GLOBAL MANGROVE ALLIANCE

THE STATE OF THE WORLD'S MANGROVES 2021

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THE GLOBAL MANGROVE ALLIANCE

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Mangroves in Southwestern Madagasca
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Nahtik Marine Protected Area in Pohnpei, Micronesia
© Nick Hall

FOREWORD

FOREWORD BY PETER THOMSON, **UNSG'S SPECIAL ENVOY FOR THE OCEAN**

MANGROVES ARE VITAL COMPONENTS OF THE PLANET'S COASTAL ECOSYSTEMS. Mangroves sequester carbon at up to four times the rate of terrestrial forests, making them tremendous allies in our struggle for net-zero carbon emissions by 2050. They stabilize coastlines, protect coastal communities against storm surges, reduce erosion, and serve as vast nurseries and habitats for fish, crustaceans, shellfish and wildlife.

And yet, for all these wonderful benefits, we have lost so many of them.

They've been chopped down for firewood. They've been cleared to make way for antibiotic sustained shrimp farms, and ever-spreading urban and leisure coastal developments. And they've also withered away due to depleted flows of fresh water or wanton human pollution.

If I sound frustrated and angry about this degradation, I am. Coming from a mangrove coast in the South Pacific, I revere mangroves in the same light as their majestic cousins, the coral reefs and tropical rainforests. If their demise is a crime against nature, then surely it's also a crime against the best interests of humanity.

ENCOURAGING SIGNS

I am, however, encouraged—in my work as the United Nations' Special Envoy for the Ocean—to have observed an acceleration of international ambition for the conservation and restoration of mangrove forests. Over the last few years, from the Kenyan coastline to Xiamen harbor in China, I've seen sustainable mangrove projects in action, and am ready, whenever and wherever, to support those at the frontline of mangrove protection and restoration.

If you have ever planted a tree and watched it grow to maturity, you know the joy of positive interaction with the majesty of nature. Observing and encouraging the growth of mangrove seedlings, known as propagules, offers the same reward—and is coupled with the knowledge that each new mangrove tree in the forest is one more small step towards a carbon-neutral world.

CHALLENGE FOR COP26

I commend the Global Mangrove Alliance for its visionary work. In the course of building a global community of stakeholders to safeguard the critical role of mangroves in coastal ecosystems, the Alliance is leveraging expertise, funding, resources and networks for the great task at hand.

Given the progress it's achieving, and its globally influential position in this area, I am putting the following challenge to the Global Mangrove Alliance:

To encourage all of the Parties of the Paris Agreement to enhance their climate ambition by prioritizing mangrove protection and restoration actions. At the UNFCCC COP26 in Glasgow this year commend those who already included mangroves in their climate mitigation and adaptation commitments, while urging others to join them for the next round of such commitments in 2025.

VALUABLE WORK

The Global Mangrove Alliance's work provides a much-valued contribution towards the implementation of the universally agreed UN Sustainable Development Goal (SDG) to conserve and sustainably use the ocean's resources (SDG14, 'Life Below Water'). In particular, the Alliance's efforts are boosting the achievement of target SDG14.2 to sustainably manage and protect marine and coastal ecosystems 'to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration.'

In sharing the challenges confronting coastal communities, and working together for coastal resilience, the Global Mangrove Alliance will no doubt also play an important role in both the UN Decade on Ecosystem Restoration and UN Decade of Ocean Science for Sustainable Development, both of which got underway this year.

I commend the Global Mangrove Alliance for fostering cross-sector collaboration on mangrove policy and science, thereby magnifying the efforts of its stakeholders and scaling up both ambition and impact.

A good example is the Global Mangrove Watch platform, launched by the Alliance last year. This is now the world's most comprehensive mangrove monitoring tool, with universal online access to near real-time data. The platform is already informing and catalyzing evidence-based protection and restoration of mangroves around the world.

> "NO HEALTHY PLANET WITHOUT A HEALTHY OCEAN."

COMPELLING REPORT

Drawing on tools such as this platform and the collective knowledge of experts across sectors and geographies, the Alliance has now produced this first State of the World's Mangroves Report.

I'm advised that the report has grown out of synergies across the dedicated membership of the Global Mangrove Alliance, and among a closely collaborating network of leading scientists. In doing so it has synthesized data, analyses and narratives into a cohesive call-to-action for leaders around the world to prioritize the conservation and restoration of mangrove forests.

The report reveals the state of the science of the world's mangroves and provides a roadmap to 2030—to raise public awareness and institutional support for advancing restoration, and building the recovery of the world's mangroves. By spurring action towards the Alliance's goal of substantially increasing mangrove cover world-wide, this report has positive implications for climate change, the health of the ocean, and sustainable development for people and the planet.

THE BENEFITS OF ACTION

You may have heard my mantra, 'no healthy planet without a healthy ocean', to which must be added 'the ocean's health is currently in decline.'

Given the critical importance of mangroves for the maintenance of both a healthy planet and a healthy ocean, I encourage governments, corporations, cities and people around the world to support the objectives and efforts of the Global Mangrove Alliance. As we emerge from the COVID-19 pandemic, it is more important than ever to include the protection and restoration of mangrove forests in our action plans for a blue-green recovery.

Do so, and in one great movement we will protect and restore coastlines, improve livelihoods, safeguard biodiversity, reduce disaster risk, and combat both the causes and effects of climate change.

Peter Thomson

Indonesian girls with crab traps. Ohoidertutu Village, Kei Islands, Indonesia
© Jürgen Freund / WWF

EXECUTIVE SUMMARY

136,000 km²
of mangroves world-wide in 2016

Raja Ampat, Papua, Indonesia
© Ethan Daniels

Mangrove forests are critical ecosystems, both for biodiversity and for humanity.

Vast areas have been lost, but things are changing. As we begin to realize their full value—as carbon stores, fish factories, coastal defenses and more—ever-greater efforts are being made to protect what remains, and to start programs of restoration.

The State of the World's Mangroves provides the very latest information on what we know about mangroves and what's being done to support these magnificent habitats.

In 2018 Conservation International (CI), the International Union for Conservation of Nature (IUCN), The Nature Conservancy (TNC), Wetlands International, and World Wildlife Fund (WWF) formed the Global Mangrove Alliance (GMA).

This partnership now includes over 25 member organizations who share the aim of scaling up the recovery of mangroves through equitable and effective expansion of both mangrove protection and the restoration of former mangrove areas. From a practical perspective, the GMA works world-wide in supporting research, advocacy, education and practical projects on the ground—typically with local and community partners.

THE STATE OF MANGROVES

The global maps developed by the Global Mangrove Watch (GMW) team, who have been working in close collaboration with GMA since 2019, provide valuable insights into the extent of mangroves. The maps show **136,000 km² of mangroves world-wide in 2016**. Southeast Asia houses almost a third of all mangroves, with Indonesia alone being home to almost 20%.

The high-resolution GMW maps also track change over time. They show a net loss of some 4.3% of mangroves in the 20 years preceding 2016. However they also show that average **rates of mangrove loss are slowing world-wide**. Alongside losses, the maps also show a growing number of locations where mangroves are expanding, colonizing new sediments or inland areas, including as a result of rising sea levels.

Given their comprehensive detail and temporal coverage, **GMW maps have been selected as the official mangrove dataset by UN Environment** for reporting on the Sustainable Development Goals (SDG 6.6.1). Countries that do not have their own national mangrove monitoring systems are encouraged to use these maps.

The GMW maps are also able to pinpoint changes at high spatial resolution. And a new feature of the platform**—Change Alerts—can track variations in mangrove cover in near real time**, enabling those on the ground to respond to emerging threats quickly.

The causes of change are many, but **direct human impacts are responsible for over 60% of mangrove loss**. Primary causes include conversion to farmland, aquaculture and urbanization. Natural or indirect human causes make up the remainder, including erosion, sea level rise, and storms, many of which are being exacerbated by climate change.

Efforts to protect mangroves have risen globally and, currently, **around 42% of all remaining mangroves exist in designated protected areas**. While this represents good progress, these are varied in distribution and, within these areas, degradation and loss still occurs due to natural causes, as well as failures of implementation or management.

Alongside protection, there is an imperative need for restoration. Mangrove restoration science is well advanced, yet **many restoration efforts that were not backed by science have failed**.

In reality, the requirements for successful restoration are well understood, and there are growing efforts to share this understanding, including by GMA partners. A recent pilot model estimated that **over 6,600 km² of mangrove area lost since 1996 is highly restorable**. Separately, efforts are underway to build a Mangrove Restoration Tracker Tool as a means to share information on existing restoration projects, thereby helping to support effective restoration world-wide.

THE BEST OF BOTH WORLDS

Mangrove forests are formed by a variety of trees and shrubs that have numerous adaptations to live in the challenging—part marine, part terrestrial—environment of the intertidal zone. They are **home to a rich fauna, including 341 internationally threatened species**, ranging from tigers to seahorses.

The structure and productivity of mangroves enables them to support rich fisheries. New research has estimated that, **in many countries, over 80% of small-scale fishers rely on mangroves, and there are over 4.1 million mangrove fishers globally**—each supporting a network or community of dependencies. Large-scale offshore fishing operations, notably for prawns, also have an often-overlooked dependency on mangroves for breeding or as nursery areas.

Since they are located where sea meets land, mangroves can reduce flooding and act as natural defenses from waves and wind. They also act as permeable dams, dampening storm surges and reducing damage. It has been estimated that **mangroves prevent more than $65 billion in property damages and reduce flood risk to some 15 million people every year**.

In the face of accelerating climate change, mangroves are particularly important contributors to ecosystem-based adaptation, with a robust capacity to support lives and livelihoods, even in the changing settings predicted by many future climate models.

A critical feature of mangrove forests is their ability to **convert carbon dioxide to organic carbon at higher rates than almost any other habitat on earth**. This 'blue carbon' is stored both in the living plants and in their thick peaty soils where it can remain, fixed, for centuries.

Currently the world's mangroves store carbon equivalent to over 21 gigatons of CO_2. Destruction of mangrove ecosystems releases this carbon back into the atmosphere, exacerbating climate change.

The GMA advocates for the inclusion of mangroves into climate adaptation and mitigation plans. Using GMW maps, pilot work has shown that **the full return of 'highly restorable' areas could restore or stabilize carbon equivalent to over 1.3 gigatons of CO_2 into the atmosphere**—equivalent to over three years of emissions for a country such as Australia, or the avoided burning of three billion barrels of oil. The halting of ongoing losses will similarly produce massive benefits in terms of emissions avoided.

Taken together, **the many values of mangroves make a compelling case that needs to be communicated, absorbed and acted upon**—from government planning to investors and insurers, through to NGOs and local communities whose lives may depend on mangroves.

LIVING WITH MANGROVES

The front line of mangrove protection, management and sustainable use involves people—communities, indigenous groups, traditional users and local governments. Around the world, **there are countless examples of collaborations that have helped coastal communities and mangroves to thrive together**.

While people have lived alongside mangroves for centuries, growing pressures and changing times have created the need to develop frameworks to ensure sustainability. Our stories from Central America and West Africa describe **new management and governance systems that are helping secure traditional livelihoods and build new ones**, such as oyster-farming and beekeeping.

The importance of **working at the community level is critical**. Communities' knowledge of mangroves is considerable, their dependence on them is great, and so their potential roles in safeguarding and stewarding 'their' mangroves are hugely important. Over-use and degradation can be common problems, but **valuable participatory approaches are supporting new and effective efforts to engage and empower communities**. Stories from Madagascar, Micronesia, Indonesia and Central America all tell of how communities are being enabled to manage their mangroves, share knowledge and engage in monitoring.

Within that process of working with communities, it is also critical to ensure equity—strengthening the rights of the poor and marginalized, and particularly engaging women and young people. Our stories from Vietnam, Papua New Guinea and Honduras are among many that show how engagement of those three groups can secure a better future, both for mangroves and for local communities.

The local value of mangroves is often well understood by communities; however their global significance is widely overlooked. Stories show that **efforts to raise awareness of the full and varied value of mangroves may be critical in building a long-term sustainable future**—as illustrated here by programs from the Philippines to Bangladesh, and from the Bahamas to China and Senegal.

THE WAY AHEAD

Collaborative efforts will be essential to increase effective and equitable protection of mangroves, as well as to expand restoration.

The GMA is committed to its focus on halting any ongoing mangrove loss, advancing science-based restoration and increasing public awareness.

The great improvements in mangrove information and understanding are making it possible to write **transformative policies, which are often a prerequisite to effective management and investment**.

Multiple international agreements support and shape policy development at the national level. Practical applications of policy, by contrast, need to be tailored to local contexts and community needs.

Building on the remarkable advances in both science and practice we have now seen the launch of **the Global Mangrove Watch (GMW) web platform**. This has enabled the viewing and interrogation of very large volumes of data—including the GMW habitat and change maps, and a growing range of maps on mangrove values for carbon, fisheries and more. In the future, users will be able to model restoration potential, and run their own queries to generate detailed, policy-relevant outputs.

Efforts to protect and restore mangroves, engage communities and support research and monitoring depend on both public and philanthropic grants, but these are not always effective, or sufficient. More funds are clearly needed.

New financial mechanisms—like carbon markets, blue bonds, and insurance-based investments—represent a growing opportunity for mangrove protection and restoration. 'Blended' finance models which combine private capital with philanthropic or government grants are also being developed, and can be used to 'de-risk' investments in the short-term.

A CALL TO ACTION

There is an urgent need to protect all remaining mangroves, to enhance recovery and restore lost forests. Such actions will support coastal communities, jobs and food security, alongside providing global climate mitigation benefits.

Governments need to build mangrove management into policy, planning and law, allowing for local use, and halting harmful subsidies.

The **international community** needs to promote the adoption and scaling up of nature-based solutions that highlight mangroves. The **private sector** needs to recognize mangroves as assets and to increase investment in protection and restoration. **NGOs and advocacy groups** need to both raise awareness and catalyze funding and protection, while the **academic and research community** must prioritize supporting such efforts with data, models and tools.

For the GMA in particular, achieving our goals will require support, driven by increased public engagement, and clear policy frameworks driving equitable outcomes. It will also need considerable resources, including public, philanthropic and private investments.

The public, world-wide, must advocate for mangroves, generating interest, sharing stories of their immense value, and demanding their safeguarding. We need to leverage the momentum the mangrove community has created, and keep in mind what this work means to the world.

THERE IS AN URGENT NEED TO PROTECT ALL REMAINING MANGROVES, AND TO ENHANCE RECOVERY AND RESTORE LOST FORESTS

Woman sorting dried fish on Mousuni Island, Sundarbans, India
© Simon Rawles / WWF

Mangroves and seagrasses, Jardines de la Reina, Cuba
© Mark Spalding / TNC

1.1 SETTING THE SCENE

Mark Spalding, **The Nature Conservancy**

WE HAVE REACHED A CRITICAL MOMENT IN THE HISTORY OF OUR PLANET

Scientists, public figures and the population at large increasingly recognize that we're on the cusp of multiple tipping points. The next few years may well determine environmental conditions for generations to come.

From that perspective, our mangrove forests are critical, and in many ways also symbolic.

These are boundary ecosystems, straddling land and sea. They have suffered substantive losses—perhaps greater than many other ecosystems—which have already had repercussions for both local populations and the planet.

Livelihoods have been lost where mangrove fish nurseries have been replaced by short-lived aquaculture ponds. Land, homes, and even lives have been lost as storms have ripped through places where once mangroves acted as natural sea defenses.

Also, of all the world's ecosystems, mangroves are the most effective per unit area at trapping and storing carbon. So, at the widest of scales, the losses of the mangroves and their soils has led to significantly increased greenhouse gas emissions.

> "IT IS INCREASINGLY CLEAR THAT WE CAN PULL MANGROVES BACK FROM THE BRINK"

CAUTIOUS OPTIMISM

Yet, in the face of such impacts, there is now growing hope and considerable potential for increasing protection and restoring lost mangroves. Recent years have seen a surge of science and a groundswell of action. Patterns of ongoing loss have been replaced by a more complex array of losses and gains. Greater awareness has accelerated efforts to protect what remains.

Mangroves are now among the best protected of all ecosystems—42% of current mangroves are now located in protected areas and, even beyond those, measures are often in place to prevent further losses.

In addition, at the start of the UN Decade on Ecosystem Restoration, efforts are growing everywhere to restore mangrove forests, and those stories are now being shared.

This report is the first of a series that will share our state of knowledge of mangroves. It builds on a surge of major achievements in the sphere of mangrove science, and a host of experiences in the practical conservation, management and restoration of mangrove forests on the ground.

Linked to much of this is a newly formed partnership—The Global Mangrove Alliance. This is a collaborative effort by a host of NGOs, scientists, and other partners, who have joined forces to combine their experience in a concerted effort to secure a reversal of fortunes for mangroves.

SCIENCE IS LEADING POLICY AND INVESTMENT

Behind our cautious optimism is a remarkable surge of science. We now have highly detailed and up-to-date maps that document the location and changing extent of mangroves. Research has revealed and quantified patterns of carbon stored in mangrove plants and their soils.

Other work has mapped the harvest of fish and shellfish from mangroves, and yet more has quantified the value of mangroves in protecting coasts from waves and storms. That value is enormous and, once understood, makes it almost impossible to make any cogent argument in support of further mangrove loss.

Policy, too, is advancing at a tremendous rate. Much of that relies on the bedrock of accurate and repeatable scientific frameworks. For example, mangroves are now being incorporated as mitigation and adaptation opportunities in countries' national climate action plans—like Nationally Determined Contributions and National Adaptation Plans—recognizing their carbon stock value and vital role in improving resilience.

Likewise, there is a growing array of financial instruments to support mangroves. Funds are now being invested in mangroves to support coastal protection through green infrastructure, often at lower costs than sea walls and breakwaters.

LEADING BY EXAMPLE

The ideas and approaches backed by the science, and encouraged by new policy and finance mechanisms, are being mirrored by action on the ground. Throughout this report, and in many more online examples, there are stories from around the world of practical actions and activities highlighting successes. Many of these are stories of local communities, often supported by GMA members or their partners. They underscore the diversity of opportunities, and the critical need to connect to people.

Ultimately, it is local, often Indigenous, people who will be critical in supporting the recovery and sustainable use of mangroves. By catalyzing new approaches and sharing lessons between countries and cultures, it may be possible to greatly accelerate progress to secure a future for mangroves.

THERE IS MUCH MORE TO DO

All of this represents great progress, but it's still not enough.

Mangroves don't just straddle the land-sea interface. They also straddle the worlds of people and nature, of science and action, of loss and gain, and even perhaps of despair and hope.

And in resolving the challenges they face, it is critical that we also recognize that mangroves straddle the needs of both local and global communities. Indeed, mangroves are essential to the world. But it's only through local actions, supported by local communities, that we will achieve the gains we so urgently need.

We have pushed mangroves close to a tipping point, but it seems increasingly clear that we can shift the balance, and move back from the brink.

This report distils much of the latest thinking—the surge in understanding, action, and opportunity—that has grown around the world of mangroves. It also highlights the urgent need for action and what we should hope to achieve.

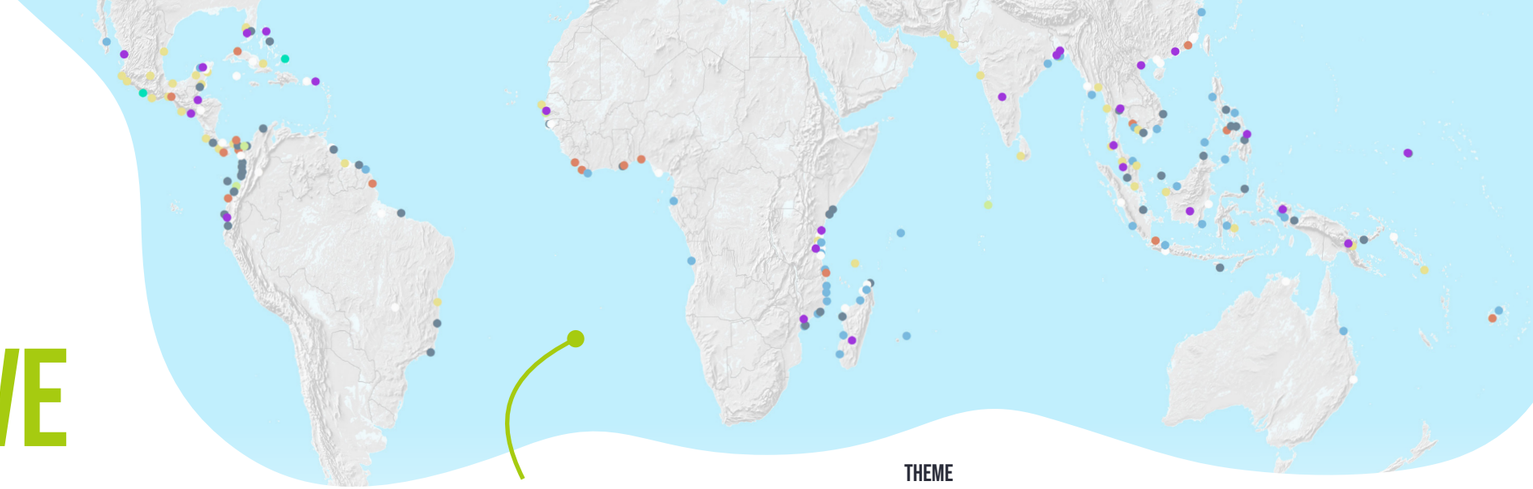
JOIN THE ALLIANCE
VISIT MANGROVEALLIANCE.ORG/JOIN-THE-ALLIANCE

1.2 WORKING TOGETHER : THE GLOBAL MANGROVE ALLIANCE

Pieter van Eijk
Wetlands International

The Global Mangrove Alliance (GMA) (mangrovealliance.org) was established in 2018 by five global organizations—Conservation International (CI), the International Union for Conservation of Nature (IUCN), The Nature Conservancy (TNC), Wetlands International (WI) and The World Wildlife Fund (WWF). It now represents a partnership of over 25 organizations with a joint strategy to:

- Increase global awareness of the value of mangroves
- Ensure integration of mangroves in conservation, climate and development policy
- Drive scaled-up conservation and restoration efforts on the ground
- Promote and leverage investment in mangroves



Map representing project sites where GMA members and partners are working around the world. Purple dots indicate the locations of stories featured in this report.

THEME

Adaption · Livelihoods · Policy · Restoration
Climate · Other · Research · Story

STRENGTH THROUGH COLLABORATION

For years, hundreds of NGOs, community groups, knowledge institutes and government agencies have been working globally to conserve mangroves. But their efforts to build scientific knowledge, to implement conservation and restoration measures, and to integrate mangroves into policy have often been scattered and poorly coordinated.

This has resulted in great inefficiencies and missed opportunities that might have come from a wider sharing of experiences and the scaling up of optimal approaches. There has been a lack of learning, a misalignment of knowledge agendas, and general failure to pull off the scaling approaches that are required to turn the tide for mangroves.

STRATEGIC FOCUS

The GMA aims to remedy that, and has adopted various thematic work areas, such as promoting conservation and restoration of mangroves for climate mitigation and adaptation, enhancing food security and human well-being, and sustaining biodiversity.

