Linking Coastal Ecosystems and Human Well-Being:

Learning from conceptual frameworks and empirical results

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Lone fisherman in western Sri Lanka © Niroshan Mirando

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Executive summary

In the aftermath of the devastation caused by the Indian Ocean tsunami in 2004, awareness that there is an inextricable link between the status of coastal ecosystems and the vulnerability of coastal inhabitants to natural disasters was brought forcefully to the forefront, because a direct correlation between the health of coastal ecosystems and the degree of shoreline protection provided by them was demonstrated clearly.

However, the value of coastal ecosystems is not just limited to the benefits of shoreline protection and extends to many other indirect services supporting income from, for example, fisheries and tourism. Hence, the degradation of coastal ecosystems has real and profound economic and social costs, not just in terms of losing shoreline protection services, but also in terms of loss of livelihoods. As such, coastal ecosystems provide products and services which yield both direct and indirect benefits to residents in coastal areas, and impact their well-being. This clear link between ecosystem status and human well-being was initially and clearly presented in the Millennium Ecosystem Assessment (MA, 2005).

In light of the findings of the MA and the clear visual post-tsunami evidence that coastal ecosystems provided valuable services, pressing appeals were raised for the need to restore and rehabilitate coastal ecosystems. In response to these appeals, a number of projects emerged including a project entitled 'Rehabilitating Coastal Ecosystems in a Post-Tsunami Context: Restoration of Mangroves in Sri Lanka and Thailand' which was developed and implemented during 2005-2006. This project focused primarily on restoring mangrove ecosystems in and around priority protected areas within the immediate context of supporting post-tsunami reconstruction, while operating under a broader framework of strengthening coastal conservation and livelihoods rehabilitation.

This paper builds on the conceptual basis developed under Phase 1 of the project and presents a framework, which illustrates the various components of an integrated ecosystem service and human well-being assessment.

It describes and uses the clear, analytical framework presented in the Millennium Ecosystem Assessment - which links ecosystem services with human well-being - and shows how post-tsunami awareness and action created the recognition that coastal ecosystems and human well-being are interconnected and interdependent. This report describes the different services provided by coastal ecosystems and demonstrates clearly the critical importance of these interconnections.

The challenges of investing in coastal ecosystem restoration are discussed under the premise of Total Economic Evaluation. Valuation of coastal ecosystems and ecosystem services can highlight both the benefits of conservation, as well as the costs of degradation and damage to both livelihoods and economies. This is demonstrated clearly by results from phase one and other studies from Sri Lanka and Thailand. In doing so, this report extends awareness on the value of coastal ecosystems, their products and services for human well-being (i.e., livelihood security and development benefits) and shows how economic valuation of coastal ecosystem services can be a valuable tool for conservation managers and development decision-makers.

This report recognises that there is an urgent need to communicate clearly a framework, which would provide the conceptual basis for an integrated ecosystem service and human well-being assessment. It presents an integrated framework that includes four sub-assessments: on biodiversity, ecosystem services, economic values, on livelihoods and human well-being. It shows how, together, these four assessments provide an integrated framework that yields all required data for informed decision-making.

The report also provides an overview of the indicators that could be used under each sub-assessment, as well as an example of an ecosystem assessment for Sri Lanka, that illustrates the information required for establishing a baseline.

Building the capacity of coastal conservation and development decision-makers and managers in undertaking such an assessment is also a key priority. This is addressed by a second activity of this project, through the production of another output, namely a field manual.

Acknowledgements

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Mangrove nursery © IUCN Thailand

Introduction and overview

In the aftermath of the devastation caused by the Indian Ocean tsunami in 2004, awareness that there is an inextricable link between the status of coastal ecosystems and the vulnerability of coastal inhabitants to natural disasters was brought forcefully to the forefront.

By merely examining the magnitude and distribution of destruction caused by the tsunami, it became very clear that there was a direct correlation between the health of coastal ecosystems and the degree of shoreline protection provided by them. There is ample evidence to show that coastal communities sheltered by a well-stocked mangrove stand experienced much less damage, compared to communities exposed directly to the force of the waves.

The value of coastal ecosystems is, however, not just limited to the benefits of shoreline protection. Mangroves, for example, also provide products such as food (fish, shrimp, crab), timber and fuelwood, as well as other indirect services supporting income (i.e. from fisheries and tourism).

Hence, the degradation of coastal ecosystems has real and profound economic and social costs, not just in terms of losing shoreline protection services, but also in terms of loss of livelihoods. As such, coastal ecosystems provide products and services which yield both direct and indirect benefits to residents in coastal areas, and impact their well-being. The clear link between ecosystem status and human well-being was initially and clearly presented in the Millennium Ecosystem Assessment (MA, 2005).

In light of the findings of the MA and the clear visual post-tsunami evidence that coastal ecosystems provided valuable services, pressing appeals were raised for the need to restore and rehabilitate coastal ecosystems. The importance of integrating environmental restoration and rehabilitation into the post-tsunami reconstruction phase was emphasised. It was assumed that investments in such natural infrastructure would play a key role in maintaining and/or improving the physical and socio-economic security of coastal settlements and livelihoods in the future, as well as to reduce their vulnerability to natural disasters and extreme weather events.

In response to these appeals, a number of projects emerged including a project entitled '*Rehabilitating Coastal Ecosystems in a Post-Tsunami Context: Restoration of Mangroves in Sri Lanka and Thailand',* which was developed and implemented during 2005-2006. The project focused primarily on restoring mangrove ecosystems in and around priority protected areas within the immediate context of supporting post-tsunami reconstruction, while operating under a broader framework of strengthening coastal conservation and livelihoods rehabilitation.

Even though the project generated important information on the value of coastal ecosystems towards local livelihoods, there is still a need to further refine a framework, which illustrates clearly the inter-linkages between ecosystem services and human well-being, as well as detailing the synergies between coastal conservation and socio-economic development. In acknowledgment of this need, a second phase of the project was developed, and the present report is the first of a number of outputs generated under this second phase.

This report has four specific objectives.

1. To build on the conceptual basis developed under Phase 1 of the project and present a framework which illustrates the various components of an integrated ecosystem service and human well-being assessment.
2. To highlight results from Phase 1 and other studies and extend awareness on the value of coastal ecosystems, their products and services for human well-being (i.e., livelihood security and development benefits).
3. To present the data requirements for undertaking an integrated ecosystem service and human well-being assessment, as well as the common indicators used for establishing a baseline, through the use of an example.
4. To assist coastal conservation and development planners and managers to act on and examine the impacts on well-being (including local livelihoods) from ecosystem restoration initiatives, as well as to strengthen and promote the prioritisation of ecosystem conservation as an integral part of development infrastructure.

Connecting ecosystem status and human well-being: the conceptual basis applied for Phase I of this project

The continued degradation of the world's natural ecosystems and increased recognition of its negative impacts on human well-being resulted, in the year 2000, in the UN Secretary General calling for a global assessment of the health of the earth's ecosystems. In response to this call, the Millennium Ecosystem Assessment (MA) was initiated involving more than 1,300 experts from 95 countries with a mandate to *'assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being'* (MA, 2005).

Among the many outcomes of the MA two, specifically, are relevant for this report. Firstly, the MA presented a clear analytical framework which linked ecosystem services with human well-being. The framework convincingly ends the perception that development objectives are inherently at odds with environmental objectives. By making these linkages explicit, the MA sheds light on how changes to the environment affect ecosystem services, which, in turn, influence human well-being. Secondly, the MA provided a review of response options to environmental degradation, concluding that environmental management must be integrated into development policy. It identified key drivers of ecosystem change and appraised response options on the basis of their effectiveness in stemming the decline of ecosystem services. For example, to conserve biodiversity, the MA suggests that the designation of protected areas and international cooperation through multilateral environmental agreements are 'promising' responses to the key drivers of adverse environmental change. Furthermore, policy changes are considered necessary to improve the state of the environment, including implementing market-based instruments, participatory and adaptive processes in environmental management, and establishing coherence among environmental strategies, trade and macro-economic policies (for example, fiscal policies).

In addition, the MA's framework of direct and indirect drivers is easily comprehensible to policy makers and makes it possible to identify and assess trade-offs and synergies between development strategies and the environment.

Ecosystems, ecosystem services and human well-being – the MA framework and findings

The MA framework elucidates clearly the links among ecosystems, ecosystem services[1] and human well-being. The MA defines ecosystems as '*dynamic complexes of plant, animal and micro-organism communities and their non-living environment interacting as functional units*' (MA, 2005). The functions and processes of ecosystems produce ecosystem services which are beneficial to humans. The MA defines ecosystem services as the benefits ecosystems provide people (MA, 2005). Therefore, whenever ecosystem functions and processes are disrupted, for example, through damaging activities that impact their health, it diminishes the rate and capacity of an ecosystem to produce products and services of economic value. For example, in mangrove ecosystems many plant, animal and micro-organism communities (or more generally biodiversity) make it possible for fish to breed, develop and thrive. When these plants, animals and micro-organisms are damaged or lost within a habitat or geographic area, greater fluctuations in ecosystem processes tend to occur and the ecosystem as a whole tends to become less stable. This instability limits the system's resilience – i.e., its ability to withstand stress, extreme conditions and catastrophic events. Conversely, when the status and health of an ecosystem is maintained or improved, its stability and resilience improves.

The services provided by ecosystems range from tangible products such as fuelwood, timber, fish and water to more intangible services such as habitats for fish, regulation of flow for water supply and flood control, maintenance of biodiversity and so on. The MA has identified four main classes of ecosystem services: provisioning, regulating, supporting and cultural services (see Figure 1 on the following page).

Provisioning services cover natural resources and products derived from ecosystems, and represent the flow of goods. Regulating and supporting services are the actual life-support functions that ecosystems provide and are determined normally by the size and quality (the stock) of the ecosystem. Cultural services are the non-material benefits provided by ecosystems - such as aesthetic, spiritual, educational and religious significance.

[1] The MA itself categorises products and services as ecosystem services because often the differences are not straightforward. For example, it is not easy to distinguish whether water supply is a product or a service.

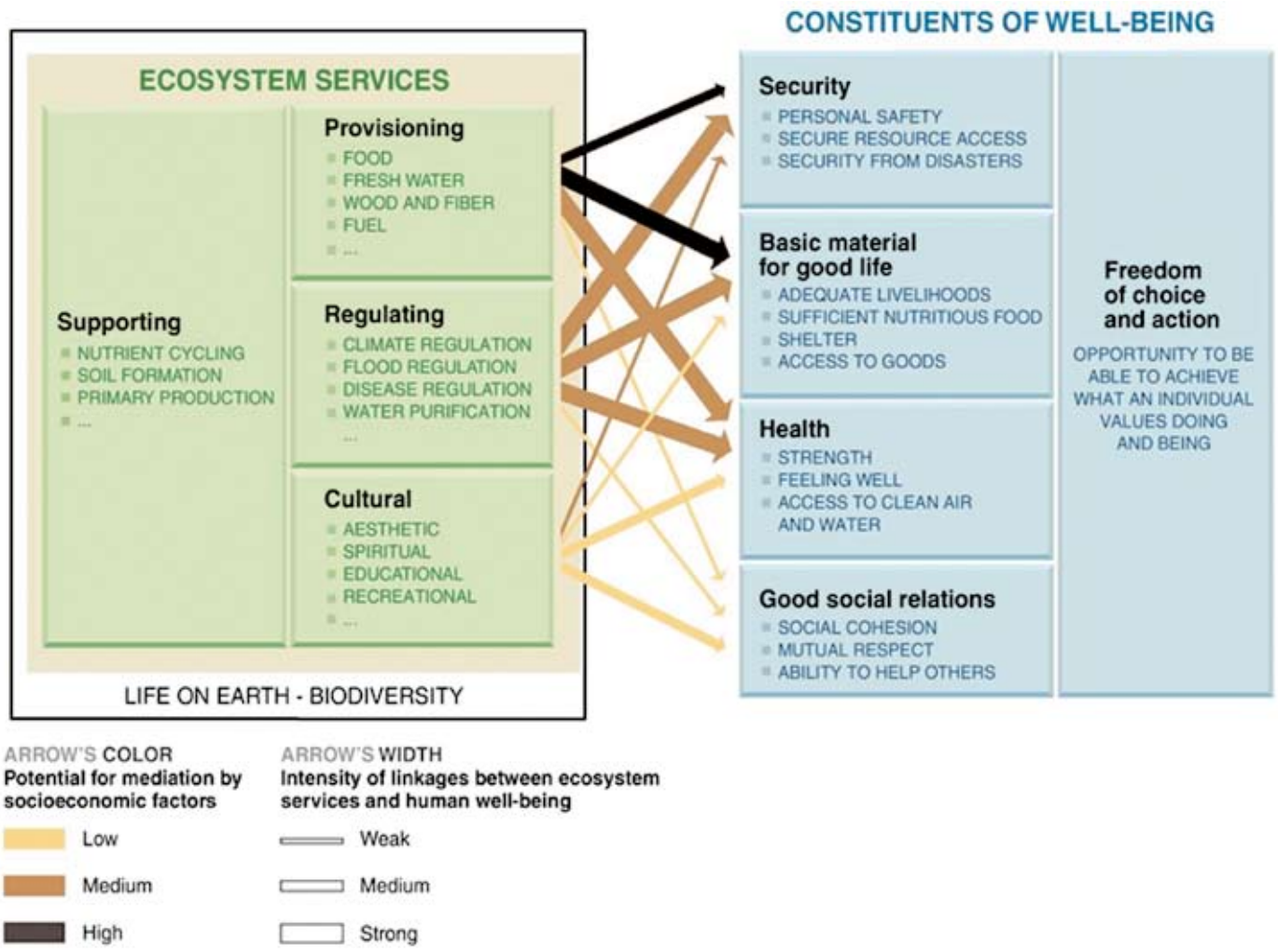

Figure 1: The Millennium Environmental Assessment Framework. Source: (MA, 2005)

The MA framework has also been instrumental in recognising and articulating that our current understanding of human well-being extends way beyond adequate cash income. According to the MA, human well-being is now seen as the creation of an enabling environment, which allows people real choices and actions, and enables them to enjoy long, healthy, productive and secure lives. Put differently, although income in a cash economy is necessary, real human well-being is measured through increase in the quality of people's lives – all the constituents of well-being, basic material needs for good life, good health, good social relations, security, and freedom of choice and action (MA, 2005).

