



Seagrasses and Sand Dunes

Coastal Ecosystems Series (Volume 3)

Sriyanie Miththapala



Ecosystems and Livelihoods Group Asia, IUCN



Bundesministerium
für Umwelt, Naturschutz
und Reaktorsicherheit



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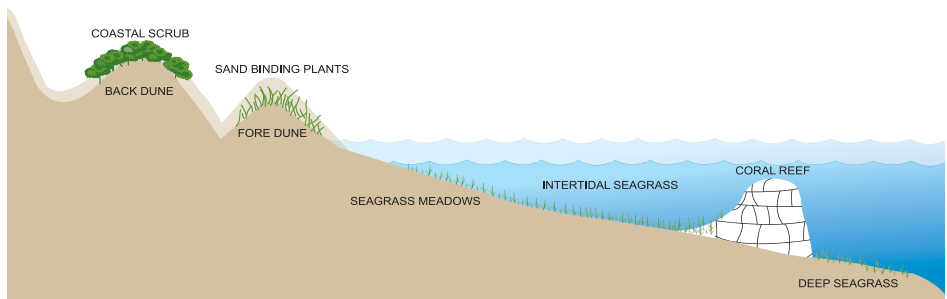
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In the recent past, after the Indian ocean tsunami of 2004, much attention has been paid to mangrove ecosystems because their value of shoreline protection was highlighted in the aftermath. Coral reefs, with their colourful residents and their easy access to divers and snorkellers, also receive their fair share of publicity.

Lesser known coastal ecosystems are seagrass meadows and sand dunes that are located landward from coral reefs and sometimes seaward from mangroves. (At other times mangroves lie between seagrasses and sand dunes.) These ecosystems are also important for coastal communities in the services that they provide and are critical components of a vital, interdependent and interconnected series of coastal ecosystems (Kallesøe et al., 2008).

Along coastlines, mangroves, coral reefs, seagrasses and sand dunes are often found together and form a mosaic of micro-organism, algal, fungal, floral and faunal communities. Each of these form integral parts of interdependent coastal ecosystems (Kallesøe et al., 2008).



Source: Adapted from Short et al., 2007

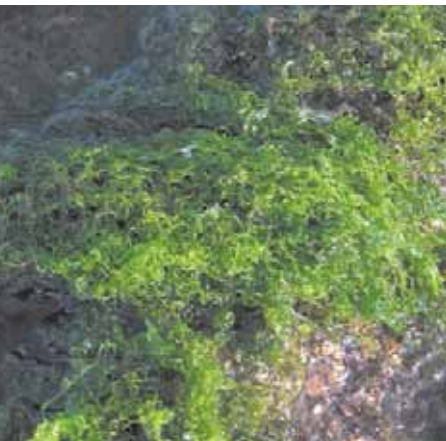




What are seagrasses?

Seagrasses are seed-bearing, flowering, rooted plants, which grow submerged, exclusively in marine coastal waters and coastal wetlands. There are only about 60 species of seagrasses (Phillips & Menez, 1988). The actual number of species is being reviewed currently (Spalding et al., 2003). Like grasses in terrestrial habitats, they form meadows on the bed of coastal seas. They are dependent on light penetration for photosynthesis, therefore they generally grow only in clear, shallow waters, in estuaries and coastal seas. They cannot survive out of water, therefore they often grow where there is shelter from a sand bar or coral reefs.

Seagrasses should not be confused with seaweeds. Multi-cellular green and brown algae – also found in marine environments - are usually called seaweed or kelp (see picture at bottom left). Although they can photosynthesise and make their own food, seaweeds lack complex specialised cellular tissues for transport of food and water that are found in seagrasses. They also lack flowers and fruits - structures that are specialised for reproduction - as well as roots. (Instead, algae anchor to the substrate by holdfasts¹.)



¹ A holdfast is a root-like structure that anchors aquatic, non-moving organisms to the substrate.

What are sand dunes?

Soil washes from inland rivers and finds its way to the sea. When this happens, soil layers – for example, humus, clay and sand – separate. Sand deposits on beaches, while clay, which is heavier, reaches open oceans.

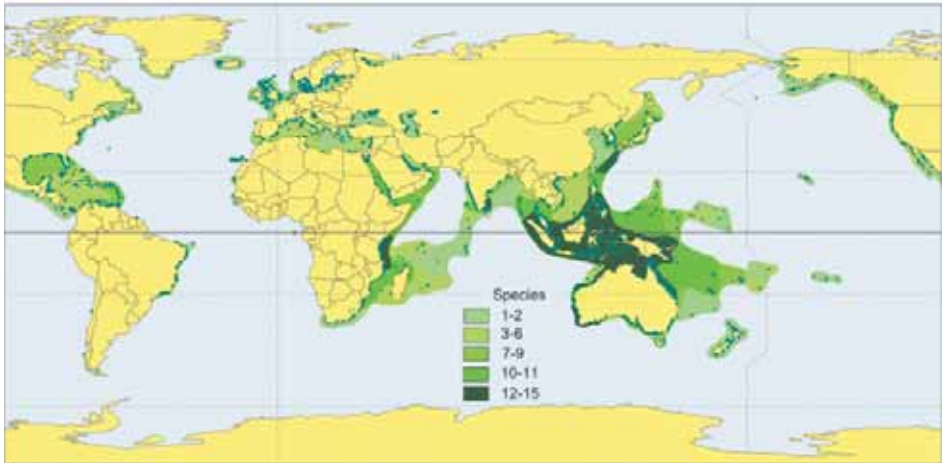
This deposited layer of sand is shifted constantly by wind and waves. Waves wash sand onto the beach. At low tide, this sand dries and the finest fraction of sand is blown further landward by winds, and can not now be reached by normal waves. The wind keeps pushing this sand landwards in a motion like a sheet moving. The moment the sand reaches the side away from the wind, it settles and forms sand dunes. Some of this sand collects behind rocks or clumps of seaweed. Here, the roots and underground parts of grasses and other vegetation trap the sand from being blown away. The wind then starts eroding sand particles from the windward side and depositing them on the side protected from the wind. Gradually, this action causes the dune to move inland, accumulating more and more sand as it does so. Subsequently, more vegetation grows on these dunes (Hesp, 2000).



