

Training Resource Material

Coastal and Marine Biodiversity and Protected Area Management

Module 1

An introduction to coastal and marine biodiversity

For MPA Managers



भारतीय वन्यजीव संस्थान
Wildlife Institute of India

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für Internationale
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On behalf of:



Federal Ministry
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Building and Nuclear Safety

of the Federal Republic of Germany





Training Resource Material

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Module 1

An introduction to coastal and marine biodiversity

For MPA Managers

Summary

This module serves as 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.

Imprint

Training Resource Material:

Coastal and Marine Biodiversity and Protected Area Management for MPA Managers

Module 1: An Introduction to Coastal and Marine Biodiversity

Module 2: Coastal and marine Ecosystem Services and their Value

Module 3: From Landscape to seascape

Module 4: Assessment and monitoring of coastal and marine biodiversity and relevant issues

Module 5: Sustainable Fisheries Management

Module 6: Marine and Coastal Protected Areas

Module 7: Governance, law and policies for managing coastal and marine ecosystems, biodiversity and protected areas

Module 8: Coasts, climate change, natural disasters and coastal livelihoods

Module 9: Tools for mainstreaming: impact assessment and spatial planning

Module 10: Change Management and connectedness to nature

Module 11: Communicating Coastal and Marine Biodiversity Conservation issues

Module 12: Effective management Planning of coastal and marine protected areas

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Zusammenarbeit (GIZ) GmbH
Indo-German Biodiversity Programme
A-2/18, Safdarjung Enclave
New Delhi 110029, India
T +91-11-4949 5353
E biodiv.india@giz.de
W <http://www.indo-germanbiodiversity.com>

Wildlife Institute of India (WII)
P.O. Box 18, Chandrabani
Dehradun 248001
Uttarakhand, India
T +91-135-2640 910
E dwii@wii.gov.in
W www.wii.gov.in

Indira Gandhi National Forest Academy
(IGNFA)
Post Office New Forest,
Dehradun - 248006
Uttarakhand, India
Phone +91-135-2757316
Fax +91-135-2757314
E-Mail : director@ignfa.gov.in

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With guidance of:

Dr. Amita Prasad, Additional Secretary, Ministry of Environment, Forest and Climate Change (MoEFCC) Government of India
Dr. J. R. Bhatt, Advisor, Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India
Dr. Konrad Uebelhör, Director, Indo-German Biodiversity Programme, GIZ India
Dr. V. B. Mathur, Director, Wildlife Institute of India
Dr. Shashi Kumar, Director, Indira Gandhi National Forest Academy, India
Dr. J. Michael Vakily, Team Leader, CMPA Project, Indo-German Biodiversity Programme, GIZ India

Compiled and edited by:

Dr. Neeraj Khera, Senior Advisor, Indo-German Biodiversity Programme, GIZ India
Dr. K. Sivakumar, Scientist F, Wildlife Institute of India

Text and editing contributions from:

Dr. Sarang Kulkarni, Marine Biologist, Indian Institute of Scuba Diving and Aquatic Sports (IISDA), Dr. J.A. Johnson, Scientist D, Wildlife Institute of India; Dr. Ramesh Chinnasamy, Scientist C, Wildlife Institute of India; Dr. D. Adhavan, Project Associate, Wildlife Institute of India; Dr. Pradeep Mehta, Research and Programme Manager, Earthwatch Institute India; Mr. Luke Mendes, Writer, Filmmaker and Media Trainer, Mumbai; Mr. S. Gopikrishna Warriar, Regional Environment Manager, PANOS South Asia; Mr. Darryl D'Monte, Chairperson, Forum of Environmental Journalists of India (FEJI); Dr. Dirk Asendorpf, Journalist and Media Trainer, Germany; Ms Atiya Anis, Communications Expert, Indo-German Biodiversity Programme, GIZ India; Mr. Sanjay Dave, Charkha and Mr. Bharat Patel, MASS Gujarat [case studies of turtle rescue and community plantation of mangroves]; Dr. R. Ramesh and team, NCSCM [ecosystem services, differences between terrestrial and coastal ecosystems, GIS]; Ms Helina Jolly [economic valuation methods and examples]; Dr. S. Senthil Kumar, IGNFA.

Photos by:

Dr. Neeraj Khera, unless otherwise credited

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Photo by: Sarang Kulkarni

Table of contents

1.1 Basic concepts of biodiversity	11
1.1.1 Definitions of biodiversity	11
1.1.2 Three levels of biodiversity	12
1.1.3 Three forms of biodiversity	15
1.2 Conservation shortcuts	21
1.2.1 Keystone species	22
1.2.2 Umbrella species	22
1.2.3 Indicator species	23
1.2.4 Flagship species	23
1.3 Coastal and marine ecosystems in the context of biomes	25
1.3.1 Mangroves	27
1.3.2 Wetlands	28
1.3.3 Mudflats	29
1.3.4 Rocky Shores	31
1.3.5 Sandy Beaches	31
1.3.6 Lagoons	31
1.3.7 Esturies	32
1.3.8 Oceans	32
1.3.9 Coral Reefs	34
1.4 Key coastal and marine species	39
1.4.1 Marine Algae	40
1.4.2 Sea Grasses	40
1.4.3 Fish	41
1.4.4 Reptiles	41
1.4.5 Mollusks	45
1.4.6 Sea Cucumber	49
1.4.7 Coastal Birds and Seabirds	52
1.4.8 Marine Mammals	53
Main sources	57
Further resources	60



Photo by: Dr. Deepak Apte/ BNHS

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).

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 and species interaction. However, this is difficult and time consuming. The second one uses surrogates (known as conservation shortcuts). This is simpler and based on the assumptions that the conservation benefits of surrogate species extend to a larger set of species and/or habitats. Therefore, measuring a surrogate species will provide us an idea of how the ecosystem is doing. The Tiger, turtles and the Whale Shark are well known surrogates.

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 and coral reefs , providing important ecosystem services for the overall human well-being.