When the two components of the MA Framework are brought together – ecosystem services and the constituents of human well-being – it is discovered that human well-being depends very much on a range of services provided by healthy functioning ecosystems (see Figure 1 above). More importantly, if there are changes in ecosystem status because of damage (either natural or human induced) these will result in a change to the services and will influence all components of human well-being. As a result of this, the case for action to maintain and improve the management of the environment has never been stronger, nor has the link between development and the environment ever been clearer.

Yet, despite the unprecedented recognition of the importance of ecosystems and their valuable contribution to human well-being, ecosystems and the services they provide continue to decline in both extent and quality. The MA notes that all ecosystems have been transformed by human actions, with the loss of 35% of mangroves, 20% of coral reefs and an estimated decrease in global forest cover from 31.2% in 1990 to 30.2% in 2005 (MA, 2005). Over half of the 14 biomes that the MA assessed have experienced a 20–50% conversion to human use, with temperate and Mediterranean forests and temperate grasslands the most affected (approximately three quarters of these biomes' native habitats have been replaced by cultivated lands), and in the last 50 years, the rates of conversion have been highest in tropical and sub-tropical dry forests (MA, 2005). The increases in point and non-point pollution have also had a negative impact on ecosystem services; the provisioning services especially have suffered. For example, since 1960, the amount of reactive nitrogen found in terrestrial ecosystems has doubled and phosphorus amounts tripled (MA, 2005).

The loss and degradation of coastal ecosystems also has important implications for people, especially poor coastal households. Loss of coastal ecosystems can seriously undermine local livelihoods, which is important to consider, given that 50% of the global population live within 60 kilometres of the coast. For a more detailed overview of the status of coastal ecosystems see Figure 2 below.

HABITAT TYPE	STATUS	COMMENTS
Estuaries	Substantial loss	e.g., < 10% natural coastal wetlands remain in California, with over half of U.S. coastal wetlands substantially altered
Mangroves	35% loss in last two decades for countries with data	>80% loss in some countries
Coral reefs	20% severely damaged and unlikely to recover (2004 estimate); 70% are destroyed, critical, or threatened (2004 estimate)	Caribbean and Southeast Asia most degraded
Intertidal habitats and deltas	Substantial degradation	37% loss on Yellow Sea coast of China since 1950; 43% loss in South Korea since 1918
Beaches and dunes	Complete loss or degradation in many places	
Seagrass beds	Major losses in Mediterranean, Florida, and Australia	Degradation expected to accelerate, especially in Southeast Asia and the Caribbean
Kelp forests	Probably none exists in a natural condition	
Saltmarshes or ponds	Massive alteration and loss	
Semi-enclosed seas	Becoming highly degraded	
Other bottom communities	Severely impacted by effects of fishing	Strong evidence for impacts on ecosystem function and resilience

Figure 2: Global status of coastal ecosystems. Source: (MA, 2005)

Some of the main reasons or drivers of change for coastal ecosystem degradation and loss identified by the MA include population growth, unsustainable harvest levels and methods, climate change, and economic development. In addition, poorly constructed policies are being blamed increasingly for the deterioration of our natural assets. Agricultural and fisheries subsidies often act as perverse incentives undermining sustainable use and are amongst the most powerful drivers of over-harvesting. The value of fisheries subsidies as a percentage of the gross value of production in the OECD[2] countries was about 20% in 2002 (MA, 2005). Also, other financial instruments - such as tax breaks - can act as detriments to conservation by, for example, supporting land conversion to aquaculture.

Another often-given reason for the persistence of ecosystem degradation is the usual rhetoric of lack of political will. Contrary to this commonly held perception, many policymakers, including those in developing countries, do, in fact, appreciate the importance of the environment for their country's sustainable development. Yet, each of them struggles with difficult questions of how to assess the impacts of ecosystem degradation on human well-being, as well as how to provide an economically convincing case of why investments in ecosystems and ecosystem services should be made.

The Indian Ocean tsunami: a window of opportunity

The Indian Ocean tsunami in 2004 was a horrific natural disaster that destroyed coastal areas and local livelihoods and claimed the lives of close to a quarter of a million people. However, it presented an ideal opportunity to assess the actual roles played by coastal ecosystems in buffering communities against a natural disaster.

With the MA framework in focus, assessing the devastation caused by the tsunami in Sri Lanka and Thailand revealed an unequivocal reality: healthy coastal ecosystems, especially mangroves, had, in fact, provided a level of protection that saved the property and lives of thousands.

As a result, much effort has been expended to create awareness on the importance of integrating coastal ecosystem restoration and rehabilitation into the post-tsunami relief and rehabilitation work.

[2] OECD – Organisation for Economic Co-operation and Development

During Phase 1 of this project, activities were undertaken in support of the objectives to:

1. Facilitate mangrove and coastal forest restoration in and around priority protected areas.
2. Document and share policy and technical information, as well as lessons learned, in order to promote the integration of mangrove conservation and restoration into post-tsunami reconstruction and coastal management processes.

Activities included:

- Determining the long-term conservation and livelihood goals and benefits of mangrove restoration, in collaboration with local partners.
- Raising local awareness on the importance of mangrove ecosystems to biodiversity, coastal protection and livelihoods and the need for sound management of both natural and rehabilitated systems.
- Information-sharing with local planners, administrators and local communities.
- Facilitating the development of participatory mangrove restoration strategies based on forest landscape restoration approaches, particularly through capacity building of local authorities and communities to participate in management, and setting up appropriate institutional/implementation structures.
- Implementing mangrove restoration activities on a pilot basis in and around up to three PAs, including the establishment of mangrove nurseries at pilot sites.
- Conducting rapid assessments of the environmental and socio-economic value of mangrove ecosystems.
- Producing information briefs for post-tsunami planners and decision-makers.
- Through a series of targeted roundtables for national and local-level decision makers, disseminating information and strengthening awareness/capacity on factoring ecosystem restoration into post-tsunami reconstruction and coastal management.

For a more elaborate description of Phase 1 results and findings see Annex 1.

While acknowledging that focussing on raising awareness was important it was, however, also recognised that there is a need to communicate clearly a framework, which would provide the conceptual basis for an integrated ecosystem service and human well-being assessment. This framework could then be used to examine the impacts on well-being from ecosystem restoration investments.

Clearing damaged mangroves after the tsunami, Sri Lanka © Vimukthi Weeratunge

One key feature that emerged in post-tsunami awareness and action was the recognition that coastal ecosystems are interconnected and interdependent. In fact, the concept of integrated coastal zone management (ICZM) espoused previously by coastal conservationists had been premised on this insight. Along coastlines, mangrove forests, coral reefs and seagrasses are often found together. Coastal ecosystems consist of a mosaic of interconnected environments and associated plant, animal and micro-organism communities, which are integral parts of interdependent coastal ecosystems. Coastal ecosystems mainly include mangroves, coral reefs and seagrasses, but also include estuaries and marshes, lagoon and salt ponds, inter-tidal zones, kelp forests, rock and shell reefs and inner shelf.

Box 1

Overview of coastal ecosystems

Mangroves

Mangroves are woody plants or plant communities which are found in the intertidal zone between the sea and the land in areas which are inundated by tides for part of the time. Mangrove forests make up one of the most unique ecosystems on earth in that they thrive where no other trees can survive – in the transition zone between the ocean and land. They are among the world's most productive ecosystems.

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

Coral reefs

Corals are colonial invertebrates, all of which are marine. Coral reefs are based on rigid lime skeletons; themselves formed through successive growth, deposition and consolidation of the remains of reef-building corals and coralline algae, through millions of years. The basic units of reef growth are the coral polyps and the associated symbiotic algae that live in the coral tissues. This symbiotic relationship is the key factor explaining both the productivity of reefs and the somewhat strict environmental requirements of corals. Coral reefs are found only where the sea is less than 100m deep, and the temperature is between 25° and 29°C. They are therefore restricted within the latitude of 30°N to 30°S and found only in tropical seas. Coral reefs form a unique ecosystem, richer in biodiversity than any other ecosystem in the world.

Sea Grass beds

Sea-grasses are flowering plants which grow submerged exclusively in marine coastal waters. There are about 60 species all over the world (Phillips and Menez, 1988). Like grasses in terrestrial habitats, they form meadows on the bed of coastal seas. They are dependent on light penetrating for photosynthesis, so they grow only in shallow waters, in estuaries and coastal seas. They cannot survive outside water, so they often grow where there is shelter from a sand bar or coral reefs.

Sea-grasses are found in coastal waters of every continent except Antarctica. In tropical oceans, they are nearly always found near mangroves and coral reefs.

The provisioning services of coral reefs are critical to about 500 million people worldwide (Wilkinson, 2004), through fishing and mariculture etc. Occurring along the shoreline, mangroves provide a complex habitat structure for numerous juvenile fish species. In fact, it is estimated that up to 80% of global fish catches are directly or indirectly dependant on mangroves (Sullivan, 2005). Seagrass ecosystems are other highly valuable habitats that occur within the reef system. Seagrasses form the base of the food web for species such as sea cows, sea turtles, fish, and invertebrates. Like mangroves, seagrasses also provide a structurally complex refuge from predation for many juvenile fish species. In addition, seagrasses may be the permanent habitat of epibenthic[3] fish species. In addition, they may provide food and shelter for migrating pelagic[4] species. Obviously, environmental changes that threaten the vitality and persistence of seagrass meadows also endanger indirectly the ecological functions that seagrass meadows may have for fish.

Food provisioning in the form of fisheries catch is one of the most important services derived from coastal ecosystems, and constitutes the main or even the sole source of animal protein for poor coastal communities. Fisheries and fish products provide direct employment, as well as those indirectly involved in the fisheries industry (FAO, 2006). Other habitats such as beaches, dunes, salt marshes, estuaries, and mudflats also play an important role in the life cycle of - for example - fish, shellfish, and migratory birds.

[3] referring to fish living on the bottom surface

[4] living on or in the open seas

Coastal ecosystems also provide products such as fuelwood and building materials (for example, for boat and house construction).

In addition to providing essential habitat, sea grasses and mangroves stabilise near shore sediments and help mitigate coastal erosion. Mangrove forests form dense thickets of prop roots and aerial stems, which, in turn, trap sediments and move the shallow mud flats and delta areas seaward. Seagrasses also trap and stabilise bottom sediments leading to an increase in water clarity. Clearer waters improve light penetration, and consequently increase photosynthesis and rates of organic matter production. Sediment trapping contributes to coastal accretion, while sediment stabilisation helps prevent coastline erosion, especially under storm conditions. The removal of terrigenous[5] sediment from lagoon and estuarine water is a very important function of sea grasses, and may be essential in some areas to allow sediment-sensitive corals to exist on adjacent reefs.

Mangroves and seagrasses also interrupt freshwater discharge, are sinks for organic and inorganic materials as well as pollutants, and can generate an environment with clear, nutrient rich water that promotes the growth of coral reefs offshore (Ogden, 1988). Coral reefs return this favour by acting as physical buffers for oceanic currents and waves, creating, over time, a suitable environment for sea grasses and mangroves. In addition to these physical interactions there are several biological and biogeochemical interactions between these interconnected ecosystems (see Figure 3 below).

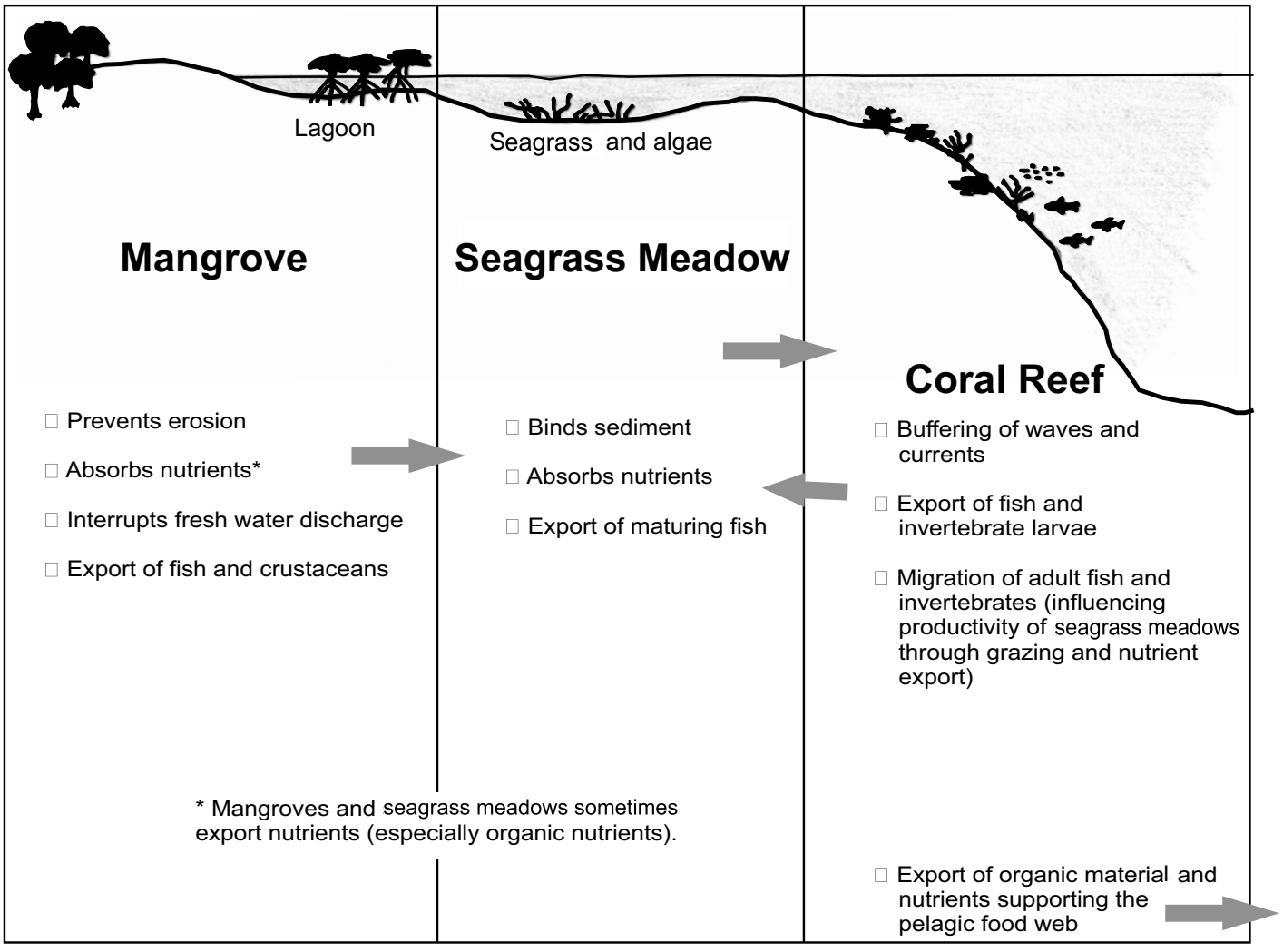

Figure 3: Interactions in coastal ecosystems: mangroves, seagrass meadows and coral reefs. Source: (Ogden, 1988)

Coral reefs are also a tourist attraction, contributing to local economies, income and foreign exchange. In addition, they form a unique natural ecosystem, with important biodiversity value, as well as scientific and educational values. Finally, coral reefs function as a natural barrier providing protection against wave erosion.

