Ministry of Environment, Forest and Climate Change, Government of India

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
of the Federal Republic of Germany

Curriculum on

Coastal and Marine Biodiversity and Protected Area Management

Module 1

An Introduction to Coastal and Marine Biodiversity and Ecosystem Services

For Field-Level MPA Managers

Imprint

Training Resource Material:

Coastal and Marine Biodiversity and Protected Area Management for Field-Level MPA Managers

Module 1: An Introduction to Coastal and Marine Biodiversity and Ecosystem Services
Module 2: Coastal and Marine Biodiversity and Ecosystems Services in the Overall Environment and Development Context
Module 3: Mainstreaming Coastal and Marine Biodiversity into Overall Development and Environmental Planning
Module 4: Coastal and Marine Protected Areas and Sustainable Fisheries Management
Module 5: Governance, Law and Policies for Managing Coastal and Marine Ecosystems, Biodiversity and Protected Areas
Module 6: Assessment and Monitoring of Coastal and Marine Biodiversity and Relevant Issues
Module 7: Effective Management Planning of Coastal and Marine Protected Areas
Module 8: Communicating Coastal and Marine Biodiversity Conservation and Management Issues

ISBN 978-81-933282-1-7

October 2015

Published by:

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
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GIZ is a German government-owned not-for-profit enterprise supporting sustainable development.

This training resource material has been developed under the Human Capacity Development component of the project 'Conservation and Sustainable Management of Existing and Potential Coastal and Marine Protected Areas (CMPA)', under the Indo-German Biodiversity Programme, in partnership with the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India. The CMPA Project has been commissioned by the German Federal Ministry for Environment, Nature Conservation, Building and Nuclear Safety (BMUB) with the funds provided under the International Climate Initiative (IKI). The CMPA Project is being implemented in selected coastal states in India and focuses on capacity development of the key stakeholders in the forest, fisheries and media sectors.

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Suggested Citation:
Neeraj Khera, K. Sivakumar and Sarang Kulkarni (Comp.). 2015. Training Resource Material on Coastal and Marine Biodiversity and Protected Area Management for field-level MPA managers. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) India and the Wildlife Institute of India. ISBN 978-81-933282-1-7. Pp 604 (set of 8 modules).

Curriculum on

Coastal and Marine Biodiversity and Protected Area Management

Module 1

An Introduction to Coastal and Marine Biodiversity and Ecosystem Services

For Field-Level MPA Managers

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. An overview of the concept of the ecosystem services and examples of the four types of ecosystem services- provisioning, regulatory, supportive and cultural, are followed by a detailed description of the key coastal and marine habitats and species. The module ends with a discussion on the key differences between the terrestrial and coastal marine ecosystems.

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Acronyms

ABNJ	Areas Beyond National Jurisdiction
CBD	Convention on Biological Diversity
EEZ	Exclusive economic zone
ENVIS	Environmental Information System
ERSST	Extended Reconstructed Sea Surface Temperature
MEA	Millennium Ecosystem Assessment
MPA	Marine protected area
NCSCM	National Centre for Sustainable Coastal Management
NOAA	National Oceanic and Atmospheric Administration
SAC	Space Applications Centre
UNCLOS	United Nations Convention on the Law of the Sea
UNDP	United Nations Development Programme
UNISDR	United Nations International Strategy for Disaster Reduction

