Managing Coastal and Marine Biodiversity and Protected Areas

For MPA managers

Module 1

An introduction to coastal and marine biodiversity

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Summary

This module provides the foundation of the course by providing the basic concepts of biodiversity at the genetic, species and habitat levels, focussing on the examples and peculiarities of the coastal and marine ecosystems

Key Messages

'Biological diversity or biodiversity refers to the diversity of life in all its forms and at all levels of organization.' The levels of biodiversity are the diversity within a species (genetic diversity), the diversity of species (species diversity) and the diversity of ecosystems (habitat or ecosystem diversity). Each of the three levels can be described further: What types of elements are there and in what numbers (compositional biodiversity), how they are arranged (structural biodiversity) and what role they play in the system (functional biodiversity).

Ecosystems provide a variety of benefits to people, including provisioning, regulating, cultural and supporting services, known as 'Ecosystem Services.'

Biodiversity is the foundation of resilient ecosystems supporting a vast array of 'functions.' Genetic, species (animal and plant) and habitat diversities have important roles to play in provision of ecosystem services.

Changes in biodiversity can influence all these functions (e.g., pollination, nutrient cycling) and the products arising out of these (e.g., food, medicinal plants).

When it comes to measuring and monitoring biodiversity, there are two ways of doing it: The first is to measure actual processes (functional biodiversity), e.g., regeneration rates and patterns, rates of productivity, species interaction. However, this would be difficult and time consuming. The second one

is, therefore, the way out and uses surrogates (known as conservation shortcuts), which is simpler and based on certain assumptions that the conservation benefits of surrogate species extend to a larger set of species and/or habitats. Therefore, measuring a surrogate species would provide us an idea of how the ecosystem is doing. Some famous surrogates are Tigers, Turtles, Whale Sharks, etc.

There are several types of coastal ecosystems in India: inland freshwater wetlands, inland brackish water wetlands, estuarine wetlands, coastal mudflats, sand dunes, rocky shores, mangrove forests, coral reefs and other coastal and marine ecosystems.

Marine and terrestrial ecosystems are different with respect to the aquatic medium in which all marine organisms exist. Water unites, land divides—there are no discrete boundaries in marine ecosystems as seen on land.

1.1 Basic Concepts of Biodiversity

Biological diversity refers to the diversity of life in all its forms and at all levels of organization.

Biodiversity can be described at three levels: the diversity within a species (genetic diversity), the diversity of species (species diversity) and the diversity of ecosystems (habitat or ecosystem diversity).

Each of the three levels, can be described further: What types of elements are the rein what numbers (composition)? How are they arranged (structure)? What is their role in the system(function)?

Compositional diversity

Compositional biodiversity describes the type of biodiversity elements (at all the levels: viz genes, species and habitat) present in an area. Examples can be genetic composition of populations, identity and relative abundances of species in a natural community, and kinds of habitat sand communities distributed across the landscape.

Structural diversity

Structural biodiversity describes the variety of arrangement of these components, i.e. variety of ways in which different habitats, species or genes are arranged over space (spatial biodiversity) or time temporal biodiversity). Examples of spatial biodiversity can be different species assemblages in different patches in a forest, sequence of pools and riffles in a stream, and the vertical layering and horizontal patchiness of vegetation. Similar to spatial heterogeneity, temporal fluctuations in environmental factors also regulate the biodiversity of a specific space.

An example for the importance of time in relation to biodiversity is the dependency of fish breeding patterns on water availability or changing water temperature, as well as seasonal flooding events, which are necessary for entire ecosystems functionalities. These temporal fluctuations support different species over different seasons/time scales and have a critical influence on ecosystem dynamics.

Functional biodiversity

Functional diversity is the variety of biological processes, functions or characteristics of a particular ecosystem/ area. Functional biodiversity, therefore, describes the enormous variety of processes that occur due to interaction of different species with each other and the interactions of the species with their physical environment. These processes include the climatic, geologic, hydrologic, ecological, and evolutionary processes that generate biodiversity and continuously change it, e.g. nutrient cycling, pollinations, predation, parasitism, germination etc.

An example of functional biodiversity is the balance in the number of filter feeders in an ecosystem compared to the number of grazers. The more diverse the ecosystem is in terms of functions, the more stable the ecosystem can be. Functional biodiversity is thought to be one of the main factors determining the long-term stability of an ecosystem and its ability to recover from major disturbances5. Loss of structural and functional biodiversity (largely through habitat destruction and fragmentation) affects ecological systems and impairs their ability to continue self-maintenance.

1.2 Keystone species, umbrella species, indicator species and flagship species of coastal and marine environment

Species conservation can be subjective because it is hard to determine the status of many species. With millions of species of concern, the identification of selected *keystone species*, or *umbrella species, indicator species, flagship species* makes conservation decisions easier.