[5] originating on land

The coasts around the world are of great spiritual importance to many people, providing cultural and spiritual services. Coastal tourism is one of the fastest growing sectors of global tourism and is an essential component of the economies of many Small Island Developing States (SIDS). The cultures of many people are connected closely to coasts and oceans, and traditional knowledge has become an integral part of the dynamics of island and coastal ecosystems and their management. In addition, coastal habitats are areas of research and efforts in education and public awareness. Coastal ecosystems provide supporting services in the form of a wide range of habitats. Coastal ecosystems play an important role in photosynthesis and productivity. For a comprehensive overview of services provided by different coastal ecosystem see Figure 4 below.

Coastal ecosystems provide a wide range of services to people, but it is extremely clear that many of these services demonstrate the interrelationships among these ecosystems, showing the critical importance of these interconnections.

ECOSYSTEM SERVICES	Coastal									Marine		
	Estuaries and marshes	Mangroves	Lagoon and salt ponds	Intertidal	Kelp	Rock and shell reefs	Seagrass	Coral reefs	Inner shelf	Outer shelves edges slopes	Seamounts & mid-ocean ridges	Deep sea and central gyres
Biodiversity	X	X	X	X	X	X	X	X	X	X	X	X
Provisioning services												
Food	X	X	X	X	X	X	X	X		X	X	X
Fibre, timber, fuel	X	X	X						X	X		X
Medicines, other resources	X	X	X		X			X	X			
Regulating services												
Biological regulation	X	X	X	X		X		X				
Freshwater storage and retention	X		X									
Hydrological balance	X		X									
Atmospheric and climate regulation	X	X	X	X		X	X	X	X	X		X
Human disease control	X	X	X	X		X	X	X				
Waste processing	X	X	X				X	X				
Flood/storm protection	X	X	X	X	X	X	X	X				
Erosion control	X	X	X				X	X				
Cultural services												
Cultural and amenity	X	X	X	X	X	X	X	X	X			
Recreational	X	X	X	X	X			X				
Aesthetics	X		X	X				X				
Education and research	X	X	X	X	X	X	X	X	X	X	X	X
Supporting services												
Biochemical	X	X			X			X				
Nutrient cycling and fertility	X	X	X	X	X	X		X	X	X	X	X

Figure 4: The variety of ecosystem services provided by coastal ecosystems. Source: (MA, 2005).

The broader understanding of coastal ecosystems, the services they provide and the links to human well-being can be illustrated and specified using the MA framework (see Figure 5 on the facing page). The figure demonstrates clearly links between key coastal ecosystem services and human well-being: shoreline and coastal protection leads to security; coastal food provisioning and other products provide the basic material for good life; water quality maintenance yields good health; tourism and recreation, good social relations; and all the ecosystem services and constituents of well-being enhance freedom of action and choice.

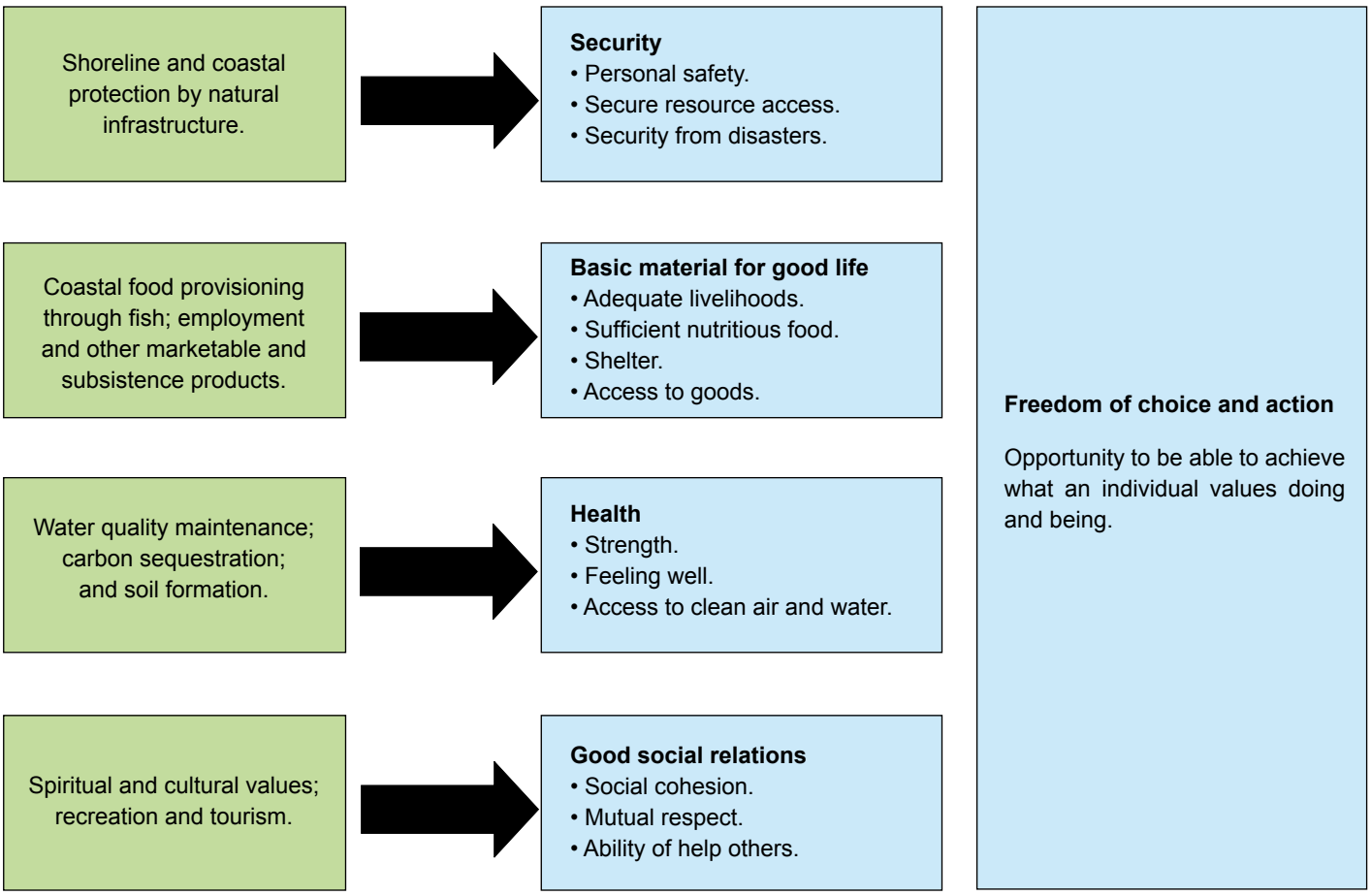

Figure 5: Links between coastal ecosystem services and coastal well-being

The challenges of investing in coastal ecosystem well-being

Largely as a result of a number of post-tsunami awareness and action initiatives, there is now a growing interest in promoting investments in coastal ecosystems as an integral part of development infrastructure (IUCN, 2006). Such investments are argued as being vital in the rehabilitation and reconstruction phase because they result, over time, in restored and improved outputs and productivities – in this case, ecosystem services which sustain and improve human well-being (IUCN, 2006).

However, promoting investments in ecosystem rehabilitation and conservation still remains difficult, as most coastal ecosystem services are not traded in markets and hence, do not come with convenient price tags. As a consequence, they often remain undervalued or even omitted completely from conventional investment appraisals. Furthermore, the mentioned complexities of ecosystems and the dynamics of the human-environmental interphase add difficulties to the full understanding of the loss of productivity and human well-being associated with ecosystem degradation and damage or how well-being improves from maintaining and increasing the capacity of ecosystems to deliver vital products and services. In a situation of undervaluation and partial information, investments in ecosystems are traded off for seemingly more profitable and important uses that often simultaneously impair and degrade them. Therefore, identifying the economic benefits associated with investing in sustaining or even improving ecosystem services is important if wise decisions are to be made.

The breakdown of values associated normally with an ecosystem, and premised on the Total Economic Value Framework is presented below in Figure 6.

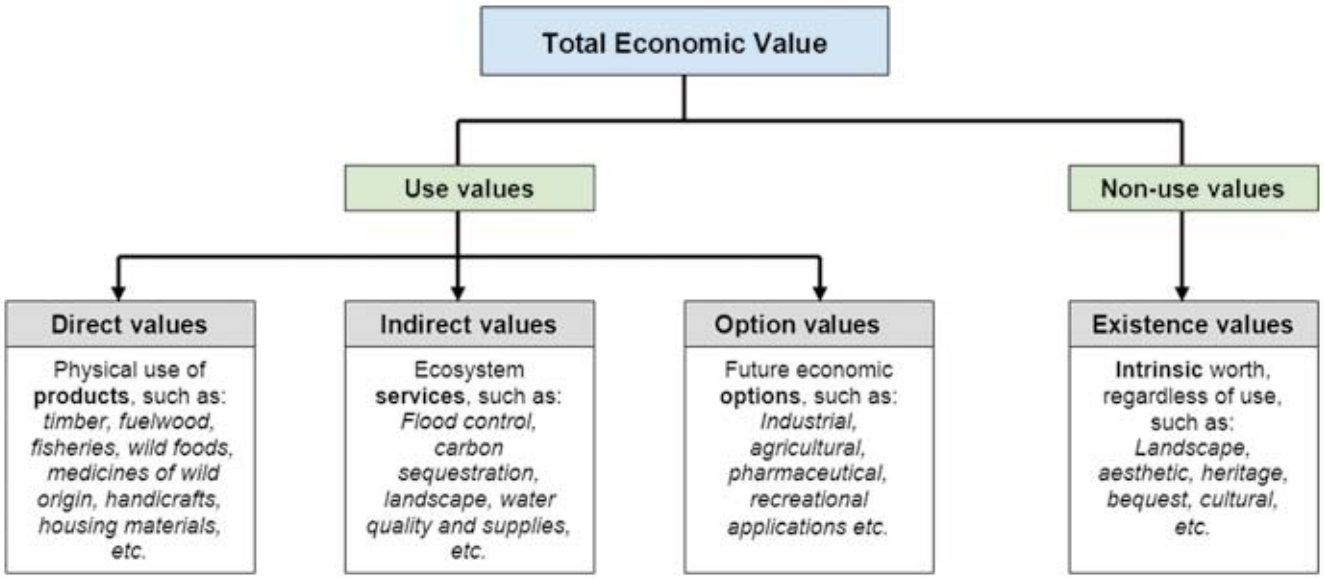

Figure 6: Total Economic Value of Ecosystems

Economic valuation of coastal ecosystems and ecosystem services can highlight both the benefits of conservation as well as the costs of degradation and damage to both livelihoods and economies – see Boxes 1 and 2 on the following pages for some examples. Furthermore, valuation studies can and have been used to improve decision-making on how resources are managed, used and allocated. Economic valuation of coastal ecosystem services can, therefore, be a valuable tool for conservation and development decision-makers to use to generate both positive conservation and well-being benefits as well as understand the existing trade-offs between conservation and well-being.

Mangroves in north western Sri Lanka © Vimukthi Weeratunge

Box 2

Valuation, rehabilitation and conservation of mangroves in tsunami affected areas in Sri Lanka

With an overall aim of informing the discussions on the importance of promoting sustainable rehabilitation, management and conservation of tsunami affected coastal ecosystems, IUCN, in 2006, conducted an economic valuation of mangroves in Hambantota district of Sri Lanka.

The main objectives of the study were to facilitate the restoration of local livelihoods in tsunami affected areas through mangrove rehabilitation and to improve awareness on the economic values of mangroves. The latter was carried out in order to justify mangrove rehabilitation and conservation, as well as to minimise ecosystem damage during the tsunami reconstruction process. To achieve these objectives three main activities were carried out: 1) assessing the economic value of selected coastal mangrove ecosystems, 2) rehabilitation, restoration and conservation of tsunami affected mangrove areas, and 3) dissemination of mangrove valuation study results and advocacy. In addition, a number of sub-activities where undertaken, including establishing several small mangrove nurseries, replanting of 38 hectares of damaged mangroves, conducting training events on sustainable mangrove replanting and management, and holding workshops and awareness meetings for community based organisations (CBOs) and local NGOs on the economic value of mangroves.

Valuation Results

Among the villages selected as pilot sites where Medagama, Rekawa-west and Netolpitiya-south. For these villages, ecosystem products and services provided by their adjacent mangroves were assessed and valued.

Two methods were used to calculate the direct values. These were Market Prices (MP), and Participatory Environmental Valuation (PEV) – a technique where local villagers can express the value of different mangrove products through a ranking exercise. PEV was used to verify the values derived from the MP method for products consumed primarily within the household and was based on the premise that mangrove products, which are traded rarely, tend to be undervalued by the market. In the present study, fuelwood, timber, poles, herbs and vegetables were the only mangrove products used exclusively for subsistence and hence, subject to PEV.

The indirect values assessed were the restocking of near-shore fisheries (supported by the services of providing fish nurseries and breeding grounds) and the shoreline protection. The value of mangroves to near-shore fisheries was calculated as a range, based on the assumption that between 30% and 80% of the total annual value of near-shore fisheries can be credited to mangrove services based on the recommendation of Rönnbäck (1999). The value of shoreline protection was estimated based on the damage costs avoided.

The study showed that poorer households are more dependent on natural resources than richer households, and that market prices tend to undervalue ecosystem products and services, which are used exclusively for subsistence purposes. For example, in the case of fuelwood, market prices at best managed to capture only 45% of the true value of fuelwood as expressed by the collecting households.