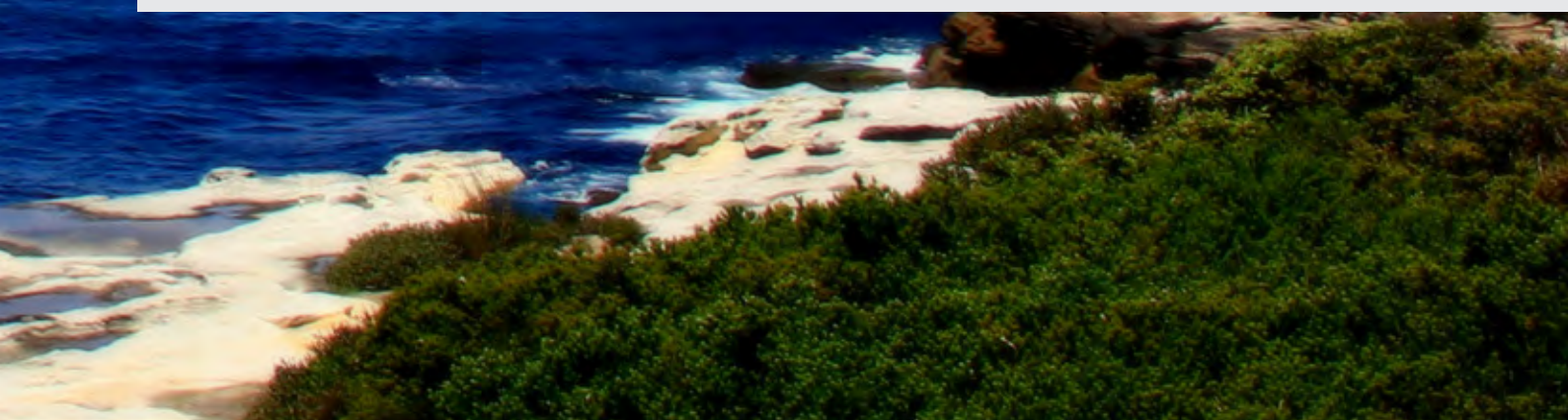
Learning outcomes

After completing this module, the participants are able to

- explain the term 'Biodiversity' and describe different aspects of the concept;
- illustrate different types of coastal and marine habitats and species
- outline different types of ecosystem services arising out of coastal and marine biodiversity;
- understand the ecological basis for conserving coastal and marine biodiversity;
- express the differences between terrestrial and coastal ecosystems with clear examples;
- explain the key differences between landscapes and seascapes; and appreciate the difference in socio-economic and political contexts of terrestrial and coastal-marine ecosystems and their management.

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.'Implementation, compliance and enforcement of these regulations remain a challenge.
- 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 Definitions of biodiversity

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

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[1].

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 https://www.cbd.int/convention/articles/default.shtml?a=cbd-02

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).

1.2.1 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 ensures that parents pass on the traits (such as disease resistance and physical features) that their offspring need to survive. With more variation, it is more likely that some individuals in a population will possess variations of alleles that are suited for the environment. Those individuals are more likely to survive to produce offspring bearing that allele. The population will continue for more generations because of the success of these individuals (Bijukumar and Nair, 2014).

Genetic diversity is high when the individuals of a species/population differ from each other. For example, marine algae and Black-lip Pearl Oyster (*Pinctada margaritifera*) have high levels of genetic diversity. On the other hand, the Hawaiian Monk Seal has low levels of genetic diversity

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, and climate variability and change.

The genus Penaeus represents an economically important group of shrimps and prawns (Dall et al. 1990[2]; BaileyBrook and Mass 1992[3]; Rosenberry 2001[4]). These shrimps are an ecologically diverse group of species and important resources for fisheries and aquaculture worldwide (Chatti et al., 2008[5]).

Black tiger shrimp, *Penaeus monodon*, is one of the most economically important penaeid species, widely distributed in the Indian Ocean and Western Pacific Ocean (Holthius, 1980[6]). Quality production of the shrimp *P. monodon* in hatchery operations depends heavily on genetic diversity and population structure of brood stocks. Their populations along the Andhra Pradesh coast are genetically diverse and show high genetic diversity among *P. monodon* broods.

Source: Khedkar et al, 2013 and Megarajan, 2014.

2 Dall W, Hill BJ, Rothlisberg PC, Staples DJ (1990) The biology of Penaeidae. Adv Mar Biol 27:1–484

3 Bailey-Brook JH, Mass SM (1992) Penaeid taxonomy, biology and zoogeography. In: Fas WA, Lester LJ (eds) Marine shrimp culture: principles and practices. Elsevier Science Publishers, Amsterdam, pp 9–23

4 Rosenberry B (2001) World shrimp farming 2000. In: Rosenberry B (ed) Shrimp News International, USA. Shrimp News International, San Diego, CA, USA, p 324

5 Chatti, R. Z., Chatti, N., Elouaer, A. and Said, K. 2008. Genetic variation and population structure of the caramote prawn Penaeus kerathurus (Forsskal) from the eastern and western Mediterranean coasts in Tunisia. Aquacult. Res., 39: 70-76

6 Holthius, L. B. 1980. Shrimps and prawns of the world. FAO Species Catalogue: an annotated catalogue of species of interest to fisheries FAO Fishery Symp., p. 125-261.

Black-lipped Pearl Oyster *Pinctada margaritifera*

High genetic diversity is also essential for species' evolution. Healthy reproduction becomes increasingly difficult with very little genetic variation within a species, and offspring often deal with problems similar to those of inbreeding. The vulnerability of a population to certain types of diseases can also increase with a reduction in the genetic diversity.

Hunted to near extinction in the late 19th century, the endangered and endemic Hawaiian monk seal *(Monachus schauinslandi)* exhibits extremely low genetic diversity[7]

Levels of genetic diversity (Source: FAO 1994)

Marine invertebrates show wide variation in levels of genetic diversity. In 26 species of mollusc heterozygosities range from 2 to 32% (Johannesson et al. 1989[8]). Crustacea have lower levels of genetic diversity ranging from 0.4 to 10.9% in 44 species of decapod (Nelson and Hedgecock 1980[9]), from 0.8 to 6.4% in six species of tropical decapod and two species of tropical Stomatopod from the Gulf of Carpentaria (Redfield et al. 1980[10]), and from 0.6 to 3.33% in 13 species of Australasian prawns (Mulley and Latter 1980[11]).