Keystone species

A keystone species has a disproportionately large impact on its community or ecosystem relative to its abundance. A classic example is a starfish (*Pisaster ochraceus*) occurring in the rocky intertidal of the Pacific Northwest: *P. ochraceus* is an efficient predator of the common mussel, *Mytilus californicus*. This mussel is able to compete for resources better than other species and thus reproduce faster. Predation by the starfish keeps the mussel population at moderate levels, allowing other macro invertebrates to persist in that ecosystem. The removal or decline of the star- fish population will inadvertently increase the mussel population, resulting in a decline of other macro invertebrate species. The starfish is therefore the keystone species' of this ecosystem, which helps in maintaining high species diversity in this intertidal community.

Umbrella species

Apart from their disproportionately high impact on the ecosystem, species can also be very important for conservation if they are associated with many types of habitats and ecosystems that span large geographical spaces.

These species are called umbrella species and are defined as "a species whose conservation confers protection to a large number of naturally co-occurring species" in several ecosystems and habitats. Monitoring this one species and managing the ecosystem for its continued success results in the maintenance of a high quality habitat for other species in the area. Sea turtles are a very good example of an umbrella species for ocean ecosystems.

Indicator species

Indicator species are organisms whose presence, absence or abundance reflects a specific environmental condition. Indicator species can signal a change in the biological condition of a particular ecosystem, and may therefore be used as a proxy to diagnose the health of an ecosystem. These species are very valuable in conservation planning and management, as these can be used to indicate the status of an environmental condition, identify a disease outbreak, or monitor pollution or climate change. For example, corals are used as indicators of marine processes such as siltation, seawater rise and sea temperature fluctuation. In the Philippines, indicator species are used to assess the status of marine and coastal biodiversity, including population trends in whale sharks, hump- back whales and Irrawaddy dolphins.

Flagship species

Flagship species are popular, charismatic species that serve as symbols and rallying points to stimulate conservation awareness and action. A flagship species acts as an ambassador for less-recognised or less-beloved animals and organisms in a habitat. For example, polar bears are a flagship species for conservation in the Arctic region. Interestingly, Polar bears are also ‘climate change flagship species’. Flagship species may or may not be keystone species or good indicators of biological processes.

There are some species that can be both a keystone and an umbrella species such as elephants, turtles and whale sharks while other species can be a flagship species as well as a keystone species, such as tigers, turtles and mangroves.

1.3 Coastal and marine biodiversity

Different types of terrestrial and coastal and marine biomes and habitats

Ecological communities of living things, such as microorganisms, plants and animals form as a result of the physical surroundings, including land, air and water in an area. For example, deserts, grasslands and tropical rainforests are biomes.

Classification of biomes

Aquatic biomes

- Freshwater
- Ponds and lakes
- Rivers and streams
- Wetlands

Coastal

- Mangroves
- Tidal mudflats
- Lagoons
- Sandy beaches
- Rocky shores
- estuaries

Marine

- Oceans
- Coral reefs
- Seagrasses
- Deep sea

Desert biome

- Hot and dry deserts
- Semi-arid deserts
- Coastal deserts
- Cold deserts

Grasslands

- Steppes
- Prairies
- Pampas
- Savannas

Forests

- Tropical forests
- Deciduous forests
- Alpine forests
- Boreal forests or Taiga

Water is the common link among the five biomes and it covers the largest part of the biosphere, consisting of nearly 75 per cent of the earth's surface. Aquatic regions house numerous species of plants and animals, both large and small. In fact, this is where life began billions of years ago when amino acids first started to come together. Without water, most life forms would be unable to sustain themselves and the earth would be a barren, desert-like place. Although water temperatures can vary widely, aquatic areas tend to be more humid and air temperature on the cooler side.

The aquatic biome can be broken down into two basic regions, freshwater and coastal-marine.

1.3.1 Freshwater regions

Freshwater has a low salt concentration — usually less than 1 per cent. Plants and animals in freshwater regions are adjusted to the low salt content and will not be able to survive in areas of high salt concentration (i.e, ocean). There are different types of freshwater regions: ponds and lakes, streams and rivers, and wetlands. The following sections describe the characteristics of these three freshwater zones.

1.3.1.1 PONDS AND LAKES

These regions range in size from just a few square metres to thousands of square kilometres. Scattered throughout the earth, several are remnants from the Pleistocene glaciation. Many ponds are seasonal, lasting just a couple of months (such as sessile pools) while lakes may exist for hundreds of years or more. Ponds and lakes may have limited species diversity since they are often isolated from one another and from other water sources like rivers and oceans. Lakes and ponds are divided into three different 'zones' which are usually determined by depth and distance from the shoreline.