At a global level, through dedicated working groups, Alliance members are able to pool their complementary experiences. Together, they develop knowledge, guidance and tools that help policy-makers and practitioners integrate mangroves into their work.

These include standardized guidance for the implementation and monitoring of restoration projects. There are geospatial data layers that help prioritize conservation efforts. And there are also communications materials and policy briefs that are raising the profile of mangroves among the global community.

The Global Mangrove Watch platform (globalmangrovewatch.org) forms an integral part of the Alliance's collaborative work. This is a web platform that provides the latest, detailed information to support the prioritization, planning, and evaluation of conservation efforts.

Increasingly, Alliance members are also finding each other at a local level. National-level Mangrove Alliance chapters are today in various stages of development in Colombia, Mexico, Indonesia and other countries.

Members of national chapters are working to strengthen conservation and restoration on the ground. They're taking best-practice guidance and down-scaling information from the global models. And they're using that to develop mangrove strategies—and mobilize joint implementation programs—in close collaboration with a broad range of stakeholders, including local community groups. In parallel, their work and progress is directly informing and enhancing global mapping and information resources.

GMA MEMBERSHIP

Alliance membership is open to organizations with a demonstrated mangrove track record and interest in contributing to the implementation of the GMA's global mangrove strategy.

Annual strategy meeting of Global Mangrove Alliance members, 2019

1.3 SHARING RESOURCES

Lammert Hilarides
Wetlands International

A key role of the Global Mangrove Alliance is promoting greater awareness of the changes and interventions necessary to secure the future of mangroves.

Sharing information, data and lessons is therefore right at the heart of its thinking and philosophy. The Global Mangrove Watch (GMW) platform is key to this, and aims to provide a one-stop shop for information on mangrove values, status and threats.

The platform integrates data to help raise awareness and inform policy and practice. It enables a broad community of users—policy-makers, investors, communities, industry and mangrove professionals—to make better decisions on conserving and restoring mangroves around the world.

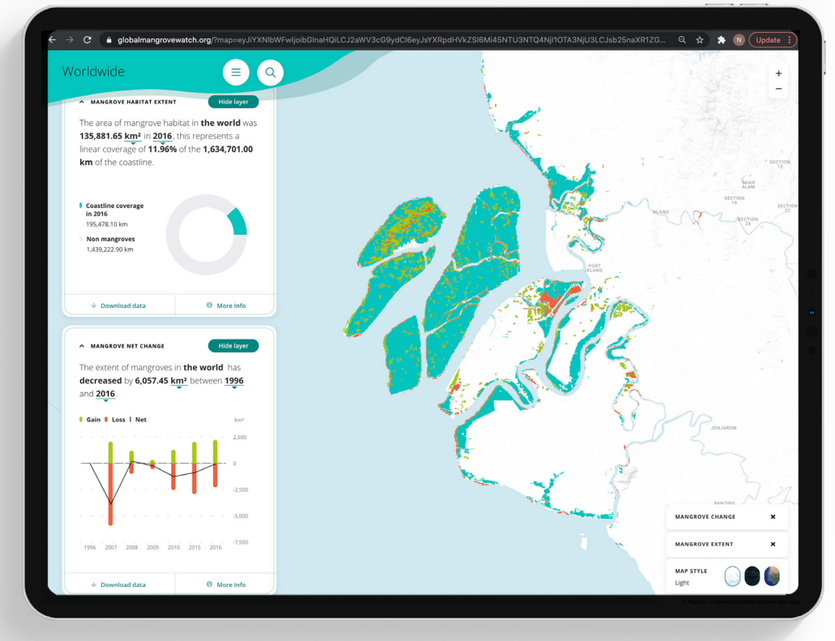
COLLABORATION BUILDS GREATER KNOWLEDGE

> "SHARING INFORMATION, DATA AND LESSONS IS THEREFORE RIGHT AT THE HEART OF IT'S THINKING AND PHILOSOPHY"

The GMW platform has, at its core, the GMW map. This is currently the most detailed map of the world's mangroves. It was developed by the Global Mangrove Watch partnership—established in 2011 between the Japan Aerospace Exploration Agency (JAXA)[1], Aberystwyth University, solo Earth Observation (soloEO) and the International Water Management Institute (IWMI). Wetlands International was incorporated into the partnership in 2014 which, in turn, joined the GMA in 2019.

Their vision was to provide open-access geospatial information about mangrove extent and changes. That began with methodology development and a limited number of pilot areas. The first GMW maps were released in 2018. The work has now grown into a global mapping and monitoring effort that involves dozens of contributing parties, all aiming to support the conservation and restoration of mangroves world-wide.

1. JAXA Earth Observation Research Center. *Advanced Land Observing Satellite (ALOS) Kyoto and Carbon Initiative—Overview, 2021.*



Sample view from the Global Mangrove Watch platform, providing access to very large data resources in a highly accessible format.

A determining factor in that success has been the open and collaborative spirit of contributing organizations. Largely thanks to that attitude, numerous other studies have enabled the GMA to expand its knowledge and understanding, and all these data layers are shared on the GMW platform too.

These enable us to track impacts and conservation progress with protected areas; to model a host of values of mangroves, including carbon and fisheries; and to begin to understand the potential of mangrove restoration world-wide. So much has been achieved through data sharing and the use of open data and open-source licenses, and through this approach of 'collaborate instead of replicate'.

INFORMING ACTION

Another cornerstone of the GMW platform is to provide ready-to-use information addressing the needs of policy makers and practitioners. These information 'users' have a broad range of needs, working across different scales. For some, the need is a simple understanding of location and extent of mangroves in a place. For others, it is to understand the benefits from mangroves, data on conservation progress through protected areas, and information about mangrove restoration.

The GMW platform provides a convening space where a broad range of stakeholders and practitioners have easy access to the best information.

As an example, there is a surge in demand for knowledge about the carbon storage and sequestration role of mangroves (see pages 48-51, and associated stories). Thanks to the collaboration and open access approach espoused by the GMA and its partners, three existing datasets have been developed[2,3,4] and integrated, to produce a single dataset that's designed to support the development of climate mitigation policy.

In addition to broad-scale mapping there is a growing demand for the sharing of smaller-scale or local information. Future iterations of the site will enable further sharing of field studies and the peer-to-peer transfer of information.

2. Bunting P, Rosenqvist A, Lucas RM, Rebelo L-M, Hilarides L, Thomas N, Hardy A, Itoh T, Shimada M, Finlayson CM. The Global Mangrove Watch—A New 2010 Global Baseline of Mangrove Extent. *Remote Sensing*. 2018;10(10):1669.
3. Simard M, Fatoyinbo L, Smetanka C, Rivera-Monroy VH, Castañeda-Moya E, Thomas N, Van der Stocken T. Mangrove canopy height globally related to precipitation, temperature and cyclone frequency. *Nature Geoscience*. 2019;12(1):40-5.
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2.1 THE WORLD OF MANGROVES

Pete Bunting,
Richard Lucas,
Aberystwyth University,
Ake Rosenqvist **soloEO,**
Lammert Hilarides
Wetlands International

Mangrove forests are intertidal ecosystems formed by a remarkable group of trees that have adapted to live in waterlogged, salty and often unstable conditions. They are distributed globally across the tropics and sub-tropics, with some occurrences in warm temperate zones.

Although not as expansive as other forest types, mangroves are critical resources. In some small island nations and arid countries, they can be the dominant forest type.

Warderick Wells Cay in the Bahamas Exuma Cays Land & Sea Park
© Mark Godfrey / TNC

THE EXTENT OF MANGROVES GLOBALLY

The most northerly mangroves can be found in Bermuda, at over 32° north, with the southernmost in Australia at over 38° south. Southeast Asia is the region with the most extensive areas of mangroves (see illustration, bottom right)—almost a third of the global total. This is a region with both extensive coastlines and the predominantly humid conditions in which mangroves thrive. Indonesia alone is home to almost 20% of the world's mangroves.

Mangroves are also extensive in other wet tropical areas of South and Central America and in West and Central Africa, forming ample forests particularly around river mouths and deltas such as those of Brazil and Nigeria. In more arid areas, mangroves can still be widespread and both Australia and Mexico are among the world's larger mangrove nations.

The two largest areas of continuous mangroves are the Sundarbans—shared by Bangladesh and India—and the Niger Delta in Nigeria, each boasting over 5,000 km² of mangroves.

ACCURATELY TRACKING MANGROVES

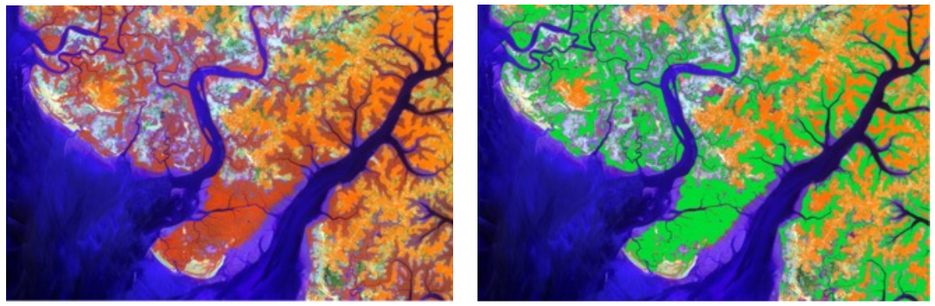
Previous global maps of mangroves, prepared in 1997 and in 2010 were drawn from mixed sources, of different ages, accuracy and resolution[1], or represented a single year[2]. Building on these efforts, the Global Mangrove Watch (GMW) map is a significant step forward. Originally published in 2018, the GMW extent maps[3] provide spatially explicit information on mangrove distribution and change. Using consistent satellite data and mapping approaches, the maps allow for direct comparisons between regions and through time. The overall mapping accuracy has been estimated as 94% and is currently considered the most complete and up-to-date global mangrove map.

BASED ON THREE DIFFERENT SATELLITE SENSORS

The GMW baseline dataset of global mangrove extent for 2010 was established using a combination of optical and spaceborne radar satellite images. Optical (light-based) imagery came from the United States Geological Survey (USGS) Landsat platforms (Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+)). Spaceborne radar data came from the Japan Aerospace Exploration Agency (JAXA), from three different missions: JERS-1, ALOS and ALOS-2 satellites.

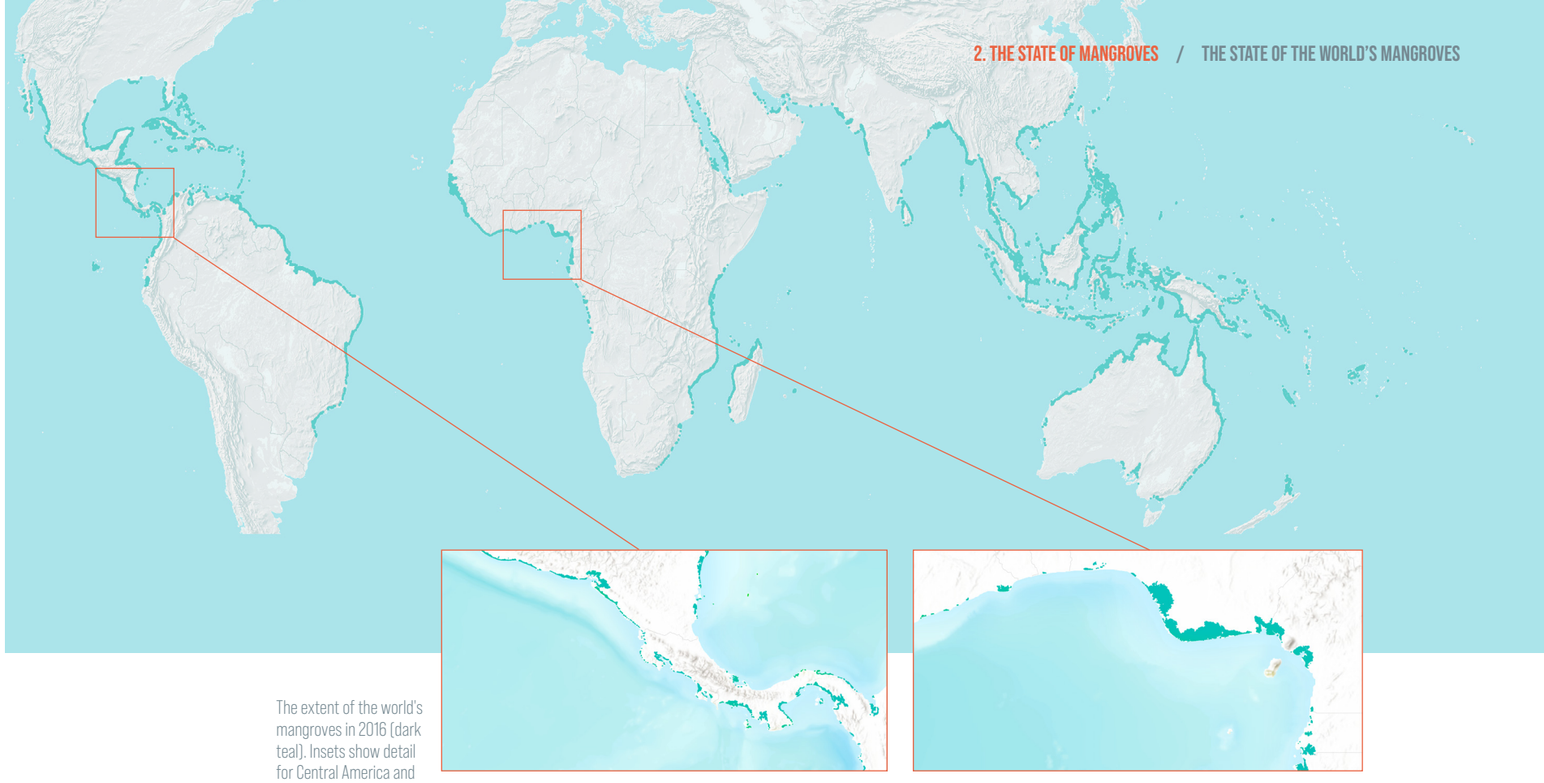
The optical Landsat data enables excellent discrimination of mangroves from other vegetation types (primarily on the landward margins). However, optical imagery can only be obtained during cloud-free conditions, which can limit the observation of mangroves in many regions.

The JAXA radar imagery is highly complementary to Landsat.



Satellite images over a part of Guinea Bissau, West Africa. Left is the data, colored using a false color composite (near-infrared, shortwave infrared and red in RGB) to highlight mangroves (shown in deeper red). Right shows the selected mangrove areas mapped by the Global Mangrove Watch (shown in green)

1. Spalding MD, Blasco F, Field CD. *World Mangrove Atlas*. Okinawa, Japan: International Society for Mangrove Ecosystems; 1997. 178 p. Spalding MD, Kainuma M, Collins L. *World Atlas of Mangroves*. London: Earthscan; 2010. 319 p.
2. Giri C, Ochieng E, Tieszen LL, Zhu Z, Singh A, Loveland T, Masek J, Duke N. Status and distribution of mangrove forests of the world using earth observation satellite data. *Global Ecology and Biogeography*. 2011;(20):154-9.
3. Bunting P, Rosenqvist A, Lucas RM, Rebelo L-M, Hilarides L, Thomas N, Hardy A, Itoh T, Shimada M, Finlayson CM. The Global Mangrove Watch—A New 2010 Global Baseline of Mangrove Extent. *Remote Sensing*. 2018;10(10):1669.



The extent of the world's mangroves in 2016 (dark teal). Insets show detail for Central America and Central Africa.

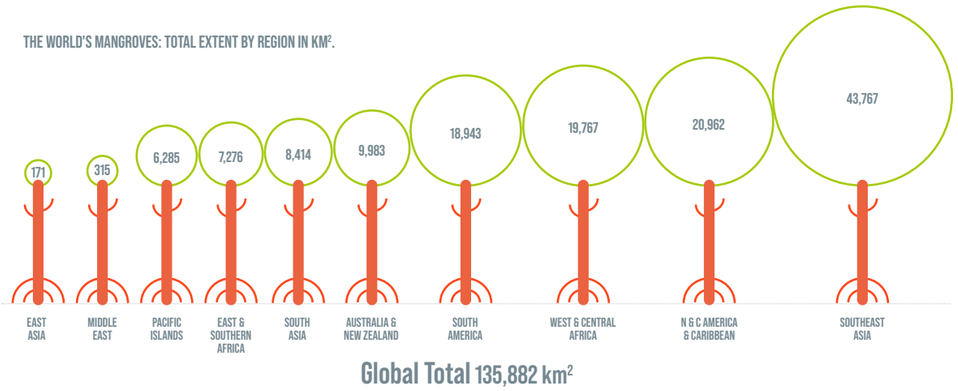
Apart from being unaffected by clouds and haze, radar signals are sensitive to the structural properties of mangrove forests, making them particularly suitable for the detection of woody vegetation changes. So, while the Landsat imagery helped in the initial mangrove identification, the Japanese spaceborne radar data was subsequently used to generate the change maps relative to the 2010 mangrove baseline.

OBSERVATION NOTES

The maps were computed at a 25m ground resolution, and this defined the size of features captured within the maps. The classification uncertainty is typically greater in complex and heterogeneous landscapes, including those fragmented (e.g. by aquaculture development) and along narrow river/estuary margins or coastal reefs. In general, the seaward borders of mangroves are more accurately delineated compared to those on the landward side, where mangroves are less distinct from other aquatic or terrestrial vegetation types such as tidal marshes, other forests or tree plantations.

A CRITICAL BASELINE

The GMW coverage forms a critical baseline from which we can understand the extent and distribution of mangroves. However, it also forms a launchpad for a host of other studies to understand mangroves in terms of their benefits to people, and in terms of what we are doing to them—both their loss and destruction, and also their management and protection—themes that are explored in the following sections.



2.2 CHANGES AND LOSSES

PETE BUNTING, RICHARD LUCAS **ABERYSTWYTH UNIVERSITY**, AKE ROSENQVIST **soloEO**, LAMMERT HILARIDES **WETLANDS INTERNATIONAL**

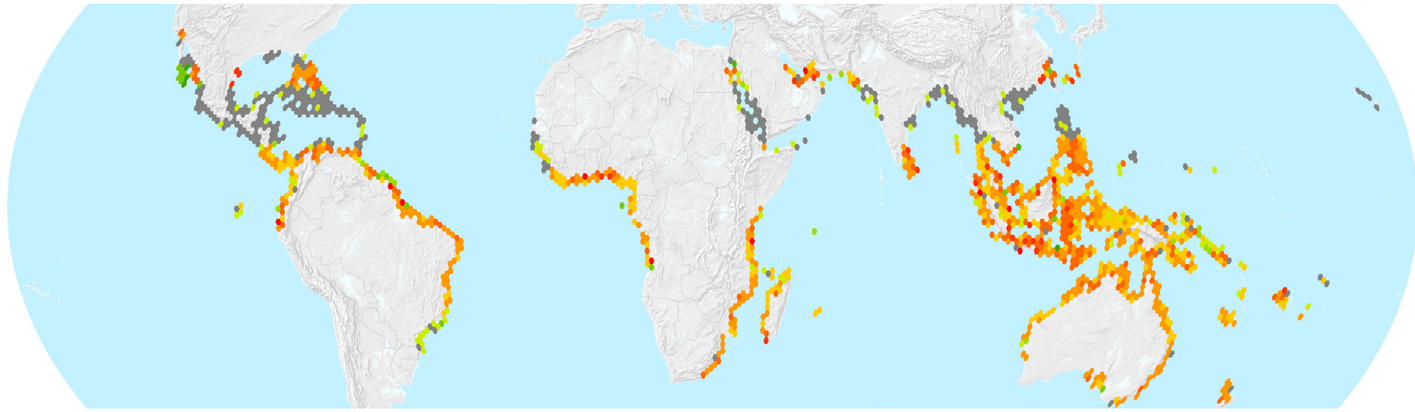
One of the most important aspects of the Global Mangrove Watch (GMW) maps is that they have been generated as a series of maps—not a one-off—enabling changes to be detected over time.

DYNAMIC ECOSYSTEMS

A key observation is the overall dynamism in mangrove ecosystems—the maps show both losses and gains in mangrove extent through time[1].

Overall, the total mangrove area was estimated to be 141,957 km² in 1996, decreasing to 135,882km² by 2016, a net loss of 6,075 km² (4.3%) (See table, p22).

While losses have been considerable, it's important to note that the rates are declining.



Percentage of gains and losses in mangrove extent from 1996 to 2016

Between 1996 and 2010, the average loss rate was estimated to be 367 km² (0.26%) per annum, but fell to a net average of 153 km² (0.11%) per year between 2010 and 2016. These declining rates of loss mirror earlier trends tracked from the 1980s[2]—albeit with less reliable data back then.

GAINS AND LOSSES

Hidden behind loss statistics are some complex patterns. From 1996 to 2016, the GMW maps actually identified approximately 15,262 km² (10.8%) of mangrove loss, but these were countered by some 9,204 km² (6.5%) of gain (see graphic, opposite). Mangroves are often opportunistic, and changes can occur relatively fast. While a small part of these gains may be due to restoration projects, it seems likely that many are natural gains. Further, only some are in areas where mangroves had previously been lost. Many more are cases of mangroves colonizing new sediments in river-mouths, or expanding landwards into areas of saltmarsh, or terrestrial habitats. This landward expansion is to some degree a natural process, albeit now exacerbated by the combination of increasing temperatures and rising seas, linked to global climate change.

1. Bunting P, Rosenqvist A, Lucas R, Rebelo L-M, Hilarides L, Thomas N, Hardy A, Tadono T, Kobayashi K, Finlayson CM. Global Mangrove Watch: Mapping Mangroves changes over two decades 1996 – 2018/20. in prep.
2. FAO. *The world's mangroves 1980-2005*. A thematic study prepared in the framework of the Global Forest Resources Assessment 2005. Rome: Forestry Department, Food and Agriculture Organization of the United Nations (FAO); 2007

GLOBAL DISPARITIES

Mangrove change is not uniform around the world.

Some of the most extensive global losses have been in Southeast Asia. **Areas of dramatic change include East and North Kalimantan, Riau, and West Papua (Indonesia); the Sundarbans (Bangladesh and India); the Mekong Delta (Vietnam), and the Irrawaddy Delta (Myanmar).**

In Africa, the Niger Delta (Nigeria), Rufiji Delta (Tanzania) and Guinea-Bissau saw significant change. In the Americas, substantive change was evident in French Guiana, Northern Brazil and in Ecuador, centered around Guayaquil.

The GMW maps have also enabled dramatic and relatively short-term changes to be monitored, as witnessed in the Gulf of Carpentaria in Northern Australia in 2014-2016 after a large dieback event[3]. Some illustrative examples of mangrove changes in the GMW datasets are provided on the following page.

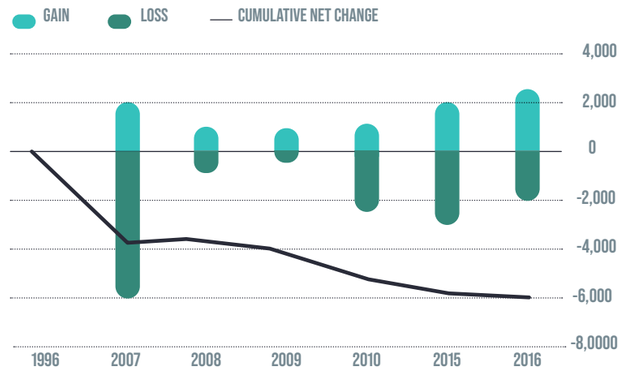
LAYERS OF DATA OVER TIME

The current release of the GMW dataset—version 2.0—consists of seven annual extent maps, spanning from 1996 to 2016, and all of these are available on the GMW platform. A major update, also including data from the years 2017 to 2020, will be released later in 2021.

