targets, agreed to at the 10th Conference of the Parties of the CBD in Nagoya, Japan (2010) have some relevance to habitat protection, and directly or indirectly to the protection of mangrove ecosystems. For example targets 5, 7, 11 and 15 relate to the protection of forests.
Ramsar Convention on Wetlands (Ramsar)	1975	159 (2009)	Ramsar`s goal is to provide a framework for national action and international cooperation for the conservation and sustainable use of wetlands and the resources they provide. Ramsar members are committed to designating different sites according to a number of categories that assign 'international importance'. This encourages parties to undertake more comprehensive reviews of their wetlands, thus facilitating their designation as protected sites. In 2009, there were 215 reported Ramsar sites (in 65 countries and territories), that included mangroves, and presently, over 15 million hectares of mangrove wetlands are under protection and sustainable use as part of the Ramsar Convention.
UNESCO Man and Biosphere Programme (MAB)	1977	105 (2008)	MAB involves the identification and preservation of biosphere reserve sites. It is not legally binding, but offers a unique cooperative approach. The sites are identified where a conservation function can be placed alongside development and science. MAB assists communities to effectively manage their resources through: establishing formal management systems, supporting scientific assessments, providing international recognition, and facilitating information sharing with other biosphere reserves across the globe. In 2008, there were 34 MABs (in 21 countries) that included mangrove sites.
UNESCO World Heritage Convention (WHC)	1975	189	WHC is an international agreement that aims to protect places of exceptional universal value. The convention links nature conservation and cultural preservation; recognizing the fundamental need to preserve the balance between humans and nature. In 2008, there were 31 designated WHC sites (in 18 countries) that included mangroves. Most of these sites had mangroves as major or defining habitats that were central to their World Heritage status.
Convention on Migratory Species (CMS)	1979	117	CMS strives to conserve terrestrial, aquatic and avian migratory species and their habitats across the globe. This convention is relevant because mangrove forests provide habits and breeding grounds for many species of migratory birds.
Convention on the International Trade of Endangered Species (CITES)	1975	175	CITES aims to monitor and regulate the international trade of wild plants and animals in order to preserve and protect these populations. Invasive species have been involved in the destruction of mangrove habitats and as such CITES is a significant policy in the effort to preserve mangroves.

* as of 2011 unless indicated

Agreement	Year of Entry Into Force	Number of Parties*	Description
Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA)	1999	65	Originally established under CMS but now an independent international treaty that covers 255 species of birds ecologically dependent on wetlands for at least part of their annual cycle. Parties are called upon to engage in a wide range of conservation actions addressing key issues such as species and habitat conservation.
United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol	2005	192	UNFCCC (through its Kyoto Protocol) is an international agreement aimed at mitigating the effects of climate change. The main feature of the agreement is that it sets binding limits for 37 industrialized countries and the European community to reduce their GHG emissions. The Kyoto Protocol is relevant to mangrove forests because deforestation is a major contributor to GHG emissions and mangroves play an important role in the global carbon cycle and CO_2 sequestration from the atmosphere. Currently, proposals to reduce emissions from deforestation and forest degradation in developing countries that are being discussed under the UNFCCC (REDD+) could have significant implications for mangrove conservation.
(UNEP) Regional Seas Programme (RSP)	1974	143	RSP aims to mitigate the degradation of the world's oceans and coastal environments (including mangrove ecosystems) through promoting sustainable management practices and encouraging countries with shared marine environments to collaborate. RSP operates through regional Action Plans, often enforced with a legal framework in the form of a regional Convention and associated Protocols. Today, more than 143 countries participate in 13 RSPs.

Mangroves in the Dominican Republic. *Carrie Waluchow*


Mark Spalding

Economic Policies for Sustainable Mangrove Management

5

Mark Spalding

Economic incentives

Governments need to provide equitable economic settings to ensure that conservation and sustainable use of mangroves is established. The high social, ecological and economic values of mangroves are well understood, but challenges remain in ensuring that such values are recognized in short-term political cycles and narrowly defined economic models. These problems are heightened by the existence of perverse incentives and policies that subsidize or encourage damaging activities, such as tax breaks for aquaculture, non-equitable land tenure settlements, or failure to recognize the key values of mangroves in maintaining coastal protection and artisanal fisheries. The move towards a more equitable and holistic economic approach must also include more inclusive and longer term accounting of the ecosystem goods and services that mangroves provide.