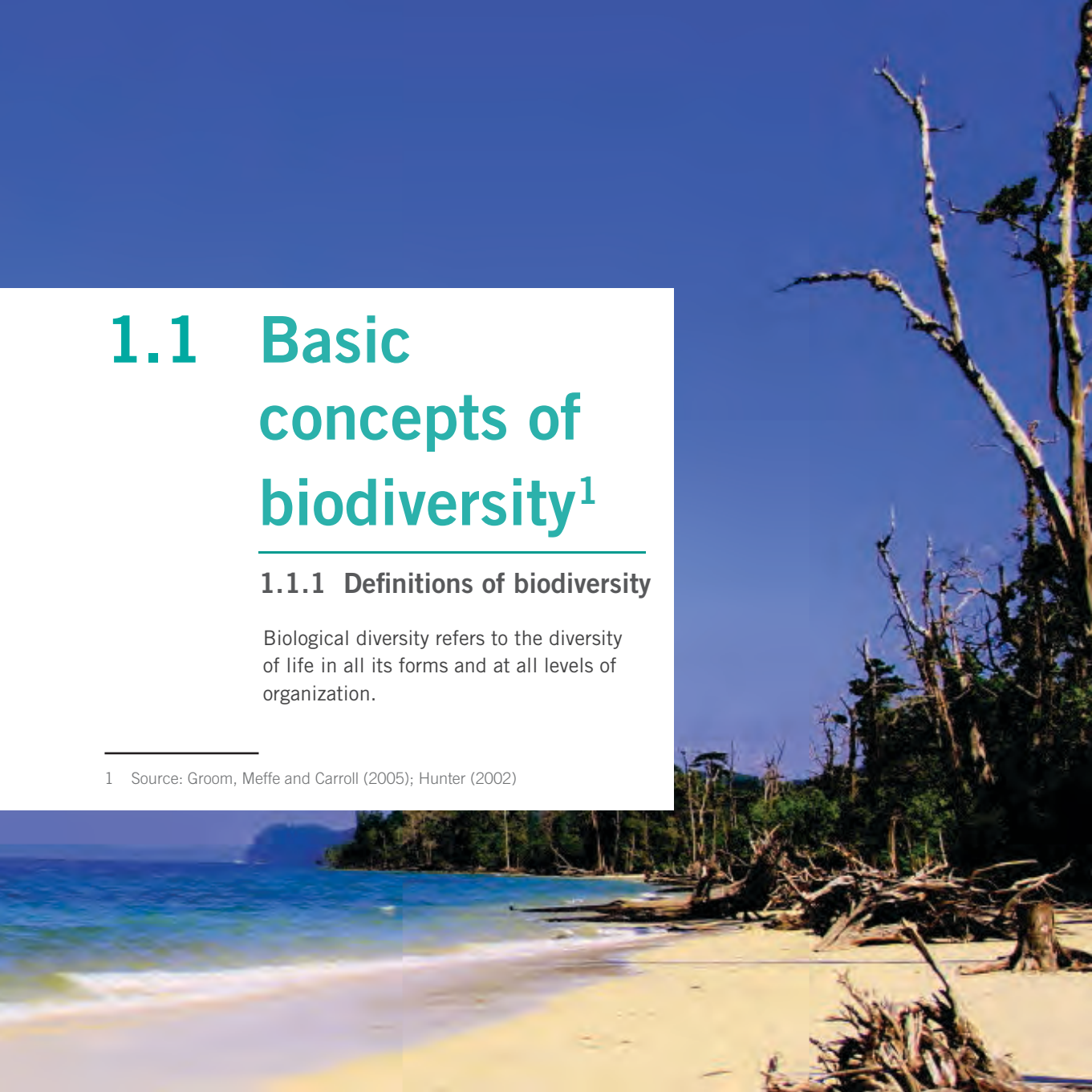


1.1 Basic concepts of biodiversity¹

1.1.1 Definitions of biodiversity

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

¹ Source: Groom, Meffe and Carroll (2005); Hunter (2002)



According to the Convention on Biological Diversity (CBD) of 1992, biological diversity means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part. This includes diversity within species, between species and of ecosystems.

Biologist E.O. Wilson has a more detailed definition (Wilson 1988): 'The variety of life at every hierarchical level and spatial scale of biological organizations: genes within populations, populations within species, species within communities, communities within landscapes, landscapes within biomes, and biomes within the biosphere.'

1.1.2 Three levels of biodiversity

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).

GENETIC DIVERSITY

Genetic diversity refers to the variation of genes within a species. This includes genetic variation between distinct populations of the same species or variation within a population.

Genetic diversity plays a very important role in species' survival and adaptability to changing environmental conditions. Genetic variations enable changes to occur in an organism's anatomy or physiology between generations that are subsequently instrumental in adaptation and survival.

A species that has a high genetic diversity will have more variation that can respond in many different ways, which is essential for surviving in case of external stress, such as disturbances, natural disasters, disease spread, pollution, climate variability and climate change.

Species diversity

Species diversity refers to the variety of species within a given context, which can be a geographical region/location/ecosystem or a marine space. The two main factors taken into account, when measuring diversity, are richness and evenness.

Richness is a measure of the number of different kinds of organisms present in a particular area. For example, the number of different fish species present in communities A and B in Figure 1 is three, so the richness of both communities is three. However, diversity depends not only on richness, but also on evenness. Evenness compares the similarity of the population size of each of the species present. The relative abundance of the three species is more even in community A than in B, so community A has a higher evenness than B. Therefore, the product of richness and evenness shows that overall 'species diversity' is higher in community A.

Species-diverse ecosystems are more likely to be stable because there is a higher chance of availability of another species to take up the functions of the species that may be lost due to environmental change, disasters or any other reason. High species diversity also means less empty niches in the ecosystem and therefore less chances of invasion by exotic species.² Disease spread in a diverse ecosystem is relatively low and less severe due to a proportionately lower number of hosts available for the parasite.

² See 'Species diversity and invasion resistance in a marine ecosystem.'
Available at <http://noss.cos.ucf.edu/papers/Stachowicz%20et%20al%201999.pdf>

Community A



Community B



Figure 1 : Species diversity and its inter-relationship with species numbers (richness) and evenness (spread)

HABITAT DIVERSITY

“Ecosystem” means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.

A community consists of the assemblage of populations of plants and animals that occupy an area and their interactions with each other and their environment.

“Habitat” means the space where an organism or population naturally occurs.

Habitat diversity refers to the distribution and abundance of habitats in a given geographical space. A region possessing a wide variety of habitats supports a much greater diversity of species

than one in which there are few different habitats. The presence of a variety of habitats also supports a different set of species exhibiting different genetic variations in that region/space.

Ecosystem diversity is a term that incorporates both habitat and community diversity.

An increase in the number of habitats and/or, an increase in their structural complexity leads to increased species diversity. Different ecosystems maintain different material and energy cycles with interconnected threads with other ecosystems and habitats. Maintaining ecosystem and habitat diversity therefore is crucial for ensuring overall health of all ecosystems.

1.1.3 Three forms of biodiversity

The levels of biodiversity have been already discussed in the previous section. Each of the three levels can be described further: What types of elements are there and in what numbers (composition), how they are arranged (structure) and what role they play in the system (function).

COMPOSITIONAL BIODIVERSITY

Compositional biodiversity describes the type of biodiversity elements (at all the levels, viz, gene, 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 habitats and communities distributed across the landscape.

STRUCTURAL BIODIVERSITY

Structural biodiversity describes the variety of arrangement of these components, i.e., the 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 wetland.

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 ecosystem functionalities. These temporal fluctuations support different species over different seasons/timescales and have a critical influence on ecosystem dynamics.