The oldest annual layer, representing 1996, was generated from data from the JERS-1 satellite, while the four annual layers available from the 2007-2010 time period, coincide with the operations of the ALOS satellite. The maps from 2015, including those still being developed, are based on data from the ALOS-2 satellite. Prior to 1996, global estimates of the extent of mangroves are less certain, but it is clear that very large losses occurred before this time. (see Story: Long-Term Losses)

MANGROVE NET CHANGE

The extent of mangroves globally, showing the mix of gains and losses, and the cumulative net decline from 1996 to 2016.



3. Duke, et all. 2017. Large-scale dieback of mangroves in Australia's Gulf of Carpentaria: a severe ecosystem response, coincidental with an unusually extreme weather event. Marine and Freshwater Research 68:1816-1829.

Many aquaculture ponds in Southeast Asia were converted from former mangrove in the 1970s. Others trace back centuries

© Mark Spalding / TNC

LONG-TERM LOSSES

The GMW provides a critical time-series, however large areas of mangroves were already lost prior to 1996. Across South and Southeast Asia conversion to fish ponds traces back centuries, while the surge in shrimp aquaculture began here in the 1970s, and extended, soon after, to South America. By 1997, Vietnam, the Philippines and Thailand had all lost half or more of their mangrove cover.

Over-exploitation for timber and other products also led to losses and some of the earliest edicts for mangrove protection date back to the 18th Century in Brazil. There is no map of original cover, so we cannot know how much has been lost. The FAO estimated a total cover in 1980 of almost 190,000 km^2 and others have estimated original cover to have been considerably more than 200,000 km^2.

Mark Spalding, **The Nature Conservancy**

Mangrove Extent over Time (total area in km^2)

REGION	1996	2007	2008	2009	2010	2015	2016
North & Central America & the Caribbean	22,591	21,888	21,986	21,849	20,875	21,205	20,962
South America	19,512	19,105	19,146	19,145	19,127	18,907	18,943
West & Central Africa	20,016	19,913	19,933	19,930	19,916	19,807	19,767
East & Southern Africa	7,577	7,317	7,341	7,332	7,311	7,271	7,276
Middle East	330	321	324	325	324	315	315
South Asia	8,625	8,497	8,493	8,483	8,495	8,404	8,414
Southeast Asia	46,491	44,355	44,378	44,314	44,051	43,587	43,767
East Asia	170	169	167	165	164	170	171
Australia & New Zealand	10,278	10,172	10,186	10,187	10,201	9,980	9,983
Pacific Islands	6,368	6,325	6,326	6,326	6,333	6,278	6,285
GRAND TOTAL	141,957	138,064	138,279	138,054	136,798	135,925	135,882

REAL-TIME MONITORING

The GMW annual mangrove extent maps provide historical data, recording past changes. Yet there remains a clear need for up-to-date monitoring to track changes in near real time.

To address this, a method to identify mangrove loss within the GMW extent has been developed using European Space Agency Sentinel-2 and the United States Geological Service (USGS) Landsat satellite imagery. This approach generates 'Disturbance Alerts' which can enable actors on the ground to respond to emerging threats quickly. (See, p73 - Disturbance Alerts)

At present, the alerts are released on a monthly basis via the GMW portal for Africa, but further expansion is planned to build this into a global monitoring system.

> "GREATEST NET LOSSES OF MANGROVES WERE IN SOUTHEAST ASIA (6%) AND NORTH AND CENTRAL AMERICA AND THE CARIBBEAN (7%)"

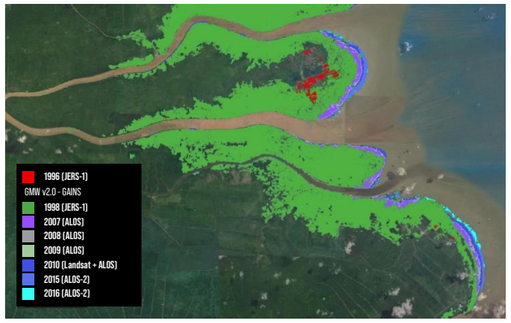
1. FAO. *The world's mangroves 1980-2005*. A thematic study prepared in the framework of the Global Forest Resources Assessment 2005. Rome: Forestry Department, Food and Agriculture Organization of the United Nations (FAO); 2007
2. Spalding MD, Blasco F, Field CD. *World Mangrove Atlas*. Okinawa, Japan: International Society for Mangrove Ecosystems; 1997. 178 p.
3. Spalding MD, Kainuma M, Collins L. *World Atlas of Mangroves*. London: Earthscan; 2010. 319 p.

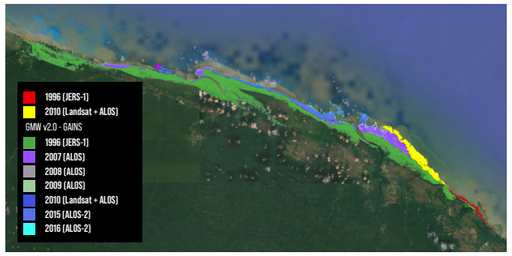
UN SUSTAINABLE DEVELOPMENT COMPLIANCE

In recognition of their global value, the GMW maps have been selected by the UN Environment Programme as its official mangrove dataset.

As part of the United Nations Sustainable Development Goals (SDG), Indicator 6.6.1, all Member States are required to report changes in the extent of their water-related ecosystems. Countries that lack their own national mangrove monitoring systems may choose to use the GMW maps.

Right: Change over time, as displayed on the GMW platform. A close-up of the Kahan river delta, North Kalimantan, Indonesia, showing the sequential loss of mangroves from 1996-2016.





Patterns of loss and gain are picked up over 20 years. Left: Riau, Indonesia showing mangrove accretion on new silt deposits at the delta mouth and mangrove loss on the landwards margins.

Below: French Guiana, showing the dramatic natural migration of mangroves along the coast colonising sediment deposits from the Amazon river. Green shows extent in 1996, with accretion shown in purple, blue and cyan, and losses in red.

6,075 km^2

net loss of mangroves from 1996-2016

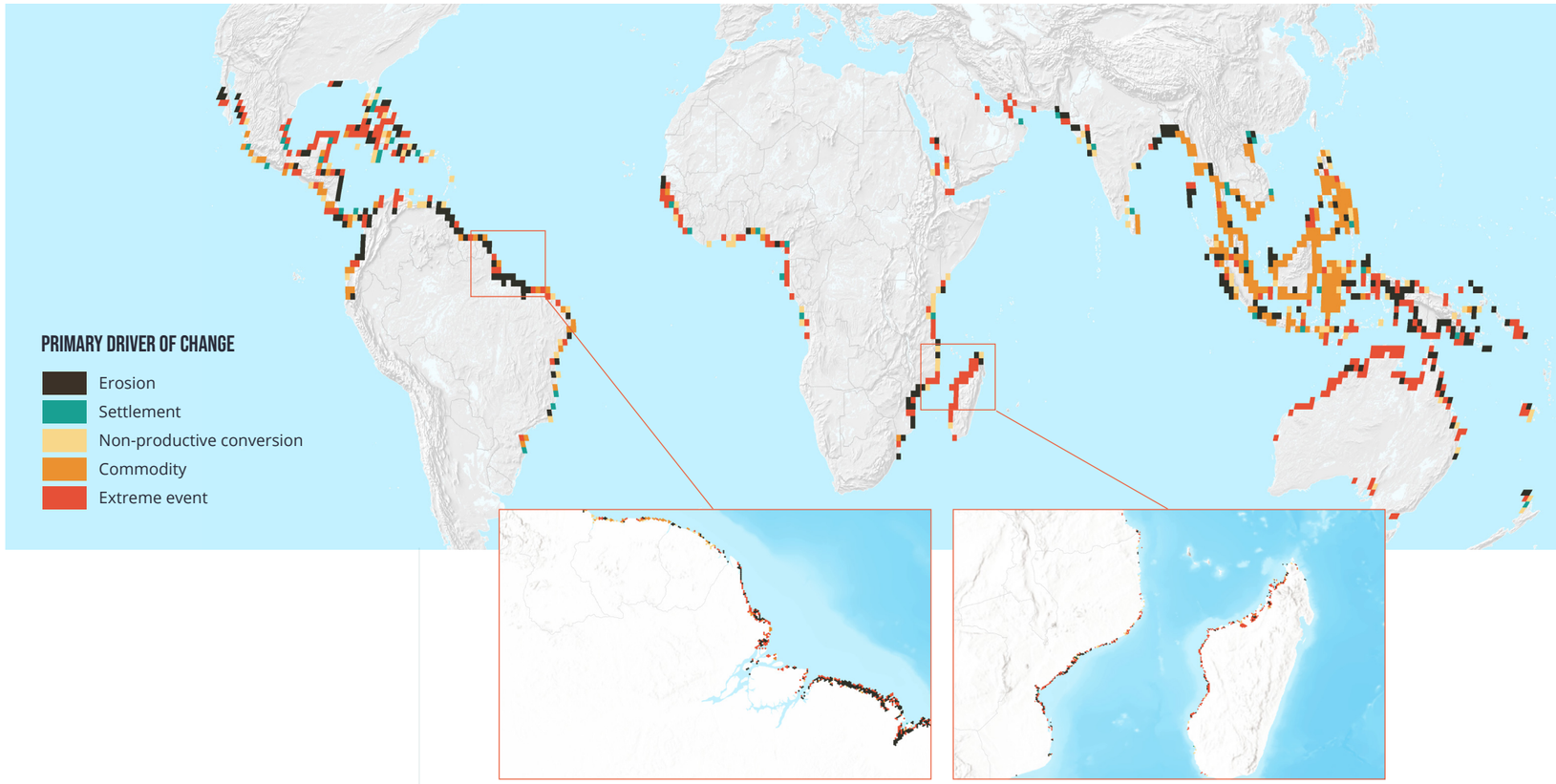
Urban development on former mangrove areas in Punta Gorda, Florida

© Carlton Ward Jr.

2.3 DRIVING FORCES OF MANGROVE DECLINE

TEMILOLA FATOYINBO, DAVID LAGOMASINO, LIZA GOLDBERG
NASA

Vast areas of mangroves were lost over the twentieth century and, although the rate of mangrove conversion decreased dramatically in the 21st century, climatic factors have become increasingly important drivers of global losses[1].



Mangroves, after being cut off from the sea by a road and railroad development, Salt River, Jamaica

© Tim Calver

HUMAN IMPACTS

Mangroves thrive in level, low-lying ground in coastal and riverfront areas—places that are highly desirable to humans for a range of uses.

They are most frequently converted to aquaculture ponds for fish and shrimp farming, to agriculture, and to urban areas and settlements. Mangroves are also lost to over-harvesting as they provide high-quality timber and charcoal, and are cut both commercially and on a small scale.

The drivers of mangrove loss since 2000 have been mapped in a detailed new analysis utilizing over one million satellite images, which revealed that over 60% of losses were due primarily to direct and indirect human impacts.

The conversion of mangrove areas for the production of commodities was the number one cause of loss (47%). This is strongly driven by fish and shrimp aquaculture expansion, and by rice farming[2]. The expansion of oil palm cultivation is also becoming significant.

The second leading human cause of mangrove deforestation (12% of losses) is so-called Non-Productive Conversion—where mangrove areas become unused land. These include direct losses through clearance—primarily for charcoal and timber extraction—as well as indirect impacts from changes in water occurrence, distribution, movement and quality. That includes pollution from oil and gas extraction and from nutrient runoff.

Finally, the conversion of mangroves to infrastructure, urbanization and even accommodation for coastal tourism is another driving force of mangrove loss, representing 3% of the total.

The latest analysis not only distinguishes the drivers of loss, but also shows geographic patterns (See image above).

Nearly 80% of human-driven losses occur in just six nations: Indonesia, Myanmar, Malaysia, the Philippines, Thailand, and Vietnam.

In the remaining 110 mangrove-holding nations, only a third of all losses are directly due to human

1. Goldberg L, Lagomasino D, Thomas N, Fatoyinbo T. Global declines in human-driven mangrove loss. *Global Change Biology*. 2020;n/a(n/a).

2. Richards, D R and Friess, D A, Rates and drivers of mangrove deforestation in Southeast Asia, 2000–2012. *Proceedings of the National Academy of Sciences*, 2015. 113(2): p344-349.

THREATENED MANGROVES

Sonneratia griffithii
© John Yong

Despite their strong adaptability to life in a stressful environment, mangrove ecosystems have faced unprecedented challenges in the Anthropocene, which in turn have threatened the very survival of some of the species that form the forests. Those species most at risk of global extinction include those at the interface with human activities, such as the high intertidal – *Heritiera* spp—or those with small localized populations, like *Bruguiera hainsii* and *Sonneratia griffithii*.

Limited range compounded with patchy distribution, and traits such as slow propagation rates, also threaten the long-term survival of many species, such as *Camptostemon philippinense, Pelliciera rhizophorae and Avicennia rumphiana*. The IUCN Mangrove Specialist Group conducts periodic reviews of the global conservation status of all mangrove species to inform the IUCN Red List and the global community.

Joe Shing Yip Lee, **The Chinese University of Hong Kong Mangrove Specialist Group**

SHRIMP AQUACULTURE IN THAILAND

In Thailand, it's estimated that shrimp farm development alone has led to the loss of 50-65% of mangroves since 1975. Thailand has been one of the major leaders in farmed shrimp production to supply the US, Japan and Europe.

This has led to many negative impacts in coastal communities, including land degradation, loss of resource-based livelihoods, poverty, increased vulnerability to natural disasters, and the deterioration of artisanal fisheries.

Worse still, over time the productivity of shrimp ponds often declines and many are abandoned, leaving wide areas with neither mangroves nor aquaculture.

Alfredo Quarto, **Mangrove Action Project**

Abandoned shrimp pond on former mangrove forest, Java, Indonesia
© Ellen Hines

influence. Distinct hotspots of conversion for commodities are present in the Kalimantan and Sulawesi regions of Indonesia, the Mekong Delta in Vietnam, and Rakhine state of Myanmar.

HOPE FOR THE FUTURE

While these changes are clearly of concern, the declining rates of loss noted in the previous section should also provide some hope.

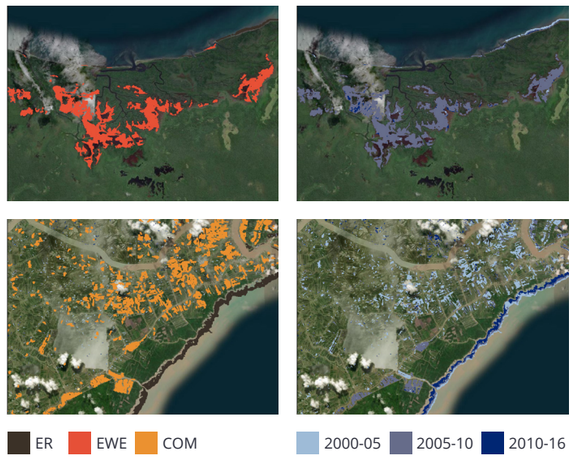
This might be due to increasing recognition—on local to global scales—of the importance of mangrove forests to human wellbeing. Although it could also be the result of a lack of remaining viable and available mangrove areas for conversion to aquaculture or infrastructure.

CLIMATE DRIVERS

Naturally driven events such as erosion, sea level rise, hurricanes and drought—which are exacerbated by climate change—are also leading to the die-off and loss of mangroves.

Shoreline erosion, the second largest overall cause of mangrove loss, contributed to 27% of global losses, while extreme weather events made up 11% percent of the total.

Mangroves are highly resilient ecosystems and can expand in extent, both landward and seaward, as conditions change.
But sea-level rise and other climate-related influences, combined with more direct human impacts, are making it difficult for mangroves to keep pace.



Examples of drivers leading to mangrove loss. Top left showing losses to extreme weather events (EWE) resulting from Cyclone Guba in Oro Province, Papua New Guinea. Bottom left showing simultaneous losses to erosion (ER) and conversion to commodities (COM) in the Mekong Delta, Vietnam. Right-hand images show the time period during which losses were recorded.

Although almost all countries with mangroves experienced impacts from erosion or extreme weather, there are regions with significant hotspots. At the continental scale, North America and Oceania (i.e. Australia and the islands of the South Pacific) are most affected by natural phenomena with nearly 50% of losses resulting from extreme weather events. Shoreline erosion was the leading cause of mangrove loss in South America, stemming from changes in sediment delivery and river discharge along the Amazonian coast.

Looking more closely, erosion was the leading cause of loss in Bangladesh, contributing to nearly 80% of national losses. Also, catastrophic cyclones, though relatively infrequent, can contribute to substantial loss of mangrove forests—as seen in Papua New Guinea following Cyclone Guba in 2007 (see images, pg 26).

However, mangrove losses from natural phenomena and human disturbances do not just occur independently of each other. For example many of the mangrove river deltas of Southeast Asia are being squeezed by land conversion on one side and shoreline erosion on the other, which is compounding localized rates of loss.

Erosion can be natural, but is often exacerbated by changes to sediment supplies, and by rising sea levels (Java, Indonesia)

© Mark Spalding / TNC

WESTERN INDIAN OCEAN MANGROVES

Mangroves play an important role for nature and the livelihoods of millions of people in the Western Indian Ocean. Kenya, Tanzania, Mozambique and Madagascar have over 700,000ha of mangroves, but they have seen a combined loss of 30,000 hectares over the last 20 years.

The losses seen were most severe in Mozambique, where more than 6% of mangrove cover has been lost.

In this light, GMA partners have started collaborating, and as part of the Save Our Mangroves Now! initiative, have set the bold target of achieving 0 net loss by 2030 and making the region a champion in mangrove conservation. Towards the end of 2021, we will produce a spin-off of this report focusing specifically on the Western Indian Ocean region, and disseminate results to policy makers.

Menno de Boer, **Wetlands International**

Mangroves in Lamu, Kenya
© Jonathan Caramanus / Green Renaissance / WWF-UK

MANGROVE SILVICULTURE—THE EXAMPLE OF MATANG

The Matang Mangrove Forest Reserve in Peninsular Malaysia—established in 1902—is being studied closely, as it has the longest documented track-record of all managed mangroves.

Its *Rhizophora* mangrove trees are managed on 30-year cycles with two thinnings and one clear cutting, followed by reafforestation. The aim is to maximize the yield of the monospecific stands, mainly for use in producing charcoal.

The 120-year history of silviculture here is exceptional and being studied closely from silvicultural, ecological, socio-economic and public health perspectives. Indeed, experts from fields as diverse as vegetation science, remote sensing, carbon cycling, historical ecology, socio-economy and ethnobiology are taking a keen interest.[1,2]

Farid Dahdouh-Guebas, **Université Libre de Bruxelles**

1. Dahdouh-Guebas F, Hugé J, Abuchahla GMO, Cannicci S, Jayatissa LP, Kairo JG, Kodikara Arachchilage S, Koedam N, Mafaziya Nijamdeen TWGF, Mukherjee N, Poti M, Prabakaran N, Ratsimbazafy HA, Satyanarayana B, Thavanayagam M, Vande Velde K, Wodehouse D. Reconciling nature, people and policy in the mangrove social-ecological system through the adaptive cycle heuristic. *Estuarine, Coastal and Shelf Science*. 2021;248:106942.
2. Lucas R, Otero V, Van De Kerchove R, Lagomasino D, Satyanarayana B, Fatoyinbo T, Dahdouh□Guebas F. Monitoring Matang's Mangroves in Peninsular Malaysia through Earth observations: A globally relevant approach. *Land Degradation & Development*. 2021;32(1):354-73.

2.4 SAVING MANGROVES

MARK SPALDING **THE NATURE CONSERVANCY**, DOMINIC A ANDRADI-BROWN **WWF**, KATE LONGLEY-WOOD **THE NATURE CONSERVANCY**, THOMAS A. WORTHINGTON **UNIVERSITY OF CAMBRIDGE**

Over the last 20 years, mangrove forests have shifted from being one of the fastest-diminishing habitats on Earth to being one of the best protected.

Currently some 42% of all remaining mangroves fall within legally designated protected areas, albeit recognizing that the levels of actual protection these provide can be variable.

Such areas range from tiny, locally managed sites to vast nationally governed forests, such as the Sundarbans—which is protected across almost all its extent in both Bangladesh and India. Many of the remarkable creatures associated with mangroves are also safeguarded—from tigers and proboscis monkeys to sawfish and seahorses.

When implemented well, these areas can also protect human lives and livelihoods, enabling a sustainable supply of fuelwood, supporting fishing, slowing erosion, and cleaning watercourses. Many mangrove protected areas are also popular with visitors. Sites such as Can Gio in Vietnam, JN Ding Darling in Florida, USA, and the Nakama River in Iriomote, Japan, all receive over half a million visitors annually.

PATTERNS OF PROTECTION

From a regional perspective, the most comprehensive coverage by protected areas is in South America where over 74% of all mangroves fall within them (see graphic, pg 30). By contrast, only 13% of mangroves in East Asia and 9% of mangroves in the Pacific Islands fall within protected areas—although traditional ownership and use in the latter locations may provide partial protection.

Of the larger mangrove nations, the very low coverage in Myanmar, Papua New Guinea and Nigeria is notable—these countries host almost 10% of all mangroves, but only have between 3% and 5% of those in protected areas. Some of the highest coverage among the major mangrove nations is in Bangladesh (92%), Brazil (86%) and Mexico (75%).

THREATS TO PROTECTION

Unfortunately, not all designated protected areas provide strong protection.

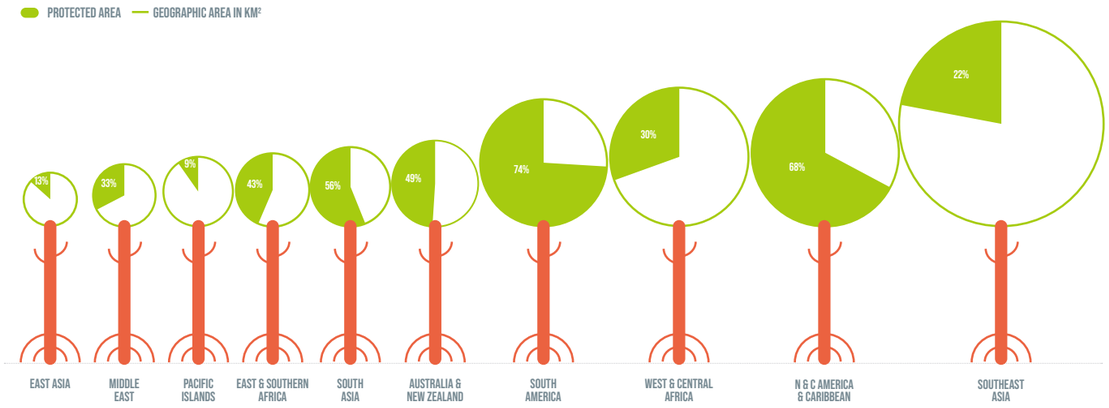
Global change maps show that losses still happen in many such areas, and that is confirmed by on-the-ground observations.