Incentives need to be created that promote more environmentally responsible behavior and enhance local livelihoods. This may be particularly important in the near future while perverse incentives are still distorting markets and payments for ecosystem services are still under development. Incentive-based conservation approaches recognize that potential loss of income and access to resources must be offset by aligning current financial prices with socially desirable outcomes. These approaches encompass policy tools that range from pollution taxes, subsidies and marketable permits, to deposit-refund systems and performance bonds. If implemented properly, and in combination with so-called 'command and control' approaches (standards), they can help create dynamic incentives for more environmentally responsible behaviour and shift from short-term opportunism to long-term stewardship.

Payments for Ecosystem Services (PES)

The fact that mangrove forests are increasingly recognized as a valuable source of revenue should in theory make it easier to entice those who benefit from mangroves to make payments for the ecosystem services that they generate. Payments for Ecosystem Services (PES) are an economic instrument designed to provide incentives to land users for (agricultural) land and coastal or marine management practices that are expected to result in continued or improved ecosystem service provision, so a specific user or society will benefit more broadly. PES schemes can provide a new source of income to be used towards land management, restoration, conservation, and sustainable use activities and have the potential to provide a direct economic benefit and incentive to protect and sustainably use mangrove forests. So far, PES schemes have been developed around three main groups of services: water quality and quantity, carbon sequestration, and biodiversity conservation. Policy based decision support tools, such as the 'Trade-Off Analysis' and 'Cost Benefit Analysis', can help policy makers investigate the economic and institutional feasibility and benefit of using PES to protect mangroves, as an alternative to conventional environmental policy tools. Important aspects to consider for implementation are clearly defining and allocating local property rights to mangrove resources and determining the level of social impact that certain interventions could have. In many developing countries, the people who benefit the most from mangroves do not have the money to make payments for ecosystem services. This leaves payments for carbon storage ecosystem services through 'carbon markets' as a more promising way to fund the protection and restoration of mangrove forests. A significant opportunity for additional payments for conservation and improved land management may flow from the scheme for Reduced Emissions from Deforestation and Forest Degradation (REDD+).

Accounting for Biodiversity Ecosystem Services (BES)

An accurate reflection of the true value of BES will help policy makers make more informed decisions and ensure that the benefits derived from mangrove ecosystem services are taken into account. The costs and benefits of action on climate change (carbon offsets) have been reasonably defined; this is less so for economic arguments that have been made for maintaining Biodiversity Ecosystems Services (BES). The full value of BES is rarely incorporated into economic and political decision making which is a major shortcoming as these two policy agendas are strongly linked; long term climate targets will not be met unless a wide range of natural resources are managed sustainably. One potential area of growth is accounting for BES and national biodiversity offsets. A method for delivering these biodiversity offsets is so called 'habitat banking'; turning credits into assets that can be traded and effectively creating a market system for compensation liabilities (Crowe and ten Kate, 2010). Opportunities for investment into maintaining BES by the corporate and business sectors to finance the protection and sustainable use of biodiversity should also be further explored.

Mangroves and carbon financing

By better connecting mangrove ecosystems with the role they play in the global carbon cycle and climate system we could change the economic calculus for mangroves. The key role of mangrove ecosystem management and restoration approaches in national strategies to address climate change is increasingly being recognized. Because mangrove forests store significant amounts of carbon and are threatened by the economic allure of conversion, these ecosystems could be ideal targets for carbon financing. Preventing carbon emissions that result from the removal of blue carbon ecosystems (coastal ecosystems), or so called 'avoided loss', could become a major carbon market application. Global efforts to reduce GHG emissions, principally emission trading systems, 'cap and trade'