Where are seagrasses found in the world?

Seagrasses are found in clear, shallow coastal waters of every continent except Antarctica. In tropical oceans, they are nearly always found near mangroves and coral reefs. In temperate areas, they are found near salt marshes and kelp forests (Bjork et al., 2008).

They survive in inter-tidal areas in sites sheltered from wave action or where water is trapped at low tide (Hemminga & Duarte, 2008).



Source: Short et al., 2007

About half the world's seagrass species are tropical, while the other half is temperate (Bjork et al., 2008). The Indo-Pacific region is the centre of seagrass diversity of the world, with 24 species and large underwater meadows (Short et al., 2007).

Sixteen species of seagrasses have been recorded from the Philippines, 13 from Papua New Guinea and 16 from northern Australia (Short et al., 2007).

Where are sand dunes found in the world?

Sand dunes form in intertidal zones of coastal beaches, where there is enough sand and adequate wind. Sand dunes range in size from ridges less than 1m in height and width, to massive dune fields that extend inland for many kilometres (Hesp, 2000).

They are found worldwide but are less developed in tropical and subtropical zones (where wind velocities are lower and the soil is damper) (Packham & Willis, 1997).

Special adaptations of seagrasses

Seagrasses are the only flowering plants that have adapted to a completely submerged life in the sea (Orth et al., 2006). Because of this, they have some special adaptations.

Adaptations to withstand wave energy

Underground plant parts such as rhizomes² and roots are extensive and close to each other, providing anchorage in many places to these plants (Dawes, 1981).

In addition, leaves of seagrasses are usually flat, ribbon-shaped and flexible; the stems are also flexible (as seen in *Enhalus*, *Thalassia* and *Cymodocea* spp.). Because of this, the force of waves does not break the leaves. Instead, the leaves bend with the water.

Adaptations to growing when completely submerged

1) Sub-marine pollination

All except one group of seagrasses are pollinated in sub-marine conditions (Orth et al., 2006). Male and female parts of flowers extend well above the petals and so allow for easy movement of pollen in the water. Pollen grains are oval-shaped or joined together to become elongated and so move easily in the water (as seen in *Halophila* spp.) (UNEP-WCMC, 2003; <http://hypnea.botany.uwc.ac.za/marbot/seagrasses/seagrass-adaptations4.htm>).



² A rhizome is an underground stem that stores food and grows horizontally.



Further, as flowers are either male or female, cross pollination is favoured (Les et al., 1997). Some species have single sex plants, increasing this cross pollination (Bjork et al., 2008).

Seagrasses also reproduce asexually. They produce new shoots from underground roots and rhizomes as they spread across the sea floor. This produces new units (Short et al., 2007). Remarkably, seagrasses can grow asexually for thousands of years, extending over many hectares (Bjork et al., 2008).

Air-filled tissue

Seagrasses have extensive air-filled tissues called *lacunae*, which contain oxygen that is needed for the life activities of these submerged plants. These lacunae also help in flotation of the leaves. The leaves have a very thin cuticle or outer layer. Gas exchange with the environment is facilitated by this thin cuticle and by the air-filled tissue.

Salt tolerance

Compared to land plants, seagrasses can tolerate high salt concentrations found in oceans - up to 36 parts per thousand (Short, personal communication).

Growth

Seagrasses grow underwater rooted to the sea floor. The underground rhizomes and roots are in black sediments with no oxygen and therefore, need for their survival, sugars and oxygen produced during photosynthesis in the above-ground parts. Thus, seagrasses need more sunlight than algae, which do not have underground parts. This limits the depth to which seagrasses can grow (Orth et al., 2006, Short, personal communication). They need more than 10% of the light falling at the water surface compared to algae, which only need 1% (Bjork et al., 2008).



Special adaptations of sand dune vegetation

Sand dune plants grow in areas where the temperature is high and the winds and waves are strong. This leads to lack of firm anchorage, drying up of plant tissue and breakage (Packham & Willis, 1997). These plants have developed specialised adaptations which help them cope with these problems.

Adaptations to growing with strong winds and waves, as well as without proper anchorage

In addition to the strong winds and waves in this environment, the sand is loose and porous – constantly shifting the substrate. Therefore, plants closest to the sea have roots and shoots that grow sideways and hug the ground. These roots and shoots form a dense mat on the surface as seen in Goat's Foot (*Ipomoea pes-caprae*) and Spinifex (*Spinifex littoreus*). Further inland, where dunes are more stable, plants grow more upright.

Adaptations that prevent desiccation

On clear, sunny days, the temperature in sand dunes can rise to as much as 50°C. There is also a lack of fresh water. Because of this, sand dune plants have evolved xeromorphic³ characteristics. The outer layer of leaves is very thick and leaves are often reduced to spiny projections (as seen in Spinifex) or rolled up (as seen in Goat's Foot) aiding in preventing water loss.



³ Xeromorphic characters are adaptations that enable plants to conserve water.