Much of this may be natural losses, driven by erosion or storms. Other sites, however, are compromised by ineffective management or capacity shortfalls, preventing proper implementation of regulations.

Damage can also be driven by activities in adjacent areas—where changes to water flows may increase erosion, for example, or cut off freshwater or sediment supplies. In a few cases protected areas themselves might be downgraded or degazetted by governments in favor of new activities and developments.

42% of mangroves are now located in protected areas

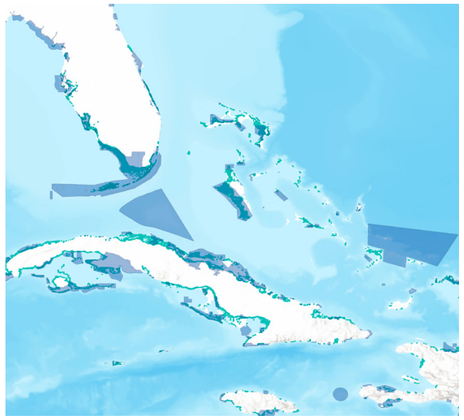
Everglades National Park, Florida
© Mark Spalding / TNC



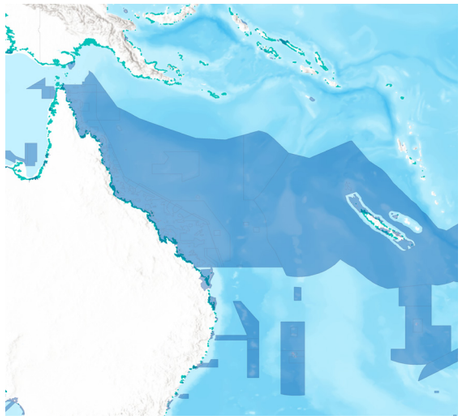
Protected area of mangroves by region represented as a percentage of total mangrove extent

PROTECTED AREAS
MANGROVES

NORTH CARIBBEAN



AUSTRALIA AND THE WESTERN PACIFIC



EFFECTIVE AND EQUITABLE

The most effective protected areas are those that have the support and engagement of local communities and other stakeholders. Wherever local people feel the benefits from mangroves and play a part in setting the regulations and ensuring compliance, protected areas rarely fail.

OTHER FORMS OF PROTECTION

While protection under conservation regimes can be highly effective, other approaches also play a role in saving mangroves. Local or community ownership of mangroves, even outside protected areas, can often lead to sustainable management practices.

A number of financial mechanisms are also becoming more widely used as a means to build the long-term security of mangroves. Payments are being provided to governments or communities in return for capturing carbon, or delivering some of the other benefits that the mangroves provide (see section 5.4).

Other regulatory regimes can also be used to prevent mangrove loss. In some places, coastal setback regulations restrict development within a specified distance of rivers and coastlines. Elsewhere, 'no net loss' regulations require any loss or clearance to be countered by an equal (or larger) area of equivalent habitat restoration.

Ultimately, the value of mangroves—both to local communities and the wider world—demands that we halt any ongoing mangrove loss and, indeed, secure the restoration of wide areas. The levelling of loss rates and a surge in protection are encouraging pointers, and targeted prioritization of protection efforts will help further.

Much of the ongoing work highlighted in this report will play a role in this vision, showing where mangroves offer some of the greatest benefits to biodiversity and people.

Bengal tiger resting in the mangrove forest in the Sundarbans.
© Tim Laman / naturepl.com / WWF

CAUTIOUS OPTIMISM FOR THE MIGHTY INDIAN SUNDARBANS MANGROVE FOREST

The Indian Sundarbans is by far the largest single mangrove forest in that country, and supports unique biodiversity as well as the livelihoods of millions. A team of scientists from Australia, India, Singapore and the UK recently utilized the standardized techniques developed by the IUCN for a Red List of Ecosystems, to objectively assess the status of this forest[1]. They found that substantial losses over the last 250 years, and recently diminishing fish populations meant the Indian Sundarbans ecosystem as a whole was classified as Endangered [2]. In addition to these threats, populations of the endangered Bengal Tiger have also declined.

However, since the declaration of the Sundarbans as a World Heritage site in the 1970s, forest loss has greatly declined, while tiger numbers are now slowly increasing. Only a small proportion of the mangrove trees are considered degraded. While threats—such as hydrological modification—still remain, with effective management there is reason for cautious optimism[2].

Michael Sievers, Rod Connolly **Griffith University,**
Mahua Roy Chowdhury **Department of Marine Science, University of Calcutta**

PROTECTING MANGROVES IN THE BIRD'S HEAD SEASCAPE, PAPUA, INDONESIA

FULL STORY ONLINE

A fisher in West Papua is one of the many beneficiaries of new protected areas in Eastern Indonesia
© Jürgen Freund / WWF

1. Keith DA, Rodríguez JP, Brooks TM, Burgman MA, Barrow EG, Bland L, Comer PJ, Franklin J, Link J, McCarthy MA, Miller RM, Murray NJ, Nel J, Nicholson E, Olivera-Miranda MA, Regan TJ, Rodríguez-Clark KM, Rouget M, Spalding MD. The IUCN Red List of Ecosystems: motivations, challenges and applications. *Conservation Letters.* 2015; 1-13
2. Sievers, M., et al., Indian Sundarbans mangrove forest considered endangered under Red List of Ecosystems, but there is cause for optimism. *Biological Conservation.* 2020. 251: p. 108751.

Community mangrove restoration in Madagascar
© WWF / Madagascar

2.5 RESTORING MANGROVES

THOMAS A WORTHINGTON, KATE KINCAID **UNIVERSITY OF CAMBRIDGE**, YASMINE GATT **NATIONAL UNIVERSITY OF SINGAPORE**, PIETER VAN EIJK **WETLANDS INTERNATIONAL**, DOMINIC CJ WODEHOUSE **MANGROVE ACTION PROJECT**

While protecting the world's remaining trees remains a priority, the opportunity to restore lost or degraded mangrove areas is also increasingly being addressed. Given their catastrophic losses from many coastlines, and recognizing the benefits that mangrove reestablishment will bring, such restoration is both logical and a tremendous opportunity.

Indeed at the start of the UN Decade of Restoration, and through partnerships such as the Global Mangrove Alliance and the Bonn Challenge, it seems likely that efforts to restore mangroves are going to accelerate considerably. Yet, to turn ambition into on-the-ground action, there is a strong need for sound restoration science.

RESTORATION IN PRACTICE

Mangrove restoration aims to return a mangrove forest to—or close to—its original condition.

Such restoration can take many forms. It might be a question of removing a specific threat or leaving things free so the mangroves can regenerate naturally. Alternatively, stronger intervention may be necessary, such as re-establishing hydrological connectivity, sediment balance and soil conditions. The active replanting of new trees is widespread and can accelerate recovery, but is by no means a necessary part of all restoration projects.

Restoration has been attempted in many areas and at a range of scales—from local community efforts of a few tens of square-meters, to large-scale planting programs involving a million mangrove propagules. However, many of these projects have not been successful.

Failures often happened because of poor site selection and incorrect matching of species to sites. Different mangrove species grow in varying salinities and nutrient compositions, and at different elevations within the intertidal zone.

ENABLING NATURAL MANGROVE RECOVERY

Many attempts at mangrove planting fail, for reasons that are often highly predictable. The GMA is actively promoting a range of 'best practices', one of which is Community-Based Ecological Mangrove Restoration (CBEMR). This works to remove barriers in an effort to promote natural regeneration. Those barriers might be physical, on-site obstacles, but they can also be social impediments.

The Mangrove Action Project (MAP) has joined forces with Wetlands International, Save Our Mangroves Now, the World Wildlife Fund (WWF) and the US Forestry Service to train local community practitioners in CBEMR approaches. MAP is working on the ground to encourage natural mangrove regeneration.

Villagers in Southern Thailand have depended on mangroves, and their rich biodiversity, for centuries. But in the 1990's, an industrial shrimp farming boom left just half of the original mangrove cover in place, along with many abandoned shrimp ponds.

CBEMR was applied at this site, an abandoned shrimp pond at Thung Yor in Krabi Province. Just a few years after its water flows were restored it was colonized by 12 mangrove species, and many crustaceans, mollusks and fish species also returned.

Leo Thom, **Mangrove Action Project**

Allowing mangroves to recover naturally in an abandoned shrimp pond in Thailand
© Mangrove Action Project

MOZAMBIQUE MANGROVES – RESPONDING TO CYCLONES

The active unblocking of creeks has been shown to greatly enhance restoration success in Mozambique
© Henriques Balidy

FULL STORY ONLINE

BUILDING WITH NATURE INDONESIA

In Java, Indonesia, permeable dams are being used to retain sediments and allow natural mangrove recovery
© Nanang Sujana

FULL STORY ONLINE

LENDING RECOVERY A HELPING HAND

A group of stakeholders in the British Virgin Islands came together to support natural mangrove recovery after devastation by two Category 5 storms.
© Susan Zaluski

FULL STORY ONLINE

Sonneratia mangroves (circled in red), invading native mangroves
© Haichao Zhou

REMOVING INVASIVE MANGROVES

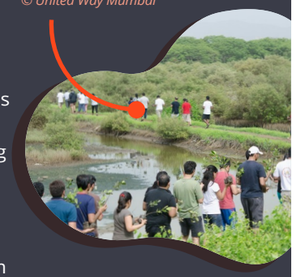
In China, the Shenzhen Mangrove Wetlands Conservation Foundation (MCF) is working to restore native species of mangrove, after a non-native species—*Sonneratia*—rose to dominance.

The *Sonneratia* plants were introduced towards the end of the 20th Century as part of a bid to restore vast areas of coastal mangroves that had been lost. But it spread rapidly to unintended areas and outcompeted native species.

In 2017, the Shenzhen Mangrove Wetlands Conservation Foundation (MCF) conducted a trial for clear-felling these exotic mangroves and replanted the area with native species. That led, in 2020, to a project to restore a healthy mangrove ecosystem. As well as clear-felling of *Sonneratia* plants, that included hydrological rehabilitation by recreating tidal streams; experimenting with and optimizing methods of replanting, and maintaining mudflats for migratory birds as feeding grounds. The project is designed to demonstrate best practice ecosystem management for exotic mangroves in China.

Mouxin Ye **Shenzhen Mangrove Wetlands Conservation Foundation**

© United Way Mumbai



MISSION MANGROVES

United Way Mumbai launched Mission Mangroves in June 2015 in an effort to rejuvenate the fast-depleting mangrove cover around Mumbai.

As of February 2021—through a sustained program of planting and maintenance by 2,753 volunteers—the project now covers 33 hectares of wetlands with 127,625 mangroves. Moreover, over five tons of waste has been cleared from the wetlands.

In parallel, the initiative has also raised awareness of the importance of mangroves—'the shore keepers'—with 11,864 people through classroom sessions, nature trails and virtual sessions.

Mission Mangroves was set up as a public-private partnership and now has 27 corporate partners.

Ajay Goval **United Way Mumbai**

If species are improperly matched to locations within the restoration sites, or non-native species are used, it could mean a failed effort, and even significant consequences for the rest of the ecosystem (see Story: Removing Invasive Mangroves).

There is therefore an urgent need to address these challenges globally—by sharing best practices, and also by translating science into practical advice.

ANALYZING BENEFITS VERSUS COSTS

At the broadest scales, a crucial step can be to better understand how best to invest the limited amount of conservation funding. Predicting the capacity of an area to be restored, or the variation in restoration and opportunity costs, has—to date—been an imprecise art.

In the first global effort to address this[1], GMA funded scientists working with GMW data have developed a pilot model to quantify the restoration potential of different areas more fully.

The analysis combines geospatial data—on environmental conditions and on the size and boundary configuration of lost mangroves—to rank the relative suitability for restoration. It also filters out locations where the technical challenge or cost of restoration may be too high, such as in urban areas or those subject to erosion. This pilot analysis estimated that over 6600km^2 are 'highly restorable'.

Such data on the feasibility of restoration can be further enhanced by information on the likely benefits of restoration (see Chapter 3). This initial pilot estimates the benefits of assuming restoration to full ecological function (see maps on screenshot, opposite). A new and enhanced version of this dataset is currently under development.

> "OVER 6,600KM^2 ARE 'HIGHLY RESTORABLE'."

LOCAL CHALLENGES

There are also challenges at a local level. Short-term funding and inappropriate metrics of success—such as maximizing the area or the numbers of trees planted[2]—have been made worse by challenges of dealing with land ownership or tenure[3].

Indeed, many restoration efforts have failed because, in their efforts to circumvent complex land ownership issues, they have avoided areas such as abandoned aquaculture ponds in favor of mangrove planting in seaward locations. Planting in these areas can damage mudflats and seagrass beds, and such areas are also more deeply flooded by the tides, often outside the physiological limits of the mangroves being planted[2].

We have the knowledge and the tools to address these issues. There has been a concerted effort to encourage a move away from single species planting and to champion the use of ecological restoration. This, combined with greater community engagement, a focus on addressing land tenure issues, and providing other holistic solutions to challenges facing a community, will make restoration more successful in the future.

MONITORING MOTIVATES MOMENTUM

Tracking and recording what's done, and where, is essential to fully benefit from restoration efforts. That makes it easier to notice and learn from mistakes, identify factors driving success, and monitor progress made towards global conservation targets.

For this reason, the Global Mangrove Alliance and the wider mangrove community are collaborating to develop a tool to capture the information needed to holistically describe a restoration project. This will include factors that are often overlooked such as costs or socio-economic outcomes.

It is hoped that—by recording this information, sharing it with other practitioners through an online platform (see pg 72), and encouraging openness about both the successes and failures of restoration—better and more successful restoration can be encouraged.

Mangrove restoration can be a powerful tool to enhance biodiversity, and to support and protect local communities.

Sample maps from the pilot model for mangrove restoration potential showing the proportion restorable (top), and the likely gains from full recovery of restorable areas in terms of commercial fish catch enhancement (bottom left, the number of additional young fish entering the ecosystem thanks to mangrove recovery) and carbon in the above-ground forest (bottom right). These can be viewed online on: https://maps.oceanwealth.org/mangrove-restoration/

1. Worthington T, Spalding M. *Mangrove Restoration Potential. A global map highlighting a critical opportunity.* The Nature Conservancy, IUCN, University of Cambridge; 2018

2. Wodehouse DCJ, Rayment MB. Mangrove area and propagule number planting targets produce sub-optimal rehabilitation and afforestation outcomes. *Estuarine, Coastal and Shelf Science.* 2019;222:91-102.

3. Lovelock CE, Brown BM. Land tenure considerations are key to successful mangrove restoration. *Nature Ecology & Evolution.* 2019;3(8):1135.

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3.1 THE BEST OF BOTH WORLDS

Mark Spalding **The Nature Conservancy,**
Farid Dahdouh-Guebas
Université Libre de Bruxelles

Mangroves are frontier ecosystems, straddling land and sea.

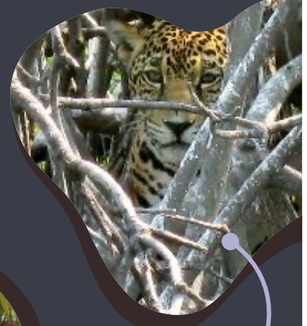
They're highly productive, but survive in conditions that are harsh in many ways. Mangrove soils are permanently waterlogged, oxygen-poor, and have constantly changing salinities—they are sometimes submerged, sometimes dry.

The fact that they thrive in such conditions is already remarkable. But more incredible still is that they generate such abundance, producing benefits that accrue not only to nature, but to humans as well.

JAGUARS AND MANGROVES

Voluntary conservation areas are being established in the largest mangrove wetland on the northern pacific coast of Mexico—a habitat for key species such as the jaguar. The Marismas Nacionales Nayarit Biosphere Reserve and Ramsar Site extends for 80,000 hectares. As well as establishing the voluntary conservation area (ADVC), community monitoring brigades are being set up to protect the habitat for a population of 30 jaguars in the Toro Mocho-La Bajada biological corridor. The initiative was driven by the National Protected Area Commission (CONANP) which engaged with the local communities of San Blas and Santiago Ixcuintla.

Yves C Paiz
The Nature Conservancy



A juvenile lemon shark using mangrove habitats as a nursery.
© Shutterstock

© Dan Quinn / TNC

MANGROVES AND MARINE MEGAFAUNA

Mangroves are important habitats for many more marine megafauna than previously thought—making conservation an even greater priority.

Many large animals—including sharks, turtles, dolphins and porpoises, manatees and dugongs, crocodiles and alligators—live, feed and breed, in and around mangrove forests.

And this often happens in areas of high mangrove loss. The Global Wetlands Project at Griffith University identified and mapped key conservation hotspots—in Central America, Indonesia and Malaysia—of high megafauna biodiversity in at-risk areas[1].

Improving awareness of the importance of mangroves to marine megafauna provides yet more impetus to encourage mangrove conservation.

Michael Sievers and Rod Connolly **Griffith University**

1. Sievers M, Brown CJ, Tulloch VJD, Pearson RM, Haig JA, Turschwell MP, Connolly RM. The Role of Vegetated Coastal Wetlands for Marine Megafauna Conservation. *Trends in Ecology & Evolution*. 2019.

THE BEST OF BOTH WORLDS

Approximately 70 species of trees and shrubs make up the key mangrove plants of the world.

Although not all closely related to one another, these are all species that have developed the capacity to live in the intertidal zone. They have adaptations to exclude or extrude salt from their tissues, their roots provide support in soft mud, and many roots have aerial extensions to channel air into the waterlogged soil.

Regular flooding is also a challenge when it comes to setting seed, and many species are viviparous—they have developed mechanisms to reduce that challenge, and their young plants begin growing before they even fall from their parent tree.

MANGROVE DIVERSITY

The most diverse mangrove forests are found in the hot and humid estuaries and deltas across South and Southeast Asia. Thirty or more species can be found in zones across some forests.

Away from those areas, diversity declines. Along many dry and desert coastlines, and towards the cooler southern and northern limits of mangroves, just one or two species survive.

From a biogeographic perspective, the center of diversity is also at the heart of a vast realm that stretches from South Africa and the Red Sea right across to the central Pacific Ocean (the Indo-West Pacific). A second realm incorporates the Americas and West Africa (the Atlantic East Pacific). These two realms have completely distinct species, with the latter having far fewer, but with its own small center of diversity in Central America.

MANGROVES CREATE DIVERSE AND IMPORTANT HABITATS

Mangrove trees and shrubs combine to build and shape a habitat on which countless species depend.

Terrestrial wildlife—from insects and reptiles to monkeys and tigers—live in the drier parts of the habitat. And, in the pools and channels around their roots, mangroves are home to fish, mollusks, crustaceans, even sharks, crocodiles and dugongs (see Story: Mangroves and Marine Megafauna).

1. Worthington TA, Ermgassen PSEz, Friess DA, Krauss KW, Lovelock CE, Thorley J, Tingey R, Woodroffe CD, Bunting P, Cormier N, Lagomasino D, Lucas R, Murray NJ, Sutherland WJ, Spalding M. A global biophysical typology of mangroves and its relevance for ecosystem structure and deforestation. *Scientific Reports*. 2020.

Complex, meandering channels in the mangrove forests carry water from inland rivers, and also transmit tidal movements upstream. These provide connections to many other ecosystems enabling larger creatures to visit, or to use mangroves as nursery grounds.

Mangrove forests are places of exchange. Minerals and particles from inland or along the coast can be deposited in them, keeping the land in a continual state of change. And the rich productivity of the mangroves can also be exported to surrounding waters—both from the migration of fish and other animals, and through the constant export of organic matter from the forests themselves.

For a few species, mangroves are a critical habitat—they either live nowhere else, or have found themselves using mangroves as a final refuge when other habitats have dwindled or been lost.

Indeed, some 341 species that use mangroves are considered threatened—vulnerable, endangered or critically endangered—by the international community and IUCN. These include an extraordinary range, from tigers to seahorses, sawfish to sea eagles, orchids to sea cucumbers, and more.

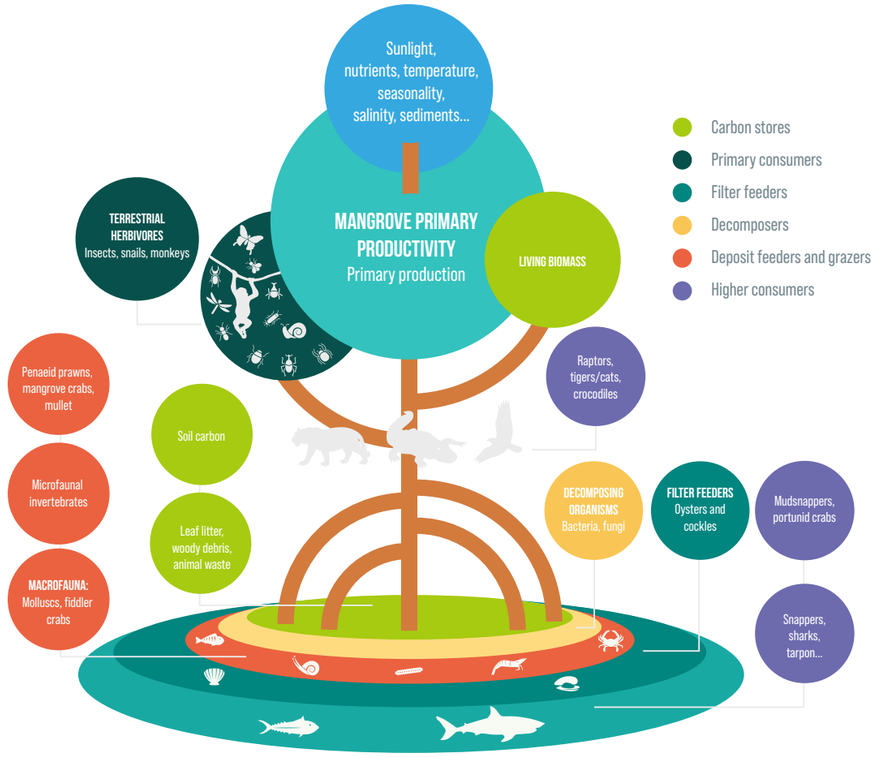
MANGROVE TYPES

Mangroves reach their greatest extents as large estuarine and deltaic forests, particularly in the wet tropical areas. These comprise over two thirds of all mangroves by area. They can extend far inland along tidal rivers, growing in nearly fresh waters.

Fringing mangroves—which make up 21% of the world's total—line many shores in more sheltered waters, around island archipelagos and behind barriers such as coral reefs.

Of course, mangroves are unable to grow on wave-swept shores but, in such areas, the waves often generate barriers of sand or rocks which protect sheltered coastal lagoons. Lagoonal mangroves thrive in these calm backwaters, making up the remaining 11% of the world's mangroves[1].

The ecology of these mangrove types can be quite different and our understanding of this helps in building a better picture of the many processes which, in turn, can influence productivity and the many benefits which humans derive from mangroves.