The topmost zone near the shore of a lake or pond is the littoral zone. This zone is the warmest since it is shallow and can absorb more of the sun's heat. It sustains a fairly diverse community, which can include several species of algae (like diatoms), rooted and floating aquatic plants, grazing snails, clams, insects, crustaceans, fishes, and amphibians. In the case of the insects, such as dragonflies and midges, only the egg and larvae stages are found in this zone. The vegetation and animals living in the littoral zone are food for other creatures such as turtles, snakes and ducks.

The near-surface open water surrounded by the littoral zone is the limnetic zone. The limnetic zone is well-lit (like the littoral zone) and is dominated by plankton, both phytoplankton and zooplankton. Plankton are small organ- isms that play a crucial role in the food chain. Without aquatic plankton, there would be few living organisms in the world, and certainly no humans. A variety of freshwater fish also occupy this zone.

Plankton have short life spans. When they die, they fall into the deep-water part of the lake/pond, the profundal zone. This zone is much colder and denser than the other two. Little light penetrates all the way through the lim- netic zone into the profundal zone. The fauna are heterotrophs, meaning that they eat dead organisms and use oxygen for cellular respiration.

Temperature varies in ponds and lakes seasonally. During the summer, the temperature can range from 4° C near the bottom to 22° C at the top. During the winter, the temperature at the bottom can be 4° C while the top is 0° C (ice). In between the two layers, there is a narrow zone called the thermocline where the temperature of the water changes rapidly. During the spring and fall seasons, there is a mixing of the top and bottom layers, usually due to winds, which results in a uniform water temperature of around 4° C. This mixing also circulates oxygen throughout the lake. Of course there are many lakes and ponds that do not freeze during the winter, thus the top layer would be a little warmer.

1.3.1.2 STREAMS AND RIVERS

These are bodies of flowing water moving in one direction. Streams and rivers can be found everywhere—they get their starts at headwaters, which may be springs, snowmelt or even lakes, and then travel all the way to their mouths, usually another water channel or the ocean. The characteristics of a river or stream change during the journey from the source to the mouth. The temperature is cooler at the source than it is at the mouth. The water is also clearer, has higher oxygen levels, and freshwater fish such as trout and heterotrophs can be found there. Towards the middle part of the stream/river, the width increases, as does species diversity—numerous aquatic green plants and algae can be found. Toward the mouth of the river/stream, the water becomes murky from all the sediments that it has picked up upstream, decreasing the amount of light that can penetrate through the water. Since there is less light, there is less diversity of flora, and because of the lower oxygen levels, fish that require less oxygen, such as catfish and carp, can be found.

WETLANDS

Wetlands are areas of standing water that support aquatic plants. Marshes, swamps, and bogs are all considered wetlands. Plant species adapted to the very moist and humid conditions are called hydrophytes. These include pond lilies, cattails, sedges, tamarack, and black spruce. Marsh flora also include such species as cypress and gum.

Wetlands have the highest species diversity of all ecosystems. Many species of amphibians, reptiles, birds (such as ducks and waders), and furbearers can be found in the wetlands. Wetlands are not considered freshwater ecosys- tems as there are some, such as salt marshes, that have high salt concentrations—these support different species of animals, such as shrimp, shellfish, and various grasses.

1.3.2 Coastal and Marine regions

Coastal

- Mangroves
- Tidal mudflats
- Lagoons
- Sandy beaches
- Rocky shores
- estuaries

Marine

- Oceans
- Coral reefs
- Seagrasses
- Deep sea

Marine regions cover about three-fourths of the earth's surface and include oceans, coral reefs, and estuaries. Marine algae supply much of the world's oxygen supply and take in a huge amount of atmospheric carbon dioxide. Evaporation of seawater provides rainwater for the land.

1.3.2.1 OCEANS

The largest of all the ecosystems, oceans are very large bodies of water that dominate the earth's surface. Like ponds and lakes, ocean regions are separated into separate zones: intertidal, pelagic, abyssal, and benthic. All four zones have a great diversity of species. Some say that the ocean

contains the richest diversity of species even though it contains fewer species than there are on land.

The intertidal zone is where the ocean meets the land—sometimes it is submerged and at other times exposed, as waves and tides come in and out. Because of this, the communities are constantly changing. On rocky coasts, the zone is stratified vertically. Where only the highest tides reach, there are only a few species of algae and mol- lusks. In these areas usually submerged during high tide, there is a more diverse array of algae and small species, such as herbivorous snails, crabs, sea stars and small fishes. At the bottom of the intertidal zone, which is only exposed during the lowest tides, many invertebrates, fishes and seaweed can be found. The intertidal zone on sandier shores is not as stratified as in the rocky areas. Waves keep mud and sand constantly moving, thus very few algae and plants can establish themselves—the fauna include worms, clams, predatory crustaceans, crabs and shorebirds.

The pelagic zone includes those waters further from the land, basically the open ocean. The pelagic zone is gener- ally cold though it is hard to give a general temperature range since, just like ponds and lakes, there is thermal stratification with a constant mixing of warm and cold ocean currents. The flora in the pelagic zone include sur- face seaweeds. The fauna include many species of fish and some mammals, such as whales and dolphins. Many feed on the abundant plankton.