A 50% reduction of water loss is seen in the sand dune grass *Cynodon dactylon* as a result of leaf rolling (Walter, 1971, in litt. Packham & Willis, 1997).

There is also more water storage tissue making leaves spongy (as seen in Goat's Foot) (Packham & Willis, 1997).

Sand dune plants often have very long tap roots (extending for as long as one metre) that can search for fresh water (Packham & Willis, 1997).

What is the importance of seagrass meadows and sand dunes?

Seagrass meadows and sand dunes form ecologically and economical important habitats because they provide many ecosystems services.

Provisioning services:

Seagrasses and sand dunes provide goods for human use.

- Many edible fish are found living in seagrass beds. Seagrass meadows, like mangroves, are nursery areas for many finfish and shellfish. Because of this, they are critical in coastal fisheries (Heck et al., 2003).
- Subsistence fishing - as practised on the island of Zanzibar - is totally dependent on seagrass meadows (Bjork et al., 2008).

- Eight hundred and seventy six hectares of seagrass meadows support, on average, 178 tons of prawns caught, valued at about 1 million USD per year in Queensland, Australia (Watson, et al., 1993).
- One hectare of seagrass meadows is worth around 17,700 USD per year, for its provision of food and shelter to valued fish and seafood such as prawn populations (<http://cms.iucn.org/index.cfm?uNewsID=1367>).

- Fish, clams and shrimp are collected from seagrass beds as a primary protein source in many parts of the world (Green & Short 2003).
- In Sri Lanka, Bristle worms (Polychaetes) are harvested from seagrass beds as broodstock feed for aquaculture (Kallesøe et al., 2008).
- Aquarium fish are also harvested (Kallesøe et al., 2008).
- Until the last century, in Europe, dried seagrass material was used commonly as housing insulation. Air-filled tissue provided properties suitable for insulation and sound proofing. Because seagrasses have a high silicon content in their leaves, this insulation is non-flammable (Hurley, 1990).
- Until recently, seagrasses were also used to thatch roofs in rural coastal areas in Europe and the UK as a substitute for straw (Hurley, 1990).

- Because seagrass meadows naturally bind soil and prevent erosion, seagrasses were used to bind soil in embankments, such as in the dikes of the Netherlands. Presently, seagrasses are being used in sand-dune restoration in Australia (Hurley,1990).
- Before the advent of plastic, seagrasses were used as stuffing for pillows and upholstery, and for packing. For example, in Chesapeake Bay in the USA, exported crabs were packed in seagrass (Hurley,1990).
- Seagrasses were also used as traditional medicines in the Mediterranean and in Africa (Bjork et al., 2008).
- Sand and minerals are extracted from beaches, washed and used in the construction industry. When the demand is high, sand dunes are also used for extraction.

Ilmenite and beach sand are mined from sand dunes in the eastern coast of Sri Lanka - estimated at 500-1000m³/km/year (CCD, 2004).

Regulating services:

Seagrass meadows act as filters for coastal waters.

The leafy 'canopy' of seagrasses slows down water currents, trapping particles, nutrients organic matter and pollutants washed from inland waters to coastal seas. Because of this, seagrasses act as a filter of coastal waters, clearing and cleaning water (Short & Short, 1984).

Seagrass meadows stabilise the floor of coastal seas.

The underground stems of seagrasses prevent the sediment trapped by leaves from being resuspended, thereby stabilising the sea bed and preventing sand from being washed away and churned up by wave action (Bjork et al., 2008).

Sand dunes protect the land behind them from erosion.

The sediment in sand dunes protects the land behind them from storm erosion and potential sea level rise. Sand dune vegetation traps sand and prevents it from being blown further inland. The constant changing of erosion and accretion⁴ of sand dunes - their self-repairing dynamics - are extremely important in hazard mitigation (Dahm et al., 2005).

Specialised vegetation with extensive root systems such as Goat's Foot and Spinifex are essential in this process of trapping sand.

Sand dunes provide protection against flooding.

When there are storm surges and waves, sand dunes prevent flooding inland. 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), Natural and human made gaps in some dunes reduced this effectiveness (R. Galappatti, personal communication).

⁴ Accretion is the slow addition to land by the deposition of sediment carried in water.



Supporting services:

Seagrasses and sand dunes support coastal biodiversity.

Although there are relatively few species of seagrasses, they can house hundreds of other species - microorganisms, algae, invertebrates and vertebrates. Because of their three-dimensional structure in the water, seagrass meadows provide protection for juvenile fish and many marine larvae. It is estimated that a single acre of sea-grass may support as many as 40,000 fish, and 50 million small invertebrates. Seagrass meadows are the feeding sites of juvenile Horseshoe crabs - which belong to an ancient evolutionary lineage (Ruppert et al., 2003).



Globally threatened vertebrate species such as seahorses, marine turtles and marine mammals (e.g. Dugongs) are also found in these ecosystems in the tropics (http://www.sms.si.edu/IRLspec/Seagrass_Habitat.htm). In temperate regions many swans and geese are found in seagrass meadows (Bjork et al., 2008).



- Species diversity inside seagrass meadows is an order of magnitude higher than in areas outside (Hemminga & Duarte, 2000 in litt. Orth et al., 2006).
- In a bay in New South Wales, Australia, some 248 species of arthropods, 197 molluscs, 171 polychaetes, and some 15 echinoderms were recorded from seagrass beds (Hutchings, 1994, in litt. Spalding et al., 2003).