REDUCED EMISSIONS FROM DEFORESTATION AND FOREST DEGRADATION (REDD) AND REDD + PARTNERSHIPS

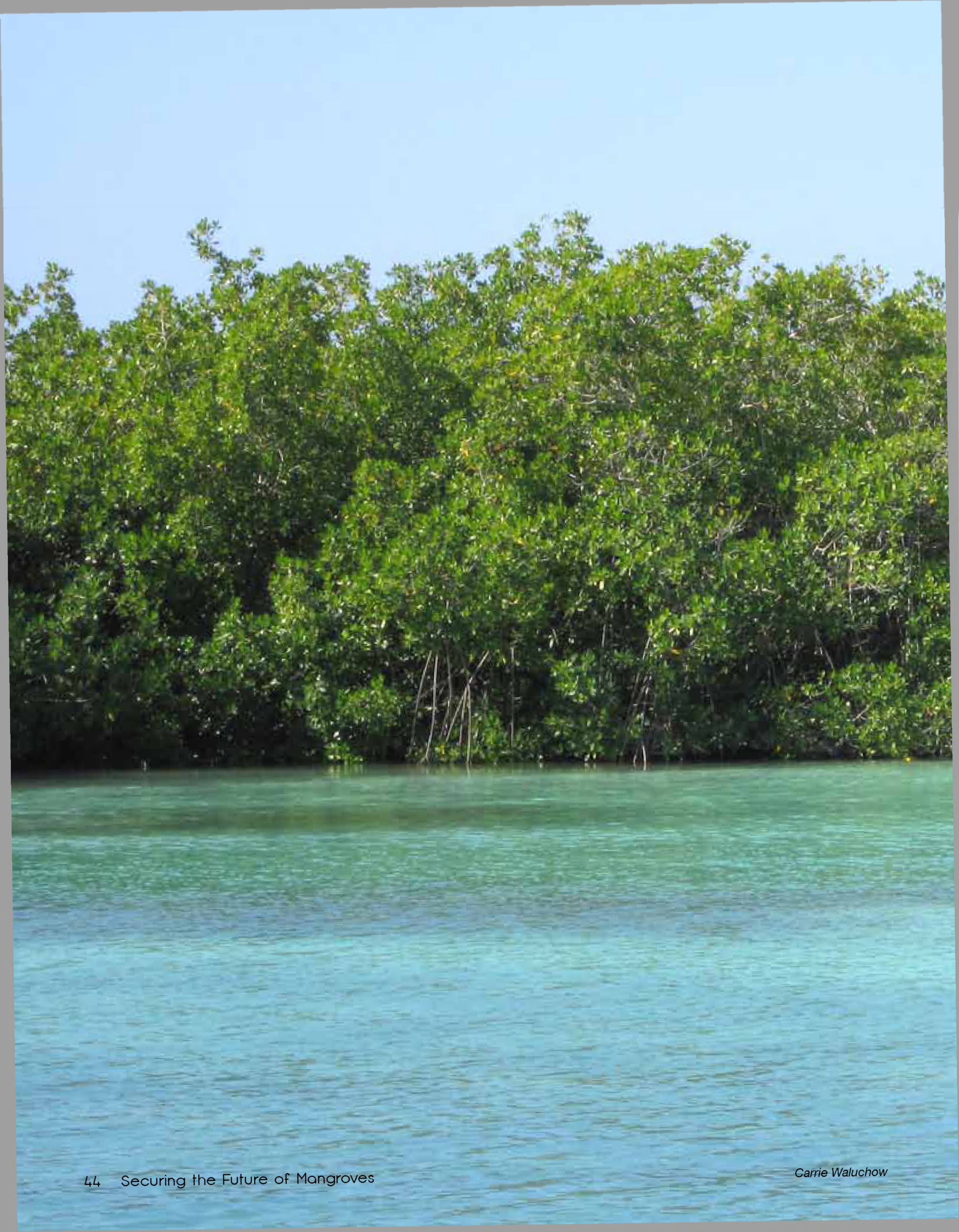
REDD aims to counter GHG emissions from deforestation and forest degradation while generating financial flows from north to south. Based on payment for carbon storage ecosystem services, REDD could lead to an estimated halving of deforestation rates by 2030, cutting emissions by 1.5-2.7 Gt CO_2 per year. REDD+ (post Kyoto: 2013 onwards) not only includes protection, sustainable management and maintenance of forests but also other measures that restore and enhance forest carbon stocks. Under REDD+, developing countries can apply for funds to reduce loss of forest coverage, restore areas and/or increase areas of new forest. The REDD+ structure and procedures could serve as a model for development of international and national financing mechanisms that incentivize policy and management measures for reducing GHG emissions. REDD+ can also create a revenue stream that is attractive to national and regional governments, cost-effective for industrial polluters seeking options to meet their emission reduction targets and can benefit local communities including the rural poor. A number of pilot PES and REDD+ schemes are already in development, although there have been teething problems associated with misconceptions and oversimplification as natural ecological limitations have not been factored into the design, timeframe and execution of many of these schemes (Alongi, 2011).