The benthic zone is the area below the pelagic zone, but does not include the very deepest parts of the ocean (see abyssal zone below). The bottom of the zone consists of sand, silt, and/or dead organisms. Here temperature de- creases as depth increases toward the abyssal zone, since light cannot penetrate through the deeper water. Flora are represented primarily by seaweed while the fauna, since it is very nutrient-rich, include all sorts of bacteria, fungi, sponges, sea anemones, worms, sea stars and fishes.

The deep ocean is the abyssal zone. The water in this region is very cold (around 3° C), highly pressured, high in oxygen content, but low in nutritional content. The abyssal zone supports many species of invertebrates and fishes. Mid-ocean ridges (spreading zones between tectonic plates), often with hydrothermal vents, are found in the abyssal zones along the ocean floors. Chemosynthetic bacteria thrive near these vents because of the large amounts of hydrogen sulfide and other minerals they emit. These bacteria are thus the start of the food web as they are eaten by invertebrates and fishes.

1.3.2.1 MANGROVES

Mangroves are tidal forest ecosystems in sheltered brackish to saline environments. Mangrove forests are found from the highest level of spring tides down almost to mean sea level on sheltered sedimented shores throughout the tropics.

They dominate approximately 75 per cent of the world's coastline. They occur in fully saline waters but also penetrate considerable distances into estuaries. The mangrove ecosystem constitutes a bridge between terrestrial and marine ecosystems.

Tropical mangroves are a globally important ecological, environmental and socio-economic resource, yet they form an extremely fragile land-water interface highly susceptible to global change. Mangroves are genetically extremely diverse providing an important habitat for numerous marine and terrestrial species, including nurseries for commercial species. They also provide crucial economic livelihoods and are important for coastal protection. Their intertidal setting and rapid commercial development subjects mangroves to escalating climatic and other anthropogenic pressures. Sea level rise is the largest threat, and associated socio-economic impacts include increased flood risk, coastal erosion and inland retreat, saline intrusion and storm surges. In addition, direct human interventions by river damming; agricultural and coastal development; cutting off freshwater supplies to creeks lined with mangroves; direct felling; and dumping of wastes that choke waterways etc are other important threats.

The Sundarbans is the largest single block of tidal halophytic mangrove forest in the world with ~60 per cent located in Bangladesh and the rest (~40%) in India. It is a UNESCO World Heritage Site. The Sundarbans are situated between the latitudes 22°15' and 21°30' North and 88°10' and 89°51' East. The total area of Sundarbans in India is 4,262 sq km. India is home to some of the best mangroves in the world. West Bengal has the maxi- mum mangrove cover in the country followed by Gujarat and the Andaman and Nicobar Islands. The Ministry of Environment and Forests (MoEF) has established a National Mangrove Genetic Resources Centre in Orissa. Mangrove vegetation has been reported in all the 13 coastal states/union territories.

Mangroves provide a variety of benefits. They are a source of firewood, wood products such as timber and posts; non-wood produce such as fodder, honey, wax, tannin, dyes; and plant materials

for thatching. Mangrove wet- lands and forests can act as a shelter belt against cyclones, and even tsunamis. In Orissa state, villages surrounded by mangrove forests survived the fury of the super cyclone in 1999, unlike other villages; similarly villages in Cud- dalore and Nagapattinam districts of Tamil Nadu that were buffered by mangroves suffered relatively less damage in the 2004 Indian Ocean tsunami. They also prevent coastal erosion. The most important role of mangroves is the relative quiet conditions they provide which serve as nursery grounds for a number of commercially impor- tant fish, prawn, crabs and molluscs. The mangrove food web is complex and enhances the fishery production of nearby coastal waters by exporting nutrients and detritus. They also provide habitats for wildlife ranging from migratory birds to estuarine crocodiles (e.g. Bhitarkanika National Park), tigers (Sunderbans), etc

Mangroves are restricted to the intertidal zone along the coasts and are becoming increasingly depleted due to an- thropogenic pressures. They are also extremely vulnerable to the effects of climate change, such as rising sea levels, resulting in loss of habitat and changes in salinity, changes in precipitation and wave climates and an increase in the frequency of natural disasters. The 6,000 sq km of mangrove forest along the coast of India and Bangladesh is the largest such forest in the world.