FUNCTIONAL BIODIVERSITY

Functional biodiversity is the variety of biological processes, functions or characteristics of a particular ecosystem. 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 and germination.

Functional biodiversity is one of the main factors determining the long-term stability of an ecosystem and its ability to recover from major disturbances.

India Biodiversity Portal:

A unique repository of information on India's biodiversity. The Portal aims to provide open and free access to biodiversity information. The portal enables widespread participation by all citizens in contributing to and accessing information on Indian biodiversity.

<http://indiabiodiversity.org/>



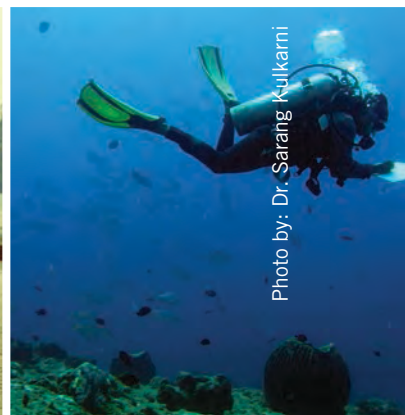
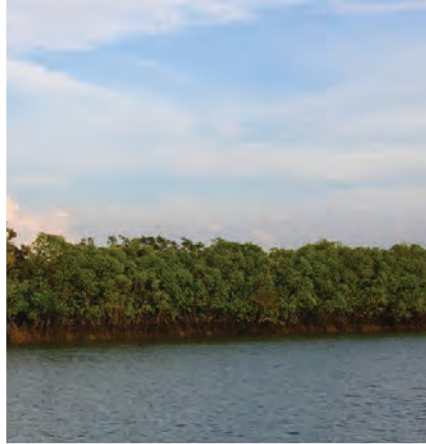


Photo by: Dr. Sarang Kulkarni





1.2 Conservation shortcuts

There are two ways to measure and monitor biodiversity:

1. Measuring actual processes (functional biodiversity), e.g., pollination rate and pattern, rates of productivity, species interaction. However, this would be difficult and time consuming.



2. Using surrogates, 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. These are called 'conservation shortcuts.'

Some conservation shortcuts are keystone species, umbrella species, indicator species and flagship species.

However, there are different views on the use of these surrogates or conservation shortcuts. More information is available at

<http://www.pnas.org/content/97/11/5954.long>

1.2.1 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: It 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 starfish 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.

Read more examples here <http://www.vigyanprasar.gov.in/Radiosericals/keystone2.pdf>

1.2.2 Umbrella species

Some 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 umbrella species for coastal marine ecosystems.

1.2.3 Indicator species

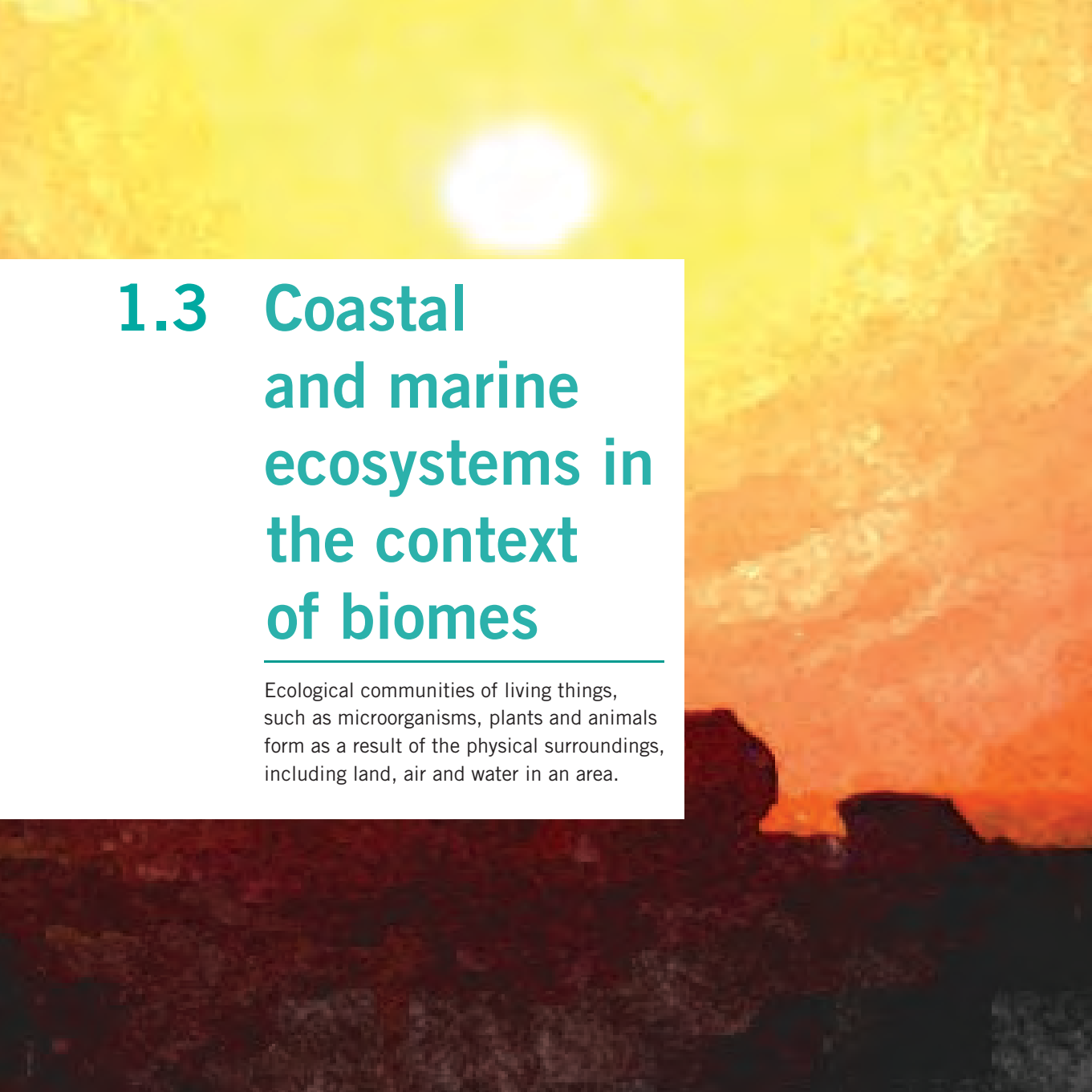
Indicator species are organisms whose presence, absence or abundance reflects a specific environmental condition. Indicator species can signal a change in the biological condition of a particular ecosystem, and may therefore be used as a proxy to diagnose the health of an ecosystem. These species are 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, Humpback Whales and Irrawaddy Dolphins.