3.2 RICH NATURAL RESOURCES

PHILINE ZU ERMGASSEN **UNIVERSITY OF EDINBURGH**,
MARK SPALDING **THE NATURE CONSERVANCY**

For coastal peoples, mangroves have long been recognized as a critical ecosystem because of the many benefits they bring. As well as coastal protection and climate change mitigation—two focal points of this report—other benefits abound. In a world beset by accelerating impacts from climate change, these benefits may be increasingly important and the safeguarding of mangroves may play a critical role in supporting coastal communities in adapting to change and uncertainty.

FOOD SUPPLIES

Mangroves are food factories. Their high productivity supports rich food webs, often enhanced by the nutrients brought in by rivers and streams.

The habitat itself encourages that abundance. The roots provide a surface that oysters and other mollusks can colonize and grow on. And the complex structure of meandering channels enables fish to find shelter, or to live in relative safety from predation during their initial life phases.

Among the key species harvested from mangroves are shrimps, oysters and many different kinds of small fish. Fishing here is dominated by small-scale or artisanal fishers, largely for local consumption. Often these fisheries are completely beyond the review of national governments—overlooked, but critically important.

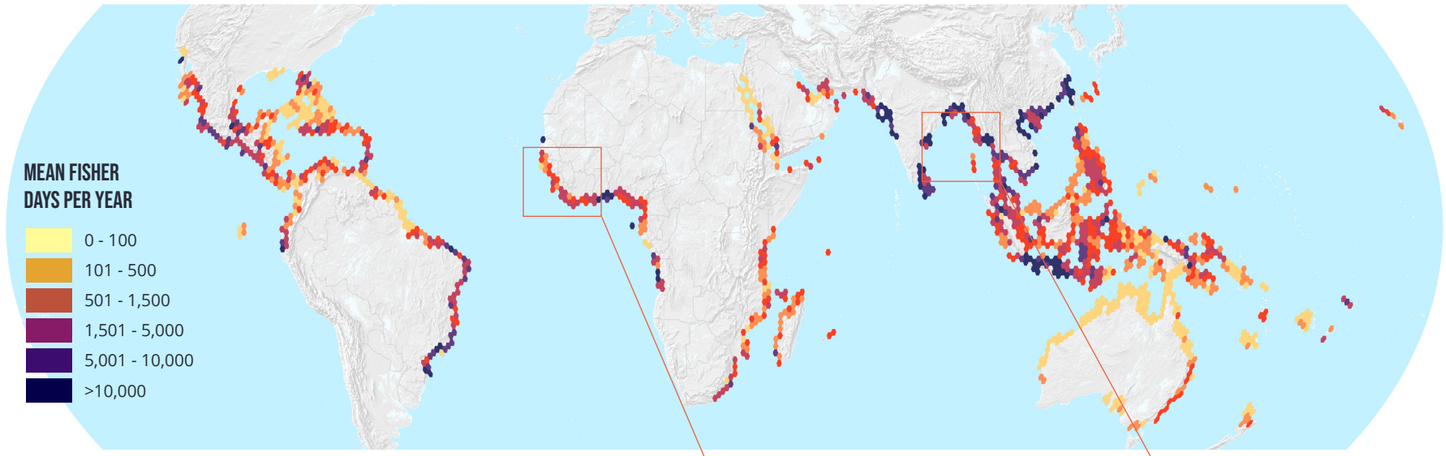
Other fisheries are better known. Certain species—such as mud-crabs, oysters and shrimp—have high values, and many are traded to large, or even export markets.

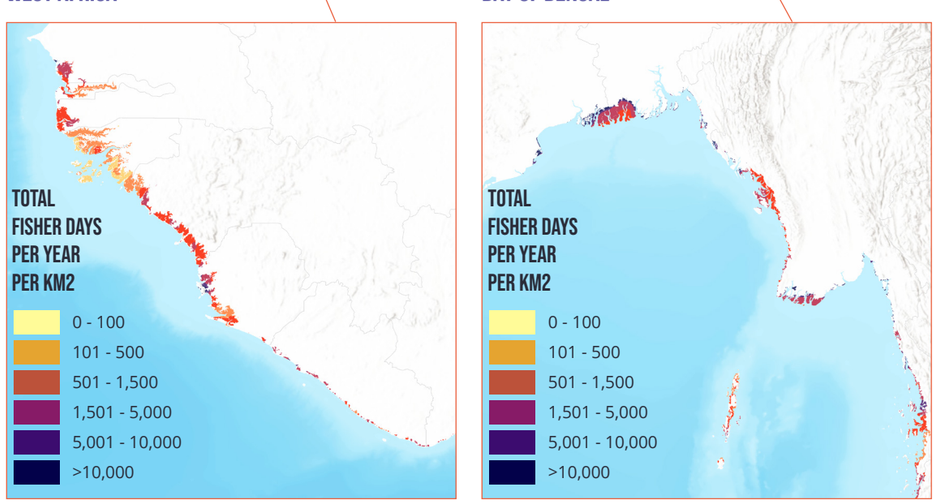
A new GMA-supported study estimates that well over one third of small-scale fishers in mangrove countries rely on these forests. That number rises to over 80% in many countries, notably in Central and West Africa.

The numbers of mangrove fishers, world-wide, is estimated at 4.1 million[1]. For every one of those fishers there may, in turn, be many others who rely on them, both for their jobs and for their main source of protein.

Alongside small-scale fisheries there are some larger commercial ones that also rely on mangroves. Although adult shrimp are caught in abundance offshore, their young are dependent on nutrient-rich, mangrove-dominated estuaries for fast growth and protection from

1. zu Ermgassen PSE, Mukherjee N, Worthington TA, Acosta A, Rocha Araujo ARd, Beitl CM, Castellanos-Galindo GA, Cunha-Lignon M, Dahdouh-Guebas F, Diele K, Parrett CL, Dwyer PG, Gair JR, Frederick Johnson A, Kuguru B, Savio Lobo A, Loneragan N, Longley-Wood K, Mendonça JT, Meynecke J-O, Mandal RN, Munga CN, Reguero BG, Rönnbäck P, Thorley J, Wolff M, Spalding M. Fishers who rely on mangroves: Modelling and mapping the global intensity of mangrove-associated fisheries. *Estuarine, Coastal and Shelf Science*. 2020:106975.





The numbers of fishers using mangroves, modelled as the total numbers of days individual fishers spend per km2 of mangrove per year.

4.1 million
fishers in mangrove forests world-wide

Fisherman in the mangroves near La Boquilla, Colombia.
© WWF-US / Keith Arnold

© Maksud / BEDS

WILD HONEY COLLECTORS IN THE SUNDARBANS

Local honey collectors in the Sundarbans mangrove, in Bangladesh, have transformed their lives by improving their business and marketing operations. The Sundarbans mangrove is the main source of natural honey in Bangladesh. The local honey collectors—known as mowals—faced major hardships, including poverty; extortion from middlemen and money lenders, and the threats of being robbed, or attacked by wildlife. Now some 50 honey collector families—including women workers—are processing, packaging and marketing their product for themselves. And, under their new MOWAL brand, they're able to sell at four times the price, which has changed the entire value chain of the Sundarbans wild-honey trade. This transformation came about through an initiative of the Bangladesh Environment and Development Society (BEDS) and Japan Environmental Education Forum (JEEF). The honey collectors were helped with conservation knowledge, as well as some packaging and marketing capacity.

Md. Maksudur Rahman **Bangladesh Environment and Development Society**

POLLINATORS PROMOTE BIODIVERSITY

Villagers in Nai Nang, Southern Thailand, have been reintroducing native bees to promote biodiversity, and generate new livelihoods

© Leo Thom

FULL STORY ONLINE

predators. Mangroves are also critical nursery grounds for species such as banana prawns which are arguably the most important in the Indo-West Pacific for trawl fishing.

The most important countries for mangrove fishers, with the modelled estimates of fisher numbers and the proportion of small-scale fishers (SSF) who fish in the mangroves.

COUNTRY	Mangrove fisher estimate	Percentage SSF mangrove fishers
Indonesia	893,000	39%
India	570,000	38%
Bangladesh	286,000	82%
Myanmar	286,000	69%
Brazil	278,000	53%
Vietnam	240,000	44%
Mexico	208,000	73%
Nigeria	150,000	89%
Thailand	127,000	55%
Philippines	118,000	41%

1. Spalding MD, Parrett CL. Global patterns in mangrove recreation and tourism. *Marine Policy*. 2019;110:103540.

TIMBER AND FUEL

In some countries, mangroves provide the only accessible wood. But even where other trees are abundant, mangrove wood is often highly valued because of its resistance to rot and the damage caused by termites. As timber, it is used in buildings, and as polewood for fencing and the production of fish traps. It is also burned as fuel for cooking, while the dense wood is widely converted to high grade charcoal.

Although the harvesting of mangrove trees is, in many places, a cause of mangrove decline, there are other areas where sustainable harvesting has been maintained for a century or more (See story in 2.4: Mangrove Silviculture).

FILTERS

Mangrove forests trap sediments, helping to fortify coasts in some places, and also preventing the same sediments from smothering coral reefs offshore.

At the same time, complex ecological pathways—of microbes and filter feeders—around mangrove roots help to purify the water that passes over them. These play a critical role in taking up both pollutants and nutrients, delivering considerable health benefits to adjacent ecosystems as well as to people.

DESTINATIONS TO VISIT

Many mangroves are also popular destinations for visitors. GMA scientists recently published a survey of data from TripAdvisor identifying almost 4,000 mangrove 'attractions' in 93 different countries and territories[1].

While many were reviewed by international holidaymakers, it's clear that mangroves are also very popular with local visitors. Activities range from simple walks or hikes—often on guided trails—to water-based boating activities and specialist wildlife watching. Some rather unusual activities are available, such as watching night-time firefly displays or in-water bioluminescence[1], for example.

Although not captured well in this survey, recreational fishing in mangrove areas is also proving to be increasingly valuable.Top locations for fly fishing generate hundreds of dollars per day from discerning clients seeking good sport in undisturbed locations.

ECOSYSTEM-BASED ADAPTATION

The acceleration of the impacts of climate change in coming decades is a near certainty, even under optimistic mitigation scenarios. The repercussions for coastal communities may be considerable—from rising seas, coastal flooding and storms; from uncertainty of food and water supplies linked to changes in temperatures and rainfall patterns, and from the social disturbances that may arise from these. The role of mangroves in supporting and securing coastal societies is likely to be critical, not least because healthy mangrove ecosystems are remarkably robust and likely to survive many of the changes that are forecast.

Mangroves, securely managed with equitable access, will help to protect coastal peoples (see next section), and to provide livelihoods, and reliable supplies of food, timber and fuel over the long term, even in the face of uncertainty and change. Such a role needs to be highlighted in all climate change adaptation planning.

Visitors to mangrove protected areas: Left Everglades, Florida. Right Cagar Alam Pulau Dua, Java.

© Mark Spalding / TNC

3.3 DEFENDING COASTS

PELAYO MENÉNDEZ **UNIVERSITY OF CALIFORNIA SANTA CRUZ,** MARK SPALDING **THE NATURE CONSERVANCY,**
SIDDHARTH NARAYAN **EAST CAROLINA UNIVERSITY,**
MICHAEL W BECK **UNIVERSITY OF CALIFORNIA SANTA CRUZ**

Mangroves thrive on the front line, traversing both land and sea.

Coastlines are dynamic places—they grow or shrink with the erosion or deposition of sediments, driven by the power of storms, the impact of waves, surges and winds.

Mangroves can provide substantial natural defenses along the coast, mitigating or diminishing these impacts. In reality, that role is complex and nuanced—their value is variable, but can be very great.[1]

ATTENUATING WAVES

In many tropical and subtropical regions mangroves reduce waves and storm surges, and serve as a first line of defense against flooding.

Any wave passing over or through a complex structure will quickly lose its energy—slowing down and losing height. Bottom friction, cross-shore width, tree density and tree structure (roots, trunks and canopy) make mangrove forests well-designed for this function. They present a rough, three-dimensional obstacle with complex roots, trunks and canopy that reduces the force of oncoming wind and waves, and so also reduces flooding.

It's been shown that a wave passing through just 100 meters of mangrove forest can lose two-thirds of its energy. And it works even when trees are relatively young or recently restored.

HOLDING OR BUILDING LAND

The aerial roots of mangroves retain sediments and prevent erosion. By slowing the flow of water they facilitate the settlement of sediments, and also reduce the outflow of fallen leaves and branches.

That enables mangrove soils to be maintained or even to grow vertically upwards. In some places the vertical accretion can be sufficient not just to maintain mangroves, but to keep pace with rising sea levels.

HOLDING BACK STORMS

Major storm events are not uncommon in many mangrove nations. Even in these extreme conditions, mangroves can help by attenuating waves and physically holding the land together. The forests can also act as a safety net, trapping large debris such as cars, boats and pieces of buildings which often cause significant damage once in coastal waters.

In addition, tropical storms sometimes drive surges that can raise the entire sea surface by several meters. Mangroves can act like permeable dams, helping to hold back and dampen the surges, greatly reducing inland flooding.

SMART MODELLING OF FLOOD RISKS

The Institute of Environmental Hydraulics (IH) of Cantabria, University of California Santa Cruz, and The Nature Conservancy have worked together to develop models to rigorously value the flood protection benefits of mangroves[2,3]. The models use approaches from coastal engineering and the insurance industry to assess flood risk and adaptation solutions (see Story, Mangroves in Florida).

A recent global study showed that mangroves reduce flood risk to more than 15 million people and prevent more than $65 billion in property damages every year.

Vietnam, India and Bangladesh benefit the most from mangroves in terms of people protected, due to the high density of coastal populations in those countries. The proportional importance of this protection, set against overall GDP, is particularly high in countries with lower GDPs where exposure is concentrated along vulnerable coastlines—Belize and Mozambique, for example.

In severe storms, there will always be flooding, even on defended coastlines, but these models assess how much greater those damages would be if the mangroves weren't there. It is that additional damage—measured as threats to lives as well as monetary damage to infrastructure—that gives a true sense of the extraordinary value of mangroves.

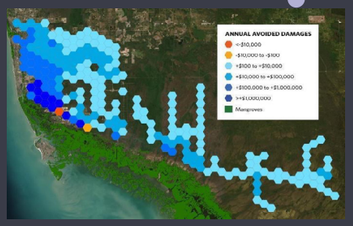
IMPLICATIONS

This work identifies where mangroves provide the greatest flood reduction benefits—helping inform policies for adaptation, sustainable development and environmental restoration.

1. Spalding M, McIvor A, Tonneijck FH, Tol S, van Eijk P. Mangroves for coastal defence. Guidelines for coastal managers and policy makers: Wetlands International and The Nature Conservancy; 2014. 42 p.

2. Narayan S, Thomas C, Matthewman J, Shepard CC, Geselbracht L, Nzerem K, Beck MW. Valuing the Flood Risk Reduction Benefits of Florida's Mangroves. *The Nature Conservancy*. 2019.

3. Menéndez P, Losada IJ, Torres-Ortega S, Narayan S, Beck MW. The Global Flood Protection Benefits of Mangroves. *Scientific Reports*. 2020;10(1):4404.



Effects of mangrove presence (green shading) on annual average losses for properties behind the mangroves in Collier County.

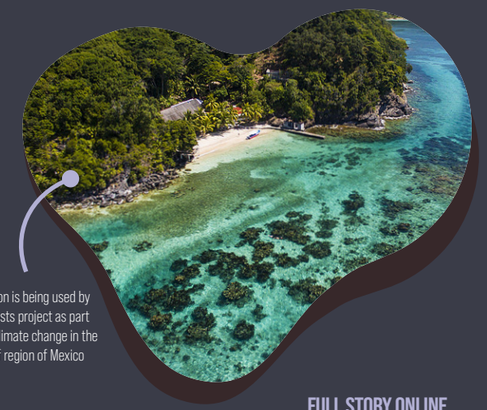
MANGROVES IN FLORIDA – A NATURE-BASED SOLUTION FOR COASTAL DEFENSE

University of California Santa Cruz, Risk Management Solutions and The Nature Conservancy used an insurance industry catastrophe model to show that mangroves in southern Florida helped prevent hundreds of millions of dollars in damages during Hurricane Irma, and continue to reduce annual damages from storm surges in Collier County.

In Collier County, mangroves reduced annual flood risk by 25.5% to properties behind them, with many areas receiving over $1 million of benefits annually. Major storms are a particular concern and during Hurricane Irma in 2017 the catastrophe model estimates that mangroves averted several hundreds of millions of dollars in storm damages across southern Florida, protecting more than 626,000 people, and providing an average risk reduction of $7,500 per hectare of mangroves. Importantly, this study shows that the extraordinary protective value of mangroves is evident within risk models used by the flood risk insurance sector.

Siddharth Narayan, Christopher Thomas, **East Carolina University;** Michael W Beck, **University of California Santa Cruz;** Christine Shepard, Laura Geselbracht, **The Nature Conservancy**

CLIMATE SMART COASTAL MANAGEMENT



Mangrove restoration is being used by the WWF Smart Coasts project as part of its response to climate change in the Mesoamerican Reef region of Mexico
© WWF

FULL STORY ONLINE

Cat Island, Bahamas
© Shane Gross

MANGROVES AND SEA-LEVEL RISE (SLR)

Mangrove forests are on the front line against SLR. Mangrove species have different tolerances to flooding; increased flooding can push out less tolerant species, and even lead to an unvegetated mudflat.

Luckily, mangroves have two mechanisms to potentially adapt to SLR. Firstly, they can increase their elevation relative to the tidal frame – their soils can increase vertically – through many processes, including root production and sediment accretion [1]. A high sediment supply is a key contributor to resilience of minerogenic mangroves, but at a certain point, mangroves may not be able to keep pace with rising seas. The geological record suggests that mangrove sediment accretion cannot keep pace with SLR of >6.1 mm per year [2]. In the Indo-Pacific, large areas may be vulnerable to submergence by 2070, though other areas are expected to be resilient [3].

Mangroves may also 'migrate' landwards to higher elevations, as SLR opens up new areas for colonization, in areas where barriers do not hinder such retreat. This is potentially the case for estuarine mangroves or undeveloped coastlines.

Dan Friess, **National University of Singapore**

1. Krauss KW, McKee KL, Lovelock CE, Cahoon DR, Saintilan N, Reef R, Chen L. How mangrove forests adjust to rising sea level. *New Phytologist*. 2014;202(1):19-34.
2. Saintilan N, Khan NS, Ashe E, Kelleway JJ, Rogers K, Woodroffe CD, Horton BP. Thresholds of mangrove survival under rapid sea level rise. *Science*. 2020;368(6495):1118-21.
3. Lovelock CE, Cahoon DR, Friess DA, Guntenspergen GR, Krauss KW, Reef R, Rogers K, Saunders ML, Sidik F, Swales A, Saintilan N, Thuyen LX, Triet T. The vulnerability of Indo-Pacific mangrove forests to sea-level rise. *Nature*. 2015;526:559.

The results can be helpful for different stakeholders such as governments and NGOs, who can better gauge how much to scale up their support for mangrove restoration. Coastal developers can then more easily quantify the value of mangrove defenses for national adaptation, land use, risk management and development plans.

These values can also be used by engineers and insurers to include mangrove natural defenses in cost-benefit analyses—indeed, their government and private clients should demand that. Economists can include the values in national accounts (e.g. GDP). Finally, investors and insurers can also use them to develop new financial tools that support restoration for risk reduction.

SELF-REPAIRING DEFENSES

Not even purpose-built and engineered sea defenses can be guaranteed to survive against all impacts. But one of the most valuable qualities of natural sea defenses, such as coastal mangroves, comes from their ability both to build themselves, and also re-build themselves if they are damaged.

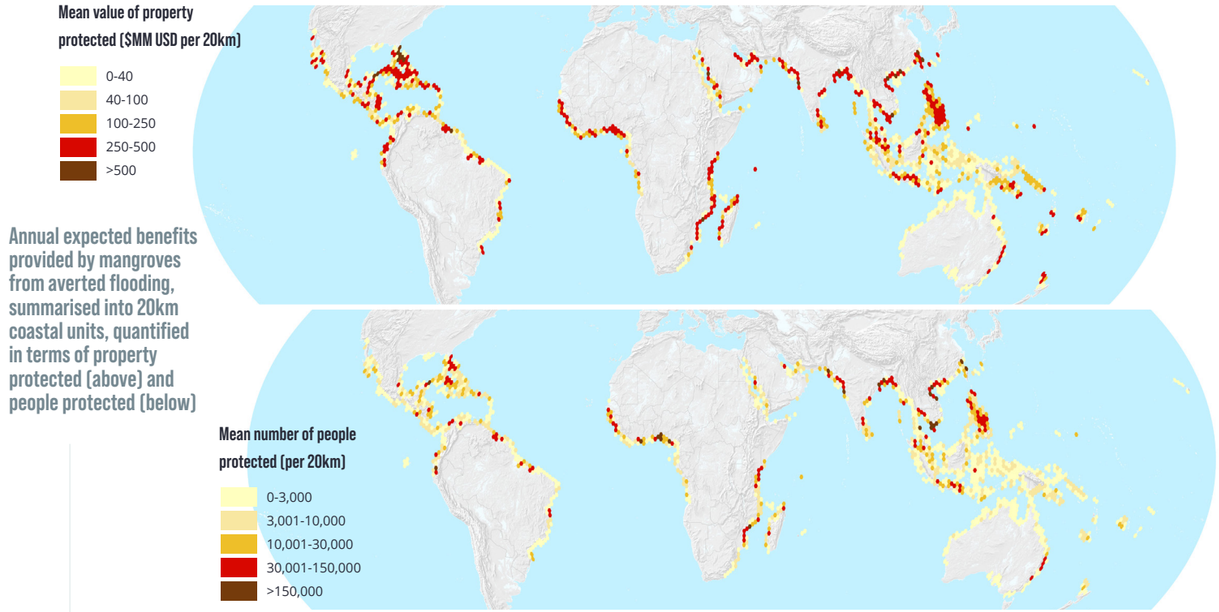
VITAL PROTECTION

In Cuba over **3,900km²** are protected from flooding annually by the presence of mangroves, over 3,100km² in Vietnam

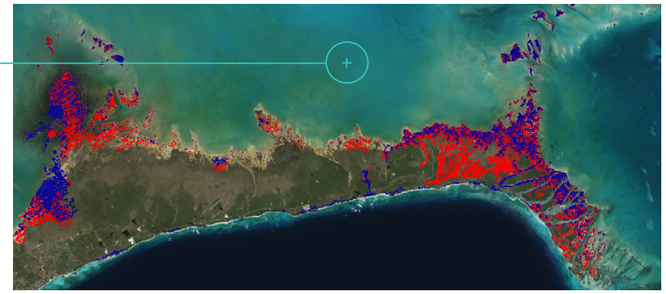
In Vietnam over **7 million people** are protected from flooding each year, almost 3 million in India

Mangroves defend over **US$11 billion** worth of property each year in the USA, and in China US$8.6 billion

The property protected from flooding in Belize every year has a value equivalent to **29%** of national GDP, and in Suriname over **21%** of national GDP.