For the resource dependent households participating in this study, mangrove products generate gross economic benefits that are above the average household income recorded in Hambantota district. For value details see the table below.

Summary of estimated mangrove values in selected villages (`000 USD)

Village	Annual mangrove NTFP values	Annual per hectare supporting near-shore fisheries values	Per hectare coastal protection values
Medagama	1,638	1,276-3,403	9,011
Rekawa-west	1,360	4,861-12,964	2,196
Netolpitiya-south	136[1]	1,464-3,905	9,884

[1]The reasons for this low number are: 1) that households have more restricted access to the mangrove compared to the other sites; and 2) that households have other major income sources and livelihood options as the village is located near a large road and a number of government jobs are available near by

Source: Ranasinghe and Kallesøe (2006)

Box 3

Counting the environmental costs of natural disasters:

evaluating tsunami-related damages to coastal ecosystems in Thailand

Shortly after the Indian Ocean Tsunami, UNEP commissioned IUCN to undertake an economic assessment of the damages suffered by coastal ecosystems in Thailand and the implications thereof on local livelihoods as well as the national economy.

For the coastal poor in Thailand, as well as the managers of coastal ecosystems, the value of maintaining coastal ecosystems is important. Local users have long recognised the socio-economic and ecological benefits of mangroves, coral reefs and sea grass ecosystems to their lives and livelihoods. Well-protected mangroves, for example, have been dubbed the 'supermarkets' of the coastal areas. It has been stated that communities, which conserved mangroves for example, drew a better dividend from these coastal resources than those that did not. However, these facts are often not understood fully and appreciated by policy and decisions-makers, and hence, the general aim of this study was to make these stakeholders more aware of the economic and development rational for including ecosystem conservation in general coastal zone development and in particular, in the post-tsunami reconstruction process, by demonstrating and articulating the economic values of coastal ecosystems.

Valuation Results

Four provinces of Andaman Sea coast of Thailand impacted by the tsunami were selected for the rapid assessment, namely Trang, Krabi, Phang Nga and Ranong.

A rapid environmental economic damage valuation methodology was developed looking at indicative costs associated with the loss of ecosystem services including environmental goods, reef-based fisheries (a joint value of mangroves, reefs and sea grasses) as well as the costs of physical rehabilitation of damaged ecosystems. Participatory data collection methods were combined with a brief household questionnaire for the purposes of collecting primary data. The study also relied on secondary sources for data related to the economic benefits and costs of coral reefs and sea grasses.

The results of the study showed that there are significant economic costs related to damages to coastal ecosystems (see table below). In particular, Phang Nga, which suffered the highest damages to its coastal ecosystems, also suffered the highest economic costs ranging from 10.47-11.15 million USD. Most of these costs are borne by the coastal communities themselves, as they are heavily dependent on these ecosystems for their livelihoods. In fact, the study revealed the high values associated with the direct use of mangrove forests, and hence, estimates the economic costs of damages to mangroves in Phang Nga to almost 6.1 million USD (in NPV – Net Present Value). Damage to these resources means that livelihood and subsistence options for these communities and households have been restricted severely. Finally, the results of the study point to the economic and development wisdom of rehabilitating, managing and conserving coastal ecosystems post-tsunami, and factoring ecosystems into coastal zone development and rebuilding to assure sustainable provincial incomes and sustainable livelihoods of particularly the poor coastal communities.

Summary of provincial estimated economic costs of coastal ecosystem damages in Net Present Value (`000 USD)

Province	Mangrove NTFP damages	Reef fisheries damages	Loss of coastal protection		Total economic costs in Year 0
			Coral reef	Mangrove	
Trang	1.47	0	0	4.12	5.59
Krabi	0	35.00-126.76	1,973	0	2,007-2,099
Phang Nga	607.01	262.06-942.65	9,213	286.47	10,468-11,149
Ranong	73.82	48.82-176.47	2,939	112.06	3,174-3,302

Source: IUCN/UNEP (2006)

These valuation exercises have show-cased the economic values of coastal ecosystems and their importance for local livelihoods. For example, the studies show that ecosystem services are not only of direct value to people, but also offer tremendous indirect benefits in terms of supporting and regulating services.

The usefulness of undertaking environmental valuation was also recognised under Phase 1 of this project, and valuation studies where undertaken in both Sri Lanka and Thailand. Summaries of the findings of these studies are presented in Annex 1.

Tsunami damaged mangroves, Thailand © IUCN/Thailand

Conceptual and applied framework connecting coastal ecosystems and well-being

By expressing the values of ecosystem services in monetary terms, it is possible to make direct relationships with the constituents of well-being, and informed decision-making when investments are appraised, activities are planned, policies are formulated, or land and resource use decisions are made. While a better understanding of the economic value of coastal ecosystems is vital, it is also important to remember that this is only one step in undertaking an integrated ecosystem service and human well-being assessment.

What is becoming increasingly clear is that while coastal conservation and development decision makers and planners are paying attention to poverty reduction and economic growth, they are missing the conceptual and practical tools that can help harmonise the interests of sustainable development – environmental, social and economic.

It is also apparent that an integrated assessment is needed if long-term sustainable development is to be achieved in coastal areas. The economic values of coastal ecosystems have to be presented in such a way that ecosystem conservation becomes an essential part of poverty reduction and economic development agendas, while also making the economic case for ecosystem service investments. In essence, economic valuation can place coastal ecosystems into mainstream development so that they become visible and competitive alongside other possible uses of land, resources and funds.

The conceptual framework shown on the following page presents a framework for undertaking an integrated ecosystem service and human well-being assessment.

Biodiversity Assessment

Establishes the composition and structure of the ecosystem, its status and health.

Service Assessment

Focuses on identifying the services being provided by the ecosystem, as well as the expected impacts on the provision of these services from changes in biodiversity composition and structure.

Economic Assessment

Values the significance of ecosystem services as shown through their contribution to the various elements of human wellbeing.

Livelihood Assessment

Describes the elements and factors that determine human well-being in relation to the services provided, the economy and other factors.

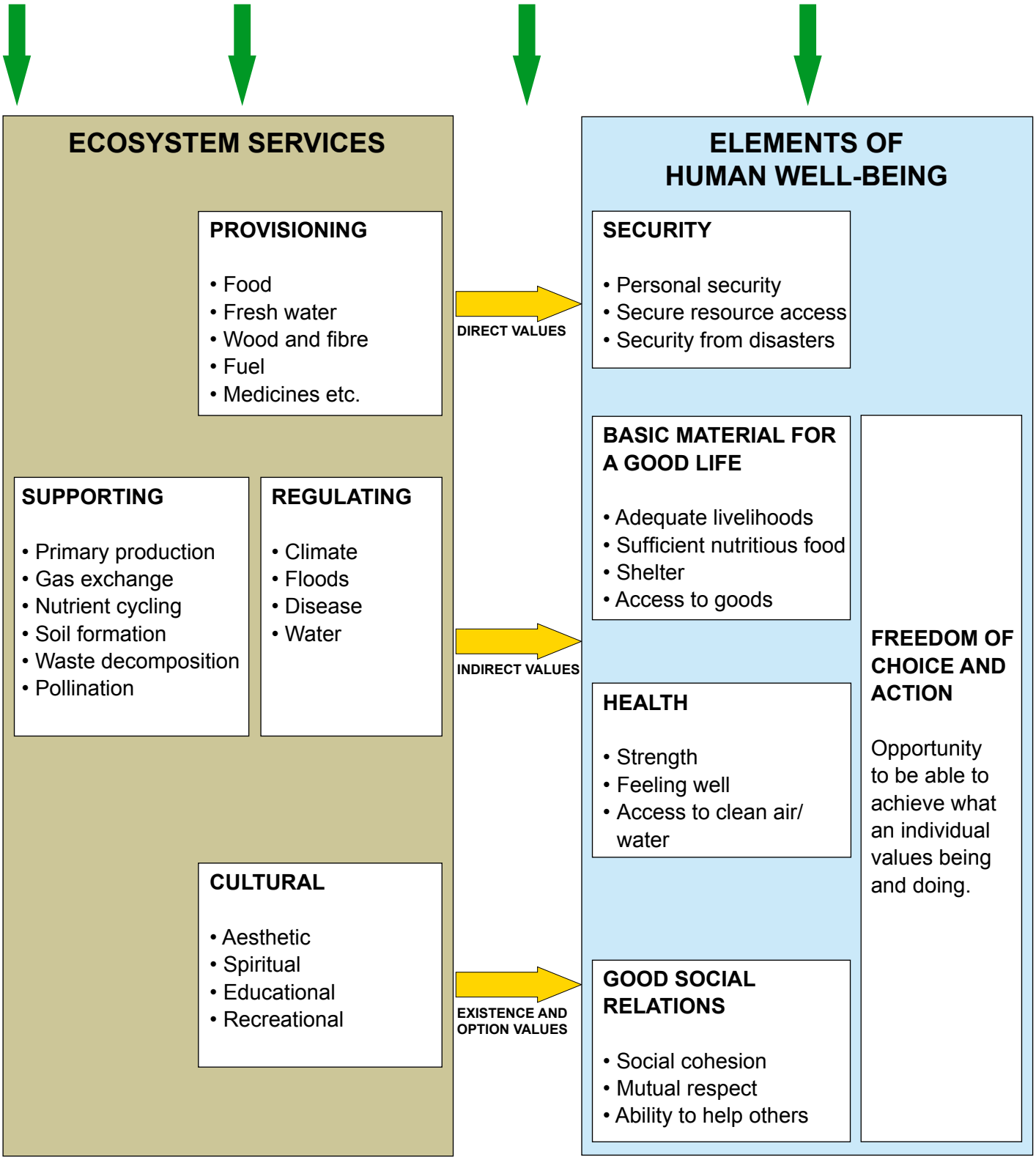

Figure 7: Framework for integrated ecosystem services and human well-being assessment.

The framework includes four sub-assessments: on biodiversity, ecosystem services, economic values, on livelihoods and human well-being.

The Biodiversity Assessment establishes the composition and structure of the ecosystem, its status and health, while the Ecosystem Service Assessment focuses on identifying the services being provided by the ecosystem, as well as the expected impacts on the provision of these services from changes in biodiversity composition and structure. The Livelihood Assessment describes the constituents and determinants of human well-being in relation to the provision of ecosystem services, the economy and mediating factors. Finally, the Economic Assessment values the significance of ecosystem services as manifest through their contribution to the various constituents of human well-being.

Together, these four assessments provide an integrated framework that yields all required data for informed decision-making.

Table 1 below provides an overview of the indicators that could be used under each sub-assessment, and Annex 2 provides an example of an ecosystem assessment for Sri Lanka illustrating the information required for establishing a baseline.

Building the capacity of coastal conservation and development decision-makers and managers in undertaking such an assessment is also a key priority. This is addressed by a second activity of this project, through the production of another output, namely a manual (Miththapala, in prep.) This table presented here is still in a draft form as it will be field tested before finalisation.

Table 1: Draft summary worksheet for integrated assessments (Miththapala,in prep.)

DRAFT WORKSHEET FOR INTEGRATED ASSESSMENTS		
Name, location and coordinates:		
Date:		
Type of ecosystem (habitat)		Description
For example Lagoon/Estuary/Mangrove/Saltmarsh/ Tank/Pond		
Approximate area:		
Management and Jurisdiction		
Responsible government institution		
Is it a protected area		Yes/No
BIODIVERSITY ASSESSMENT		
Species Diversity (Fauna)		Number
Birds	Number of species	
	Abundance	
	Breeding colonies	Yes/No
Other vertebrate fauna (Define group)	Number of species	
	Abundance	
Fish (Subsistence catch)	Number of species	
	Abundance	
Fish (Commercial catch)	Number of species	
	Abundance	
Macro-invertebrates (crabs, shrimps,molluscs, butterflies, dragonflies)	Number of species	

Emerging flora	Number of species	
	Abundance	High/Moderate/Low
Submerged flora	Number of species	
	Abundance	High/Moderate/Low
Floating flora	Number of species	
	Abundance	High/Moderate/Low
ECOSYSTEM SERVICE ASSESSMENT		
Service component/type	Indicator	Details (qualitative/ quantitative data)
Provisioning services		
Food	Fruits, vegetables, fish	
Fuelwood		
Drinking Water		
Medicinal plants		
Other . . .		
Supporting services		
Biodiversity	Species richness	
Nutrient cycling		
Primary production	Quality of vegetation	
Regulating services		
Protection from hazards	Vegetation stands	
Flood control	Protection of infrastructure	
Carbon sequestration	Canopy cover	
Pollution control	Tree cover	
Cultural services		
Recreational/aesthetic	Tourism	
Educational/Research	Relevant Facilities	
Traditional knowledge	Traditional practices	
Other . . .		

ECONOMIC ASSESSMENT		
Type of value	Indicator	Valuation method and data requirements
Direct use value	Economic value of provisioning services harvested (e.g. food, NTFPs, freshwater, wood and fibre, fodder, fuel and medicines)	For products which are traded *Market price method*: Local price X quantity of products harvested over a given time period For products which are not traded, but consumed within the household or exchanged without cash payments If the product is traded locally, even if it is not traded by the user himself: *Market price method:* Local price X quantity of products harvested over a given time period If the product is not traded, but has a close substitute (e.g. kerosene for firewood, purchased foods for wild foods, roofing tiles for thatch): Substitute price/replacement cost method: equivalent quantity of substitute used over a given time period X local market price of substitute If the product is not traded, and has no close substitutes which are traded: it may not be possible to get an economic value
Indirect use value	Economic value of regulating, supporting and cultural services utilised	First of all it is necessary to determine what quantity or magnitude of service the ecosystem provides (see ecosystem service assessment findings). Note: it is always better to use several methods to calculate the value, and present a range of possible values. If the service contributes clearly towards a specified output or production process as a raw material or input (e.g. year-round water for irrigation, soil nutrients for agriculture, nursery habitat and productivity for fisheries): effect on production method: establish the relationship between changes in a given ecosystem service and changes in production over a given time period, value this contribution to production in terms of market prices of the output. If the service can be at least partially provided through artificial means (e.g. through built shoreline protection, sediment trapping, water purification, erosion control measures): replacement cost method: establish the works required to replicate the ecosystem service over a given time period, and calculate the physical costs (capital and recurrent) of building the infrastructure to provide an equivalent type and level of services If the loss of the service will give rise to effects which would require mitigation[6] or avertive[7] action (e.g. building a reservoir to ensure year-round water supplies, purchasing clean water, providing emergency food supplies): *mitigative/avertive cost method*: establish the measures required to mitigate or avert the effects of the loss of an ecosystem service for a given area or population over a given time period, and calculate how much these measures would cost to implement.