Mangroves play an important role in the global carbon cycle. *Hanneke Van Lavieren*

or ‘carbon markets’, creates a potentially large economic incentive and significant new funding source which could provide a convincing argument to prevent the conversion of mangrove habitat. Payments for carbon storage ecosystem services could also become part of non-market payments from new financial mechanisms that do not impinge on emission compliance mechanisms. Several international actors are facilitating the development of market based financing mechanisms and piloting new avenues to deepen the reach of the carbon market. For example, the World Bank’s new ‘blue’ portfolio initiatives and investment funds such as the forest Carbon Partnership Facility, Forest Investment Program, and the Pilot Program for Climate Resilience, provide exciting new opportunities to better protect natural capital, benefit communities, and utilize cost effective green technologies to address the challenges of climate change.

Blue carbon (mangrove) financing schemes need to be promoted under the UN Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol. Despite some progress over the past couple of years, so far there has been a lack, or limited inclusion, of blue carbon in the international dialogue on carbon emission offsets and in the domain of eligibility under UNFCCC financing schemes. In its current form the UNFCCC refers only minimally to blue carbon ecosystems, which excludes them from existing carbon markets. The only blue carbon activities that are currently covered under UNFCCC financial mechanisms are mangrove restoration through the Clean Development Mechanism (CDM) and sustainable management and protection of mangroves under the auspices of the Reduced Emissions from Deforestation and Degradation (REDD+). On the contrary, in the case of terrestrial forests (green carbon), there are a suite of market mechanisms aimed at reducing GHG emissions caused by deforestation and degradation; these mechanisms could be adapted to mangrove ecosystems. A critical detail that needs to be defined however is what specific carbon pools (soil carbon pool or just the above ground biomass pool) will count under REDD+. Excluding below ground carbon would substantially undercut the blue carbon potential of mangroves. Further work will be necessary to develop clear IPCC reporting guidelines, define the boundaries of blue carbon eligibility, propose appropriate methods for quantification, and determine the best way to achieve inclusion in the market.

Integrate blue carbon (mangrove) management and conservation into the Voluntary Carbon Markets (VCM). The voluntary carbon market is still small and falls outside of the regulated international trading mechanisms; however, it is more open to blue carbon restoration and conservation projects. Methodologies for the application of blue carbon projects in the voluntary market are more developed and could ultimately serve as the basis for the development of regulated market methodologies. The voluntary carbon market could initially be targeted for funding with an ultimate goal to eventually sell to the regulatory market (where returns are higher).