1.2.4 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-recognized or less-beloved animals and organisms in a habitat. For example, the Polar bears are a flagship species for conservation in the Arctic region. Interestingly, the 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 species and an umbrella species, such as Elephants, Turtles and Whale Sharks, while other species can be flagship species as well as keystone species, such as the Tiger, turtles and mangroves.





1.3 Coastal and marine ecosystems in the context of biomes

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.

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

Fresh Water is a basic requisite of life on mother earth, and is available in aquifers under the ground and on surface as rivers and lakes. 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).

Freshwater

- Ponds and lakes
- Rivers and streams
- Wetlands

Coastal

- Mangroves
- Tidal mudflats
- Lagoons
- Sandy beaches
- Rocky shores
- Estuaries
- Wetlands

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

around the world⁴. 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. Following is an overview of selected coastal and marine ecosystems:

1.3.1 MANGROVES

Mangroves are trees or plants which grow in the area between the land and water, and bridge the terrestrial and marine environments. 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 occur in fully saline waters but also penetrate considerable distances into estuaries. Mangroves are genetically extremely diverse providing an important habitat for numerous marine and terrestrial species, including nurseries for commercial species.

They dominate approximately 75 per cent of the world's coastline. Indian mangrove vegetation covers about 6,749 km² . The entire mangrove habitats are situated in three zones: (1) East Coast, about 4700km² , (2) West Coast, about 850 km² , and (3) Andaman and Nicobar Islands about 1190 km² These zones have been further categorized into Deltaic, Coastal, and Island habitats. It is estimated that worldwide 48 to 90 species of mangroves exist, and India with rich mangrove species diversity inhabits 82 species of mangroves.

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 wetlands 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 Cuddalore 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

4 MEA 2005

erosion. The most important role of mangroves is the relative quiet conditions they provide which serve as nursery grounds for a number of commercially important 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 anthropogenic 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.

1.3.2 WETLANDS

‘Wetland’ means an area of marsh, peatland or water, natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters, and includes all

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.

<https://www.youtube.com/watch?v=dyY3aUqhVZs>

Mangroves - Guardians of the Coast: A film by ‘Mangroves for the Future’
<https://www.youtube.com/watch?v=4SY7X9zdZ-U>

Guardians of our Coast showcases the fascinating web of life that surrounds these tidal forests. The movie highlights the unique collaboration between governments, regional and local institutions, NGOs and local communities, in efforts to save these vulnerable ecosystems and restore them to their former glory.

inland waters such as lakes, reservoirs, tanks, backwaters, lagoons, creeks, estuaries and man-made wetlands and the zone of direct influence on wetlands, that is to say the drainage area or catchment region of the wetlands⁵.

Wetlands have the highest species diversity of all ecosystems. Many species of amphibians, reptiles, birds (such as ducks and waders), can be found in the wetlands.

India, with its annual rainfall of over 130 cm, varied topography and climatic regimes, supports and sustains diverse and unique wetland habitats. Natural wetlands in India consists of the high-altitude Himalayan lakes, followed by wetlands situated in the flood plains of the major river systems, saline and temporary wetlands of the arid and semi-arid regions, coastal wetlands such as lagoons, backwaters and estuaries, mangrove swamps, coral reefs and marine wetlands, and so on. Wetlands in India occupy 58.2 million ha, including areas under wet paddy cultivation

1.3.3 MUDFLATS

These are important sub-environments found on the fringe of estuaries and in low relief sheltered coastal environments. Both terrestrial and marine environments contribute to the

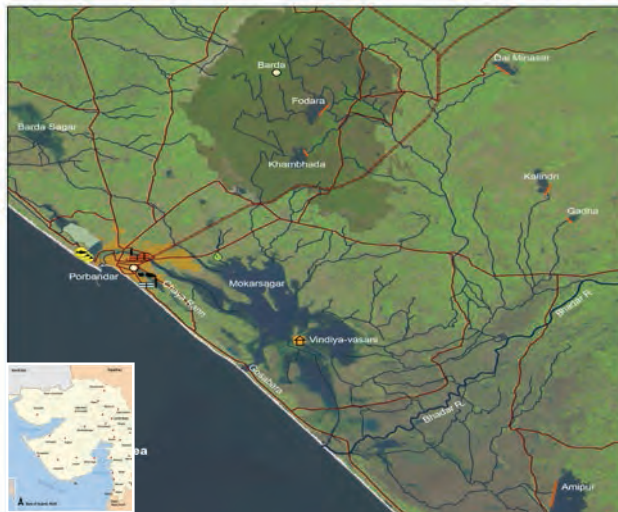
Gosabara-Mokar wetland area is located in Porbandar district in the Saurashtra region of Gujarat, which covers an area of 2,316 km² with a total human population of 5,86,060 people. The three talukas in the district comprises a total of 182 villages, and three talukas in the district. Porbandar district has been carved out from Junagadh district. The Arabian Sea in the west, Devbhumi-Dwarka district in north, Jamnagar in the east and Junagadh in south form the boundaries of Porbandar district.

Gosabara-Mokar is a unique mosaic wetland ecosystem harbouring 112 species of resident and migratory bird. It is a natural lagoon modified by construction of large check dam to control intrusion of sea water. During high tide, sea water enters in a part of the lagoon

5 <http://www.bgci.org/worldwide/article/0373>

making it a unique habitat of saline and freshwater mosaic. Large and shallow spread of water in the wetland attracts large number and variety of migratory birds including some globally threatened species such as the Greater Spotted Eagle, Dalmatian Pelican and Peregrine Falcon, making it a wetland of International Importance. Gosabara hosts more than 1 lakh birds of 112 species belonging to 17 families, indicating the excellent ecological health of this wetland ecosystem. The Lesser Flamingo has the largest population at Gosabara. The Northern Pintail is the most dominant among ducks. Two species of cranes are found here—Common Crane and Demoiselle Crane. The Black-tailed Godwit is dominant among the shore birds. A record 27 Mallards have been counted in Gosabara. There are two waders that breed in Gosa Bara—the Collared Pratincole and Kentis Plover. The first one is called 'Mota Tejpar' and the latter 'Dhongili'. Both are ground nesting birds. Other shore birds include the Black-tailed Godwit, Spotted Redshank, Common Redshank, Golden Plover, Marsh Sandpiper, Curlew Sandpiper and Wood Sandpiper.

The area qualifies as a potential Ramsar Site from Gujarat according to a SACON (MoEFCC) report.



final grained sediments of the inter-tidal mudflats. Mudflats are a major sink of trace metals and organic matter (Siraswar and Nayak, 2011) The Indian coastline has extensive mud flats covering an area of more than 38,000 km². Most of the larger river mouths are concentrated in the northeast and northwest coastal areas and hence the muddy coasts of India are mainly located in these areas. India's non-vegetated mudflats have a total area of about 22300 km², 90% of which are located in the state of Gujarat in the north-west of the country.