As a result of rising sea levels, 7,500 ha of mangroves in this tract along the shores of the two countries are lost due to inundation (http.www//assets.panda.org/downloads/wwfparksbro.pdf). Mangrove forests are home to a number of species such as the critically endangered tiger, the Eurasian otter, five species of marine turtles and the estuarine crocodile and large numbers of crustaceans and fishes. With a 1 m rise in the sea level, the Sundarbans are likely to disappear, which may result in the extinction of the tiger, as well as the other species in these habitats (Smith et al 1998). [Savarkar 2014, ENVIS publication]

1.3.2.2 ESTUARIES

Estuaries are areas where freshwater streams or rivers merge with the ocean. This mixing of waters with such different salt concentrations creates a very interesting and unique ecosystem. Microflora like algae, and macroflora, such as seaweeds, marsh grasses, and mangrove trees (only in the tropics), can be found here. Estuaries support a diverse fauna, including a variety of worms, oysters, crabs and waterfowl.

Oceans and major seas cover 70.8% or 362 million sq km of the earth, with a global coastline of 1.6 million km. Coastal and marine ecosystems are found in 123 countries around the world. Marine ecosystems are strongly connected through a network of surface and deep-water currents, and they are among the most productive eco- systems in the world. Coastal and marine ecosystems include sand dune areas, where freshwater and seawater mix, near-shore coastal areas and open-ocean marine areas. Marine systems extend from the low-water mark, i.e. 50 m depth, to the high seas, and coastal systems stretch from the coastline to depths less than 50 m.

Different types of terrestrial and coastal and marine biomes and habitats in India

There are several types of coastal ecosystems in India: inland fresh water wetlands; inland brackish water wetlands; estuarine wetlands; coastal mudflats; sand dunes; rocky shores; mangrove forests; coral reefs; and marine areas.

The significance of India's biological riches will further be greatly reinforced if viewed in the perspective that India has 16 per cent of the world's human population (>1.2 billion people) and 18 per cent of the world's cattle population on 2.5 per cent of the world's landmass and yet it ranks 12th among the 17 mega diversity countries in the world.

Table 1: Overview of Coastal Wetlands in India

Wetland Category	Number of Wetlands	Total Wetland area	% of wetland area	Open water	
				Post monsoon area	Pre-monsoon area
Coastal Wetlands natural	10204	3703971	24.27	930663	750339
Coastal Wetlands man made	2829	436145	2.86	301767	281010
Total Coast	**13033**	**4140116**	**27.13**	**1232430**	**1031349**

Source: NCSCM report/ SAC, 2011. National Wetland Atlas. SAC/EPSA/ABHG/NWIA/ATLAS/34/2011, Space Applications Centre (ISRO), Ahmedabad, India, 310p.

Table 2: Coastal Wetlands Categories and their extent in India

Wetland category	Number of Wetlands	% of Wetland area	Total Wetland area	Open water	
				Post monsoon area	Pre-monsoon area
Coastal Wetlands natural					
Lagoon	178	246044	1.61	208915	191301
Creek	586	206698	1.38	199743	189489
Sand Beach	1353	63033	0.41	–	–
Intertidal mudflat	2931	2413642	15.82	516636	366953
Salt Marsh	744	161144	1.06	5369	2596
Mangrove	3806	471407	3.09	–	–
Coral reef	606	142003	0.93	–	–
Salt pan	609	148913	0.98	105253	94047
Total Coast	**13033**	**4140116**	**27.13**	**1232430**	**1031349**

Source: NCSCM report/ SAC, 2011. National Wetland Atlas. SAC/EPSA/ABHG/NWIA/ATLAS/34/2011, Space Applications Cen- tre (ISRO), Ahmedabad, India, 310p.

1.3.2.3 CORAL REEFS

Coral reefs are widely distributed in warm shallow waters. They can be found as barriers along continents (e.g., the Great Barrier Reef off Australia), fringing islands and atolls. Naturally, the dominant organisms in coral reefs are corals. Corals are interesting since they consist of both algae (zooxanthellae) and tissues of animal polyp.

Since reef waters tend to be nutritionally poor, corals obtain nutrients through the algae via photosynthesis and also by extending tentacles to obtain plankton from the water. Besides corals, the fauna include several species of microorganisms, invertebrates, fishes, sea urchins, octopuses and sea stars.

Coral reefs are formed by colonies of coral polyps which are marine animals that belong to Class Anthozoa of *Phylum Cnidaria* (earlier known as Coelenterata). *Phylum Cnidaria* contains over 10,000 species of animals found exclusively in aquatic and mostly marine environments. Their distinguishing feature is cnidocytes, specialised cells that they use mainly for capturing prey. A coral 'head' is a colony of thousands of genetically identical polyps. Each polyp is a spineless animal typically only a few millimetres in diameter and a few centimetres in length with an exoskeleton base and a set of tentacles surrounding a central mouth opening. Over many generations, the colony thus creates a large skeleton that is characteristic of the species. Most coral reefs are built from stony corals. Coral reefs are often called 'rainforests of the sea' as they are highly diverse ecosystems because of the variety of niches provided by the reef structures.

The most important ecosystem services that coral reefs deliver are to tourism, fisheries and shoreline protection.