Carrie Waluchow

6 Coordinate International Policy Agendas

Ken Drouillard

Mangroves, biodiversity and climate change

The unique location of mangroves between the land and sea, their carbon management role, and the fact they are coastal wetland forests allows them to be considered under a range of global policy agendas; coordinated action must be ensured. Action on climate change has opened a way to broaden the portfolio of actions aimed at protection of mangroves. The inclusion of mangroves and blue carbon in climate change agendas, such as the UNFCCC, would be a good first step towards coordinated action. A second step could aim for climate change to be mainstreamed across the different international biodiversity, forest, wetland and coastal portfolios, to ensure coordination and incorporation of climate change into new policies (World Bank, 2008). Some efforts are already underway. Biodiversity related conventions (such as the CBD and RAMSAR) have urged their member countries to integrate climate change issues and actions into national strategic biodiversity action plans (NBSAPs) and at the same time include mangrove ecosystems in their climate change national adaptation plans of action (NAPAs). Efforts to raise blue carbon awareness are mounting and a number of multilateral, bilateral and private sector initiatives exist which support blue carbon investments in coastal wetland projects. For example, the Blue Carbon Policy Framework aims to integrate blue carbon activities into the policy and financial work of the UNFCCC, and intends to guide and coordinate the activities of Blue Carbon stakeholders including NGOs, governments, multi-lateral institutions, the private sector and research institutions.

Mangroves are considered as coastal wetlands and forests. *Hanneke van Lavieren*

Coordinate International Policy Agendas

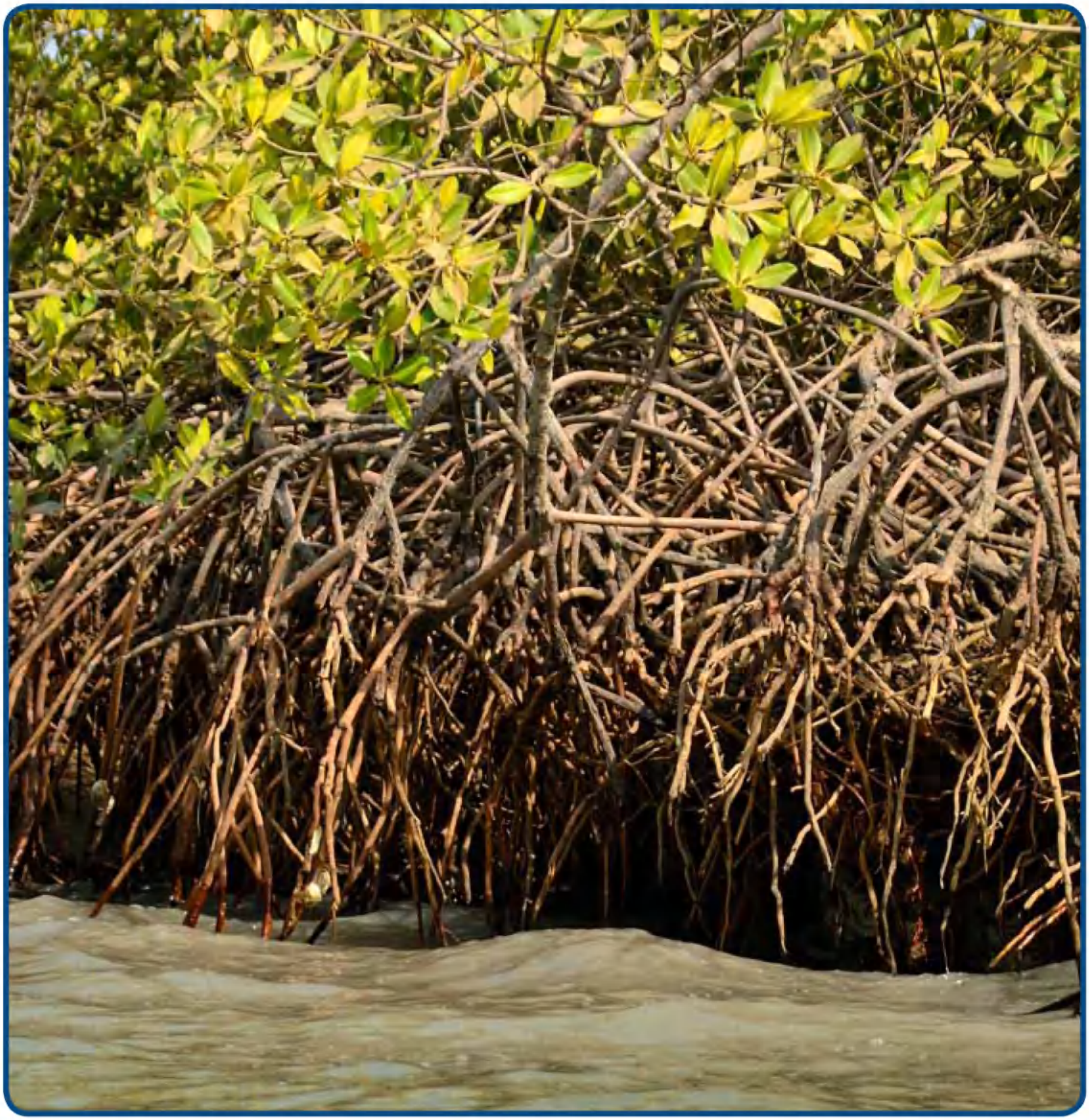
Mangrove planting in Sabah, Malaysia. *Shigeyuki Baba*