1.3.4 ROCKY SHORES

Rocky shores provide good refuge for numerous life forms such as frog shells, periwinkles, oysters, barnacles, cowries, crabs, star fishes, sea urchins and a variety of algae and sea weeds. Rocky shores covered with algal beds are ideal substrate for many intertidal species.

1.3.5 SANDY BEACHES

In this habitat, animals are adapted for burrowing. Bivalves, olive shells, worms, arthropods, sand anemones, and crabs prefer this habitat. High variation in the composition of the sand profile of different beaches results in great faunal diversity among the beaches.

1.3.6 LAGOONS

A lagoon is a shallow water body along the low lying coast separated from the ocean by a barrier but also connected to the ocean by one or a few restricted inlets. They usually form on gently sloping coasts where barrier islands can form off the coast and are generally shallow. Lagoons include coastal and atoll lagoons. There are 8 major lagoons on the East Coast and 9 on the West Coast. Major lagoons on the East Coast are Bende, Chilka, Gulf of Mannar, Muthupet, Muthukadu, Nizampatnam, Pennar and Pulicat. Lagoons on the West Coast are Asthamudi, Ettikulam, Lagoons of Bombay Coast, Lagoons of Lakshadweep atolls, Paravur, Murukumpuzha, Talapady, Veli and Vembanad. Lagoon ecosystems are also getting adversely affected by the urbanization, industrialization and aquaculture activities in the same ways as estuarine ecosystems (Saxena, 2012).

1.3.7 ESTUARIES

Estuaries mark the transitional zone between the lower tidal region of a river and the marine environment. 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.

They are sheltered coastal water bodies which act as nutrient traps, shelter and nursery for a wide variety of marine life forms. They are very important from commercial, industrial and recreational point of view. A total of 14 major, 44 medium and 162 minor rivers draining fresh water into the sea through about 53 estuaries in India. Several of Indian estuaries have become danger prone zones. The estuarine ecosystems are under heavy anthropogenic pressures mainly due to urbanization and industrialization. Dumping of sewage, inflow of municipal waste water and industrial effluents into these water bodies are causing extensive damage to these ecosystems. The aquaculture activities around estuaries have also resulted in heavy accumulation of heavy organic and inorganic pollutants. (Saxena, 2012)

1.3.8 OCEANS

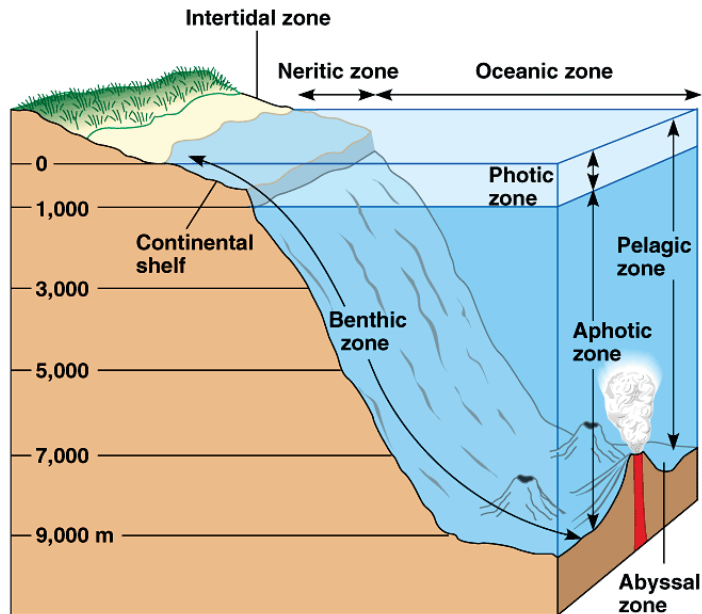
The largest of all the ecosystems, oceans are very large bodies of water that dominate the earth's surface. Like ponds and lakes, ocean regions are separated into separate zones: intertidal, pelagic, abyssal, and benthic. All four zones have a great diversity of species.

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 mollusks. 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 generally 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 surface 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,



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and/or dead organisms. Here temperature decreases 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.

1.3.9 CORAL REEFS

Corals are invertebrate animals belonging to a large group of colourful and fascinating animals called Cnidaria. Each individual coral animal is called a polyp, and most live in groups of hundreds to thousands of genetically identical polyps that form a 'colony'.

Corals are generally classified as either "hard coral" or "soft coral". Soft corals, which include sea fans, sea feathers and sea whips, don't have the rock-like calcareous skeleton like the others, instead they grow wood-like cores for support and fleshy rinds for protection. Soft corals also live in colonies, that often resemble brightly coloured plants or trees. Hard corals extract abundant calcium from surrounding seawater and use this to create a hardened structure for protection and growth. There are around 800 known species of hard coral, also known as the 'reef building' corals. Coral reefs are therefore created by millions of tiny polyps forming large carbonate structures.

Most corals contain algae called zooxanthellae, which are plant-like organisms. The zooxanthellae living in the soft tissue of a coral polyp use sunlight to produce food through photosynthesis and create a byproduct that the coral can use as food. Thus, in a symbiotic relationship, zooxanthellae provide corals with food and provide it with the colour; in return,

the coral provides the zooxanthellae with shelter and nutrients. 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.

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. 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 Plate coral or Bowl coral (e.g. *Turbinaria mesenterina*), Branching coral (*Acropora spp*), Brain coral (e.g. *Symphyllia spp.*), Moon corals (e.g. *Favia spp.*).

The most important ecosystem services that coral reefs deliver are to tourism, fisheries and shoreline protection. Coral reefs are critical to the fisheries and protecting coasts from

wave action and erosion. 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.

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 2012;Savarkar 2014)