[6] To act to lessen severity or intensity

[7] An action that avoids the loss of service.

		If the loss of the services will give rise to clear damages to infrastructure, production, etc. (e.g. flood damage to roads and bridges, drought damage to agriculture, damages from rising sea level): damage costs avoided method: establish the level of damages and affected area/ population resulting from the loss of an ecosystem service over a given time period, and calculate the economic costs or losses associated with these damages If calculating the recreational value of an ecosystem: travel cost method: collect data from visitors on the costs incurred in visiting and using the site including both direct expenses (such as fuel and fares, food, equipment, accommodation) and time spent on the trip, carry out a statistical regression to test the relationship between visitation rates and other explanatory factors, Construct a demand curve relating number of visits to travel cost, model visitation rates at different prices, and calculate visitor consumer surplus. Note: this is a complex method which requires extensive data collection, detailed data analysis, and a high level of training in environmental economics.
Option value	Economic value of provisioning, regulating, supporting and cultural services kept for future use	*Contingent valuation method:* how much would people be willing to pay to ensure that the ecosystem is conserved for possible use in the future or how much compensation would people be willing to accept for the loss of the ecosystem and the consequent loss of possible use in the future Note: this is a complex method which requires extensive data collection, detailed data analysis, and a high level of training in environmental economics
Non use value (Existence and bequest value)	Economic value of provisioning, regulating, supporting and cultural services appreciated for their existence but never intended to be used	*Contingent valuation method:* how much would people be willing to pay to ensure that the ecosystem is conserved or how much compensation would people be willing to accept for the loss of the ecosystem Note: this is a complex method which requires extensive data collection, detailed data analysis, and a high level of training in environmental economics

Bruguiera leaves © Vimukthi Weeratunge

LIVELIHOODS ASSESSMENT		
Basic Materials for life	Indicator	Details (qualitative/ quantitative data)
Adequate livelihoods		
	Total income/month/ household	Higher than national average/lower than national average/below poverty line.
	Total income/month/ person	Higher than national average/lower than national average/below poverty line.
	Sources of total income	Dependent on natural or other resources.
	Subsistence and non marketed income	From fruit/vegetables/agriculture/fish//livestock/fuelwood/fodder/ medicinal plants/nuts (Non-timber forest products NTFPs).
	Percentage of total income derived from fisheries	
	Percentage of households that are employed in fishing	
	Percentage of households that are employed in coastal tourism and tourism-related activities	
	Total number of households (in a village) directly dependent on fishing for their livelihoods	
	Total number of households (in a village) indirectly dependent on fishing for their livelihoods (net making etc.)	
	Total Assets	Cultivable land/other land/Cart/boat/plough/thresher/water pump/ livestock/poultry.
	Percentage of households that own boats	
Sufficient nutritious food/water		
Food per 24 hr consumption		
Frequency of meals	Frequency of meals	1/2/3
Balanced diet	Type of food	Protein/starch/fat/minerals.

	Sources of food	
Food source	Quantity of monthly Household consumption that is derived from fisheries	
	Quantity of daily protein intake that is derived from fisheries	
Water per capita	Access to safe drinking water	Personal piped water/Community piped water/Spring/Personnel Well/ Community Well/Delivered/Purchased water/Other.
	Distance to water source	Hours/days/km etc.
	Cost	Weekly spending if bought.
Shelter		
Housing	Permanency	Permanent/semi-permanent.
	Ownership	Owned/rented/shared/other.
	Personal space	Number of people/m^2
Access to housing goods	Percentage of households that use timber, thatch from surrounding coastal ecosystems	
	Frequency of use of timber, thatch from surrounding coastal ecosystems	
	Quantity of timber, thatch use/house household/year	
Fuel	Type	Gas/wood/other.
	Weekly requirement	
	Source	Gas pipeline/gas stove/wood from forest.
	Cost	Weekly spending if bought.
Access to fuel	Total number of households dependent on fuelwood from the surrounding ecosystem	
	Quantity of fuelwood collected by average household per month	
	Distance and time to collect fuelwood	
Health & Sanitation		
Feeling well	Prevalence of diarrhoea	Number of cases per day/per month.

	Prevalence of infectious hepatitis	Number of cases/day/month
	Prevalence of infectious malaria	Number of cases/day/month
	Prevalence of acute respiratory infections (ARI)	Number of cases/day/month
	Prevalence of acute chronic infections (CRI)	Number of cases/day/month
	Maternal mortality rate (to be collected at community level)	Number of deaths/year
	Infant mortality rate (to be collected at community level)	Number of deaths/year
	Under 5 mortality rate (to be collected at community level)	Number of deaths/year
	Access to family health services	Easy/Fair/Difficult
	Access health clinic services	Easy/Fair/Difficult
	Access to hospital services	Easy/Fair/Difficult
	Type of health services available	Mobile/clinic/door to door nurse/maternity clinic/midwife/hospital.
	Distance to above services	Hours/days/km etc.
	Proportion acutely malnourished	Proportion of children stunted for age
	Proportion chronically malnourished	Proportion of children underweight for age
	Incidence of diseases in children	Water related and others
	Proportion of income spent on health per month	
	Access to sanitation	Exclusive to the HH/Shared with other HHs/Community toilet/No toilet
	Type of sanitation	Water seal/Pit type/Temporary covering/Other
Security	Indicator	Details (qualitative/ quantitative data)
Personal security	See under Hazard assessment	
Resource access	See under provisioning services	
Security from disasters	See below	

Alternate livelihood strategy in case of disasters		Yes/No
Good social relations		
Social cohesion	Frequency of verbal exchanges	Greetings only/conversation/visits/attendance at family functions such as marriages.
Mutual respect		
Ability to help others		
	Existence of a community based organisation (CBO) to manage ecosystem use	Yes/No
	Membership in the CBO from different income groups	Yes/No
	Frequency of CBO meeting	Weekly/biweekly/monthly/quarterly
	CBO plan includes disaster risk reduction	Yes/No
Education	Years of formal education on average	
	Primary education	Number of children
	Secondary Education	
	Tertiary education	
ASSESSING DRIVERS OF CHANGE		
Direct drivers of change		
Over-exploitation	Prevalence	Magnitude
Harmful fishing practices Dynamiting Small mesh nets	Yes/No	High/Moderate/Low
Other (specify)	Yes/No	High/Moderate/Low
Spread of IAS		
IAS flora	Yes/No	High/Moderate/Low
IAS fauna	Yes/No	High/Moderate/Low
Habitat destruction		
Clear felling of habitats	Yes/No	High/Moderate/Low

Filling of wetlands	Yes/No	High/Moderate/Low
Land reclamation	Yes/No	High/Moderate/Low
Development – roads, infrastructure	Yes/No	High/Moderate/Low
Pollution	Area	
Solid waste	Yes/No	High/Moderate/Low
Water pollution	Yes/No	High/Moderate/Low
Diminished water quality	Foul smell	Yes/No
	Foaming	Yes/No
	Silting	Yes/No
Indirect drivers of change		
External drivers	Prevalence	Magnitude
Prawn farming	Yes/No	High/Moderate/Low
Agricultural fields	Yes/No	High/Moderate/Low
Industrial areas	Yes/No	High/Moderate/Low
Human habitations and population density	Yes/No	High/Moderate/Low
Vulnerability to natural hazards	Yes/No	High/Moderate/Low
Historical impacts from natural hazards	Yes/No	High/Moderate/Low
Other (specify)		
HAZARD ASSESSMENT INFORMATION		
		Magnitude
Kind of hazard		High/Moderate/Low
Frequency		
Location of hazard		
When does it occur		
Which sector of the community is most affected		
How many deaths?		
How many displacements?		
What used natural resource is affected most?	i.e, Fish, fuelwood	

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Mangrove restoration in Aceh, Indonesia (c) Elaine Slamet, UNDP

Annex I: Phase I Case Studies

The following two case studies summarise the findings and lessons learnt from Phase 1 of this project. Laemson National Park was selected in Thailand, and Kumana National Park in Sri Lanka.

Sri Lanka Case Study

Kumana National Park is located in Ampara District in the Eastern province of Sri Lanka and covers 18,196ha including 626ha of wetlands.

Biophysical and socio economic description of the park and environs

Date established	Established in 1938 as a sanctuary, upgraded to a National Park in 1970.
Extent	18,196ha including 626ha of wetlands.
Location/altitude	6^0 42' and 81^0 10'0N and 81^0 45'0E; 740588N and 518420E to 681687N and 582979E, 90 above mean sea level.
Mean temperature and average rainfall	27.3 ^{0}C and 1,300mm per year, but sharply seasonal.
Habitats	Semi-arid thorn scrub, mangroves, pristine riverine forest, villus,[8] estuary, a chain of brackish to saline lagoons.
Fauna	Many wetland birds, including many migrants, as well as mammals and reptiles, among others.
Flora	Dry zone and riverine species such as *Terminalia arjuna* as well as mangrove species.
Adjoining villages	Panama, situated 1km from the park boundary.
Population	One thousand three hundred and ninety five families and 5,900 people.
Livelihoods	Paddy cultivation is the main income generating activity (contributing to 70% of total income). There is a high resource (mangrove and lagoon) dependence for fisheries. Lagoon species caught include *Caranx* spp., *Liza* spp., *Lutjanus* spp., *Oreochromis* spp, *Penaeus* spp., *Macrobrachium rosenbergii*, *Scylla serrata*. Most of these are consumed and only high value species are sold. Hired labour, masonry and carpentry and livestock rearing are also livelihoods in this village.
Women's livelihoods	Fisheries related activities and assisting in cultivation, but also small scale activities such as weaving and thatching.
Tsunami impacts	Seventy small boats, 45 traditional crafts, 500 acres of rice paddy fields and crop lands (cashew, banana and other vegetables) were destroyed.
Income level	Most of the population lives below the poverty line of USD 1 per day; 90% receive government assistance.
Other amenities	One school, a pre-school, playground, hospital, telecommunication facilities, access to water and electricity. However, road infrastructure is very poor and the road is often inundated. The village is in a conflict area and also experiences floods every year. Under such circumstances, the community has little or no access to markets.
Literacy	97%.

[8] A natural lake or pond formed from water percolation to the surface and with no visible source of external drainage (Eisenberg & Lockhart, 1973)

Figure 8: Study area in Sri Lanka

Implementation

A number of interventions were undertaken during the project in order to:

1) Increase awareness and capacity regarding mangroves and mangrove restoration,
2) Restore selected mangrove areas, and
3) Carry out valuation of mangroves in the area.

A summary of the specific interventions is provided below.

1) Increasing awareness and capacity

The key awareness activities that were carried out at local and/or national level included:

- Stakeholder meetings with the Panama Abeysinghepura Small Fisheries Society, a local Community Based Organisation (CBO), which was identified as the most appropriate vehicle for enhancing local participation and for over seeing replanting activities.
- Three capacity building workshops on selecting the most appropriate mangrove species for replanting, establishing mangrove nurseries, how to physically replant, and after-care and monitoring.

Generally, the community seemed to have a good understanding of the provisioning services provided by mangroves, especially those dependent on fisheries resources from the lagoons. They also appreciated the protection provided by the mangroves during the tsunami, and reported of observations where the destruction in villages sheltered by mangroves was much less than their exposed neighbours.

2) Restoration activities

The major rehabilitation activities that were carried out at site level included:

- Establishing a nurserey were around 45,000 mangrove plants were raised by the CBO for replanting.
- Replanting about 20ha of mangroves with *Rhizophora mucronata* and *Avicennia marina* raised in the nursery.

Even though the replanted area only accounted for 10% of the tsunami affected mangrove area, strategic replanting and facilitation of natural regeneration, through removal of debris and sand deposits, was undertaken in an effort to secure the highest possible rehabilitation of mangrove cover.

Physical locations and targets for replanting were agreed upon by IUCN and the CBO but recruitment and management of labour (including women) was the sole responsibility of the CBO. Monitoring and financial resources were provided by IUCN.

3) Economic valuation study and results

Unlike the Thailand case study, the economic valuation exercise that was undertaken for Kumana National Park focussed only on the direct values provided by mangroves. However, additional research was undertaken to better understand the distribution of these direct values to different income categories.

The study was conducted in Panama village and involved household surveys and focus group discussions (FGDs). The total sample size was 141 households, which represented about 10% of all households in the village.

Direct mangrove values - products

Most of the products harvested from the mangroves in and around Kumana National Park are used for subsistence purposes including fish, shrimp, timber and wooden poles, herbs and vegetables and fuelwood. Table 3 below summarises the direct values derived from the valuation study.

Table 1: Total gross value of mangrove products

Village		**Panama**
	SLR	USD
Total gross mangrove products value for Panama/year	164,988,045	1,633,545
Total gross mangrove products value per household/year	119,438	1,171
Total gross mangrove products value per hectare/year	938,502	9,201

1 USD = 102 SLR

According to the valuation estimates, the annual direct use value of mangrove products per household is approximately SLR 120,000 (USD 1,171) which is significant compared to an estimated provincial average per household of 92,000[9] (USD 899). This demonstrates clearly the livelihood importance and economic benefits provided by mangroves to local communities.

The valuation study also revealed that mangroves generate more direct benefits, both in relative and absolute terms, to the poorest households in Panama Village – see Table 4.

[9] Household Income and Expenditure Survey 2002, Basic Information at District Level Department of Census and Statistics Sri Lanka. The estimates given in the bulletin are based on the survey conducted in the Eastern province during the six months September 2002 - February 2003.

Table 2: Total mangrove direct values to different income groups

Village	Panama	
	SLR	USD
Annual total gross mangrove products value for poor households	159,326	1,577.49
Annual total gross mangrove products value for medium households	144,576	1,431.45
Annual total gross mangrove products value for rich households	81,406	806.00

The poor and middle-income categories harvested mainly fish, timber and wooden poles as well as vegetables. The high-income category on the other hand depended mainly on high value products such as shrimp and crab.