Mangroves for food security

Effective management of mangroves is an achievable and practical way to help ensure food security for many coastal communities. Conservation and maintenance of mangrove ecosystems is essential for the achievement of the Millennium Development Goal to eradicate extreme poverty and hunger (MDG 1). Healthy mangrove forests are critical for the maintenance and enhancement of food security; through the production of numerous fishery and forest products, by supporting commercial coastal and off-shore fisheries, and by providing locations for aquaculture. Seafood provides 4–16% of the animal protein consumed worldwide (FAO, 1997). Aquaculture for fish and shrimp is now the fastest growing food producing industry in the world; the FAO (2000) estimates that by 2030, over half of the fish and shrimp consumed worldwide will be produced by aquaculture. There is ample evidence that removal of mangroves leads to a decline in coastal fisheries production and the loss of potential for development of integrated aquaculture and fisheries within and adjacent to mangroves themselves. Healthy mangrove ecosystems will become increasingly important for food security as the demand for (sea) food increases with global population growth.

Mangrove conservation for poverty alleviation

Governments need to recognize the strong link between mangrove ecosystem degradation and the persistence of poverty in many rural coastal communities. The destruction and degradation of mangroves has strong socio-economic impacts. Improved appreciation of the range of values of mangroves may prove useful in making appropriate decisions for more efficient and sustainable use. Community based poverty reduction programmes are needed where restoration and management of mangroves is implemented while providing communities with suitable alternatives to mangroves dependency (for domestic consumption and commerce). Successfully applied, these efforts can succeed in improving the ecological conditions of mangroves as well as the livelihoods of local communities. Integrated management of biodiversity within poverty reduction strategies and food security planning is critical if MDG 1 is to be met.



Mangroves in The Gambia. *Yves de Soye*

Acronyms and Abbreviations

AEWA	Agreement on the Conservation of African-Eurasian Migratory Waterbirds
BES	Biodiversity Ecosystem Services
CBD	Convention on Biological Diversity
CDM	Clean Development Mechanism
CITES	Convention on the International Trade of Endangered Species
CMS	Convention on Migratory Species
CO_2	Atmospheric Carbon Dioxide
COP	Conference of the Parties
FAO	Food and Agriculture Organization of the United Nations
GBO	Global Biodiversity Outlook
GEF	Global Environment Facility
GEO	Global Environment Outlook
GHG	Greenhouse Gas
GLOMIS	Global Mangrove Information and Database System
IOC-UNESCO	Intergovernmental Oceanographic Commission of UNESCO
IPBES	Inter-governmental Science-Policy Platform for Biodiversity and Ecosystem Services
IPCC	Inter-governmental Panel on Climate Change
ISME	International Society for Mangrove Ecosystems
ITTO	International Tropical Timber Organization
IUCN	International Union for the Conservation of Nature
MEA	Millennium Ecosystem Assessment
MPA	Marine Protected Area
NAPAs	National Adaptation Plans of Action
NBSAPs	National Strategic Biodiversity Action Plans
PES	Payments for Ecosystem Services
RAMSAR	Ramsar Convention on Wetlands
REDD	Reduced Emissions from Deforestation and Degradation
SLR	Sea Level Rise
TEEB	The Economics of Ecosystems and Biodiversity
TNC	The Nature Conservancy
UNEP-RSP	United Nations Environment Programme – Regional Seas Programme
UNEP-WCMC	United Nations Environment Programme – World Conservation Monitoring Centre
UNESCO-MAB	United Nations Educational, Scientific, and Cultural Organization - Man and the Biosphere
UNESCO-WHC	United Nations Educational, Scientific, and Cultural Organization - World Heritage Convention
UNFCCC	United Nations Framework Convention on Climate Change
VCM	Voluntary Carbon Markets