Photo by: Dr. Sarang Kulkarni



Photo by: Dr. Sarang Kulkarni



Photo by: Dr. Sarang Kulkarni



Photo by: Dr. Deepak Apte/ BNHS

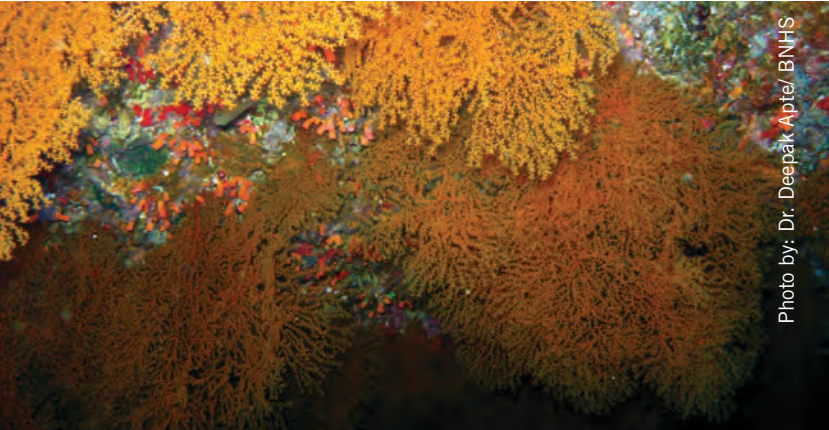


Photo by: Dr. Deepak Apte/ BNHS

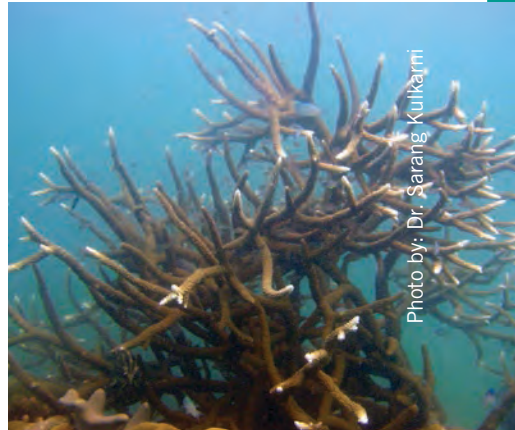


Photo by: Dr. Sarang Kulkarni



1.4 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.



1.4.1 MARINE ALGAE

Marine Algae are macro plants growing in marine environment. Marine algae are also known as seaweeds. They form the main vegetation on reef. The algae are classified in three main group, viz., Green algae, Brown algae and Red algae. The algae not only serve as the main primary producers, but they are also effective indicator to assess any change in the biotic community or environment as a whole.

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

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

1.4.2 SEA GRASSES

Seagrass is found in shallow salty and brackish water in many parts of the world, from tropic to the Arctic Circle. They are called so due to long grass like leaves. They are often confused with sea weeds, but are actually more closely related to the flowering plants that we see on the land. Sea grass have root, stem and leaves and produce flowers and seeds. Although they receive little attention, they are one of the most productive ecosystems in the world. They provide shelter, food and mating ground for various tiny invertebrates to large fish, crabs, sea turtle etc. They are in threat due to anthropogenic activity. Within seagrass communities, a single acre of seagrass can produce over 10 tons of leaves per year. This vast biomass provides food, habitat, and nursery areas for a myriad of adult and juvenile vertebrates and invertebrates. Further, a single acre of seagrass may support as many as 40,00 fish, and 50 million small invertebrates. Because seagrasses support such high biodiversity, and because of their sensitivity to changes in water quality, they have become recognized as important indicator species that reflect the overall health of coastal ecosystems.

1.4.3 FISH

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 the habitats they occupy.

The Indian fish population represents 11.72% of species, 23.96% of genera, 57% of families and 80% of the global fishes. There are more than 2,546 species of fishes in the coastal and marine ecosystems of India.

Fishes found in the coral reef ecosystems of India include groups such as the damselfish (more than 76 species), butterfly fish (more than 40 species), parrot fish (more than 24 species), sea bass, groupers and fairy basslets (more than 57 species), cardinal fish (more than 45 species), jacks and kingfish (more than 46 species), wrasses (more than 64 species), comb-tooth blennies (more than 58 species), gobies (more than 110 species), surgeonfish, tangs and unicornfish (more than 40 species) (Ramakrishna et al, 2010). Cryptic and nocturnal species that are confined primarily to caverns and reef crevices during daylight periods constitute another 20 per cent.

1.4.4 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.

Crocodiles

The saltwater crocodile (*Crocodylus porosus*) is also widely known by the common names, estuarine or Indo-Pacific crocodile, more rarely or informally referred to as the saltie, marine or sea-going crocodile. This species is the largest of all living reptiles, as well as the largest terrestrial and riparian predator in the world. The males of this species can reach sizes up to 6.3 m (20.7 ft) and weigh up to 1,360 kg (3,000 lb). However, an adult male saltwater crocodile is generally between 4.3 and 5.2 m (14 and 17 ft) in length and weighs 400 to 1,000 kg (880–2,200 lb), rarely growing larger. Females are much smaller and often do not surpass 3 m (9.8 ft). As its name implies, this species of crocodile can live in salt water, but usually resides in mangrove swamps, estuaries, deltas, lagoons, and lower stretches of rivers.

Sea turtle

Five of the seven species of sea turtles are known to inhabit Indian coastal waters and islands. These are the Olive ridley (*Lepidochelys olivacea*), Green (*Chelonia mydas*), Hawksbill (*Eretmochelys imbricata*), Loggerhead (*Caretta caretta*) and the Leatherback (*Dermochelys coriacea*) turtle. Except the Loggerhead, the remaining four species nest along the Indian coast. All the five species of sea turtles that occur in Indian coastal waters are protected under Schedule I of the Indian Wildlife Protection Act (1972), as well as listed in Appendix I of Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES) which prohibits trade in turtle products by signatory countries. All species of sea (marine) turtles occurring in the Indo-Pacific region are a priority for conservation under the Convention on the Conservation of Migratory Species of Wild Animals (CMS) and are listed on both Appendices I and II. At present there exists no commercial or international trade of marine turtles or turtle products in India. However, incidental fishing related mortality of marine turtles which is globally well documented, is also a matter of great concern for India.

Though many of the ecological interconnections influencing sea turtle behavior and biology remain unclear, it is known that sea turtles occupy a unique position within the food web. They consume an assortment of prey, including puffer fish, crustaceans, sponges, tunicates, sea grasses, and algae. The unusual life cycle of the animal plays a vital role in transportation of nutrients from the highly productive marine habitats such as sea-grass beds to energy-poor habitats like sandy beaches. This helps reverse the usual flow of nutrients from land to sea.



Green Sea Turtle (*Chelonia mydas*) (Photo – D. Adhavan)



Olive ridely (*Lepidochelys olivacea*)
(Photo - nationalgeographic.com)



Loggerhead Sea turtle (*Caretta caretta*)
(Photo - <http://scubaemporium.blogspot.com/2011/04/loggerhead-sea-turtles-compass-of-sea.html>.)