There are three principal reef types:

Fringing reef – directly attached to a shore, or borders it with an intervening shallow channel or lagoon;

Barrier reef – a reef separated from a mainland or island shore by a deep channel or lagoon; and

Atoll reef – this more or less circular or continuous barrier reef extends all the way around a lagoon without a central island.

In India, the reefs are distributed along the east and west coasts at restricted places and all the three major reef types (atoll, fringing and barrier) occur.

Off the mainland coast of India, the Gulf of Kachchh in the northwest, and Palk Bay and Gulf of Mannar in the southeast, are the two major areas where coral reefs are found.

There are patches of reef growth on the west coast, for example coral reefs at Ratnagiri and Malvan for which pro- tection has been given by declaring that area as an MPA. The Andaman and Nicobar Islands have fringing reefs around many islands, and a long barrier reef (329 km) on the west coast. In the Lakshadweep, there are 10 atolls with 36 islands. All the atolls are surrounded by prolific reefs.

The commonest corals are *Acropora* spp., *Porites* spp., *Diploastrea, Heliopora, Goniastrea retiformis* and *Lobophyllia corymbosa*.

There are amazing coral reefs among the Lakshadweep and Andaman groups of islands. The Andaman and Nicobar Islands represent unique assemblages of plants and animals and also exhibit inter-island variation and uniqueness.

Coral reefs are critical to the fisheries and protecting coasts from wave action and erosion (Middleton 1999; Ruddle et al 1988). However, they are undergoing rapid destruction (due to a number of factors including destructive fishing techniques; reef mining for calcium carbonate production; siltation as a result of deforestation; sedimentation; marine pollution with contaminants; freshwater dilution; sub-aerial exposure and disease; and global warming and climate change are posing an additional emerging and severe threat to already stressed coral reefs.

The rising sea level and changed weather patterns, such as altered El Niño and La Niña events, are already affecting coral reefs. In 1998, the tropical sea surface temperatures (SSTs) were the highest on record (the culmination of a 50 year trend), and coral reefs suffered the most extensive and severe bleaching (loss of symbiotic algae) and death on record. As a result of this El Niño event in 1998, 16 per cent of the world's coral reefs and 50 per cent of those in the Indian Ocean were destroyed. As such, reef communities have been altered in the region. Although healthy reefs are likely to adapt to projected sea level changes, coral reefs that are already stressed by other human activities and threats will not (UNISDR/UNDP 2012a, 2012b) [Savarkar 2014, ENVIS publication]

Inland freshwater wetlands

Inland fresh water wetlands of India extend over an estimated 16,00,000 ha, while brackish water wetlands occupy an estimated area of over 20,00,000 ha. Along the 7,517 km long coastline of India, there is an estimated 35,40,000 ha of backwaters and an estimated 39,00,000 ha of estuarine wetlands [Savarkar 2014, ENVIS publication]

1.3.2.4 SEAGRASSES

The only flowering plants that have colonised the ocean floor for many millions of years are seagrasses. They are believed to have originated on land but are now, except for one genus, completely adapted to living underwater. They thrive in shallow coastal seas as they require light for photosynthesis, in areas that are calm where there is shelter from wind and water currents.

Seagrasses occur in the intratidal and midtidal zones of shallow and sheltered localities of seas, gulfs, bays, back- waters and lagoons. They are monocots, related to lilies and gingers, with rhizomes to which leaves are attached. The extent of seagrass meadows depends on the clarity of water which in turn decides the availability of sunlight.

Seagrass ecosystems are an important coastal habitat for a number of species. A number of animals such as the dugong, turtles, sea urchins and some fish directly feed on the leafy blades. They also provide an excellent habitat for a number of species, including varieties of prawn and fish.

The major seagrass meadows in India are found along the southeast coast (Gulf of Mannar and Palk Bay) and in the lagoons of islands from Lakshadweep in the Arabian Sea to Andaman and Nicobar in the Bay of Bengal. Fourteen species of seagrasses are found along the Indian coast. While the Tamil Nadu coast harbours all fourteen species, eight or nine species are found in other places. Meadows are mostly heterospecific; some meadows in Lakshadweep are mono or bispecific.

Natural threats to seagrass ecosystems in India are cyclones and strong waves as well as grazing. New threats are due to changing sea levels as well as changes in water quality, especially acidification. Anthropogenic threats include the increased sediment load in the water from various sources which reduces the light availability for photosynthesis. Construction of harbours and jetties, dredging and discharge of effluents are important causes for destruction of seagrass habitats.

Higher water temperatures resulting from climate change will affect growth, reproduction and general metabo lism of seagrasses, while increased acidity will affect their productivity (Bjork et al, 2008; Short and Neckles, 1999). Increased numbers of storms will also result in physical damage to seagrass meadows and increase the turbidity of the water, affecting the availability of light for photosynthesis (Bjork et al 2008). [Savarkar 2014, ENVIS publication]

1.3.3 Key coastal and marine species

The faunal diversity of India—terrestrial, freshwater, brackish water and marine—is represented by 92,037 species, of which 2,577 belong to Protista and 89,460 to Animalia, including 31 phyla of invertebrates and chordates. These numbers account for 7.50 per cent of the total in the world. Among these are 31 species of marine mammals.