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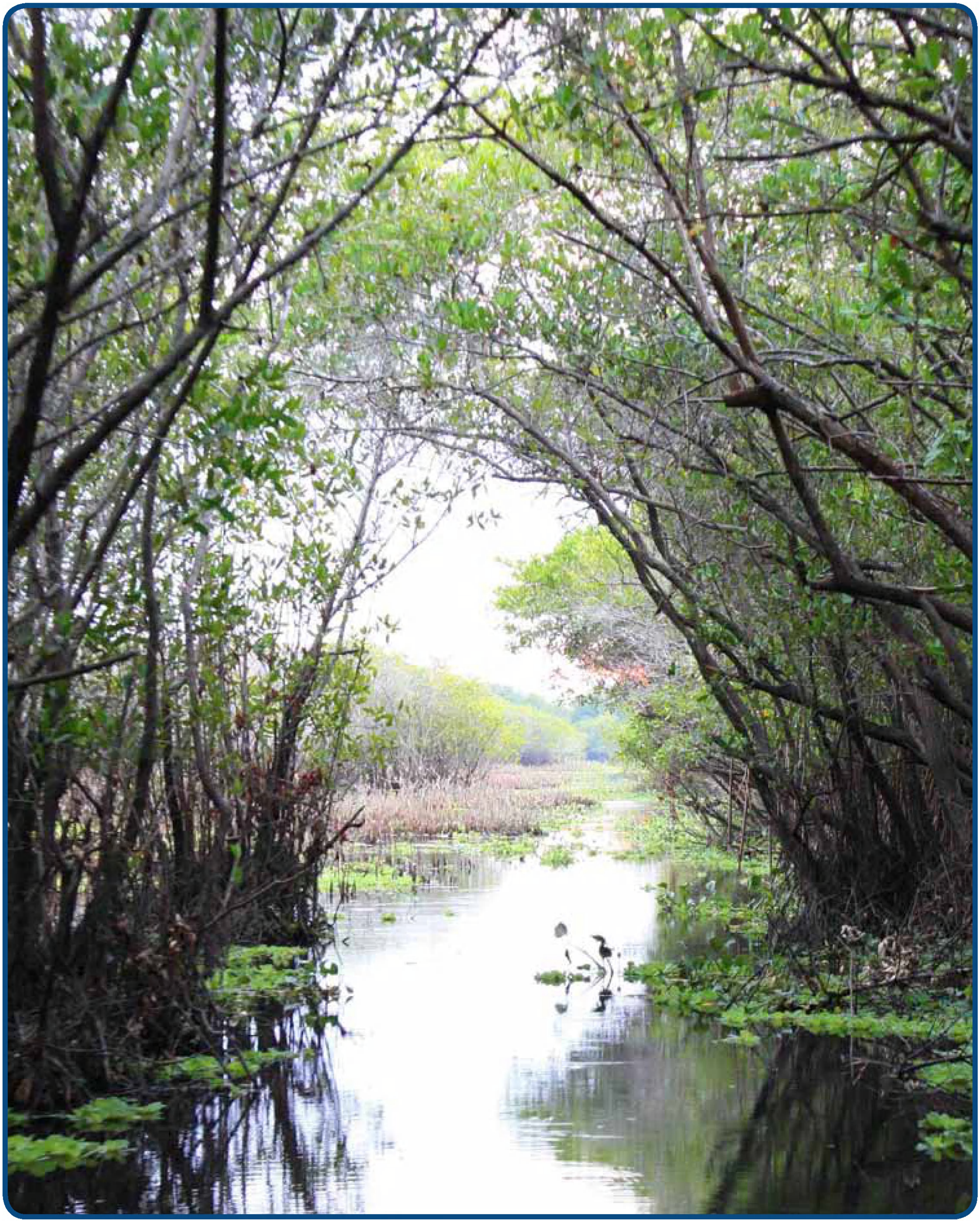