Lessons learned and impacts

The main lessons learnt during implementation and received feedback for the engaged community are summarised below:

- Working through a local CBO like the Panama Abeysinghepura Small Fisheries Society has supported local empowerment and facilitated local ownership of project activities. The inhabitants of Panama village are now much more aware of their dependence on mangroves and have a better understanding of the benefits provided by Kunama National Park.
- As a positive spin-off, the community in Panama has managed to leverage their increased capacity in mangrove management to attract other projects and financial resources in support of community lead natural resource management activities as well as other capacity building initiatives. A gender sensitive micro finance system has been set-up with seed money provided by this project, and community members can now apply for short- or long-term loans of up to SLR 20,000 or Rs. 200,000 respectively. Interest rates vary between 2-5% per annum. To date more than half of the loans have been approved or given to women.
- Applying a holistic approach to natural resource management was well perceived by the community and thought to bring about successful results on the ground.
- The community felt that the valuation study provided important information on their dependence on mangroves, which would strengthen their future interaction with the management of Kunama National Park as well as being useful for justifying their increased involvement in ecosystem management.
- Based on the valued local benefits provided by mangroves, the study managed to demonstrate clearly the local incentives for supporting ecosystem conservation and sustainable use.
- Even though the shoreline protection value of the mangroves was not assessed directly, eyewitness accounts support the claim that intact mangrove ecosystems do in fact protect human lives and property from natural disasters such as tsunamis.

Community-based mangrove restoration in southern Sri Lanka (c) Vimukthi Weeratunge

Thailand Case Study

Laemson National Park borders the Andaman Sea in Ranong and Phang Nga provinces. As a result of the tsunami, an estimated 30 hectares of mangrove forest was lost. Laemson National Park is the 6th largest marine protected area in Thailand with as much as 85% of the area as open water.

Biophysical and socio-economic description of the Park and environs

Date established	Established on 19th August 1983.
Extent	60km of coastline and 15 islands, covering a total area of 315 $km^{2.}$
Location/altitude	9° 16′ – 9° 57′N and 98° 31′ – 98° 39′E, 0 – 630m.
Mean temperature and average rainfall	26-29°C and 3000 – 4000mm per annum.
Habitats	The principal terrestrial habitat is extensive mangrove forests (approximately half of the coastal area of the park is covered by mangroves, accounting for 14km^2).
Fauna	One hundred and thirty eight species, with 80 resident, 58 migrant birds as well as mammals and reptiles, among others.
Flora	Mangrove habitat: The landward side is dominated by *Rhizophora* and *Bruguiera* species especially; *R. mucronata, R. apiculata, B. gymnorrhiza, B. parviflora* and *B. cylindrica*. Also occurring are *Xylocarpus granatum, X. moluccensis* and *Acanthus ilicifolius*. The seaward side is dominated by the pioneer species *Sonneratia alba, Avicennia alba, Ceriops tagal*, A*canthus ilicifolius* and *A. volubilis*. Beach forest habitat: *Casuarina equisetifolia, Barringtonia asiatica, Terminalia catappa* and *Derris indica*.
Adjoining villages	Eight villages: Ban Bangman, Ban Naca, Kuan Sai Ngam, Bang Kluei Nok, Nah Pru, Fai Tah, Lem Now, Rai Nai.
Population	Two thousand six hundred and forty four people, 273 and 230 households in the two surveyed villages respectively; and a total of 5,445 people, 1,175 households in all eight villages.
Livelihoods	Fisheries, agriculture (rubber, cashew, coffee and fruit orchards) and general employment. Growing ecotourism.
Women's livelihoods	Fish processing.
Tsunami impacts	Thirty hectares of mangrove forest; 238 fishing boats and numerous aquaculture cages.
Income level	The Naca Tambon budget in 2005 was five million baht and in 2006 this had increased to 13.8 million baht. In 2005, local taxes accounted for 128,242 baht of revenues, with the majority of revenue being generated through various government allocations. Population below USD 1 per day is about 2%.
Other amenities	Five primary schools, two high schools and two day care centres. Approximately 95% of the population has access to water and sanitation.
Literacy	92%.

Figure 9: Study area in Thailand

Implementation

A number of interventions were undertaken during the project in order to:

1) Increase awareness and capacity regarding mangroves and mangrove restoration,
2) Restore selected mangrove areas, and
3) Carry out valuation of mangroves in the area.

A summary of the specific interventions is provided below.

1) Increasing awareness and capacity

Key awareness activities that were carried out at local and/or national levels included:

- Two meetings involving 112 community members from the Naca Tambon villages of Ban Pak Pak Triuma, Ban Bang Kluay Nok and Ban Bang Ben.

  The meetings aimed to raise local awareness on the ecological and livelihood importance of mangrove ecosystems, as well as to determine the local needs and expectations from undertaking mangrove restoration. Discussions on the protective, ecological and economic importance of intact mangrove systems were also held and the conservation activities implemented by the Department of National Parks in Laemson NP and their Joint Management of Protected Areas Initiative was presented, thereby increasing local understanding.

- Three roundtable discussions bringing together local communities and government planners and administrators from Ranong and Phang Nga Provinces.

  The discussions aimed to facilitate and stimulate interaction and sharing of information between different coastal stakeholders, and to develop a joint strategy for mangrove restoration under the project. Furthermore, the discussions facilitated the development of a coordinated approach to mangrove restoration, promoted cooperation between the different project partners, raised awareness on the importance and value of mangrove ecosystems, and facilitated progress in integrating ecosystem concerns into the post-tsunami reconstruction process and longer-term coastal planning and development.

- A training event on restoring ecosystems for National Park staff and local communities.
- Two information briefs on critical issues in coastal zone natural resource management.

  The briefs were prepared in response to requests made by government agencies and other partners working in coastal management. They summarise information on current restoration practices hereunder the clear felling of areas prior to re-planting, the diversity of species planted, the need for silvi-cultural practices in order to maintain diversity, and the future role of mangrove related institutions in subsequent management.
- A series of summary sheets presenting key data from five sites in which mangrove restoration was taking place in and around Laemson NP.

  The sheets provide a quick reference guide and information base for those engaged in, or planning to undertake mangrove restoration. At Laemson NP, a consortium of three institutional partners was identified to facilitate the development and implementation of mangrove restoration under this project. The partners were the Laemson National Park Authorities, Kasetsart University Ranong Coastal Research Institute, and the Department of Marine and Coastal Resources Mangrove Rehabilitation Station, Ranong. All partners were already working together in and around Laemson NP, and had the strengths of a pre-existing mandate to research and undertake ecosystem conservation activities in the locality, as well as a strong past experience in dealing with restoration and conservation topics.

2) Restoration activities

The major rehabilitation activities that were carried out at site level included:

- Establishing a beach nursery for raising 400,000 saplings of eight native mangrove species.
- Replanting five hectares of mangroves.

  Seedlings raised in the beach nursery were used for replanting, which covered the villages of Bang Kluay Nok, Tung Nang Dam, Cheme and Pak Triam. Selecting priority restoration sites in and around Laemson NP was based on achieving biodiversity improvement, creating a protective green belt, increasing local income-generation, and expanding the area of coastal forest.

3) Economic valuation study and results

A valuation study was undertaken to explore the role that mangrove ecosystems play in providing and sustaining livelihoods through the diverse ecosystem products and services generating in a post tsunami context. For this purpose, and given the limited time and resources available, the study relied on a rapid ecological-economic-livelihood assessment methodology to ascertain credible, practical and policy relevant information. Not all ecosystem services were assessed in quantitative terms, but evaluated based on visual observations and discussions with local communities.

The study was conducted in two villages – Ban Bang Man and Ban Naca in Ranong Province, which relied heavily on the products and services generated by the mangrove ecosystems.

Overall the rapid assessment sought to gain a better understanding of:

1. The direct values of different mangrove products (e.g. fish, crustaceans and molluscs).
2. The indirect values of mangrove ecosystem services (e.g. coastal protection and fish nursery).
3. How, overall, the economic and financial benefits of different mangrove products and services are distributed between different beneficiaries (e.g. local communities and regional/province economy).
4. What is the economic rationale for mangrove rehabilitation and sustainable management?

Direct mangrove values - products

Table 3: Total gross values of mangrove products

Village	Ban Naca		Ban Bangman	
	THB	USD	THB	USD
Total gross mangrove products value per village/year	25,643,041	64,1076	63,484,437	1,587,111
Total gross mangrove products value per household/year	377,736	9,443	577,101	14,428
Total gross mangrove products value per hectare/year	53,423	1,336	132,259	3,306

1 USD = 40 THB

As can be seen from Table 1 above, mangrove products like fish, molluscs and crustaceans provide local households with annual benefits in the order of USD 9,500-14,500. On a per hectare basis, the mangroves found in and around Laemson NP generate products every year worth between USD 1,336-3,306.

Around 60% of all mangrove products collected are sold in the market. The rest is harvested for subsistence purposes and hence, constitute a major source of local livelihood.

Indirect mangrove values - services

To ascertain the economic value of the mangrove ecosystem service of providing fish nurseries, the effect on production method was applied. Two hypothetical scenarios were developed where changes in mangrove status was associated with a certain negative decline in off-shore fish catch as a consequence of loss in fish nurseries. The negative impact on off-shore fish catch from fish nursery loss was assumed to have materialised fully after five years. A 2% annual increase in demand for fish products was also assumed.

The first scenario simply assumed no change in mangrove area and hence treats current off-shore fish catch as the baseline. Scenario two, on the other hand, assumed a 50% decrease of mangrove area resulting in a 30-60% reduction in off-shore fish catch. The assumed impact on off-shore fisheries was based on a review of the ecological literature and consultations with ecologists. Translating the effect on production into monetary terms revealed that the opportunity cost of reducing the mangrove area in the study site by 50% was between USD 995-1,975 per hectare/year for Ban Naca and between USD 2,462-4,887 per hectare/year for Ban Bangman. Stated differently, the mangrove ecosystem service of providing fish nurseries is worth between USD 995-4,887 per hectare/year for the surveyed villages.

The economic value of shoreline protection was, unfortunately, not calculated because of time and financial constraints, but visual observations and discussions with local communities pointed clearly towards the fact that the mangroves had buffered against the tsunami waves thereby reducing the loss of human lives, houses and infrastructure. As such, it would seem fair to assume that the indirect values of mangrove ecosystem services in the study area are substantially above the values associated with simply providing fish nurseries.

Relative contribution of mangrove products to the provincial economy – scaling up

Based on the findings by Balk et. al (2005) roughly about 2% of the provincial population lives within 1km of the coastline accounting for 9,574 people (roughly 2,100 households). In an effort to assess the relative size of the coastal economy compared to the province as a whole the assumption is made that the coastal population contributes on equal grounds as everyone else. As the provincial economy is recorded as 12,300 million THB (307.50 million USD), and as 2% of the provincial population are living in coastal areas, the coastal economy is calculated as 246 million THB (2% of the provincial economy).

In Table 2 below, the incremental contribution to the coastal economy from mangrove products harvested from the study site and sold is estimated.

Table 4: The contribution of Laemson National Park to the Coastal Economy

Province		Ranong
	THB	USD
Gross coastal economy - 2% of provincial economy	246,000,000	6,150,000
Population living within 1km of the coastline	9,574	9,574
Households living within 1km of the coastline	2,100	2,100
Per capita income in coastal area	25,695	642
Per household income in coastal area	117,143	2,929
Total income from selling mangrove products harvested by the two surveyed villages - assuming that 60% of all mangrove products collected are sold (see Table 1)	53,476,487	1,336,912
Percentage contribution to gross coastal economy	22%	22%

1 USD = 40 THB

As can be seen from Table 2 above, Laemson National Park contributes about 22% towards the coastal economy.

Lessons learned and impacts

The main lessons learnt during implementation of the above-summarised activities are presented below:

- Reviewing the impacts and feedback from the awareness raising and capacity building activities, it became clear that effective advocacy on conservation requires a holistic approach where participants are not just limited to conservation agencies and protected area authorities, but also include development sector planners and policy-makers. Catering to both conservation and development actors and using an applied approach, proved to be extremely valuable in placing mangrove conservation and sustainable use on post-tsunami reconstruction and coastal development agendas.
- Employing a participatory approach to restoration activities, in terms of involving local communities in establishing and running nurseries, as well as building their capacity in mangrove replanting and management, will provide longer-term community benefits.
- Engaging and working through Community Based Organisations (CBOs) and building their capacity in coastal ecosystem management has provided sustainability to restoration activities, which are expected to continue into the future beyond the immediate project lifetime.
- Developing and applying a rapid ecological-economic-livelihood assessment methodology where there is no compromise methodologically or technically is possible and beneficial. An integrated assessment can provide greater insight to decision-making by being practical and allowing greater technical insight through collaboration among specialists.
- Putting mangrove socio-economic values in practical terms also meant that the assessment contributed significantly to the growing debate and awareness on the economic value of mangrove ecosystems that, until recently, has been left out of coastal planning and development initiatives.
- Highlighting the importance of mangrove ecosystem services (e.g. coastal protection and fish nurseries) has strengthened the local interest in mangrove conservation and sustainable management. Overall, the assessment and restoration activities demonstrated the role ecosystem products and services played in different constituents of coastal well-being, namely the basic material for good life, security and good social relations.
- Viewing mangroves as an integral part of coastal ecosystem connectivity is vital, and rehabilitation and economic values of a particular ecosystem and its services cannot be seen in isolation. However, the focus on mangrove rehabilitation and valuation is an important start and pathway for broader awareness and integration of coastal ecosystem conservation and management.

- Acknowledging that while economic assessments are vital to raising awareness of the values of ecosystem products and services and the role these play in the well-being of coastal populations, still further work is needed on developing tools that help integrate these values into coastal planning and development (investment) processes. Ultimately, this will allow coastal decision-makers, planners and managers to assess the synergies and tradeoffs between development imperatives and environmental objectives.

Using *Nypa* palms, Thailand © IUCN/ Thailand

Annex II: An example of an ecosystem assessment for Sri Lanka

Mangroves

The extent of mangroves in the island was estimated at 6,080ha in year 2002, with the Batticaloa district harbouring the highest extent (1,638ha). About 40 species of flora have been recorded from mangroves, which includes 25 true mangrove species. Because the tidal amplitude of the island rarely exceeds 75cm, mangroves are restricted to narrow belts in inter-tidal areas of lagoons, estuaries, or associated islands and river outlets. A 50% reduction of mangrove cover has occurred during the past two decades in the island, as a result of encroachment and transformation into other land uses, such as shrimp culture, coastal agriculture, tourism and housing related constructions. Clearance for security reasons, change of water regimes (due to drainage of irrigation water) and bank erosion have also affected mangrove ecosystems. The Districts of Putlam, Mannar, Kilinochchi, and Jaffna have lost over 35% of mangrove cover during the past two decades. Aquaculture development projects alone have destroyed about 4,000ha of mangrove forest since 1989 (CCD 2004; Joseph 2004; http://www.wrm.org.uy/bulletin/29/SriLanka.html). The status of ecosystem services related to mangrove ecosystems in Sri Lanka is summarised in Table 1 below.