India has 919 species of plants and animals that are globally threatened.

1.3.3.1 MARINE ALGAE

Marine macro algae (seaweeds): A recent report identifies a total of 936 species of marine algae from different areas of India (Rao, 2010).

The greatest number of species have been recorded in Tamil Nadu (302), followed by Gujarat (202), Maharashtra (159), Lakshadweep (89), Andhra Pradesh (79) and Goa (75). Recent studies conducted by the Botanical Survey of India have recorded 206 species of seaweed in the Andaman and Nicobar Islands

The scanty records from other maritime states may not necessarily mean that there is a paucity of algal species but may rather reflect a lack of intensive surveys.

Seaweeds are harvested mainly for raw material for production of agar, alginates and seaweed liquid fertiliser.

The estimated total standing crop of seaweeds in the intertidal and shallow waters of the Indian coast is 91,345 tonnes wet weight and that in deep water is 75,373 tonnes, which includes 6,000 tonnes of agar-yielding seaweeds (Roy and Ghosh, 2009). Red algae are used for manufacture of agar, and brown algae are used for alginates and seaweed liquid fertilisers. The bulk of the harvest is from the natural seaweed beds of the Gulf of Mannar Islands. Recently, *Euchema cottonii* has been introduced in the Gulf of Mannar for commercial farming. Its effect on native species, not known so far, remains a matter of great concern.

1.3.3.2 FISHES

Fish constitutes almost half of the total number of vertebrates in the world. They live in almost all conceivable aquatic habitats. They exhibit enormous diversity of size, shape and biology, and in the habitats they occupy. India's extensive coastline is rich in diverse living resources. These resources continue to deteriorate with rampant harvesting or are altered for other uses such as aquaculture and fisheries (Marale and Mishra, 2011).

The Indian fish population represents 11.72% of species, 23.96% of genera, 57% of families and 80% of the global fishes. The exact number of species associated with the coral reefs of India is still to be determined; however, there are more than 2,546 species of fi shes in the coastal and marine ecosystems of India

1.3.3.3 REPTILES

Reptiles are the most diverse terrestrial vertebrates with about 12,000 described forms, including about 9,350 currently recognized species and about 3,000 subspecies Out of which, about 100 have re-entered the ocean. Among them are seven species of sea turtles and about 80 species and subspecies of sea snakes, as well as a few other species that are occasionally or regularly found in brackish waters, including various other snakes, the saltwater crocodile, and the marine iguana of the Galapagos Islands. Of the more than 300 species of turtles only seven are truly marine while about 50 species are fully terrestrial, belonging to the family of tortoises, the Testudinidae. However, there are some brackish water Turtles as well, including species that spend a portion or all of the year in estuarine habitats are the mangrove terrapins (Batagur affi nis and B. baska) of south-east Asia and India (Rasmussen et al, 2011). The most widespread and successful brackish water homalopsids are the bockadams (Cerberus sp) which are distributed from the vicinity of Mumbai, India in the east to Palau, Micronesia in the west, and range southward into the Indonesian Archipelago, New Guinea, and northern Australia (Rasmussen et al, 2011).

In India, all the three living orders of reptiles have their representatives - Crocodylia (crocodiles), 38 Testudines (turtles and tortoises) and Squamata (lizards and snakes). The diversifi ed climate, varying vegetation and different types of soil in the country form a wide range of biotopes that support a highly diversifi ed reptilian fauna (Aengals et al). A total of 32 species of marine reptile

have been reported from Indian seas, including 26 species of sea snake, fi ve species of sea turtles and the saltwater crocodile. Among the turtles, the fi ve species are: leatherback sea turtle- a rare species; green turtle; Olive Ridley; hawksbill; and the loggerhead turtle.

1.3.3.4 COASTAL AND SEABIRDS

The marine ecosystem offers a feeding and breeding ground for a number of birds. Although there is not much diversity among seabirds, a number of seabirds are found regularly in marine and estuarine ecosystems. So far a total of 69 marine bird species have been reported from India, which is representative a wide ranging orders (BNHS/ENVIS, 2011).

1.3.3.5 MARINE MAMMALS

Marine mammals include representatives of three major orders:

- Cetacea (whales, dolphins and porpoises),
- Sirenia (manatees and dugong) and
- Carnivora (sea otters, polar bears and pinnipeds).

The Indian seas support 25 species of marine mammals. All the marine mammal species reported from Indian waters are protected under the Wildlife (Protection) Act 1972.