Sand dunes are essential components of coastal vistas and biodiversity. They also harbour endangered species - such as marine turtles - that return to the sites where they were born to lay their eggs on sandy beaches. The lower slopes of sand dunes with natural vegetation such as Goat's Foot and Spinifex are ideal nesting sites for turtles (Choudury et al., 2003).

- Sand dunes in Sri Lanka are the nesting habitat of five species of globally threatened turtles (Bambaradeniya et al., 2002).
- One hundred and twenty four plant species have been recorded in sand dunes in Yala, in southern Sri Lanka (De Silva & Premachandra, 1998).



Seagrasses are primary producers.

A single acre of sea-grass is estimated to produce over nine tonnes of leaves per year, providing a vast amount of food for many fauna (see previous page). Seagrasses rank with coral reefs and mangroves in their productivity (Coles et al., 2007).

Seagrasses enrich nutrients in coastal waters.

Seagrasses take up nutrients from the soil, and nutrients and carbon from the water column and sediments to use for maintaining their very high productivity. When the numerous plants and animals found in this three dimensional habitat - as well as seagrasses - die, the released nutrients enter the marine system as carbon and other nutrients (http://www.sms.si.edu/IRLspec/Seagrass_Habitat.htm).

Seagrass meadows are carbon sinks.

Seagrasses absorb carbon dioxide from the oceans when they photosynthesise. Like forests on land, they function, therefore, as carbon sinks, removing carbon dioxide from the sea (Spalding et al., 2003).



Cultural services:

Recreational services:

Beaches are popular for recreation and many people enjoy walking on the beach and paddling on beach fronts. Sand dunes can provide source sand for the maintenance of beaches. In many countries, coastal tourism relies on intact sand dunes and beach fronts as part of their marketing packages.

Seventy percent of all hotels registered with Sri Lanka Tourist Board are located in the coastal zone (CCD, 2004).

Seagrass meadows, like coral reefs, attract divers and snorkellers.

Traditional services:

In many countries, traditional fishing practices are supported by seagrass meadows and sand dunes. As above, sand dunes indirectly support traditional fisheries.

- Traditional stilt fishery and beach seine fishery are supported indirectly in Sri Lanka by the combination of the presence of sand dune ecosystems and sandy sea beds (Kallesøe et al., 2008).
- In Australia and Polynesia, Aboriginal and Polynesian traditional fishing and hunting techniques and rituals are associated with seagrass meadows (Coles et al., 2007).



Other Services:

'Biological sentinels'

Seagrasses have been called 'biological sentinels' or 'coastal canaries' (Orth et al., 2006). Like canaries that were taken into coal mines to test the quality of the air, seagrasses respond to changes in the quality of water, indicating deterioration of the environment by degrading and declining before dying. These changes are visible very quickly so that it is possible to take management action (Orth et al., 2006).

In a US study, seagrasses were used as one of five indicators of pollution (Bricker et al., 2003, in litt. Orth et al., 2006).

Being part of an interconnected mosaic.

Along coastlines, lagoons and estuaries, mangroves, sand dunes, seagrass meadows and coral reefs are often found as interdependent and interconnected ecosystems (Kallesøe et al., 2008; Short et al., 2007). In concert, this mosaic stabilises the coastline (Short et al., 2007).

What are the threats to seagrass meadows and sand dunes?

Many human activities impact on seagrass meadows and sand dunes. Like all coastal ecosystems, seagrasses and sand dunes are subject to multiple impacts that are often from inland sources, at local, national and global levels (Orth et al., 2006).

It is estimated that, to date, 65% of seagrass meadows has been lost as a result of coastal development and alteration (Bjork et al., 2008).

Nineteen percent of the world's population lives near seagrass meadows (Alder, 2004).

Pollution:

Sedimentation affecting water clarity

One of the most major and common threats to seagrass meadows is the deterioration of water clarity through sediment loading. Because seagrass meadows are dependent on sunlight for photosynthesis, water clarity and quality are important for the health of this ecosystem. When there is excessive sedimentation and the turbidity of the water increases, then seagrass meadows are affected. When there is too much sediment, seagrasses can

become smothered (http://www.sms.si.edu/IRLspec/Seagrass_Habitat.htm). Dredging and coastal development can also cause water turbidity, affecting seagrasses.

Sedimentation has the greatest impact on tropical seagrasses (Duarte et al., 2008 in litt. Bjork et al., 2008).

A study in the Philippines showed empirically that the species diversity of seagrass decreased along an increasing sediment gradient (Bach et al., 1998).

Eutrophication - as a result of industrial and domestic pollution - affecting water quality

When runoff from inland waters - carrying with it excessive nitrogen and phosphorus from fertilisers, animal and domestic waste - increases minerals in coastal waters, there is an extreme burst of growth of algae (i.e., causes massive algal blooms). Algae block light and oxygen from reaching the waters below the surface. The water then turns cloudy and green, further blocking light penetration. The balance in the ecosystem is destroyed by this process - which is called eutrophication. Seagrass meadows are extremely susceptible to eutrophication (http://www.sms.si.edu/IRLspec/Seagrass_Habitat.htm).

Eutrophication is more common in temperate regions, in developed countries (Bjork et al., 2008).

Chincoteague Bay in eastern USA has lost over 50% of its seagrass meadows as a result of eutrophication (Short et al., 2006).

Other sources of pollution

Marine pollution can also cause damage to seagrasses through engine oil discharge. Thermal effluents from industries also affects the condition of seagrasses. Such effects have been documented in Florida (Zieman & Wood, 1975).

Habitat destruction/degradation:

Beach infrastructure

Many Asian countries lack coastal legislation preventing irresponsible and damaging infrastructure building on beaches. Structures such as beach huts and beach restaurants are often built destroying sand dunes.