Annual expected benefits provided by mangroves from averted flooding, summarised into 20km coastal units, quantified in terms of property protected (above) and people protected (below)



Areas projected to be flooded on Grand Bahama Island for a 1-in-10-year storm with (blue), and without (red), mangroves

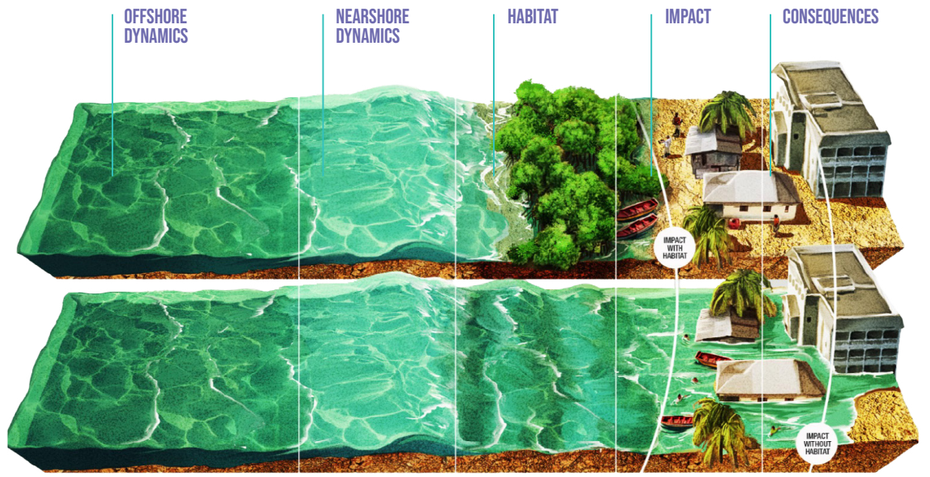
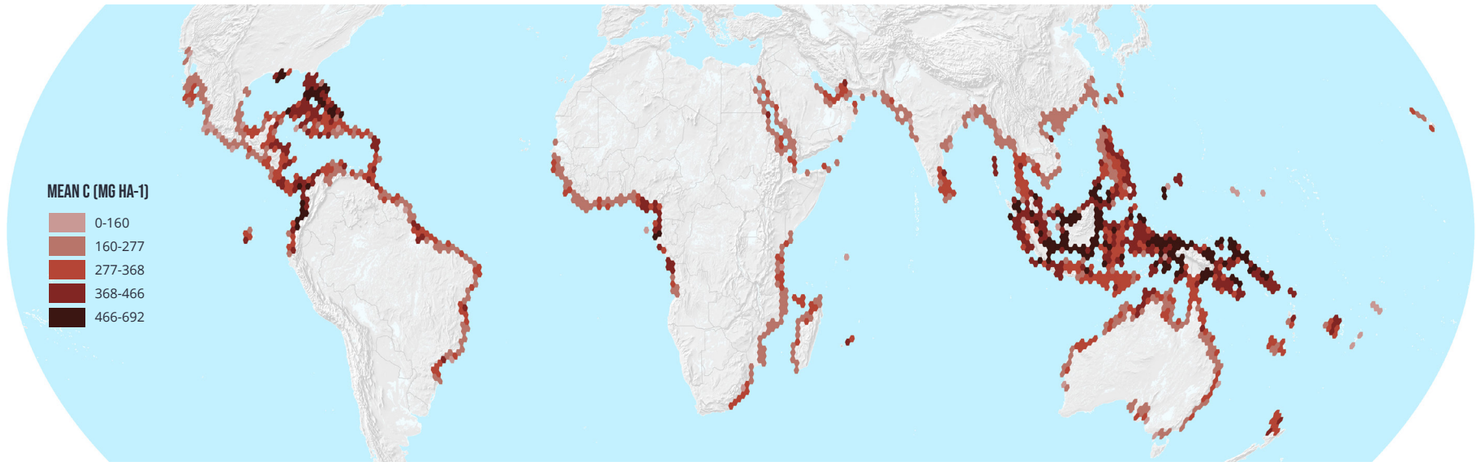


Illustration of the role that mangroves can play in protecting both people and infrastructure during storms and flooding. From Beck et al. (2019) ©Puntoaparte [4]

4. Beck, M. W., S. Narayan, I. J. Losada, A. Espejo, S. Torres. 2019. The Flood Protection Benefits and Restoration Costs for Mangroves in Jamaica, In Castaño-Isaza, J., Lee, S., Dani, S. (eds) Forces of nature: assessment and economic valuation of coastal protection services provided by mangroves in Jamaica. World Bank, Washington.

3.4 STORING CARBON



CATHERINE LOVELOCK **UNIVERSITY OF QUEENSLAND**, JONATHAN SANDERMAN **WOODWELL CLIMATE RESEARCH CENTER**, MARC SIMARD **NASA JET PROPULSION LABORATORY**

Mangrove forests are hotspots of carbon accumulation, storing it both in the living plants and in their rich peaty soils.

Like all forests, mangroves convert carbon-dioxide—captured through the process of photosynthesis—into leaves, wood and roots, increasing their carbon stocks in biomass as they grow.

PRODUCTIVE 'BLUE CARBON' CAPTURE

Indeed, mangroves are among the most productive carbon-capture ecosystems on the planet. They convert carbon dioxide to organic carbon at higher rates than almost any other habitat on earth (see diagram opposite).

Moreover, unlike many other forests, the carbon added to the soil through litterfall and root growth decomposes very slowly because soils are water-logged with tidal water (see diagram on page 51). That slow decomposition results in the build-up of carbon-rich soil over hundreds—to thousands—of years.

For example, some mangroves in Belize are rooted in ten-meter-thick peat—highly organic soil composed entirely of dead and decomposing mangrove roots and leaf litter.

Additionally, many species of mangrove trees have above-ground roots that trap sediment and other organic matter that enters the forest during tidal flooding. That further contributes to the burial and build-up of carbon-rich soil over time.

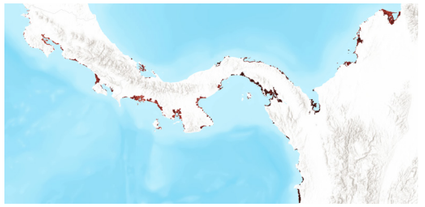
THE IMPORTANCE OF PROTECTING MANGROVES

The end result of this productivity is that mangroves surpass most other ecosystems, not only as carbon stores, but also as hugely important assets in strategies to sequester CO_2 from the atmosphere.

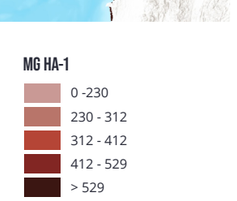
When mangroves are cleared or degraded, they release their stored carbon. That carbon, released as CO_2, can be considerable, particularly where soils are excavated—as when building shrimp aquaculture ponds.

Therefore, not only is the protection and conservation of mangroves imperative as a means to reduce new emissions of CO_2 into the atmosphere, but restoring even a fraction of the large area of mangroves that has been cleared or degraded can contribute to increasing the capture and storage of carbon.

Malaysia and Western Indonesia

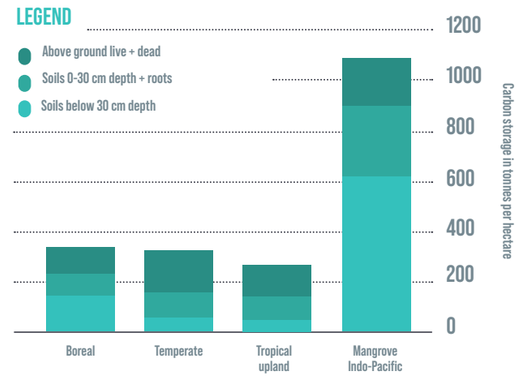


Costa Rica and Panama



ECOSYSTEM C STORAGE (Mg Ha^{-1})

A comparison of the carbon stored in various forest types, showing the contribution of aboveground plants, shallow and deep soil. Adapted from Donato et al[1]



1. Donato DC, Kauffman JB, Murdiyarso D, Kurnianto S, Stidham M, Kanninen M. Mangroves among the most carbon-rich forests in the tropics. *Nature Geoscience*. 2011;4(5):293-7.

Mangroves in Berau, Indonesia.
© Green Renaissance / WWF-US

Mangroves in Berau, Indonesia.
© Mark Spalding / TNC

CARBON MARKETS

Carbon markets have emerged to incentivize a transition to low carbon development. Tradable carbon credits are generated from activities that deliver either emission reductions (or avoided emissions) and/or carbon removals. Protecting threatened mangroves and restoring degraded mangroves can deliver both of these.

To guarantee their integrity, compliance markets (regulated by law) must be surplus to the existing expected commitments made by national governments (under their NDC, see 5.2). In voluntary markets, there is a risk that credits are used as a shortcut to avoid other emissions reductions. It is therefore critical to map out and implement approaches to avoid and reduce all possible emissions prior to, or alongside, restoration and off-setting [1].

One recent work estimated that around 20% of the world's mangroves could be eligible for some funding through carbon markets [2]. The fraction of this which might generate viable investment returns is highly dependent on market prices, but could become a dominant proportion if markets develop as predicted and the price of carbon increases.

In all cases it is critical that priority be given to projects entering into carbon markets that tackle the drivers of deforestation and ecosystem loss in a manner which takes into account livelihoods and ensures an equitable distribution of benefits.

Stefanie Simpson **The Nature Conservancy**, Karen Douthwaite, Josefina Brana Varela and Brittany Williams **WWF**

1. Stevenson M. 2020. First Things First: Avoid, Reduce ... and only after that–Compensate. *WWF Discussion Paper*.
2. Zeng Y, Friess DA, Sarira TV, Siman K, Koh LP. Global potential and limits of mangrove blue carbon for climate change mitigation. *Current Biology*. 2021;31(8):1737-43.e3.

VALUING CARBON STOCKS AT THE MUNICIPALITYLEVEL IN MEXICO

Preventing deforestation in just 25 Mexican municipalities would cut future impacts and social costs from the release of carbon by 50%

© Octavio Aburto

FULL STORY ONLINE

MAPPING POTENTIAL CO_2 EMISSIONS

The carbon stocks in mangrove soils and biomass have been mapped at a global scale (see map on pg 49).These figures have been combined in the GMW data portal and show a total of over 21.9 gigatons of CO_2 equivalent held in the current extent of mangroves. Most of this—about 87%—is from the soil, and that only includes the carbon in the top meter of soil. If released this would be equivalent to 7.5 years of emissions from the European Union, or the burning of 51 billion barrels of oil.

There is high variation in biomass and soil carbon over the global distribution of mangroves due to variations in environmental conditions (e.g. in temperature, rainfall and nutrients). For example, mangroves typically have high biomass and soil carbon in the wet tropics, and lower values in temperate and arid regions.

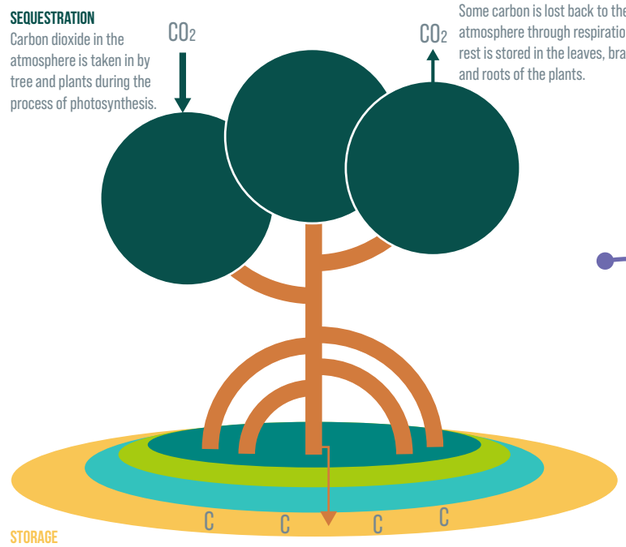
These maps help explain the levels of CO_2 emissions that might occur if mangroves were removed and destroyed. They also provide important information for predicting the levels of CO_2 capture that would be possible with investment in the restoration of mangroves.

THE VALUE OF CARBON CAPTURE

Investment in management activities that conserve and restore mangroves can be important for reducing national CO_2 emissions. Conservation is a particular priority in countries where threats to mangroves remain high, but large-scale restoration is also becoming more widespread.

In the pilot study to model mangrove restoration potential (see Section 2.5), it has been estimated that restoration of recently lost mangrove could eventually restore 0.256 gigatons of CO_2 equivalent into the biomass and, by stabilizing the soils for these areas, could avoid a further 1.1 gigatons of $C0_2$ being released into the atmosphere[3]. Combined, these would equate to a reduction equivalent to three billion barrels of oil, or over three years of emissions for a country like Australia.

Given these high values, a number of market-based methodologies are available for conservation or restoration projects to generate tradable carbon credits. They can then provide critical, sustainable income in return for projects, while also adhering to standards that ensure environmental and social integrity of the credits. (see Story opposite and Section 5.4).



The processes of carbon capture and storage in mangroves

Illustration adapted from Sutton-Grier et al, 2014

1. Simard M, Fatoyinbo L, Smetanka C, Rivera-Monroy VH, Castañeda-Moya E, Thomas N, Van der Stocken T. Mangrove canopy height globally related to precipitation, temperature and cyclone frequency. *Nature Geoscience*. 2019;12(1):40-5..
2. Sanderman J, Hengl T, Fiske G, Solvik K, Adame MF, Benson L, Bukoski JJ, Carnell P, Cifuentes-Jara M, Donato D, Duncan C, Eid EM, Ermgassen Pz, Ewers C, Glass L, Gress S, Jardine SL, Jones T, Macreadie P, Nsombo EN, Rahman MM, Sanders C, Spalding M, Landis E. A global map of mangrove forest soil carbon at 30 m spatial resolution. *Environmental Research Letters*. 2018;13:12.
3. Worthington T, Spalding M. *Mangrove Restoration Potential. A global map highlighting a critical opportunity*. The Nature Conservancy, IUCN, University of Cambridge; 2018; 36p.
4. Sutton-Grier AE, Moore AK, Wiley PC, Edwards PET. Incorporating ecosystem services into the implementation of existing U.S. natural resource management regulations: Operationalizing carbon sequestration and storage. *Marine Policy*. 2014;43:246-53.

LIVING WITH MANGROVES

© Jürgen Freund / WWF

4.1 SUSTAINABLE USE

MARK SPALDING
THE NATURE CONSERVANCY

The earliest records show that humans have lived in mangroves since prehistoric times.

Ceramics that trace their history back 7,000 years have been found in the mangroves of South America. The Warao people in the Orinoco Delta of Venezuela still live among the forests today. In East Africa, a harvest of mangrove poles has been traced back to at least 200 BC, and this was an export industry as long ago as the 9th Century.

In these and countless other cases, the traditional utilization of mangroves—as fishing grounds, or as sources of timber and fuelwood, honey or other products—has almost always been highly sustainable.

© Jaime Camacho / TNC

SUSTAINABLE SHELLFISH—PROJECT 'SOCIO MANGLAR'

Large areas of mangrove have been lost to aquaculture in Ecuador. Nonetheless, there remains an enormous dependency on what remains—more than 50,000 people rely on mangroves for living space and their livelihoods. Fishing, and the harvest of crabs and mollusks, can be traced back to pre-Hispanic times and they provide a vital food-source.

To support sustainable use and protection, the people and the Ecuadorian government designed and implemented multiple Sustainable Use and Custody Agreements of the Mangrove Ecosystem (AUSCEM)—covering 30% of the mangroves and representing some 70,000 hectares. These were designed with the local communities to ensure that sufficient mangrove is available for sustainable use by fishers.

In addition, a financial support scheme, Socio Manglar, has been established. This provides grants and economic incentives to communities and ancestral user groups on the condition they comply with the sustainable management plans. The Nature Conservancy (TNC) and Conservation International (CI) provided technical assistance to enable several communities to actively participate and meet their commitments to these plans.

Jaime Camacho **The Nature Conservancy**

© Ibrahim Aboubacar Hama

SUSTAINABLE MANGROVE COMMODITIES, SALOUM DELTA, SENEGAL

Residents of the Saloum Delta, Senegal, are working to develop a stable and secure value chain for key mangrove commodities, such as oysters and honey.

Through Mangrove Capital Africa, community members receive training in sustainable oyster farming methods, beekeeping, and non-timber forest product creation. Promoting renewable production of mangrove commodities helps create strong incentives for mangrove conservation.

Also, a partnership with the Dakar Business School has addressed challenges around access to markets and strengthened the development of viable business plans for these women-led initiatives.

Indigo Janka **Wetlands International**

MANGROVE CLUBS IN THE SALOUM DELTA

Students in Senegal, are connecting with their surrounding natural habitats through mangrove clubs.
© Ibrahim Aboubacar Hama

FULL STORY ONLINE

CBEMR IN EL SALVADOR

El Salvador has lost vast areas of mangroves. At El Lloron, an 80-hectare patch of barren land was recovered for mangroves in 2011, bringing back birds and animals, including valuable shellfish. In this case, MAP provided technical expertise for Eco Viva to implement CBEMR (see Enabling Natural Mangrove Recovery story, page 33). Local communities have now formed a coalition, called the Mangrove Association, to help protect and expand the region's mangroves.

Leo Thom **Mangrove Action Project**

Women in Mangroves: Teresita de Jesús García is President of the Local Plan for Sustainable Use (PLAS) Group of Playa Metalío, in the Barra de Santiago area, western El Salvador. Her group plays a key role in regulating the use of mangrove resources and for monitoring compliance.
© Evelyn Vargas Carmona / IUCN

FULL STORY ONLINE

The large-scale decline of mangroves came with burgeoning coastal populations, increasing local demands and industrialization. Far-flung markets created additional demand for shellfish, timber and charcoal, while mangroves were also decimated to make space for agriculture, aquaculture, ports and urban expansion.

Those twin challenges—declining mangrove extents and increasing demands for mangrove products—were never compatible but, in some places, traditional sustainable uses have continued.

Also, while globalization may have had many negative impacts, it has also enabled the transfer of knowledge. As shown in the previous section, we now understand—better than ever—the remarkable value of mangroves, and their potential. We also know that we can continue to reap these many benefits for generations, sustainably, by controlling our demands.

To remind ourselves of what's possible, this section focuses on real-world stories of how people are managing to maintain—and restore—the right balance of utilization without causing mangroves' decline.

These are stories that exemplify how to live sustainably with—and often in—mangrove forests.

4.2 COMMUNITY INVOLVEMENT

LEAH GLASS AND LALAO AIGRETTE **BLUE VENTURES**

If mangrove conservation or restoration initiatives are to succeed, it's imperative that local communities and—where relevant—indigenous or traditional users are included. And given their dependence on mangroves – for food, coastal defense and other resources – it is imperative that they do succeed.

Mangrove losses can be driven by forces outside or within coastal communities.

Often, external businesses or market drivers are the cause, but declines can also be driven by local businesses, such as clearance for agriculture or aquaculture, or even by subsistence uses such as over-harvesting for timber or fuel. In almost all cases, however, it is the communities living within and adjacent to the mangroves who stand to lose the most, and often receive an unequal share of any financial benefits which may have been gained from the conversion.

When empowered, coastal communities can help to ensure the long-term sustainability of mangroves—in large part because they have the most to gain from mangrove conservation and restoration, like enhanced food and job security, and improved livelihoods.

There are now numerous examples from around the world of community-led initiatives that are gaining traction and helping build a secure future for mangroves.

With local partners, TNC is helping establish Community Forest Associations in Lamu, Kenya who are developing Participatory Forest Management Plans including rehabilitation and restoration projects and ongoing community surveillance and enforcement to protect rehabilitated sites and control unregulated exploitation of mangroves.

© Roshni Lodhia

© Nick Hall

COMMUNITY INVOLVEMENT IN MANGROVE MANAGEMENT IN POHNPEI, MICRONESIA

Pohnpei is one of the Federated States of Micronesia, and is a high volcanic island fringed by dense mangroves, with coral reefs offshore.

Mangroves are vital to its communities, and community action plans are being implemented as the most effective mangrove management strategy to safeguard their many ecosystem services.

Following initial research studies, two state-wide mangrove conventions were held. The first, in 2020, invited traditional chiefs, and led to a call for policies and advocacy recommendations to strengthen the protection and management of mangroves.

A second convention, in early 2021, brought together state government officials, resource managers, law and policy makers, traditional leadership, and communities. Following lengthy discussions on the potential threats and key recommendations, the stakeholders were motivated to create the community action plans.

Underpinning these deliberations were some island-wide mangrove studies supported by the Micronesia Conservation Trust (MCT) in collaboration with multiple partners over five years.

They included a mangrove vulnerability assessment, a climate change prediction (WARMER model) , and the use of Forest Inventory and Analysis (FIA) every 10 years to monitor changes over time[1]. Additionally, a detailed monitoring system was established to track soil surface elevation—critical for understanding the impact of sea level rise on the mangroves.

Roseo Marquez **Micronesia Conservation Trust**

1. Micronesia Challenge: Regional Terrestrial Monitoring Initiative. https://mcterrestrialmeasures.org/

RESTORING TIDAL FLOWS

Students and volunteers have helped restore large areas of mangroves with Friends of the Environment in Abaco, Bahamas. Culverts were placed under roads, and former channels opened up to restore tidal flows.

© Friends of the Environment, Bahamas

CARBON CREDITS TRANSFORM KENYAN VILLAGES

Two villages in Gazi Bay, Kenya, raised over 2.6 million Kenya shillings (over US$118,000) in carbon credits, over two years, by halting tree felling and working to restore mangroves.

A local Community Forest Association developed a formal approach to sustainability that was secure and verifiable. Once formally certified, the project was able to sell carbon credits to generate a community income. This was achieved through Plan Vivo, an international body that regulates carbon credits.The community-led effort, called the Mikoko Pamoja project, has breathed new life into the two villages. It has improved fisheries, secured village water supplies, enabled the purchase of books for schools, and is also supporting alternative livelihoods

Alex Kubasu, **WWF-Kenya**

Members of the Mikoko Pamoja project measuring mangrove biomass

© WWF-Kenya

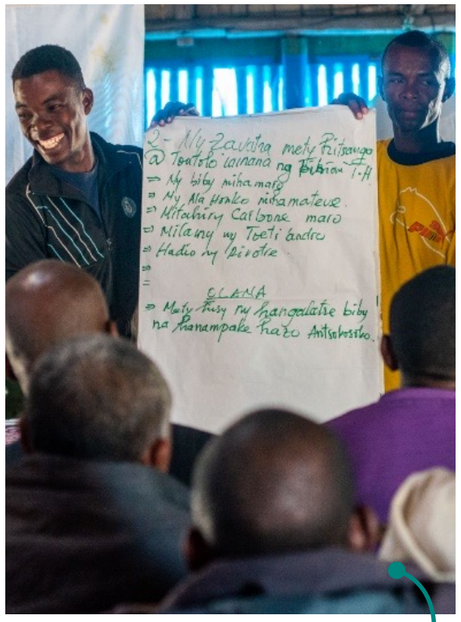
PARTICIPATORY APPROACHES

Initiatives to formalize the use and management of mangroves, and to build future security are now becoming widespread. A critical element in the success of such efforts is the widespread inclusion and strong participation of key interested parties.

Local knowledge can improve the planning of mangrove conservation and restoration initiatives. Moreover, strong engagement with local communities can lead to interventions that are far more successful overall.

Giving people a say in project design and decision-making boosts their understanding, and also creates a stronger sense of ownership and commitment. That can be a critical success factor throughout the process of resource management, from initiation to implementation, and ongoing monitoring and evaluation.