Hawksbill Sea turtle (*Eretmochelys imbricata*)
(Photo - <http://www.thinglink.com/>)



Leatherback Sea turtle
(*Dermochelys coriacea*) (Photo - en.wikipedia.org)

1.4.5 MOLLUSKS

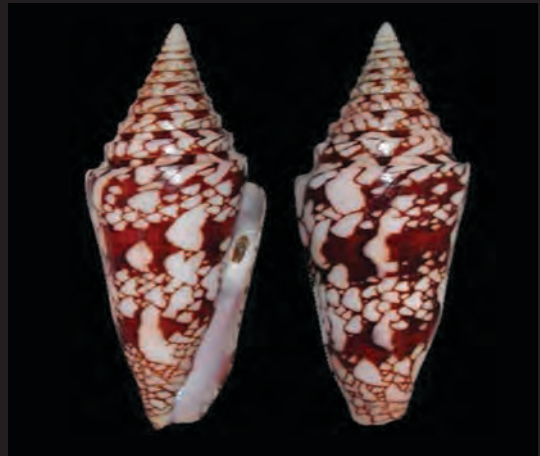
The molluscs or mollusks compose the large phylum of invertebrate animals known as the Mollusca. Around 85,000 extant species of molluscs are recognized. They are the largest marine phylum, comprising about 23% of all the named marine organisms. Many molluscs also live in freshwater and terrestrial habitats. They are highly diverse, not just in size and in anatomical structure, but also in behavior and in habitat. Cephalopod molluscs, such as squid, cuttlefish and octopus, are among the most neurologically advanced of all invertebrates. The gastropods (snails and slugs) are by far the most numerous molluscs in terms of classified species, and account for 80% of the total

Most molluscs are herbivorous, grazing on algae or filter feeders. For those grazing, two feeding strategies are predominant. Some feed on microscopic, filamentous algae, often using their radula as a 'rake' to comb up filaments from the sea floor. Filter feeders are molluscs that feed by straining suspended matter and food particle from water, typically by passing the water over their gills. Most bivalves are filter feeders.

These filter feeding organisms maintains the water quality by filtering the suspended micro particles including micro algae and microorganism. *C. tritonis* is one of the few animals to feed on the crown-of-thorns starfish, (*Acanthaster planci*) which is a threat to corals.



Helmet shell (*Cassis cornuta*) (Photo - MoEFCC)



Vazhaipoo shell (*Conus milne edwardsi*) (Photo - MoEFCC)



Rajali (*Charonia tritonis*) (Photo - MoEFCC.)



Bear Paw Clam (*Hippopus hippopus*)
(Photo -MoEFCC.)



Chambered nautilus or Elephant trunk shell
(*Nautilus pompilius*) (Photo - MoEFCC.)



Giant clam (*Tridacna squamosa*)
(Photo - MoEFCC)



Arthritic spider conch (*Lambis chiragra arthritica*)
(Photo - MoEFCC)



Lambis scorpius (Spider conch)
(Photo - MoEFCC)



Map cowrie (*Cypraea mappa*) ; Schedule 4
(Photo - MoEFCC)



Horse conch shell (*Fasciolaria trapezium*);
Schedule 4 (Photo - MoEFCC)



Cypraea talpa; Schedule 4 (Photo - MoEFCC)

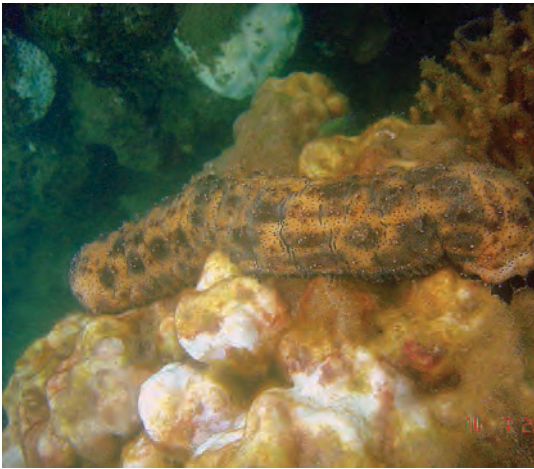


Harpulina arausiaca; Schedule 4
(Photo - MoEFCC)

1.4.6 SEA CUCUMBER

Sea cucumbers are a diverse group of worm-like and usually soft-bodied echinoderms found in nearly every marine environment, but are most diverse on tropical shallow-water coral reefs. They range from the intertidal, where they may be exposed briefly at low tide, to the floor of the deepest oceanic trenches. Some of these are about 20 cm in length, though adults of some diminutive species may not exceed a centimeter, while one large species can reach lengths of 5 m (*Synapta maculata*). Several species can swim and there are even forms that live their entire lives as plankton, floating with the ocean currents. These animals are used as delicacy and as a part of folk medicine in Asia. Despite increased exploitation of sea cucumbers, they are still numerous in the wild. Sea cucumbers are nocturnal creatures.

Sea cucumbers feed on tiny particles like algae, minute aquatic animals, or waste materials, which they gather in with 8 to 30 tube feet that look like tentacles surrounding their mouths. The animals break down these particles into even smaller pieces, which become fodder for bacteria, and thus recycle them back into the ocean ecosystem. Earthworms perform a similar function in terrestrial ecosystems.



Sea cucumber (*Euapta godeffroyi*)
(Photo - N. Marimuthu)



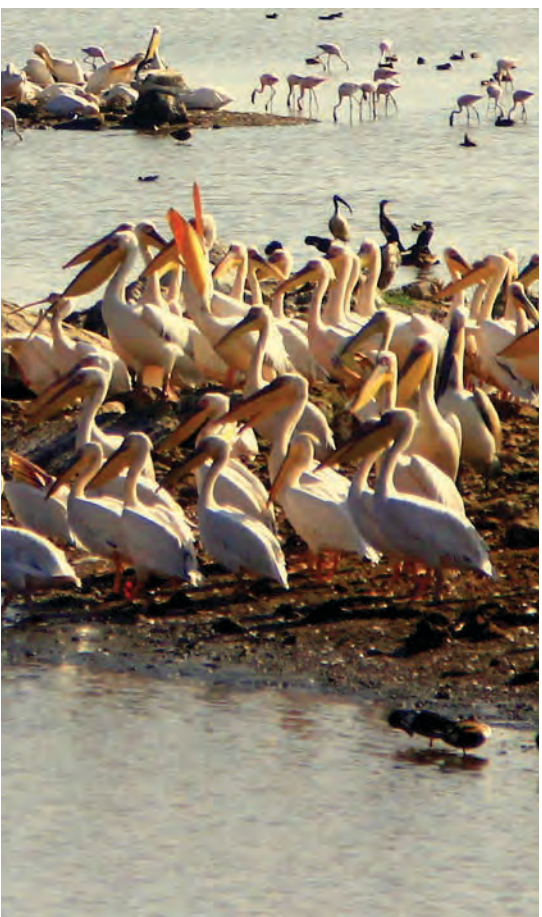
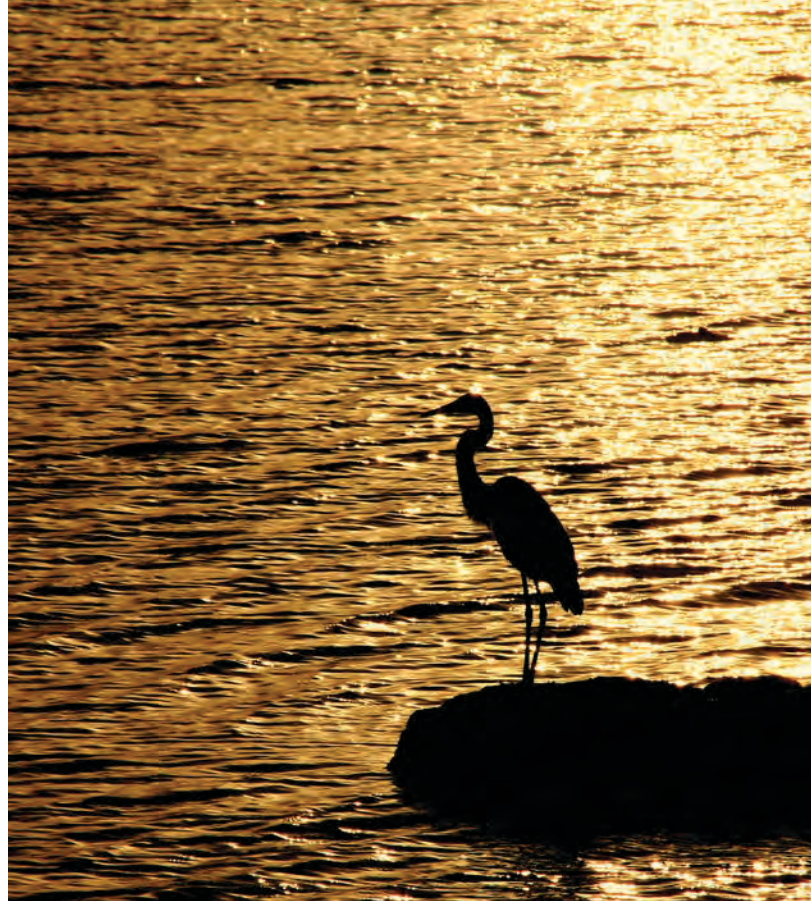
Sea cucumber (*Stichopus hermanni*)
(Photo - N. Marimuthu)