Even where infrastructure is built under legal restriction, property holders may clean beaches uprooting existing vegetation and levelling the beach. When this happens, erosion is increased, and objects such as small rocks - which can serve as centres for accretion - are removed (UK Biodiversity Group, 1999).

Artificial erosion defence structures

Artificial coastal stabilisation measures such as bulkheads, seawalls, revetments, sandbags and groynes can be built damaging seagrass meadows. Dredging for such structures also adversely affects seagrass meadows (Spalding et al., 2003).

Planting shelterbelts and replanting mangroves

After the tsunami of December 2004, some Asian governments proposed the establishment of shelterbelts, while others set about replanting mangroves. There is a great danger that sand dunes can be levelled or damaged when artificial greenbelts or mangrove replanting is undertaken. When exotic species such the Whistling Pine (*Casuarina equisetifolia*) are planted, additional problems - such as the prevention of marine turtles from nesting - also ensue (Choudury et al., 2003).

Other human influences

Port, harbour and jetty development facilities on the coastline are required for the shipping industry. Such development damages coastal habitats such as sand dunes, often decreasing incident sunlight to or fragmenting seagrass meadows (Spalding et al., 2003). Tourist infrastructure also often destroys sand dunes. A by product of such development is the increase of sedimentation, solid waste and marine pollution (Choudury et al., 2003).

In Placencia, Belize, there has been a 46% loss of seagrass cover as a result of development activities in the area (Short et al., 2006).



Overexploitation:

Sand mining and resultant erosion of sand dunes

Mining for river sand is a major threat in Asian countries. In the normal dynamics of beach morphology, sand is always lost offshore but is replaced continually by sediment that is brought from rivers. When rivers are mined, then the amount of sand being washed to coastal stretches reduces, resulting in coastal erosion (CCD, 2004). The mining of dunes occurs on the landward sides (R. Galappatti personal communication).

- Large-scale sand mining in the east and west coasts of Sri Lanka removes 500-1000 and 150,000m³/km/year respectively.
- Land lost through coastal erosion in Sri Lanka is estimated at 200,000-300,000m² a year in 685km along western, south-western, and southern coastal stretches (CCD, 2004).

Any removal of sand - inland or on the beach - affects sand dunes (Salm et al., 2000). When there is coastal erosion, nesting habits of endangered marine turtles are disrupted.

- In India, there is severe damage to the nesting beaches of Olive Ridley turtles (*Lepidochelys olivacea*) along the Orissa coast, Andhra Pradesh and Kerala as a result of sand and mineral mining on beaches (Choudury et al., 2003).



Irresponsible fishing and tourism

Mooring, propellers and jet skis are emerging as a major threat to seagrass meadows (Fonseca et al., 1998). When boats – either for fishing or recreation – enter into areas where there are seagrass meadows, their propellers can slash leaves as well as rhizomes of seagrass, leading to fragmentation of the habitat, which, in turn, leads to erosion (http://www.sms.si.edu/IRLspec/Seagrass_Habitat.htm). Similarly, irresponsible mooring and recreation can endanger these habitats. Blue crab dredging in Chesapeake Bay eastern USA has caused significant declines in seagrass cover (Fonseca et al., 1998). Trampling or using fishing gear that rakes up seagrasses is also damaging. For example, push nets and drag nets cause immense damage to seagrass meadows in coastal wetlands in Sri Lanka (C. Bambaradeniya, personal communication).

Recreation is a major use of sand dunes and beaches. They are used extensively by tourists. Excessive trampling of sand dune vegetation causes death of the flora and can result in erosion of dune sites.



Invasive Alien Species:

Invasive Alien Species (IAS) are introduced species which out-compete native species and cause economical and ecological damage by spreading in natural ecosystems (IUCN, 2000).

Common Cord Grass (*Spartina anglica*) - which grows naturally in estuaries and lagoons and has been used all over the world for coastal stabilisation - is now threatening seagrass meadows in Europe (<http://www.issg.org/database/species/ecology.asp?si=76&fr=1&sts=>). *Sargassummuticum*, a brown seaweed native to Asia, is out-competing native seagrass species in Europe and the USA where it has been introduced (<http://www.issg.org/database/species/search.asp?sts=sss&st=sss&fr=1&x=685&y=41&sn=sargassum+muticum&rn=&hci=-1&ei=-1&lang=EN>) Other species such as Prickly Pear (*Opuntia dillenii*) and Mesquite (*Prosopis juniflora*) are spreading in sand dunes and beaches and destroying natural vegetation (Bambaradeniya et al., 2006).

- In southern Sri Lanka, Prickly Pear (*Opuntia dillenii*) has spread in sand dunes and beaches after the tsunami preventing the regeneration of natural vegetation such as *Spinifex* (Bambaradeniya et al., 2006).
- Worldwide, at least 28 non-native species have become established in seagrass meadows, of which, 64% have been shown to have negative effects on the ecosystem (Orth et al., 2006).



Disease:

In the 1930s, a marine slime mould caused the die-back of over 90% of seagrass cover in the North Atlantic resulting in the collapse of scallop fisheries and a drastic decrease in waterfowl (Orth et al., 2006). This die back caused the only known extinction of a marine mollusc, the Eelgrass limpet (*Lottia alveus*) (Carlton et al., 1991 in litt. Orth et al., 2006).