Table 1: A summary of the status of ecosystem services related to mangrove ecosystems in Sri Lanka

Service components	Status	Threats/Trends/ Changes	Indicators for monitoring	Information gaps
Provisioning services				
Fish production (finfish and shellfish)	Coastal fishery contributes to 64% of marine fish production in Sri Lanka (2003 statistics) (CCD,2004); coastal fish production in 2002 was 176,250t (Joseph, 2004); 112 edible fish species have been recorded from brackish waters of Sri Lanka (Pillai, 1965); the yield estimate of fish, crab, prawns and molluscs from mangroves range from 750-2500kg/ha/year (Amarasinghe, 1996).	Threats: Unsustainable fishing practices, over-harvesting, clearing mangroves for aquaculture and tourism infrastructure; changing water regimes (freshwater drainage). Trends: Increase in the number of active fishermen in coastal fishery; stagnant coastal fish production due to over-exploitation (Joseph, 2004); potential expansion of aquaculture in eastern and northern provinces.	Monthly catches of fish/site (kg); Monthly catches of crustaceans/site (kg).	Reliable estimates of the potential fish yield from mangrove forests.
Fruit (for handicrafts, herbal drinks)	Fruits of *Cerbera manghas* exported for handicraft trade; fruits of *Sonneratia caseolaris* used by local communities to prepare cordials and jams; yield of *Sonneratia* fruits estimated at 95,200 fruits/ha/year and the value of *Sonneratia* fruit yield estimated at 501 USD /ha/year (at Rs. 0.5/fruit) (Batagoda, 2003).	Threats: Clearing mangroves. Trends: Gradual expansion of industries related to use of *Sonneratia* fruits.	Number of fruits produced/tree/year; Number of fruits harvested/ha/year.	The value of handicrafts produced from *Cerbera* wood/year; The volume of *Cerbera* wood extracted for production of handicrafts/ha/year.

Primary production	The net above-ground productivity of riverine mangals at Kala oya estuary has been recorded to be approximately 1208g m^{-2} yr^{-1} while that of lagoon/ island fringing mangals in Puttalam lagoon to be nearly 694 g m^{-2} yr^{-1}) (Amarasinghe & Balasubramaniam, 1992).	Threats: Clearing mangroves.	Above ground productivity (gm^{-2} yr^{-1}).	Average above ground productivity of different mangrove species.
Nutrient cycling	The organic matter produced by mangrove supports coastal fishery production.	Threats: Clearing mangroves; siltation.	Amount of nitrate and phosphate in mangrove soil and water.	Information on nutrient recycling in mangroves.
Regulating services				
Protection from storms, tidal surges and tsunamis	Storm protection function of mangroves in Sri Lanka is estimated at USD 76.8/ha/year (Batagoda, 2003).	Threats/issues: Clearing and reclaiming mangroves.	Area (km^2) of managed landscapes protected from storms/tsunamis/ tidal surges.	Research findings related to efficiency of mangroves to withstand storms, tsunamis and tidal surges.
Flood control	Mangroves function as a sponge to absorb flood water.	Threats/issues: Clearing and reclaiming mangroves.	Area (km^2) of managed landscapes protected from floods.	Flood control value of mangroves in Sri Lanka.
Carbon sequestration	Carbon sequestration; benefits of mangroves in Sri Lanka is valued at USD 75.5/ha/year (at USD5/T of carbon) (Batagoda, 2003).	Threats: Clearing mangroves and over-harvesting of timber.	Total carbon fixed in T/ha/year.	Carbon fixation rate of mangrove species in Sri Lanka.
Pollution treatment/ control	Pollution treatment benefit of mangroves in Sri Lanka is estimated at USD 4,494/ha/year (Batagoda, 2003).	Threats: Clearing and reclaiming mangroves.	Amount of pollutant residues in water (ppm).	Amount of pollutants in water treated by mangrove ecosystems.

Cultural Services				
Recreational and aesthetic values	The foreign visitor recreational value of Ranweli mangrove estimated at USD 1196/ha/year (Batagoda, 2003); the local visitor recreational value of Maduganga mangrove estimated at USD 933/ha/year (Batagoda, 2003).	Threats/issues: Disturbances to fauna due to motor boats and over-visitation; user conflicts with traditional fishing practices (i.e., damage to kraals and fish traps by motor boats); garbage disposal. Trends: gradual increase in local visitors to mangroves; large-scale tourism development projects earmarked for coastal areas with mangrove (could lead to further clearance).	Number of foreign visitors per site per month; Number of local visitors/site/month.	Visitation rates/figures.
Educational and Research	School and university students visit mangroves for educational purposes.	Threats/Issues: Lack of access/infrastructure to study mangroves Trends: Gradual increase in students visiting specific mangrove sites due to increase access and educational facilities (i.e., visitor centres).	Number of students visiting a mangrove/ year; number of research projects carried out on mangrove ecosystems/ year.	Students visitation rates; types of research projects carried out on mangrove ecosystems/ year.
Sustenance of traditional knowledge	Production of traditional handicrafts (i.e., masks and mats); mangroves used in traditional medicine.	Threat/issues: Gradual loss of traditional knowledge.	Number of people involved in production of traditional handicrafts.	Number of people who possess traditional knowledge on production of handicrafts using mangrove wood.

Analysing relationships and trade-offs among mangrove ecosystem services in Sri Lanka

Sustenance of biodiversity in mangroves, which is a major supporting service of this coastal ecosystem, has a governing effect on all other ecosystem service types. It has a positive influence on all provisioning services, other supporting services, regulating services and cultural services. Large scale clearance and transformation of mangrove for expansion of aquaculture, coastal tourism and human settlements over the last two decades has resulted in adverse impacts on most ecosystem services offered by this coastal ecosystem. The transformation of mangrove ecosystems into aquaculture systems in order increase shrimp production has led to drastic reductions in other ecosystem services such as the production of a variety of fish species which benefited local fishers, quantitative reduction of other natural resources produced, drastic loss of mangrove biodiversity, reduction of important regulating services such as nutrient recycling (leading to eutrophication of lagoons) and carbon sequestration, and a loss of recreational aesthetic values, affecting tourism potential. Loss of mangrove biodiversity due to aquaculture expansion may have resulted in a loss of natural resilience of this ecosystem towards disease outbreaks, which ultimately affected the aquaculture industry in the late 1990's, when it suffered a collapse due to a disease outbreak in the north-western coastal areas of Sri Lanka.

Considering the current development trends in Sri Lanka, three plausible future scenarios can be considered for the coastal zone of Sri Lanka; 1) further expansion of aquaculture, 2) expansion of coastal tourism development zones (in Puttalam District, Coastal areas of Southern province and Eastern provinces) and 3) sustainable management of the coastal zone. Predictions of changes in future delivery and demand for ecosystem services related to mangroves in the coastal zone of Sri Lanka over the next 10-20 years show contrasting outcomes of the three proposed scenarios (see Table 11 on the opposite page). Further expansion of aquaculture is envisaged in coastal areas of the southern eastern and northern provinces of Sri Lanka. This will contribute to a wide gap between a reduced delivery of ecosystem services and an increased demand for many of those services. Demand for supporting services such as nutrient recycling and regulating services, such as bio-regulation (disease control) and pollution treatment/control, is likely to increase because sustenance of aquaculture relies these services. The tourism development zones identified for coastal areas in the north-western, southern and eastern regions in Sri Lanka may involve a moderate to low reduction in the delivery of ecosystem services (due to transformation of some mangrove areas for tourism infrastructure), and a considerable increase in the demand for some ecosystem services such as biodiversity, coastal protection, flood control and recreational/aesthetic aspects, leading to a moderate gap between delivery and demand of ecosystem services. The Coast Conservation Department of Sri Lanka has prepared Special Area Management Plans for several mangrove ecosystems in the island. Under the sustainable management of mangroves scenario, the gaps between the delivery and demand for mangrove related ecosystem services are expected to be minimal. The maintenance of biodiversity within an integrated mangrove and other inter-connected coastal ecosystems management framework may ensure the delivery of most provisioning, supporting, regulating and cultural services.

Prawn fishing in Negombo lagoon, Sri Lanka (c) Vimukthi Weeratunge

Table 2: Expected delivery and demand of ecosystem services from mangrove ecosystems in Sri Lanka for three alternative future scenarios
(Note: directions of arrow heads indicate increase or decrease; arrow width specifies the intensity of such a process)

EcosystemService	Expansion of Aquaculture		Tourism development		Sustainable Management	
	Delivery	Demand	Delivery	Demand	Delivery	Demand
Fish production	↗	–	→	↗	↗	↗
Fruit production	→	–	→	↗	↗	↗
Timber (for household use and handicrafts)	→	–	→	↗	↗	↗
Fuelwood	→	↗	→	↗	↗	↗
Vegetable production	→	↗	→	↗	↗	↗
Biodiversity	↗	–	→	↗	↗	↗
Primary production	↗	–	→	–	↗	↗
Nutrient cycling	↗	↗	→	–	↗	↗
Protection from storms, tidal surges, tsunamis	↗	↗	→	↗	↗	↗
Flood control	→	–	→	↗	↗	↗
Carbon sequestration	↗	–	↗	↗	↗	↗
Pollution treatment/control	↗	↗	→	↗	↗	↗
Recreational and aesthetic values	↗	–	→	↗	↗	↗
Educational and Research	→	–	–	–	↗	↗
Sustenance of traditional knowledge	↗	–	–	↗	↗	↗

Sprats © Sriyanie Miththapala

Lagoons and Estuaries

The total extent of brackish water lagoons and estuaries scattered around Sri Lanka is estimated at 128,000ha. These ecosystems encompass mangroves, sea grass beds, salt marshes and mudflats. Overall, there are 45 estuaries, including 28 riverine types and 17 basin types. There are around 89 lagoons ranging from 3ha to 7,589ha in extent. Many of the lagoons and estuaries and the biodiversity they contain are affected mainly by pollution, eutrophication, siltation, salinity changes, encroachment, spread of invasive alien species and over-harvesting of resources (Joseph, 2004).

Table 3: A summary of the status of ecosystem services related to lagoons and estuaries in Sri Lanka

Service components	Status	Threats/Trends/ Changes	Indicators for monitoring	Information gaps
Provisioning services				
Edible fish production (finfish and shellfish).	Coastal fishery contributes to 64% of marine fish production in Sri Lanka (2003 statistics); coastal fish production in 2002 was 176,250t (Joseph, 2004).	Threats: Unsustainable fishing practices, over-harvesting – increased fishing effort in some lagoons, clearance of mangrove, and change of water regimes (freshwater drainage), pollution and eutrophication. Trends: Increase in number of active fishermen in coastal fishery; stagnant coastal fish production due to over exploitation (Joseph, 2004).	Monthly catches of fish/site (kg); Monthly catches of crustaceans/site (kg).	Reliable estimates of the potential yield from coastal fishery.
Aquarium fish production	Several fish are collected from brackish waters.	Threats: Overexploitation.	Volume of brackish water fish collected from specific localities; volume of fish species exported/month.	Data on wild collections.
Edible plant production	The seaweed, *Gracilaria edulis* is collected in boat-loads from seagrass meadows in Puttalam lagoon. This is dried and sold to traders/ exporters in Colombo.	Threats: Unsustainable fishing practices (drag nets and push nets) causes extensive damage to sea grass beds.	Weight of edible plants collected/month.	Exploitation levels.
Edible sea cucumber	Approximately 40 million tons of dried sea cucumber have been exported in 1993 (Amarasinghe *et al.* 2003)	Threats: Overexploitation, leading to population reduction of some sea cucumber species (i.e., *Holothuria scabra* in Puttalam lagoon) (Joseph & Moiadeen, 1990).	Weight of sea cucumber collected/ month.	Monthly exploitation levels.

Supporting services				
Biodiversity	Angiosperm Flora – 40 species, and many seagrasses (Joseph, 2004); 112 edible fish species have been recorded from brackish waters of Sri Lanka (Pillai, 1965); Maduganga mangrove: 248 vertebrate species (70 fish, 12 amphibians, 31 reptiles, 124 birds, 24 mammals) (Bambaradeniya et al. 2002).	Threats: Loss of mangrove areas (reclamation and transformation into other land uses); by-catch related to harmful fishing gear (many species of finfish and shellfish with no commercial value are discarded)[7]; pollution related to discharge of untreated industrial effluents, sewage and domestic waste. Trends: Drastic reduction of populations of some plants (Two of which are nationally threatened).	Species richness of birds; species richness of herpetofauna; species richness of fish; species richness of molluscs and crabs.	Quantitative data on biodiversity loss related to harmful exploitation.
Primary production	The seagrass meadows in lagoons and estuaries contribute to a high primary productivity.	Threats: Loss of seagrass meadows beds due to siltation and harmful fishing practices.	Primary productivity in lagoon sea seagrass meadows.	Primary productivity in seagrass meadows.
Nutrient cycling	The organic matter produced in lagoons supports coastal fishery production.	Threats: Increased nutrient loading through agricultural run-off, sewage, causing eutrophication.	Amount of dissolved organic matter in lagoons/estuaries.	Production rates of dissolved organic matter.
Regulating services				
Flood control	Lagoons and estuaries absorb flood water.	Trends: Reduction of water holding capacity due to reclamation; siltation and spread of invasive alien plants.	Water storage capacity.	Floodwater retention capacity of lagoons and estuaries.
Cultural services				
Traditional fishing practices	Kraal fishery, brush-pile fishery and conventional fish traps practised in lagoons and estuaries.	Threats/issues: Recreation activities - operation of motor boats carrying tourists damage kraals and brush-piles.	Number of traditional traps/site; volume of fish catch/traditional trap.	Fish catches using traditional methods.