Mangroves in Monterrico, Guatemala. *Hanneke Van Lavieren*

Atlas Partner Organizations

The International Tropical Timber Organization (ITTO) is an intergovernmental organization promoting the conservation and sustainable management, use and trade of tropical forest resources. Its 60 members represent about 80 per cent of the world's tropical forests and 90 per cent of the global tropical timber trade. ITTO develops internationally agreed policy documents to promote sustainable forest management and forest conservation and assists tropical member countries to adapt such policies to local circu stances to implement them in the field through projects. In addition, ITTO collects, analyses and disseminates data on the production and trade of tropical timber and funds projects and other actions aimed at developing industries at both community and industrial scales. All projects are funded by voluntary contributions, mostly from consumer member countries. Since it became operational in 1987, ITTO has funded 900 projects, pre-projects and activities valued at more than US$330 million. The major donors are the governments of Japan, Switzerland and the United States. www.itto.int

The International Society for Mangrove Ecosystems (ISME) was established in August 1990 with its headquarters in Okinawa, Japan. The society was registered as a non-profit organization. The statutes stipulate that ISME shall collect, evaluate and disseminate information on mangrove ecosystems, and promote international cooperation. ISME has been conducting its activities at the global level through knowledge application; training and education; and information exchange. As of 2009, ISME's membership includes 38 institutional and over 1000 individual members from 90 countries.
www.mangrove.or.jp

The Food and Agriculture Organization of the United Nations (FAO) is one of the largest specialized agencies in the United Nations system and the lead agency for agriculture, forestry, fisheries and rural development. The Forestry Department helps nations manage forests in a sustainable way. The Organization's approach balances social, economic and environmental objectives so that present generations can reap the benefits of the Earth's forest resources while conserving them to meet the needs of future generations.
www.fao.org

The United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) is the biodiversity assessment and biodiversity policy support arm of UNEP. The Centre has operated for over 25 years, providing objective, scientifically rigorous products and services to help decision-makers recognize the value of biodiversity and apply this knowledge to all they do. The Centre's core business is locating data about biodiversity and its conservation, inte preting and analysing that data to provide assessments and policy analysis, and making the results available to both national and inte national decision-makers and businesses.
www.unep-wcmc.org

UnitedNations Educational, Scientific and Cultural Organization (UNESCO) functions as a laboratory of ideas and a standardsetter to forge universal agreements on emerging ethical issues. The Organization also serves as a clearing house for the dissemination and sharing of information and knowledge while helping Member States to build their human and institutional capacities in diverse fields.TheMan and the Biosphere Programme (MAB), proposes an interdi ciplinary research agenda and capacity-building aiming to improve the relationship of people with their environment globally. It uses its WorldNetwork of Biosphere Reserves as vehicles for knowledgesharing, research and monitoring, education and training, and participatory decision-making.
www.unesco.org/mab

United Nations University Institute for Water, Environment and Health (UNU-INWEH) is the UN think tank on water and contributes to resolving the global water challenges through applied research, capacity-building and policy advice. It is a member of the United Nations University family of organizations, and is supported by the Government of Canada. A dedicated programme focuses on the integration of coastal science and management. It aims to foster sound decision-making, especially in developing countries, through scientific research, and human and institutional capacity-building. Activities particularly focus on coral reef and mangrove habitats.
www.inweh.unu.edu

The Nature Conservancy is a leading conservation organization working around the world to protect ecologically important lands and waters for nature and people. The Conservancy has more than 700 staff scientists, and uses sc ence to guide its work and to build effective conservation actions. With more than one million members the Conservancy works in more than 30 countries.With partners it has helped protect more than 480,000 square kilometres of land and more than 8000 kilometres of rivers, while it operates more than 100 marine conservation projects.
www.nature.org

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