A wide range of tools and methods now exist to support community involvement. Successful initiatives are often borne from a clear 'theory of change'—a vision which identifies core problems, and explains how proposed activities can contribute to results that can lead to intended positive impacts.



Participatory planning in Velondriake, south-west Madagascar, as a part of Tahiry Honko - the world's largest community-led mangrove carbon conservation project

© Louise Jasper

Developing the theory of change together with community groups can help ensure that everyone works towards a shared goal. It builds a vision that is more likely to fully encompass all underlying problems and potential solutions. Such participation can also help nurture understanding and ownership of the proposed activities.

Similarly, collaborative research, education and action through Participatory Action Research can help identify challenges and co-develop solutions, or test the assumptions of a theory of change.

Collective spatial methods, such as participatory mapping, can be used to co-define management zones, or identify priority conservation or restoration areas.

Strong community involvement in monitoring, control and enforcement can encourage stronger accountability as projects move forward. By transparently sharing the data from research and monitoring with community groups this can also provide them with the information they need to manage their mangroves as effectively and adaptively as possible.

In many countries, mangroves are common resources, not privately owned. This can create considerable risks that they become over-utilized in what has been called 'the Tragedy of the Commons.'

A key set of eight principles for the management of finite, common-pool resources through collective action was developed by Nobel laureate Elinor Ostrom. They include the tenets of participatory decision-making, monitoring and community organization described above.

In addition, they make it clear that common areas such as mangroves must have clearly defined boundaries both in terms of geographic space, and in terms of who can access their resources. Regulations must be locally adapted. There should be sanctions for people who abuse the system, but graduated so that abusers do not immediately lose access. There also need to be simple and low-cost processes for conflict resolution.

Community members in Ambanja, north-west Madagascar, collecting data on their mangrove forests

© Louise Jasper

4.3 EQUITY

MARK SPALDING **THE NATURE CONSERVANCY**

Improving mangrove sustainability involves managing use of the forests, and—in some cases—limiting access.

Many of the users of mangroves are extremely poor and dependent on fishing or other activities from forests which they neither own nor control. Often, such communities are also vulnerable to natural hazards such as storms, but also social, economic and cultural influences—anything from shifting markets to the building of infrastructure, or the removal of access to the natural resources on which they depend.

Within the processes of community engagement, then, it is essential to ensure that decisions about the use of—and access to—mangroves are made fairly and equitably.

Planning, and management, needs to take into account the needs of those already using the mangroves, and those that depend on them for coastal protection or food supply chains. In many cases these will include indigenous people and vulnerable groups. Often they know more about the mangroves—and about sustainable living—than anyone else.

Equally important is recognizing the need for equity within the communities that use the mangroves. Indeed, it is especially valuable to ensure that women and children are included in efforts to build up the benefits from mangroves.

© Pabla Rivera / CCO

WOMEN IN MANGROVES

A 32-year-old, single mother of three and one of the beneficiaries of the Regional Coastal Biodiversity Project, Pabla Rivera Vargas is championing the cause of mangroves in her native Barra del Motagua, on the Caribbean coast of Honduras. Her community sits within the Cuyamel-Omoa System, an internationally important (Ramsar) wetland, close to the Guatemalan border.

Pabla carries the message—particularly to youth—of the importance of maintaining and restoring the mangroves. She teaches about how they protect the community from storms and hurricanes, and also about the importance of maintaining fish populations for people's livelihoods, community income and ecological benefits.

Additionally, Pabla engages in ecological research and monitoring—undertaking mangrove georeferencing and the monitoring of the endangered yellow-headed parrot. More widely, she also promotes the strengthening of community organizations, reforestation campaigns and solid waste management.

Evelyn Vargas Carmona, **IUCN**

© Robyn James / TNC

MANGORO MARKET MERI— PAPUA NEW GUINEA'S BIG IDEA

The Nature Conservancy is working with women across Papua New Guinea on a Big Idea to address both mangrove loss and women's empowerment, called Mangoro Market Meri (MMM).

Although Papua New Guinea has some of the most intact and diverse mangrove forests in the world, they are under intense threat. Women, in particular, often rely on mangroves for fuel wood for cooking, as well as fish and shellfish for food and to sell locally. The MMM initiative attempts to address drivers of mangrove loss while bridging the economic gaps for women.

MMM brings women together from across the country to develop ways to generate income while also sustainably managing mangrove forests. Through MMM, we are supporting women to engage in relevant economic opportunities such as ecotourism, sustainable seafood markets and, ultimately, carbon markets.

Meg Bresnahan, Robyn James **The Nature Conservancy**

© Ruth Konia / TNC

EQUITY AND COMMUNITY INVOLVEMENT IN VIETNAM

Vietnam lost approximately 60% of its natural mangrove forest between 1943-2013 to war, degradation and conversion to rice fields and aquaculture areas. These losses left coastal infrastructure and livelihoods much more exposed to hazards such as flooding after storms which can damage adjacent fields, aquaculture and property.

Local women engaged in mangrove planting in Ha Tinh province.

© Phan Hong Anh / MERC

A pilot Mangrove Plantation and Disasters Risk Reduction (MP-DRR) project was launched in Thai Binh province in 1994 by Vietnam Red Cross Society (VNRC), After initial successes, this was scaled up to cover nine coastal provinces. Approximately 9,000 hectares of mangroves have been planted and protected in nearly 100 coastal communities of northern provinces. The work has included capacity building to strengthen community disaster risk reduction, with vulnerability assessments, training response teams, small infrastructure works and awareness-raising efforts.

Community involvement has been an underlying principle of MP-DRR and VNRC worked with the target communities and local government to select appropriate planting areas, map them, reach common long-term agreements, and then mobilize community participation in mangrove planting and protection.

Some of the poorest families living near mangrove forests were selected as members of forest protection teams, defending the planted mangroves. There has also been outreach to around 300 schools, building a generation that understands the long-term importance of mangroves.

Restoring mangroves at scale requires long-term commitments and this work is still ongoing. By building co-management mechanisms between local government and people a sense of community forest ownership and interest in forest management and protection has been developed, while protection from future disasters has been significantly enhanced.

Tao Van Dang, **Vietnam Red Cross;** Hung Ha Nguyen, **IFRC Country Cluster, Bangkok,** and Ninni Ikkala Nyman, **IFRC Secretariat**

4.4 PUBLIC AWARENESS

MARK SPALDING **THE NATURE CONSERVANCY**

Raising awareness is a key challenge for those working in mangroves. Many of the communities near mangroves understand their importance as fishing grounds, or sources of timber and fuelwood. Yet few people currently realize the full value of mangroves today, or their future potential. Key values often missed are:

- Their role in protecting lives and coastal resources from extreme weather is rarely calculated.
- Their importance for climate regulation is little known, and perhaps too scientific or far removed from the day-to-day needs of rural communities.
- Their potential as sources of income from tourism or from carbon markets is seldom considered.

While such knowledge now exists, both in the science and in stories such as those described in this report, it is not always communicated effectively.

When the full value of mangroves is clearly understood—by local people, by leaders, and the wider global community—recognition of the need for their conservation will outstrip demands for their continued destruction and conversion.

So, promoting that awareness is a priority. Reaching out to communities, youth and special interest groups is now a key activity for many working in mangroves. In local communities, schools are often a key target. Children not only represent the next generation, but they also take their learning home and can act as catalysts to influence entire communities.

© Friends of the Environment

SCHOOLCHILDREN IN THE MANGROVES

'The first science field trip that I remember was to the mangroves. I was about ten years old, and passed this place every day on my way to school, but hadn't given it much consideration. The scientist leading the trip scooped up small shrimp and fish among the roots to show us, and I realized this was more than just a bunch of trees. This, and subsequent experiences inspired me to dedicate my life to conservation, to ensure that future generations may have meaningful connections with our environment. I now work for the organization that helped coordinate the field trip.'

Olivia Patterson Maura **Friends of the Environment, Abaco, Bahamas**

MARVELOUS MANGROVES

The Mangrove Action Project teaches schoolchildren science-based mangrove conservation

© Hasan Mehedi / Mangrove Action Project

FULL STORY ONLINE

FULL STORY ONLINE

© Krizelle de la Cruz / Rare

BAKJUANA, SIARGAO ISLANDS, PHILIPPINES

A colorful mascot called BakJuana is being used across the largest marine protected area in the Philippines to help raise awareness among school children of the value of mangrove protection and sustainable fisheries.

The Rare campaign uses mascots to highlight the importance of marine ecosystems. So, with a tangle of leaves and bird's nest for her hair, BakJuana—a play on the Filipino word for mangrove (bakhaw) and a traditional Filipino name—is a rising star for conservation.

Through school visits, songs and training, BakJuana promotes sustainable management of natural resources, coastal fishery protection and community pride among children.

Bakjuana joined other mascots from across the Siargao Islands Protected Landscape and Seascape (SIPLAS) signifying a unified effort to promote climate resilience.

Yasmin Arquiza **Rare**

MANGROVES ON THE CURRICULUM IN SHENZHEN, CHINA

Over 2,600 school students from 25 primary and middle schools in Schenzhen, China, were able to explore local mangroves during the COVID-19 pandemic of 2020. Through a program run by Mangrove Foundation (MCF), the children discovered the biodiversity of the mangrove wetland ecosystem and could observe the migrating birds that depend on them. Shenzhen is a large metropolitan city, with a population of almost 13 million, in South China, just north of Hong Kong. It has limited mangrove wetlands. MCF has provided public education activities on mangrove wetlands since 2014, and promoted them to primary and middle schools since 2019. These outdoor education activities were designed within the curriculum standards for grades 1-9, to build awareness of mangroves' importance for sustaining life.

Zhuo Zeng **MCF - Shenzhen Mangrove Wetlands Conservation Foundation**

© Chunhui Li

5.1 A ROADMAP TO MANGROVE RECOVERY

THE GLOBAL MANGROVE ALLIANCE COORDINATING TEAM

The Global Mangrove Alliance (GMA) aims to halt mangrove loss and degradation and to increase mangrove cover using best practices and collaboration. This combination of protection and restoration helps to deliver multiple objectives, including climate adaptation, climate mitigation, sustaining biodiversity and improving human well-being.

© Christopher Brunner / TNC Photo Contest 2019

COORDINATING ACTIVITIES TO DRIVE SUCCESS

The GMA member organizations believe that coordinated efforts across organizations and geographies will enable more to be accomplished, faster.

Indeed, the global mangrove community is now focusing on being as proactive as possible. It's not enough to respond to issues as they emerge. It is essential to actively **scan the horizon and pre-empt potential threats**—either to avoid them altogether, or minimize their impacts.

Engaging in and informing policy initiatives from the start is also a key strategy. And so it is vital the GMA works more closely with governments and communities, to prepare them for a future where mangrove ecosystems play a critical role in their development and prosperity.

To **shift from reactive to proactive**, the Alliance is working collaboratively to identify where the most significant opportunities are, and to identify and overcome barriers to scale. It is also providing technical advice to governments and other stakeholders, helping translate national and international goals into action on the ground.

For the GMA, achieving its objectives will mean prioritizing three main areas: halting mangrove losses, science-based restoration and raising awareness.

Vincent "Jegg" Clarke, Saint Lucia National Trust Volunteer Project Assistant, works on mangrove restoration and conservation in Saint Lucia

© Tim Calver

HALTING ONGOING MANGROVE LOSS

While rates of global mangrove loss are declining, it's essential to prevent any further loss or degradation. Significant threats remain in key mangrove countries, arising from both human activities and natural dynamics, and compounded by the effects of climate change.

Halting ongoing mangrove loss and degradation requires **focusing on root causes**. To prevent losses to development and activities such as aquaculture, any efforts must be carefully managed to compensate and ensure that income and food security for coastal communities are not impacted by conservation efforts.

To this end, the GMA will also focus on **developing sustainable mangrove use options** that generate a diversified income portfolio at both the small and industrial scales.

Of course, natural mangrove losses will continue to occur and cannot be prevented. The impact of these, however, may be compensated if mangroves are allowed and enabled to expand naturally, for example into adjacent low-lying coastal areas to keep pace with rising seas or onto newly deposited coastal sediments.

The policy and regulatory tools for halting mangrove loss may include **community-led initiatives**, but also **protected areas**. With the latter, it is essential to strengthen existing protection alongside increasing coverage. Protected areas must be designed to be effective in achieving protection, but also equitable—the involvement of key stakeholders in design and management is essential.

None of this will succeed without an enabling environment that incentivizes mangrove conservation. So the GMA will work with governments and partners to cultivate **pro-mangrove funding models, supportive policies and capacity-building opportunities**.

1. An initial goal was established by the GMA in 2019 to restore 20% of mangrove cover by 2030. We endeavour to integrate the latest science to inform our work. As such, this goal and our roadmap for reaching it will likely be revisited following the next release of GMW data, probably in late 2021. This will likely include more specific targets and include effective and equitable protection alongside restoration.

ADVANCING SCIENCE-BASED RESTORATION

Restoring mangroves is a transformative nature-based solution to mitigate climate change and increase coastal resiliency. Simultaneously, **restored mangroves can reduce poverty and boost economic resilience** by increasing access to sustainable livelihoods and food sources.

Despite this, investment in ambitious mangrove restoration projects has been slow. Low investment may be partly linked to the failure of many poorly planned restoration efforts, and a perception that mangrove restoration can be difficult.

Large-scale mangrove restoration based on sound science, with community and stakeholder engagement, is essential to long-lasting increases in mangrove cover. GMA members are leading and working with restoration practitioners around the globe, and their experiences are being shared and pooled to improve our understanding of optimal restoration approaches.

The GMA's top priority is to **build capacity for effective restoration**. That includes developing a set of scientifically-driven guiding principles, restoration methodologies, monitoring guidelines, and instruments that have been tested and proven in the field.

All restoration activities world-wide must include **equitable engagement of stakeholders and effective financial management** to be successful and to achieve scale. To this end, the GMA is also looking to reduce average restoration costs through business case development, and by creating strategies to drive impact investment toward restoration.

INCREASING PUBLIC AWARENESS

The many values of mangroves are now relatively well documented, but they are not always broadly known. Likewise, there are numerous mechanisms to support mangrove management and conservation, but these approaches may not be widely shared.

The biggest strength of the GMA is the coordination and collaboration fostered across its large and diverse network. **The Alliance connects local communities from dozens of countries, international policy and financing experts, and leading researchers around the world** to provide comprehensive and cross-cutting solutions.

The GMA network gives its members access to, and influence on, civil society, the private sector, and governments. Sharing experience and information on mangroves with these actors will boost the success of efforts to protect, manage and restore mangroves.

The GMA members actively work as **technical advisors and on-the-ground implementors** to mangrove nations. In the years ahead, the Alliance will also focus on forging **private sector partnerships**, and developing win-win scenarios for mangrove protection, restoration and livelihoods. Efforts will also continue in support of **education, outreach and knowledge exchange** within the mangrove community and with the public.

Local West Papua children from Kwatisore village learn about mangroves from WWF Indonesia education staff

© Jürgen Freund / WWF

© Mark Antônio Teixeira / WWF Brazil

5.2 ENGAGING THE WORLD

BEATRIZ MACHADO GRANZIERA **THE NATURE CONSERVANCY**, LISA SCHINDLER MURRAY **RARE**, EMILY GOODWIN **IUCN**, KAREN DOUTHWAITE **WWF**, DOROTHEE HERR **IUCN**, JULIKA TRIBUKAIT **WWF**, TAMARA THOMAS **CONSERVATION INTERNATIONAL**

Successfully tackling the loss of mangroves and enabling their recovery requires effort at the global, national, and local level. It requires a broad understanding of the needs of the environment and coastal communities; a vision for change; a clear policy framework; and the means to ensure practical implementation on the ground.

In the development of vision and policies to support mangrove actions it is essential to be informed by reliable scientific and locally-appropriate data, and by clear and practical approaches to sustainable management.

BUILDING ON WHAT WE KNOW

The recent surge in our understanding of mangroves provides a valuable starting point for developing transformative policy and for implementing effective management. New information, such as data on carbon stocks and the economic value of mangrove ecosystems can be used to strengthen policies, for example, in the support of national or local-level prioritization of mangrove protection. The strengthening of policies could then re-shape the pressures of coastal development and other threats to mangroves.

LEARNING FROM OTHERS, WORKING TOGETHER

Alongside credible, robust, and transparent data, the rapid growth and sharing of examples of the practicalities and potential of different management interventions is further strengthening the hand of policy-makers. Approaches need to be tailored to address the main threats to mangroves in the country or target site, as well as the needs, interests, and capacities of stakeholders and users.

Policies are most likely to succeed when they fully engage—and are informed by—local Indigenous peoples, coastal communities, and in many cases, small-scale fishers. Building clarity on land and resource ownership and access rights can be a transformative early step. Community-based management can then be a highly effective tool, especially when it is fully attuned to local needs and utilizes the full capacity of the community, while not imposing burdens, such as unfamiliar reporting requirements[1].

One common challenge is a lack of government coordination. Mangroves may be affected by policies for coastal management, climate change, environmental licensing, forestry, and so on. Each of these may be regulated by different government agencies. Improving coordination or reducing conflict requires concerted efforts to harmonize regulatory processes; to integrate planning and permitting processes, and to develop more effective alignment of these institutions.

REGULATION

Legislation can be used to protect mangroves in many ways.

The establishment of protected areas as a key policy for protecting natural resources is widely accepted. In some cases with limited recognition or implementation, these can be little more than 'paper parks'. They can, however, be highly effective, especially where key stakeholders and local communities are properly engaged in establishment and management (see Section 2.4).

Other regulations which can reduce negative impacts to mangroves include specific species' protections for coastal and marine plants and animals, and the regulation of indirect impacts, such as restrictions on upstream pollution and the allocation of water resources. Local budget allocations for conservation and sustainable management activities serve as the foundation for successful implementation of mangrove protection.

Land use planning and permitting can also be used to secure mangroves. In Brazil, for example, mangroves are included in the national forest code and, as such, are subject to licensing rules which establish hard limits for mangrove clearance for both public and private developers. Other countries, including Costa Rica, Honduras, Malaysia and Sri Lanka, have similar rules that require authorization for human activities within mangrove ecosystems[1].

FINANCIAL INCENTIVES

Financial mechanisms and incentives can also be transformative. Understanding and prioritizing the considerable value of mangroves, both to local communities and to the global community, can encourage increased investment from governments or other funders to support protection efforts.

The success of market-based approaches such as carbon markets (see Stories, pg 50) depends on the existence of a strong and supportive policy base, the right legislative conditions, and ability to adhere to internationally accepted market standards to ensure environmental and social integrity. The presence of technical capacity for robust monitoring, reporting and verification is also essential to ensure sustainability of interventions, provide accountability, and build market stability.

1. Slobodian LN, Rodriguez Chaves M, Nguyen LTP, Rakotoson LN. *Legal frameworks for mangrove governance, conservation and use*: Assessment summary. Geneva and Berlin: IUCN and WWF Germany; 2018.

© Yayasan Planet Indonesia

CREATING BORNEO'S FIRST LOCALLY MANAGED MARINE AREA

In 2015, Planet Indonesia began working alongside coastal communities in Borneo to secure tenure, build capacity to support community-led management, provide incentives to create inclusive governance institutions, and connect communities to fair and equitable supply chains for mangrove products. Our work involves community healthcare, mangrove restoration, and periodic closures of the mangrove to improve mud-crab harvest rates, among other methods. In 2021, six villages combined to ratify Borneo's first Locally Managed Marine Area - covering over 12,500 hectares of coastal mangroves, mud crab fisheries, and creating six community-based no-take zones.

Adam Miller **Planet Indonesia**

LET THE CRABS DATE

In Brazil, the Let the Crabs Date campaign, promotes respect for the closed season so that mangrove crabs can breed protected
© Rare

FULL STORY ONLINE

Lamu, in Northern Kenya, has the country's most extensive mangroves
© Roshni Lodhia

KENYA REVISES ITS NATIONALLY DETERMINED CONTRIBUTIONS

Mangroves and associated blue carbon ecosystems have now been incorporated in Kenya's updated Nationally Determined Contributions (NDCs) to the Paris Agreement.

In July 2016, Kenya submitted its NDCs to UNFCCC, aiming to achieve a 30% reduction in greenhouse gas emissions by 2030. However, blue carbon ecosystems such as mangroves and seagrasses were omitted, despite their high carbon removal rates and the ecosystem services they provide.

During the second round of submission, the Directorate of Climate Change secretariat, part of the Ministry of Environment and Forestry, commissioned a Task Force to work closely with stakeholders in updating the NDCs. By bringing in blue carbon to their NDC, their emission reduction target was enhanced to 32%. The Nature Conservancy and Kenya Marine and Fisheries Research Institute also supported the process with scientific expertise.

James G Kairo, Joseph Lang'at
Kenya Marine and Fisheries Research Institute,
George Maina, Caroline Lumosi **The Nature Conservancy**

MOZAMBIQUE MANGROVES

Mozambique's government has prioritized its mangrove and coastal areas in policy through its National Mangrove Strategy

Pira Sulemane on patrol in a mangrove forest in Mozambique, WWF
© Green Renaissance / WWF-US

FULL STORY ONLINE

INTERNATIONAL FRAMEWORKS

Mangrove forests often cross over national jurisdictions. But their international dimensions go beyond shared borders, through the flow of mangrove goods such as prawns or timber, and their role in global climate mitigation and adaptation.

International policy agreements can enable collective action on global challenges, and encourage or strengthen national and local efforts. Recognition of the value of healthy ecosystems—for mitigating global climate change, safeguarding biodiversity, disaster risk reduction and achieving sustainable development goals—is woven into many international frameworks and agreements (see table opposite).

As an example, under the UNFCCC's Paris Agreement, Nationally Determined Contributions (NDCs) are critical vehicles for governments to share their commitments and implementation plans for addressing climate change.

Including mangrove protection or restoration in an NDC sends a strong signal of national policy priorities to the international community. Countries are required to periodically report their progress towards meeting their NDC goals, and the high-resolution GMW maps provide a potential resource to support this process.

Given that NDC commitments indicate national priorities, they have the potential to drive finance for mangrove protection and conservation, and for sustainable resource management.

Many international agreements have established goals which are intended to galvanize action in the short to medium term. By working together, governments, NGOs and communities will be greatly strengthened in their efforts to establish environmentally sound and robust policy frameworks to achieve global goals for climate, biodiversity, and sustainable development. It is notable that the year 2030 has been widely signaled as a key target year. The Global Mangrove Alliance aims to further encourage and catalyze progress towards protection and restoration efforts by 2030.