Climate Change:

Climate change will cause many changes in the oceans. Water temperature will be higher, acidity will increase (as a result of increased dissolved CO₂), the sea level will rise, storms and extreme weather events will increase in intensity and frequency, the amount of falling rain will change, wave climates will be altered, and sea water will intrude into fresh water (IUCN, 2007a). Presented in the following page is a table of the impacts of climate change on seagrasses and sand dunes.

Seagrasses meadows are much more at risk from climate change than sand dunes, which are affected mostly by the effects of wind (R. Galappatti, personal communication).



Effect of Climate Change	Seagrass meadows	Sand dunes
Higher temperatures	Higher water temperatures will affect directly growth, reproduction and general metabolism of seagrasses (Short & Neckles, 1999; Bjork et al., 2008). When there is eutrophication, there is competition between seagrasses and algae. Water temperature will have a profound effect on this competition (Short et al., 1995).	This will likely not affect sand dunes.
Increased storm frequency	Increased storms are known to cause physical damage to seagrass meadows (Short & Neckles, 1999). Coastal storms can also cause huge movements of sediment, which last long after the storm ceases. Increased turbidity will cause declines in seagrass growth (Bjork et al., 2008).	Increased storms increase wind power, and because of this, erosion can increase. Coastal communities living on the landward side of sand dunes are often caught in dust storms.
Sea level rise	Increasing depths will alter the amount of light reaching seagrasses and will limit food production through photosynthesis, reducing their productivity and their distribution (Short & Neckles, 1999).	Flooding can worsen erosion of beaches and thereby cause sand dunes to collapse, but this is an extreme effect (R. Galappatti, personal communication). However, nesting sites of species such as marine turtles could be lost as a result of erosion in low lying elevation sand islands such as seen in the Pacific Island nations, the Caribbean, the Maldives and the Great Barrier Reef. Here, the effects are expected to be more severe (UNEP, 2006).
Increased dissolved CO ₂	Increased acidity in the oceans will alter productivity in seagrasses. Some species may increase their productivity, others may not change, while yet others will reduce their productivity (Short & Neckles, 1999).	This will not directly affect sand dunes.

Effect of Climate Change	Seagrass meadows	Sand dunes
Changing wave climates	This will worsen the effects of sea level rise, and changes in tidal currents will affect seagrass meadows in estuaries and lagoons (Short & Neckles, 1999).	Changing waves climates will affect sand dunes either positively or negatively: they can either be accreted or eroded, depending on the direction and force of the winds (R. Galappatti, personal communication).
Sea water intrusion	Although seagrasses are adapted to live in saline water, the range of salinity can change with sea water intrusion, and this will affect species composition: those with a wide range of salt tolerance will survive and those with a narrow range will not (Short & Neckles, 1999).	Sea water intrusion will affect sand dunes flora and fauna.

Given the above multiple stressors on seagrass meadows, several species may be threatened. Currently a global assessment to Redlist seagrasses is ongoing (Suzanne Livingstone, personal communication).

- In the 1997 IUCN Redlist of plants, two species of seagrasses - Johnson's seagrass (*Halophila johnsonii*) and Surf grass (*Phyllospadix serrulatus*) were listed as vulnerable and rare (Walter & Gillet, 1998 in litt. Spalding et al., 2003).
- The World Atlas of Seagrasses lists 11 species of sea horses (*Hippocampus* spp.) that are wholly or partially dependent on seagrasses as Threatened, with five listed as Vulnerable and the rest as Data Deficient (Spalding et al., 2003).
- Juveniles of the Endangered Nassau grouper (*Epinephelus striatus*), the Vulnerable Venezuelan grouper (*Mycteroperca cidi*) and Gag grouper (*Mycteroperca microlepis*) are dependent on seagrass meadows (Spalding et al., 2003). All three of these species are important commercially but have been over-fished.
- Endangered Green turtles (*Chelonia mydas*) are strictly herbivorous, feeding on seagrasses and algae and are dependent on seagrass meadows for their continued survival (Spalding et al., 2003).
- The Dugong (*Dugong dugon*) and two Manatees - the West Indian manatee (*Trichechus manatus*) and the West African manatee (*Trichechus senegalensis*) - obligate feeders of seagrasses and kelp - are listed as Vulnerable (IUCN, 2007b).

At a glance: services provided by, and threats to sea grasses

(References as in text.)

Ecosystem Services	Description	Threats
Provisioning services (Goods)		
Food	<p>Seagrass meadows are nursery areas for many commercial fin and shell fish species as well as other species.</p> <p>Fish, clams and mussels are harvested as a source of protein from seagrass meadows all over the world.</p>	<p>Inland and coastal pollution, causing sedimentation and turbidity; dredging and coastal development; eutrophication - as a result of industrial and domestic pollution; port, jetty and harbour development; mooring, propellers and jet skis; Invasive Alien Species (IAS); disease; overgrazing and climate change.</p>
For the aquaculture and aquarium trades	<p>Polychaete worms are harvested from seagrass meadows as broodstock feed for aquaculture. Aquarium fish are also harvested.</p>	<p>Overexploitation and damaging collection practices.</p>
Housing insulation and thatching, stuffing and packing	<p>Until the last century, in Europe, dried seagrass material was used as housing insulation. Until recently, sea-grasses were also used to thatch roofs in rural coastal areas in Europe and the UK as a substitute for straw. Before the advent of plastic, seagrasses were used as stuffing for pillows and upholstery, and for packing.</p>	<p>Not used currently.</p>
For preventing erosion	<p>Seagrasses were used to bind soil in embankments, such as in the dikes of the Netherlands. Presently, seagrasses are being used in sand-dune restoration in Australia.</p>	<p>No immediate threat.</p>