The information available on the distribution and abundance of marine mammals in the marine regions of India remains scanty. A lack of capacity among marine mammalogists to conduct surveys and research has been an impediment to progress in research and gaining knowledge about species-level distribution, abundance, biology and ecological characteristics.

1.4 Understanding of Coastal livelihood

A livelihood is a means of making a living, and comprises the necessary capabilities, assets (stores, resources, claims and access) and activities required for a means of living.

People's livelihoods are not made up of simply a group of activities that they carry out in order to earn income and access the food that they require for their sustenance. While activities that generate income or secure food supplies are usually a critical part of people's livelihoods, they are shaped and influenced by a complex set of factors that need to be taken into account if people's choices and strategies for ensuring a livelihood for themselves and their families are to be fully understood.

People rely on the ocean to provide livelihoods (i.e. jobs with steady wages) and stable economies for coastal communities worldwide. The jobs and revenue produced from marine-related industries directly benefit those who are employed, but also have substantial indirect value for community identity, tax revenue, and other related economic and social aspects of a stable coastal economy.

Livelihoods need to be understood as dynamic - subject to shocks, changes and seasonal effects – particularly when they depend heavily on access to natural resources, as is often the case among people living in coastal areas. The dynamic nature of the coastal environments means that the ability of 2 people to sustain their livelihoods in the face of shocks and changes is a particularly important issue in coastal and marine livelihoods. A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain its capabilities and assets both now and in the future, while not undermining the natural resource base. The adoption of this holistic interpretation of livelihoods has important implications for our understanding of the relationship between people and the ecosystems in which they live and on which they may depend for at least part of their living. Particularly in coastal areas, dependence on the use of natural resources is often high, largely because of the relative abundance and diversity of resources that can be found in coastal areas.

Taking the term "livelihoods" to include the wide range of elements and influencing factors described above, "coastal and marine livelihoods" also need to be seen as involving far more than the direct exploitation of coastal and marine ecosystems by people living adjacent to them. Even for those directly involved in the use of coastal and marine resources, it often represents just one of the elements in their livelihoods. It may be more or less important, but it will be certainly strongly influenced by the other options open to them, by the various direct and indirect factors in play and the vulnerability context that they have to deal with.

Taking into account the discussion of livelihoods above, the terms "coastal and marine livelihoods" can be interpreted in several ways. On the one hand there are livelihood strategies that include some form of dependence on the use of marine ecosystems or the products that derive from those ecosystems. Direct users of coastal and marine resources include the owners and crews of fishing enterprises and water-born transport vessels, shrimp or fish fry collectors, coral and sand miners, salt makers and mangrove cutters.

However, an even larger group of people are "indirect" users of these resources and depend on the exploitation of coastal or marine resources to provide raw materials for their processing, trading and other activities - fish processors and traders, the operators of cold storages and ice factories, traders whose goods are transported by sea, the operators of aquaculture enterprises that make use of shrimp and fish fry, builders who make use of sand and coral for their business, sellers and traders in salt, charcoal makers who use mangroves from coastal forests. Although many of these actors may not even live in coastal areas they can all be regarded as having a "stake" in the exploitation of coastal and marine ecosystems.

In addition, it is important to take into consideration an even wider group of people who may have very little direct contact with the coastal or marine environment but who in some way benefit from the goods or services it provides. Most people living in coastal areas, including those not directly involved in the use or coastal or marine resources, are liable to benefit from the economic activity and food supply generated by fishing activities or the exploitation of other marine resources. Coastal swamps and mangroves play an important role in providing protection of coastal dwellers from storms, tidal surges and coastal erosion – part of their "vulnerability context"- whether or not they are direct users of these resources. Likewise, owners and workers in industries that rely on rivers or coastal waters for dumping waste are also "using" the coastal ecosystem.

While this analysis of coastal and marine livelihoods cannot be expanded to include all those whose livelihoods potentially have an impact on coastal and marine ecosystems in most of the coastal regions of India, a realisation of the interconnectedness of the livelihoods of those directly using those ecosystems with the livelihoods of others potentially far away who have never even seen the coast is important. Siltation and run-off entering the coastal and marine environment from upstream activities have been identified, as major factors influencing the health of these ecosystems and efforts to eventually manage such influences entails addressing the livelihoods of those that depend on the activities that may be causing them – ensuring a more sustainable livelihood for coastal fishers using coral reef resources may entail the removal of livelihood options from upland farmers many kilometres away.

The coasts provides wide variety of livelihood opportunities to coastal communities which are : 1) commercial fishing 2) mariculture 3) tourism and recreation 4) shipping and transportation 5) whale watching 6) ports and harbors 7) ship and boat building 8) renewable energy production (wind and wave).

Over 500 million people in developing countries depend, directly or indirectly, on fisheries and aquaculture for their livelihood. There are approximately 15 million fish-workers employed aboard decked and undecked fishing vessels in the marine capture fisheries sector.

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Further Resources:

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