Salt marshes (including tidal/mud flats)

There are around 23,797ha of salt marshes in the country, which are integrated mostly with lagoons, and some estuaries. The conditions under which salt marshes occur vary, but more often they are found close to the landward margin of the inter-tidal zone where the soil salinity is relatively high due to insufficient freshwater runoff to flush out the accumulated salts. In many instances, salt marshes are inter-connected with patches of mangrove and vast areas of maritime grasslands, which serve as grazing lands of livestock raised on coastal areas (e.g., in Puttalam and and Hambanthota districts). Extensive salt marshes occur in the Mannar area in the coastal belt from Mantai to Vankalai, while patchy salt marshes occur associated mainly with lagoons in areas such as Hambantota, Puttalam, Kalpitiya and Mundel (Joseph, 2004; Bambaradeniya et al., 2005). Loss of salt marshes has occurred due to conversions into other land uses, including saltpans (i.e., Hambantota and Palavi areas), shrimp culture ponds (i.e., in Puttalam area) and reclamation for housing and industries (i.e., Muthurajawela area). The present estimates of salt marshes in the country show a 20% reduction over a period of two decades, with over 85% reduction in the Puttalam district (CCD, 2004).

Table 4: A summary of the status of ecosystem services related to salt marsh ecosystems in Sri Lanka

Service components	Status	Threats/Trends/ Changes	Indicators for monitoring	Information gaps
Provisioning services				
Animal fodder	Maritime pastures associated with salt marshes function as grazing areas for livestock.	Threat/issues: Loss/ transformation of salt marshes and maritime pastures into other land-use types; over-grazing.	Number of livestock grazing/ha.	Volume of fodder produced/ha.
Salt production	Saltpans in Jaffna, Puttalam and Hambanthota Districts caters to national salt demand.	Threats/issues: Pollutants entering salt marshes and lagoons; discharge of sludge into lagoons effects lagoon organisms.	Yield (t)/annum/site.	Potential yields.
Fish fry (for aquaculture)	Salt marshes with algae form the habitat for the juveniles of a number of fish and shellfish, particularly *Chanos chanos*, fry of which are collected in large numbers for pond aquaculture.	Threats/issues: Over-exploitation.	Density of fish fry.	Volume of fish fry harvest for aquaculture.
Supporting services				
Biodiversity	Feeding habitat of native and migratory wading birds (about 100 species); mainly on tidal flats and containing about 56 species of marsh vegetation).	Threats: Reclamation and transformation into other land uses; Spread of invasive alien plants (i.e., *Prosopis* and *Opuntia*). Trends: 20% reduction in extent during past 2 decades (CCD, 2004)	Species richness of wading birds.	

Primary production	Algal mats called '*lab lab*', dominated by nitrogen fixing filamentous cynobacteria such as *Lyngbia sp*. exists on the soil surface. During high tide, when the marsh gets inundated, these algal mats contribute to enhance oxygen in marsh waters.	Threats: Loss of salt marshes due to reclamation/ transformation.	Primary production rates.	Primary production rates of salt marshes.
Regulating services				
Flood control	Salt marshes enhance the water storage capacity of lagoons and mangroves.	Threats/issues: Reclamation of salt marshes.	Water storage capacity; floodwater retention period.	Water storage capacity; floodwater retention period.

Barrier beaches, spits and dunes

The island has wide and sandy beaches along much of its 1620km coastline. Beaches have been formed by accumulation of sediment deposited on the shore. The beaches sustain two distinct vegetation types; gentle sea-shore vegetation dominated by runners and creepers, and beach shrubland towards the landward side. These vegetation types contribute to stabilize beaches and prevent shoreline erosion. Among the different types of beaches, barrier beaches, spits and dunes are delicate and vulnerable formations that are subjected to temporal and spatial changes. Barrier beaches are accumulations of unconsolidated sediments transported ashore by waves and moulded into a form that lies across a body of water, isolating it from the sea. Typical examples include the beaches at Rekawa and Panama on the southeast coast, Kogoda, Weligama Bay and between Bentota and Balapitiya on the southwest coast, between Dondra and Ambalantota, Thambalagam Bay and Karativu (Joseph, 2004).

Spits are incipient barrier beaches that project from the shore in the direction of the dominant drift and are free at one end. Examples are the shoal that builds seasonally at the mouth of the Negombo estuary and the sand spit at the Kalu Ganga estuary. Most spits appear to be unstable, especially those which protrude into estuaries. Consequently, they shift position from time to time, causing changes in the form and precise location of the inlets of estuaries (Kalu Ganga and Batticaloa estuary). The most commercially important spit is in Pulmoddai, north of Trincomalee at the outlet of Kokkilai estuary. The Ilmenite rich deposits that constitute this spit are mined on a large scale but are replenished annually from terrestrial sources during the northeast monsoons (Joseph, 2004).

Dunes are wind blown accumulations of sand which are distinctive from adjacent land forms such as beaches and tidal flats mainly due to the fact that dunes do not get the effect of tides. These dunes usually occur as parallel rows with increasing size, height, stability and complexity from the sea shore to the inland. A series of plant assemblages representing different phases of dune succession can be observed. Young mobile dunes are occupied by herbaceous plant species (up to 25cm). The accumulation of organic debris and humus increase the water holding capacity and improve the soil fertility, favouring further luxuriant growth of vegetation cover. The more stabilized older dunes occurring away from the sea are characterised by a more complex woody vegetation. The most prominent sand dunes lie along the north-eastern, north-western and south-eastern coasts of Sri Lanka, between Mullaittivu and Point Pedro, Elephant Pass and Chavakachcheri across Mannar Island, Ambakandawila and Kalpitiya, and from Ambalantota (Godawaya) in the Hambantota district to Sangamankande Point in the Ampara district. Beaches, spits and dunes in the island are adversely affected by over-exploitation of sand and other mineral resources (Joseph, 2004; Bambaradeniya et al., 2005).

Table 5: A summary of the status of ecosystem services related to barrier beaches, spits and dune ecosystems in Sri Lanka

Service components	Status	Threats/Trends/ Changes	Indicators for monitoring	Information gaps
Provisioning services				
Sand and other minerals	Large-scale mining of Ilmenite in Pulmoddai; beach sand mining in east coast estimated at 500-1000m^3/km/year (CCD, 2004); from Puttalam to Dondra, nearly 150,000m^3 of sea sand was removed in 1991 (UNEP, 2001).	Threats: Over-exploitation.	Volume of sand mined/annum.	
Supporting services				
Biodiversity	Nesting habitat of five species of globally endangered turtles; 124 plant species recorded in sand dunes of Yala (De Silva & Premachandra,1998).	Threats: Spread of invasive alien plants (*Opuntia dillennii*) leading to loss of turtle nesting habitats in southern Sri Lanka; modification of habitats due to coastal protection structures; transformation into coastal agricultural land (coconut, onion, chilli etc.)	Density of turtle nests/km	
Regulating services				
Prevention of coastal erosion	Land loss through coastal erosion estimated at 200,000-300,000m^2 a year in 685 km long western, south-western, and southern coastal stretches (CCD, 2004)	Threats: Reduction of sand supply from rivers due to inland dams (a 10 fold reduction in Walawe river and five fold reduction in Gal oya) (CCD,2004).	Area subjected to erosion/ annum.	
Protection from storms and tidal surges	Intact sand dunes were the most effective barrier against tsunami waves that affected the coastal zone of Sri Lanka in 2004 (Bambaradeniya *et al.,* 2006).	Threats: Exploitation/ removal of sand dunes for tourism and fisheries related infrastructure; loss of coastal vegetation.	Area protected from storms and tidal surges.	

Cultural services				
Coastal recreation and tourism (local and foreign visitors attracted to sand beaches)	Seventy percent of all hotels registered with Sri Lanka Tourist Board located in the coastal zone (CCD, 2004).	Threats and issues: unplanned expansion of tourism infrastructure, leading to pollution of beaches and degradation of scenic sites; coastal erosion (average coastal erosion rate estimated at 0.5m/year) (CCD, 2004); extraction of sand; modification of beach habitats due to coastal protection structures (groynes, revetments etc.); squatter settlements.	Number of local visitors to beach areas/month; number of foreign visitors to coastal hotels and guest houses/month.	Information related to visitation (local/foreign).
Traditional fishing practices	Stilt fishery (in south-western coast) and beach seine fishery.	Threats/issues: User conflicts – lack of access to beach areas for traditional fisherfolk (i.e., fishermen involved in beach seine fishery); loss of beach area due to coastal erosion and construction of coastal protection structures (revetments etc.).	Number of fishermen involved in traditional fishing practices dependant on beach habitats.	Number of fishermen involved in traditional fishing practices dependant on beach habitats.

Coral reefs

Coral reefs consist of calcareous structures secreted by a group of marine invertebrates. Extensive coral reef habitats occur in the Gulf of Mannar region, Trincomalee to Kalmunai in the east coast and in several areas of the south and south-western coast, including Rumassala and Hikkaduwa. About 2% of the coastline in Sri Lanka consists of fringing reefs.

Coral reef © Jerker Tamelander

Table 6: A summary of the status of ecosystem services related to coral reef ecosystems in Sri Lanka

Service components	Status	Threats/Trends/ Changes	Indicators for monitoring	Information gaps
Provisioning services				
Lime	Large-scale mining of coral (from inland deposits and near-shore reefs) – coral provides about 90% of lime needed for the construction industry (UNEP, 2001).	Threats: Overexploitation.	Volume of coral mined/month.	
Food fish	Nearly 50% of marine fish species caught in Sri Lanka are directly dependant on the reef ecosystem for their survival (Ohman et al., 1993); reef fish production yields an average annual catch of around 10,000 tons, which constitutes about 72% of total marine fish production. The spiny lobster harvest in 1994 was 1,000 tons (National Aquatic Resources Research and Development Agency, 1998).	Threats: coral mining, harmful fishing practices (i.e., blast fishing, moxy nets).	Yield of different fish species harvested/ month.	
Aquarium fish	In 1998, 40-50% of foreign revenue from ornamental fish exports was from reef fish (*circa* 3 million USD) (Rajasuriya et al., 2000).	Threats/issues: Overexploitation using harmful collection practices; large-scale mortality during transport.	Volume of different reef fish collected/ month.	
Curios/ornaments	Mollusc shells and corals are used as ornamental curios/ production of handicrafts.	Threats/Issues: Over harvesting.	Volume of curious collected for production of handicrafts.	Income generated through the sale of coral related curios.
Supporting services				
Biodiversity	One hundred and eighty three species of stony corals are recorded from reefs around Sri Lanka; more than 300 reef and reef associated fish species have been identified from the Bar Reef Marine Sanctuary (Rajasuriya et al., 1995).	Threats: Coral bleaching (ranged from 90-100% in coral reefs in western Sri Lanka in late 1990's); coral mining; spread of invasive species (i.e., *Acanthaster planci*); over exploitation of reef fish for ornamental industry; sedimentation' damage to reefs by boats; visitor pressure (treading on live corals).	Live coral cover; species richness of reef fish.	

Regulating services				
Prevention of coastal erosion	Coral reefs dissipate the energy of waves and currents.	Threats/issues: coral mining (including mining of inland deposits).		
Protection from storms and tidal surges		Threats/issues: coral mining (including mining of inland deposits).	Area of land protected by coral reefs.	
Carbon sequestration		Threats/issues: Coral mining; siltation.	Carbon sequestration rates; amount of carbon fixed by coral reefs/annum.	Carbon sequestration rates; amount of carbon fixed by coral reefs/ annum.
Cultural services				
Recreation/ tourism (snorkelling, diving etc.)	Sites such as Rumassala, Polhena, Unawatuna and Hikkaduwa attract divers.	Threats/issues: coral mining; coral bleaching; damage to coral caused by boats carrying visitors.	Number of visitors involved in snorkelling/diving / site/ month.	Visitor numbers/ month.

Seagrass meadows

Seagrass meadows are composed of rooted, seed-bearing marine plants. These occur in shallow, sheltered marine waters, as well as in lagoons and estuaries. Most extensive seagrass meadows occur in the northwest coastal waters of Sri Lanka (e.g. Kalpitiya to Mannar). The proximity of seagrass meadows to other critical habitats, such as coral reefs, mangrove and salt marshes, promote trophic transfers and cross-habitat utilisation by fish and other invertebrates. Seagrass meadows could be used as important indicators of coastal environmental issues. Seagrass meadows in many areas have been adversely affected by harmful fishing practices and siltation related to land-based activities.

Table 7: A summary of the status of ecosystem services related to seagrass bed ecosystems in Sri Lanka

Service components	Status	Threats/Trends/ Changes	Indicators for monitoring	Information gaps
Provisioning services				
Edible fish production	Important nurseries of juvenile fish.	Threats/issues: Damage related to detrimental fishing practices; siltation.	Yield of fish harvested/month.	
Broodstock feed	Polychaete worms are harvested from seagrass meadows as broodstock feed in aquaculture.	Threats/issue: Over-harvesting of polychaete worms.	Density of polychaete worms in seagrass meadows.	Density of polychaete worms in seagrass meadows.
Aquarium fish production	Sea horses are collected from seagrass meadows in Puttalam lagoon.	Threats/issues: Over-exploitation, harmful collection practices.	Volume of aquarium fish collected from seagrass meadows/month.	Volume of aquarium fish collected from seagrass meadows/month.
Supporting services				
Biodiversity	Feeding habitat of globally endangered marine turtles and marine mammals (i.e., dugong); promote trophic transfers and cross-habitat utilisation.	Threats: Harmful fishing practices; over-harvesting of polychaetes as broodstock feed for shrimp hatcheries.	Population of dugongs and marine turtles visiting seagrass meadows.	Population of dugongs and marine turtles that are dependant on seagrass meadows as feeding sites.

Primary production	Seagrasses and associated algae have high primary productivity	Threats/issues: Damage related to detrimental fishing practices; siltation and turbidity; eutrophication and algal blooms that reduce light penetration.	Productivity of seagrass meadows; area of live/healthy seagrass meadows.	
Nutrient cycling and sediment stabilization	The organic matter produced supports coastal fishery production; High biomass sea grass meadows trap sediments and nutrient	Threats/issues: Damage related to detrimental fishing practices; siltation.	Amount of dissolved organic matter.	
Regulating services				
Carbon sequestration	The excess organic carbon produced is buried within seagrass sediments, which are hotspots for carbon sequestration.	Threats/issues: Damage related to detrimental fishing practices; siltation.	Amount of stored carbon in seagrass sediments.	Amount of stored carbon in seagrass sediments.

Sea grass bed © Jerker Tamelander

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