Ecosystem Services	Description	Threats
Regulating services		
Preventing pollution and sedimentation of coastal waters	The leafy 'canopy' of seagrasses slows down water currents, trapping particles, nutrients and pollutants washed from inland waters to coastal seas.	Inland and coastal pollution, causing sedimentation and turbidity; dredging and coastal development; eutrophication - as a result of industrial and domestic pollution; port, jetty and harbour development; mooring, propellers and jet skis.
Stabilising the floor of coastal seas	The underground stems of seagrasses prevent resuspension of particles trapped by the leaves, helping stabilise the sea bed and preventing sand from being washed away and churned up by wave action.	Same as above. IAS; disease; overgrazing; climate change.
Supporting services		
Supporting coastal biodiversity	Because of their three - dimensional structure in the water, seagrass meadows provide protection for juvenile fish and many marine larvae. They house hundreds of other species as well - such as algae, sponges, round worms, marine worms and even threatened species - such as manatees, dugongs and turtles - that feed directly on them.	Inland and coastal pollution, causing sedimentation and turbidity; dredging and coastal development; eutrophication - as a result of industrial and domestic pollution; port, jetty and harbour development; mooring, propellers and jet skis; IAS; disease; overgrazing and climate change.
Primary production	Seagrasses rank with coral reefs and mangroves in their productivity.	Same as above.
Enriching nutrients in coastal waters	Seagrasses are important in the detrital food chain. When all the organisms found in the three dimensional habitat of seagrasses as well as seagrasses die, the released nutrients enter the marine system as carbon and other nutrients.	Same as above.

Ecosystem Services	Description	Threats
Supporting services		
'Biological sentinels' and 'coastal canaries'	Like canaries that were taken into coal mines to test the quality of the air, seagrasses respond to changes in the quality of water, indicating deterioration of the environment by declining. What is important is that these changes are visible and very quickly so that it is possible to take management action.	Inland and coastal pollution, causing sedimentation and turbidity; dredging and coastal development; eutrophication - as a result of industrial and domestic pollution; port, jetty and harbour development; mooring, propellers and jet skis; IAS; disease; overgrazing and climate change.
Cultural services		
Supporting traditional fishing practices	In many countries, traditional fishing practices are supported by seagrass meadows.	Irresponsible mooring, propellers and jet skis can damage seagrass meadows leading to fragmentation of the habitat, which, in turn, leads to erosion. Trampling or using fishing gear that rakes up the seagrasses is also damaging.



At a glance: services provided by and threats to sand dunes

(References as in text.)

Ecosystem Services	Description	Threats
Provisioning services (Goods)		
Sand and other minerals	Sand is mined heavily in many parts of the region. Beach sand mining in east coast of Sri Lanka estimated at 500-1000m ³ /km/year.	Overexploitation of both sand and river sand which results in coastal erosion.
Regulating services		
Stabilising the shoreline	The store of sediment in sand dunes protects the land behind them from storm erosion and potential sea level rise. Sand dune vegetation traps and prevents sand being blown further inland.	Sand mining and resultant erosion, beach infrastructures, artificial erosion defence structures, afforestation and other human influences such as ports and jetties are damaging or reducing the extent of sand dunes and with it, nesting habitats of endangered species.
Flood protection	When there are storm surges and waves, sand dunes prevent flooding inland. Intact sand dunes were the most effective barrier against tsunami waves that affected the coastal zone of Sri Lanka in 2004.	Same as above.
Supporting services		
Biodiversity	Sand dunes are essential components of coastal vistas and coastal biodiversity. They also harbour endangered species such as marine turtles – who must lay their eggs on sandy beaches and return to the sites where they were born. Coastal sand dunes with natural vegetation such as <i>Ipomea pes-caprae</i> and <i>Spinifex littoreus</i> are ideal nesting sites.	Same as above.

Ecosystem Services	Description	Threats
Cultural services		
Recreation	Beaches are popular for recreation and many people enjoy walking on the beach and paddling on beach fronts. Sand dunes can provide source sand for the maintenance of beaches. In many countries, coastal tourism relies on intact sand dunes and beach fronts as part of their marketing packages.	Tourist infrastructure often destroys sand dunes. A by-product of such development is the increase of sedimentation, solid waste and marine pollution.
Supporting traditional fishing practices	In many countries, traditional fishing practices are supported by sand dunes. Because sand dunes can provide source sand for the maintenance of beaches, they indirectly support traditional fisheries.	Sand mining – inland or at the coast and resultant erosion; beach infrastructure; artificial erosion defence structures, afforestation and other human influences such as ports and jetties; Climate change.

What is being done to conserve seagrasses and sand dunes?

Given that seagrasses have been identified as ‘biological sentinels’ and are excellent indicators of the state of the coastal environment, and given the recent recognition that coastal ecosystems are interconnected and interdependent (Kallesøe et al., 2008), seagrass meadows and sand dunes have now caught the attention of conservation biologists.

Establishment of marine protected areas

One of the key mechanisms of protecting seagrasses is the establishment of Marine Protected Areas (MPAs). Although marine protected areas are now being established worldwide, the ratio between MPA and terrestrial protected areas remains low at 1:7 (WRI, IUCN and UNEP 1992). Less than 1% of the world’s oceans are protected (http://www.unep.org/wed/2004/Downloads/PDFs/Key_Facts_E.pdf).

Twenty-five percent of MPAs worldwide include areas of seagrass meadows (Alder, 2004).

Because seagrasses are so rich in species and harbour several endangered species – such as marine turtles and dugongs – establishing protected areas to conserve the habitat also results in species conservation.