GLOBAL FORUM	Key components of relevance to mangroves
UNFCCC	Countries are required to conserve and enhance areas that are important green-house gas stores and sinks. Under the Paris Agreement, countries are responsible for making strong commitments called Nationally Determined Contributions (NDCs) for climate change mitigation. These can include the protection and restoration of forests, including mangrove forests.
UN Sustainable Development Goals	These set the 2030 Agenda for Sustainable Development, including calls to combat climate change (SDG13) and to conserve marine and coastal ecosystems (SDG14).
UN Convention on Biological Diversity	A post-2020 framework amendment to this convention, still in draft, sets 2030 Action Targets. These will include expansion of protected areas, and the protection of nature as a means to improve disaster risk reduction, food security, and the supply of information, including traditional knowledge, to policy-makers.
UN Office for Disaster Risk Reduction	Under the UN Sendai Framework (2015-2030), this encourages ecosystem-based approaches to reduce disaster risk, including through transboundary cooperation (Priority 2) and new investments, among other things, intended to preserve ecosystem functions that reduce risks.
Ramsar Convention on Wetlands of International Importance	This is an international agreement encouraging and supporting members to protect and sustain wetlands. 'Ramsar sites' are declared and a recent resolution (XIII.14) encourages the conservation, restoration and sustainable management of coastal blue carbon.
UN Decade of Restoration	UN partners (CBD, FAO, UNEP) are using the period 2021-2030 to host a drive for the revival and restoration of ecosystems world-wide.
Bonn Challenge	A non-binding commitment to restore degraded and deforested lands, achieving 350 million hectares by 2030. By May 2021, pledges totaling 210 million hectares had been made from 61 countries, including mangrove areas.
UN Secretary General	Although not a formal policy, the UNSG is encouraging nations to 'build back better', urging that returns from the COVID-19 pandemic be sustainable and climate positive.

Macaca fascicularis, also called 'mangrove monkeys', live and forage in the mangroves of Thailand

© IUCN / MFF

5.3 EMPOWERING WITH INFORMATION

THOMAS A WORTHINGTON **UNIVERSITY OF CAMBRIDGE**,
PETE BUNTING **ABERYSTWYTH UNIVERSITY**,
LAMMERT HILARIDES **WETLANDS INTERNATIONAL**

We are now able to monitor the earth like never before.

We are in the era of 'big data' where continuous flows of information from earth observation satellites and sensor networks generate data with increasing regularity and in ever-greater detail. In parallel, increases in computing power and cloud-based geospatial platforms are enabling massive, global-scale analyses with speed and efficiency.

The surge in new information about mangroves described in this report has grown from this same burgeoning data and analytical potential.

GLOBAL MANGROVE WATCH PLATFORM

One important outcome from these developments has been the development of ecosystem-specific data sharing platforms, such as Global Forest Watch and Global Fishing Watch, whose outputs are used to tackle real-world environmental issues.

The newly developed Global Mangrove Watch (GMW) platform joins these tools.

It provides access to multiple datasets. Users can explore global mangrove maps, tracing change over time. Through change alerts, they can even see very recent change within months of their occurrence (see Story, Disturbance Alerts). They can use tools to calculate information 'on-the-fly', and observe tree height, calculate biomass, and explore protected areas.

Data on ecosystem services are also being incorporated. For instance, the distribution of the 4.1 million mangrove associated fishers, or the location of the nearly 4,000 mangrove tourist attractions found across 93 countries.

Users can also understand the potential for mangrove restoration in different areas. The GMW platform has the latest information on mangrove carbon stocks and their relevance to global policy instruments.

EVOLVING CAPABILITIES

The world of mangrove data and research is moving fast[1]. As more analyses become available, so the GMW Platform will evolve.

The restoration potential map will be enhanced with information that helps people understand the ecosystem service benefits that will accrue for restoration in different locations, helping them prioritize new restoration.

Work is underway to identify areas where mangroves are still present, but have been degraded. New models will quantify the numbers of fish and shellfish added to the global oceans due to the presence of mangrove forests.

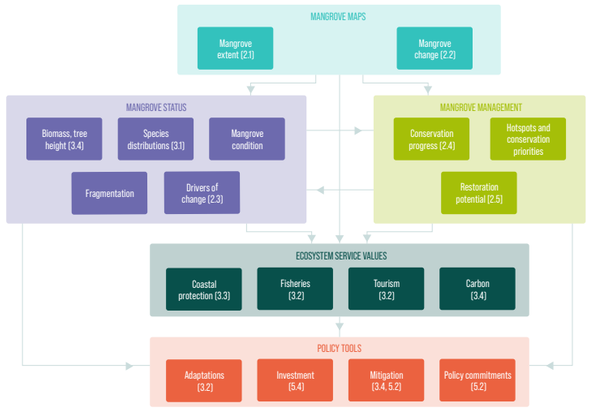
The platform will also incorporate new tools to help people interact with information. For example, as well as calculating statistics at a national scale, users will be able to select specific regions of interest, either by drawing on the map or uploading a boundary polygon. This will provide rapid and flexible access to data without the need for analytical expertise or software.

MANGROVE RESTORATION TRACKER TOOL

The Mangrove Restoration Tracker Tool is an additional application that records and visualizes the location of mangrove restoration projects.

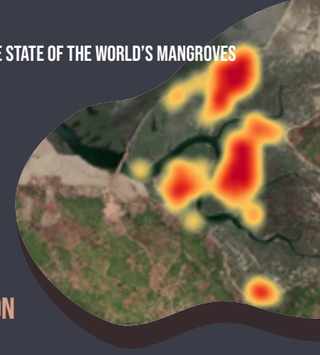
This is being created in collaboration with scientists, NGO staff and restoration practitioners from across the world. It provides a template of the key variables that should be recorded when reporting on mangrove restoration projects—including costs, aims, restoration techniques and ecological, social, and economic outcomes.

The projects will be stored on—and can be visualized through—the GMW platform. That will enable coastal managers, government scientists and NGOs to identify initiatives that have similar underlying conditions and use complementary restoration techniques—so they can learn from successes or failures within these projects.



The growing body of interconnected mangrove information, informing policy and action (numbers refer to sections in this report)

1. Worthington TA, Andradi-Brown DA, Bhargava R, Buelow C, Bunting P, Duncan C, Fatoyinbo L, Friess DA, Goldberg L, Hilarides L, Lagomasino D, Landis E, Longley-Wood K, Lovelock CE, Murray NJ, Narayan S, Rosenqvist A, Sievers M, Simard M, Thomas N, van Eijk P, Zganjar C, Spalding M. Harnessing Big Data to Support the Conservation and Rehabilitation of Mangrove Forests Globally. *One Earth*. 2020;2(5):429-43.



TAKING RAPID ACTION ON DISTURBANCE ALERTS

The addition of the mangrove disturbance alert function to the Global Mangrove Watch platform is enabling changes in mangrove cover to be identified more quickly.

Satellite remote-sensing data creates near real-time—currently monthly—alerts of mangrove losses. That means conservation or restoration efforts can be mobilized far more rapidly.

A great example of this was Guinea-Bissau in West Africa, where analysts noticed a high number of alerts in early 2021, approximately 20km north of the city of Bissau (see image, above). Wetlands International workers visited the site and discovered that a new dam had been built to convert an area of mangroves to rice agriculture.

Thomas A. Worthington **University of Cambridge**,
Pete Bunting **Aberystwyth University**,
Lammert Hilarides **Wetlands International**

DRONES FOR MONITORING AND LOCAL CAPACITY ENHANCEMENT

Aerial drones are rapidly becoming an invaluable research and monitoring tool for mangrove conservation. While still novel as research tools, they have numerous local-scale applications, especially monitoring for local management.

An urgent challenge for the mangrove research community is building local capacity for emerging technology, such as drone use. Transferring technical skills, building digital infrastructure, and building up community monitoring initiatives will strengthen mangrove conservation[1].

Astrid Hsu **Scripps Institution of Oceanography, University of California San Diego**

1. Hsu, A.J., et al., Challenges and Recommendations for Equitable Use of Aerial Tools for Mangrove Research. Frontiers in Marine Science, 2021. 8(277).

Drone training for mangrove monitoring in the Itza-Popo National Park in Mexico. *© Diego Gamero*

5.4 FINANCING FOR SUCCESS

EMILY LANDIS **THE NATURE CONSERVANCY**, DOROTHEE HERR **IUCN**, LISA SCHINDLER MURRAY **RARE**

PAYING THE REAL COST

Many of the benefits from conserving and restoring mangroves, described throughout this report, can be further underpinned by strong financial arguments. In the case of mangrove products, such as the sustainable production of timber and the collection of crabs, shellfish or honey, the immediate economic value lies in plain sight.

Economic benefits also accrue from cultural services, including eco-tourism, sport fishing and local recreational uses.

Many additional values are often overlooked. These include offshore fisheries, notably for prawns, which depend on the mangrove nursery grounds. They include the role of mangroves in capturing sediment and in cleaning coastal waters. Also the protective role of mangroves, notably from storm surges. And of course the critical role of mangroves in carbon storage and sequestration to help slow down the effects of climate change.

It has been estimated that mangroves provide an ecosystem service benefit between $462-798 billion per year[1].

However, mangrove conservation and restoration actions are not being financed to the extent necessary. To meet the global conservation funding gap, funding for conservation projects—in general—needs to be increased by at least 20-30 times[2]. For restoration, it is estimated that $11.1 billion will be necessary over the next twenty years to reinstate the extent of restorable mangrove world-wide[3].

Despite the size of the challenge, there is hope and opportunity. A number of new and innovative instruments to finance mangrove conservation and restoration are fast gaining ground.

> "$11.1 BILLION OVER THE NEXT TWENTY YEARS TO REINSTATE RESTORABLE MANGROVE AREAS WORLD-WIDE."

The appetite from private investors has increased. And opportunities for both the private sector, as well as between joint private and public—so-called 'blended'—finance have greatly expanded[3].

1. UNEP. *The Importance of Mangroves to People: A Call to Action*. Cambridge, UK: United Nations Environment Programme World Conservation Monitoring Centre; 2014.

2. Flint R, Herr D, Vorhies F, Smith JR. *Increasing success and effectiveness of mangrove conservation investments:* A guide for project developers, donors and investors. 2018. 106p.

3. *Earth Security. Financing the Earth's Assets:* The Case for Mangroves as a Nature-based Climate Solution. London and Copenhagen: Earth Security; 2020.

PHILANTHROPIC AND GOVERNMENT GRANTS

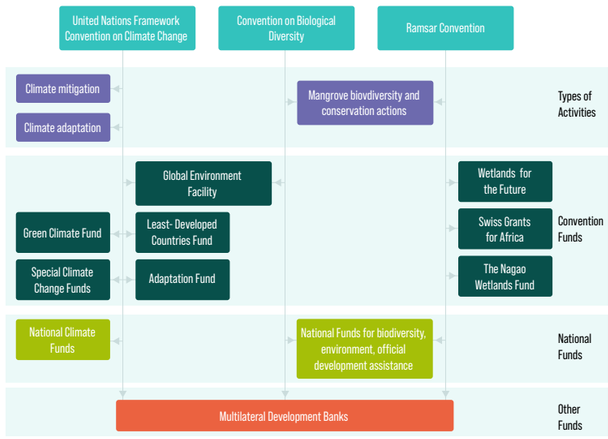
Most mangrove conservation activities are funded through government grants or philanthropic institutions. Public funding is often restricted and, in developing countries, reliance on donor funding from developed countries is particularly high. Such funds are insufficient, however, to cover all that is needed.
Both public and private grants are typically site-based and time-constrained, with only a few years to demonstrate success without long-term monitoring included.

Projects that run under such funding constraints can easily fail, while poor outcomes, in turn, then become barriers to scaling-up and building future success.

Nonetheless, grants can be critical. They also play an important role in research, and in trialing new conservation and restoration methods and approaches—and helping to de-risk projects for future financing, both from their own resources and from other sources.

LINKING FINANCE TO POLICY

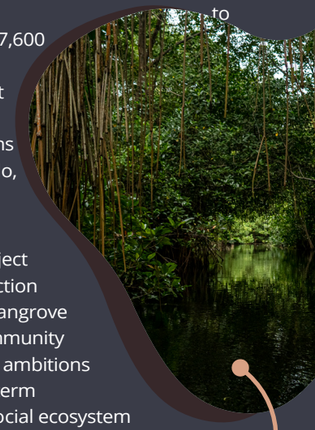
Increasingly, international environmental agreements (see section 5.2) have funding mechanisms that support national policy, as illustrated in the graphic below. By setting priorities that are adopted nationally, such agreements can also help attract other international finance for mangrove protection and management.



Graphic adapted from Herr, D., et al. "Coastal 'blue'carbon. A revised guide to supporting coastal wetland programs and projects using climate finance and other financial mechanisms." (2015).

STRENGTHENING LOCAL COMMUNITIES AND CONSERVING CARBON IN THE COLOMBIAN CARIBBEAN

A project to conserve approximately 7,600 hectares of mangrove forest will prevent almost one million tons of greenhouse gas emissions in the Gulf of Morrosquillo, Colombian Caribbean.



© Meseta Films – Conservation International

The Vida Manglar blue carbon conservation project will encourage the protection and restoration of the mangrove ecosystems through community participation. The overall ambitions include generating long-term ecotourism, cultivating social ecosystem services, and driving environmental benefits like ecological integrity and biological productivity.

Vida Manglar has met the formal requirements for listing as a Verified Carbon Standard (Verra or VCS)—making it the first blue carbon project in Colombia and the first to utilize Verra's Wetlands modules. It also contributes to national and international commitments, including multiple Sustainable Development Goals.

Paula Cristina Sierra-Correa **INVEMAR**,
María Claudia Díazgranados **Conservation International**

MIND THE GAP—BUILDING SUCCESSFUL MANGROVE CARBON PROJECTS

The 2020 paper 'Blue Carbon: Mind the Gap' sets out common legal, social, scientific and financial challenges that have been holding back the successful implementation of mangrove carbon projects—and also shares recommended solutions[1].

Despite strong demand for credible 'blue carbon' credits, the potential to produce carbon offsets to fund mangrove restoration and conservation remains largely untapped. So the Gallifrey Foundation conducted interviews with scientists, NGOs, and key industry players to find out why.

The paper has led to the development of the Fair Carbon initiative. This is a collaborative project combining new and existing resources with emerging best practice to help navigate the accreditation process.

Mark Beeston **Gallifrey Foundation**, Elizabeth Francis **Middlebury College**, John Vermilye **Gallifrey Foundation**

1. Beeston M, Cuyvers L, Vermilye J. *Blue Carbon: Mind the Gap*. Geneva, Switzerland: Gallifrey Foundation; 2020.

PRIVATE SECTOR FINANCE

A growing number of more innovative investment options are also gaining traction to reduce the impacts of climate change, to support biodiversity conservation, and to encourage sustainable management. For mangrove forests, carbon markets, blue bonds, debt swaps and insurance-based investments can all potentially attract large-scale investments. The infographic below highlights some of these new instruments.

Adoption of these has been limited in mangrove settings so far due to high upfront costs, uncertainty about returns, debt restructuring restrictions, and more competitive alternative options for conservation finance. As successful projects emerge, it is anticipated that this proof of concept will enable more financing options for mangroves.

BLENDED FINANCE

Another new approach is the development of blended finance models where grants or other development funding and private capital are jointly invested in environmental projects. Blended finance has attracted approximately $152 billion towards sustainable development in developing countries, to date.

Private investors tend to be risk-averse and want guarantees that their investments will deliver returns. By blending capital, philanthropic or government grants are used to 'de-risk' investments in the short-term. Impact investment enables projects to be run to fulfill their full conservation and restoration potential, and to demonstrate their worth as investments.

Blended financing can encourage longer-term investment, such as carbon credits that can be issued over thirty-year time scales. If implemented correctly, the pooled capital can also support larger-scale projects, and their benefits can be shared equitably across local communities, investors and governments.

Type	Name of Instrument	Purpose	Eligible	Example	Scalability
Impact-Only	Grant	A funding award given by an entity for a beneficial project	Parties, local non-governmental organizations (NGOs)	International Climate Initiative (IKI) EbA Facility	Existing Resources Available, can mobilize co-funding
Return on investment	Carbon credit	Funding for emission reduction or carbon capture projects as a means of compensating for carbon emissions	Parties, NGOs, local communities, corporations	Reforestation and restoration of degraded mangrove lands, sustainable livelihoods, and community development in Myanmar (Worldview International)	Significant but tied to local circumstances
	Equity/Impact investing	Intended to generate positive, measurable social and environmental impacts with positive financial returns	Parties, investors, blue enterprises	Sustainable Ocean Fund	Highly scalable
Debt	Microfinance	Smallest-scale type of loan, application to LDCs and SIDS	Parties, small business, local communities	Youth Volunteer's Union, Women Credit and Thrift Project	Highly scalable
	Bonds	Money lent to another party in exchange for repayment of the principal amount plus interest	Parties, investment banks	Seychelles Blue Bond, blue bonds, conservation bonds	Significant but tied to local circumstances
	Revolving loan fund	Provides lending to smallholders and small business owners who cannot otherwise access capital	Small blue business, non-profits	California Fisheries Fund	Significant but tied to local circumstances
	Large bank loans	Supports private sector development in developing countries	National or international development finance institutions, state Parties, corporations	African Development Bank	Existing Resources Available
	Debt swap	Foreign debt owed by a developing country is transferred in return for commitment to conservation	Parties, NGOs, commercial banks	Seychelles Debt-for-Nature Swap SeyCCAT	Emerging instrument - especially scalable across SIDS
Insurance	Insuring Blue Enterprises	Protects the insured from a financial loss that would be borne by the insurer	Fisheries/aquaculture business, coastal communities	Caribbean Oceans and Aquaculture Sustainability Facility	Highly scalable
	Insuring Natural Capital	Create and protect natural capital, providing a financial mechanism for restoration following extreme weather events	Parties, private enterprises, NGOs	Insurance Development Forum	Highly scalable

Table adapted from 'A Snapshot Guide on: Instruments and Mechanisms for Financing Nature-based Solutions for Adaptation in Coastal & Marine Ecosystems.' Prepared by the Nairobi Work Programme (NWP) in collaboration with the NWP expert group on oceans.

THE WAY FORWARD

The enormous value of mangrove forests to local communities and to the global community has been mapped and quantified, as illustrated throughout this report. Despite this, we have not attained the scale of investments required to secure a safe and sustainable future for mangroves. We are now entering a phase where mangrove investments can—and should—be tailored to achieve scale far beyond the traditional public and philanthropic funding seen to date.

The Global Mangrove Alliance is ambitious in its aims to increase protection and to expand restoration. Progressing these aims will require public demand and clear policy frameworks, but it will also need considerable resources, including public, philanthropic and private investments.

It is essential that the business case for investment in mangroves is clearly made and funding tools are developed. It is also important to demonstrate the ways investment can be integrated into wider governmental planning and global commitments.

Best practice science and implementation must also continue to be shared among the global mangrove community to ensure that investments maximize returns not only to investors but to biodiversity. Revenue streams must be shared fairly among stakeholders - especially with the often marginalized and vulnerable people who depend most on mangroves.

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MICROFINANCE AND EQUITY IN HONDURAS

Thanks to an innovative community microfinance scheme, women on the Pacific coast of Honduras have been able to increase their incomes by processing mangrove salt.The finance scheme, called Cajas Rurales, helps boost investment in alternative livelihoods in rural areas, based on self-managed savings and low-interest loans. It's ensured that the women and youth of Chismuyo Bay have been able to access credit so they could commercialize their salt operations. Cajas Rurales has also become a powerful beacon of environmental awareness. Members have to sign a commitment to participate in mangrove reforestation and monitoring fishing practices.The International Union for Conservation of Nature (IUCN) and its member organization, the Foundation for Rural Enterpreneurial Development of Honduras (FUNDER), originally supported the establishment of the Cajas Rurales scheme.

Judith Beyeler **IUCN**

Fany Patricia Hernández is one of the beneficiaries of microfinance in Honduras. Click here to watch more.
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6. MANGROVES: A CALL TO ACTION

The Global Mangrove Alliance Coordinating Team

Mangroves are vital to the health of the planet

Rates of mangrove loss and degradation around the world have slowed in recent years, yet many areas still face significant threats—from coastal development, clearing for aquaculture and agriculture, pollution and over-exploitation.

Natural changes, compounded by climate change, are also driving losses. The loss of mangrove habitats anywhere means a steep decline in the ecosystem services they provide—from fisheries and water quality to carbon sequestration and coastal protection. And that, in turn, threatens coastal communities, jobs and food security.

Protecting all remaining mangrove cover is just one—albeit critical—part of the solution. We also need to enhance recovery, allowing natural regeneration and afforestation of new sediments as coastlines shift and change. And we need to restore lost cover. Evidence-based, community-led restoration at scale is key.

We need to plan, fund and implement science-based restoration programs to start the needle moving in the right direction—toward global increases in mangrove cover. That means tackling the hard issues like land ownership or use-rights, halting unsustainable practices and reducing costs.

The COVID-19 pandemic has brought into stark relief the need to get back into balance with nature. The road to our recovery is made when nature recovers.

WE CALL ON GOVERNMENTS TO ACCELERATE EFFORTS TO PROTECT AND RESTORE MANGROVES BY:

- Ensuring the integration of mangrove conservation and restoration priorities into national-level laws, planning and policy processes—including coastal zone management, national adaptation plans, disaster risk response, and rural livelihoods and development.
- Ensuring that initiatives consider sustainable use allowance, and work with local and Indigenous communities.
- Halting harmful subsidies and fostering tools and mechanisms to support funding and enabling of sustainable mangrove management and use initiatives.

WE CALL ON THE INTERNATIONAL COMMUNITY TO PROMOTE THE ADOPTION AND SCALING OF NATURE-BASED SOLUTIONS THAT HIGHLIGHT MANGROVES BY:

- Calling out mangroves and other high-value coastal ecosystems within existing regulatory and finance mechanisms, with specific and ambitious targets to match both the needs, and the potential benefits, of conservation.
- Including mangroves into reporting processes for global conventions—including the Convention on Biological Diversity and the Paris Agreement—through the development of a consolidated set of indicators that measure progress towards targets.

WE CALL ON THE PRIVATE SECTOR TO INCREASE INVESTMENT IN MANGROVE CONSERVATION AND RESTORATION BY:

- Working with the conservation community and local stakeholders to invest in sustainable enterprises that value mangrove ecosystem services appropriately.
- Promoting the adoption of green-gray approaches that integrate coastal ecosystems and mangroves into traditional infrastructure solutions to climate change.
- Continuing and enhancing innovation with the development of new funds and approaches to ensure fair and equitable support for mangrove protection and restoration.

WE CALL ON THE NGO SECTOR AND OTHER PUBLIC INTEREST AND ADVOCACY GROUPS TO SECURE A FUTURE FOR MANGROVES BY:

- Catalyzing funding and supporting efforts to develop sustainable mangrove management.
- Raising awareness, sharing, and promoting information about the value of mangroves.

WE CALL ON THE ACADEMIC AND RESEARCH COMMUNITY TO SUPPORT THESE EFFORTS BY:

- Prioritizing the development of information and tools that will support policy implementation.
- Building on their current efforts by working collaboratively to improve temporal and spatial resolution of existing data and to address key knowledge gaps in all sectors, including social and economic sciences, restoration approaches, and ecosystem service benefits.

WE CALL ON THE PUBLIC TO ADVOCATE FOR MANGROVES AND DEMAND THAT:

- Mangroves world-wide and in settings that may be local to you, are afforded the protection they need to be maintained and enhanced for the many local and global benefits they provide.
- New restoration projects be supported, which are science-based, tracked, and managed so that the full suite of services mangroves provide are delivered to people.
- Coastal development doesn't come at the expense of traditional values and coastal heritage, but is built around sustaining critical coastal ecosystems such as mangrove forests and supports equitable access and benefit sharing.

Everyone has a role to play in saving mangrove forests. Let's leverage the momentum the mangrove community has created, and keep in mind what this work means to the world.


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