Sea cucumber (*Holothuria atra*)
(Photo - N. Marimuthu)



Sea cucumber (*Thelenota ananas*)
(Photo - N. Marimuthu)



1.4.7 COASTAL BIRDS 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, (BNHS/ENVIS, 2011).

There are some specialist species that are exclusively dependent on coral reef ecosystems, while a few are generalists that do not depend much on them.

Some common coastal and marine birds:

Greater Flamingo (*Phoenicopterus ruber*)

These famous pink birds can be found in warm, watery regions on many continents. They favor environments like estuaries and saline or alkaline lakes. Considering their appearance, flamingos are surprisingly fluid swimmers, but really thrive on the extensive mud flats where they breed and feed. Shrimplike crustaceans are responsible for the flamingo's pink color. The birds pale in captivity unless their diet is supplemented. Greater flamingos live and feed in groups called flocks or colonies.

Grey-headed Fish-eagle (*Ichthyophaga ichthyaetus*)

This bird of prey is found near slow-moving rivers and streams, lakes, reservoirs and tidal lagoons in wooded country, usually in lowlands but ascending locally to 1,525 m. Although widespread, this species is now only locally common and may have a moderately small population, which is thought to be undergoing a moderately rapid population reduction owing to habitat degradation, pollution and over-fishing.

Brown-headed gull (*Chroicocephalus brunnicephalus*)

This is a small gull which breeds in the high plateaus of central Asia from Tajikistan to Ordos in Inner Mongolia. It is migratory, wintering on the coasts and large inland lakes of tropical southern Asia. This gull breeds in colonies in large reedbeds or marshes, or on islands in

lakes, nesting on the ground. Like most gulls, it is highly gregarious in winter, both when feeding or in evening roosts. It is not a pelagic species, and is rarely seen at sea far from coasts⁶.



Largest of all pelicans, Dalmatian pelican a globally threatened species. They flock in groups when feeding. They consume daily more than 1 kg of fish, their preferred diet. Pelicans have a throat pouch serving as a scoop for catching fish.

1.4.8 MARINE MAMMALS

There are some 120 species of marine mammals to be found in the world and 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.

⁶ http://bnhservis.nic.in/Database/MarineBirdsIndia_837.aspx

Marine mammals include representatives of three major orders:

Cetacea (whales, dolphins and porpoises):

Cetaceans are the mammals most fully adapted to aquatic life. Their body is fusiform (spindle-shaped). The forelimbs are modified into flippers. The tiny hindlimbs are vestigial; they do not attach to the backbone and are hidden within the body. The tail has horizontal flukes. Cetaceans are nearly hairless, and are insulated by a thick layer of blubber. As a group, Cetaceans are noted for their high intelligence.

Sirenia (manatees and dugong)

The order Sirenia, has just four species in two families worldwide. The two families are the Dugongidae, the dugong family, and the Trichechidae, or the manatee family. All the four species have become rare due to human exploitation for meat and oil. All the sirenians are completely herbivorous and are confined to shallow waters of coastal areas where higher aquatic plant life is abundant. Dugongs are strictly marine mammals whilst manatees may live in the sea or in estuarine or riverine waters. Manatees can wriggle back to water if put on nearby land.

Carnivora (sea otters, polar bears and pinnipeds)

Carnivora is an order of placental mammals that includes about 270 species of bears, cats, dogs, weasels, pinnipeds, and many other meat-eaters. This order is divided into about 11 families. Members of the order Carnivora have a simple stomach and a characteristic tooth pattern that includes the carnassial pair (an enlarged fourth upper premolar and lower first molar); most carnivora have a primitive number of incisors.

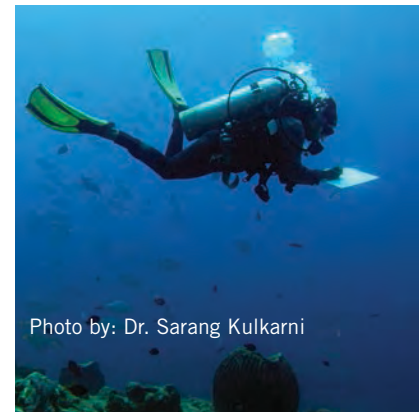
As for the marine mammals, the order Carnivora contains pinnipeds (sealions, walrus and seals), the polar bear, and the two otters.

Dugong (*Dugong dugon*)

Dugongs are one of four living species of the order Sirenia, which also includes three species of manatees. It is the only living representative of the once-diverse family Dugongidae. Dugongs are more closely related to elephants than to marine mammals such as whales and dolphins. They are sometimes referred to as “sea cows” in reference to the fact that they feed almost exclusively on sea grass. Dugongs have long been associated with myths and legends - the Ark of the Covenant was reputedly protected by dugong hide, and early sightings of the species by lonely sailors are believed to have led to the legend of the mermaids. Although commercial hunting of dugongs is now banned, the species may still be at risk from traditional hunting and the destruction of sea grass beds by human activities. Dugong play an important ecological role in coastal marine ecosystems, and the status of dugong populations in an area can be used as an indicator of general ecosystem health.



Photo by: Dr. Sarang Kulkarni



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