However, a major problem with MPAs is that they are often 'parks on paper' and a majority of MPA fail to meet their management objectives: in 1995, only 31% (1,306) MPAs were found to have met their management objectives (Jameson, 2002). Even though MPAs may be gazetted legally, enforcement of relevant laws (zoning, prohibiting certain activities) is often poor.

Prevention of over-harvesting/habitat destruction/degradation through legislation

Across the region, many species are protected under general species protection laws.

Internationally,

- Dugongs are listed on Appendix I of CITES (where trade is prohibited) all over the world except in Australia where it is on Appendix II (where trade is regulated).
- They are also on Appendix II as a species for cooperative action of the Convention on the Conservation of Migratory Species of Wild Animals (CMS) (UNEP/CMS, 2006).
- All seven species of marine turtles are either on Appendix I or II of CITES.

Nationally,

- Dugongs are protected in Sri Lanka and India.
- Four of the seven and all seven marine turtles are afforded protection in India and Sri Lanka respectively (Indian Wildlife Protection Act, 1972; FFPO, 1993).

Monitoring

Monitoring seagrasses is essential for the development of effective management strategies. It is only through monitoring that trends and patterns of use and the health of seagrass meadows can be assessed.

Currently, over 40 countries have seagrass monitoring programmes (Orth et al., 2006, in litt. Bjork et al., 2008). Now there are multinational collaborations such as the Caribbean Coastal Marine Productivity Program, the Cooperative Monitoring in the Baltic Marine Environment, Seagrass-Watch and SeagrassNet (Bjork et al., 2008). Both Seagrass-Watch and SeagrassNet are expanding monitoring programmes that investigate and document the status of seagrass resources worldwide and the threats to this important and imperilled marine ecosystem. Their ultimate aim is to preserve the valuable seagrass ecosystem by increasing scientific knowledge and public awareness of this threatened coastal resource.

Building awareness

Building awareness about seagrass meadows, their productivity and the services they provide, helps greatly in mitigating the threats to these 'biological sentinels.' Little, however, is known by the general public of the importance of this coastal ecosystem. Often, seagrasses meadows are confused with algae and kelp beds. Much needs to be done to build local and national awareness regarding seagrass ecosystems in most Asian countries. It is also critical to ensure that inland-based development takes preventative measures to prevent pollution and to safeguard seagrass meadows.

Seagrass-Watch aims to build awareness about seagrass meadows – about conditions, trends and threats – and to provide early warning about changes in the coastal environment. Seagrass-Watch successfully includes government and non-governmental organisations as well as schools, universities, research organisations and communities (<http://www.seagrasswatch.org>). Methodology and training are provided to participants and data obtained are entered into a database; publications on monitored sites are available online.

The fully illustrated World Atlas of Seagrasses is the joint effort of 50 authors from 25 countries. It contains maps of seagrass distribution both globally and regionally, as well as the status of and threats to this ecosystem (Green & Short 2003).

After the tsunami of December 2004, public awareness has grown about the worth of sand dunes that mitigated damage to inland structures from the wave surge; they also



realise the impacts on structures inland to eroded beaches (Bambaradeniya et al., 2006). However, the impacts of unplanned coastal development and inland activities (such as river sand mining) on coastal ecosystems such as seagrasses and sand dunes and their detrimental effects on ecosystem services must be brought into the central consciousness of politicians and developers.

Supporting participation and sustainable livelihoods in communities dependent on coastal ecosystems

The combined coastline in South, Southeast Asia and China is 182,036km and the combined territorial sea of 4,385,396km² (WRI, 2002). This coastline encompasses some of the most biodiverse and extensive coastal ecosystems in the world. These coastlines are also home to as many as 100 million people (Reid et al., 2007). Asia is also the home to over 70% of the world's poor, most of whom live in rural areas and many of whom live in coastal areas and depend on an easily disturbed natural resource base for their survival (Emerton, 2006).

Not surprisingly, coastal and marine resources make an important contribution to the national economies of many Asian countries, and a number of important urban, trading and port centres are located on the coastline (Emerton, 2006).

The current trend of decreasing coastal resources and damaged coastal ecosystems means that the services that they provide – often needed most by the coastal poor – are also affected. Restricting access to coastal resources for communities depending on them for their livelihoods leave these communities with even fewer options. Coastal managers are, therefore, shifting towards more integrated and participatory approaches to coastal management and conservation. Such approaches include identifying and supporting alternative livelihoods to reduce dependence on these coastal ecosystems, as well as enhancing current livelihood activities to make them more cost and resource efficient. Limited and controlled local use of seagrass meadows is now advocated in certain circumstances, instead of blanket restrictions on use. Rights to access and resolution of conflicts over resource use, community involvement and collaborative management are now being incorporated into coastal management (Whittingham et al., 2003).

Much needs to be done for the conservation of seagrasses and sand dunes, which perhaps, have not received the attention in Asia that other coastal ecosystems such as coral reefs and mangroves have received. It is imperative that policy makers and developers start viewing and treating coastal ecosystems as a part of a whole, interconnected complex, understand that inland development activities impact seriously on this coastal mosaic and take measures to prevent its damage.

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20	Coastal scene, Sri Lanka.	© Gehan de S. Wijeyeratne
25	Dugong (<i>Dugon dugong</i>) in Egypt.	© LIFE Red Sea Project
29	Seagrass monitoring at Labrador Nature Reserve, Singapore.	© Yang Shufen, National Parks Board, Singapore
31	Sea cucumber, Great Barrier Reef, Australia.	© Rudi Yoshida, Seagrass-Watch HQ.



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