Several allozyme studies have revealed cryptic species in coastal fisheries and have shown that resources considered to be single taxa consist of two or more species. Examples of cryptic species have been found in squid (Brierley et al. 1993[12], Carvalho et al. 1992[13], Smith et al. 1981[14]), octopus (Levy et al.), bivalves (Grant et al. 1984[15], Richardson et al. 1982[16], Sarver et al. 1992[17]),

7 [Extremely Low Genetic Diversity in the Endangered Hawaiian Monk Seal (Monachus schauinslandi) http:// jhered.oxfordjournals.org/content/100/1/25.full

8 Johannesson, K., Rodstrom, E.M., Aase, H. 1989. Low genetic variability in Scandinavian populations of Ostrea edulis L.- possible causes and implications. Journal of Experimental Marine Biology and Ecology 128: 177–190.

9 Nelson, K., Hedgecock, D. 1980. Enzyme polymorphism and adaptive strategy in the decapod Crustacea. American Naturalist 116: 238–280.

10 Redfield, J.A., Hedgecock, D., Nelson, K., Salini, J.P. 1980. Low heterozygosity in tropical marine crustaceans of Australia and the trophic stability hypothesis. Marine Biology Letters 1: 303–313.

11 Mulley, J.C.,Latter, B.D.H. 1980. Genetic variation and evolutionary relationships within a group of thirteen species of Penaeid prawns. Evolution 34: 904–916.

12 Brierley, A.S., Rodhouse, P.G., Thorpe, J.P., Clarke, M.R. 1993. Genetic evidence of population heterogeneity and cryptic speciation in the ommastrephid squid Martialia hyadesi from the Patagonian Shelf and Antarctic Polar frontal zone. Marine Biology 116: 593–602.

13 Carvalho, G.R., Thomson, A., Stoner, A.L. 1992. Genetic diversity and population differentiation of the shortfin squid Ilex argentus in the south-west Atlantic. Journal of Experimental Marine Biology and Ecology 158: 105–121.

14 Smith, P.J., Roberts, P.E., Hurst, R.J. 1981. Evidence for two species of arrow squid in the New Zealand fishery. New Zealand Journal of Marine & Freshwater Research. 15: 247–253.

15 Grant, W.S., Cherry, M.I., Lombard, A.T. 1984. A cryptic species of Mytilus (Mollusca: Bivalvia) on the west coast of South Africa. South African Journal of Marine Science 2: 149–162.

16 Richardson, J.R., Aldridge, A.E., Smith, P.J. 1982. Analyses of tuatua populations - Paphies subtriangulata and P. donacina. New Zealand Journal of Zoology 9: 231–238.

17 Sarver, S.K., Landrum, M.C., Foltz, D.W. 1992. Genetics and taxonomy of ribbed mussels (Geukensia spp.). Marine Biology 113: 385–390.

swellfishes (Masuda et al. 1987[18]), silversides (Prodohl and Levy 1989[19]), lizard fishes (Shaklee et al. 1982[20], Waples 1981[21], Yamaoka et al. 1989[22]), bone fishes (Shaklee and Tamaru 1981[23], Shaklee et al. 1982[24]), and small pelagics (Daly and Richardson 1980[25], Smith and Robertson 1981[26]).

Conversely, the lack of genetic differences between colour morphs of the small serranid fishes of the genus Hypoplectrus suggest that they compose a single species (Graves and Rosenblatt 1980[27]). Likewise the lack of genetic differences between specimens of the pelagic armourheads *Pseudopentaceros wheeleri* and *P. pectoralis* from the North Pacific Ocean lead to the conclusion that the armourhead consists of a single metamorphic species with different morphologies between life-history stages (Humphreys et al. 1989[28]). Lack of genetic differences at 33 loci between two species of rock lobster Jasus edwardsii from New Zealand and J. novaehollandiae from Tasmania indicates that these are conspecific populations (Smith et al. 1980[29]).

18 Masuda, Y., Takeoka, S., Tabeta, O., Dotsu, Y. 1987. Genetic differences between two newly described shellfishes of the genus Lagocephalus from s

19 Prodohl, P.A., Levy, J.A. 1989. Genetic study of Atherinidae fishes of Mangueira lagoon (RS Brazil). Comparative Biochemistry & Physiology 94B: 423–426.

20 Shaklee, J.B., Tamaru, C.S., Waples, R.S. 1982. Speciation and evolution of marine fishes studied by the electrophoretic analysis of proteins. Pacific Science 36: 141–157.

21 Waples, R.S. 1981. A biochemical and morphological review of the lizardfish genus Saurida in Hawaii, with a description of a new species. Pacific Science 35: 217–235.

22 Yamaoka, K., Masaru, N., Tanaguchi, N., 1989. Genetic divergence in lizardfishes of the genus Saurida from Southern Japan. Japanese Journal of Ichthyology 36(2): 208–219.

23 Shaklee, J.B., Tamaru, C.S. 1981. Biochemical and morphological evolution of Hawaiian bonefishes (Albula). Systematic Zoology 30: 125–146.

24 Shaklee, J.B., Tamaru, C.S., Waples, R.S. 1982. Speciation and evolution of marine fishes studied by the electrophoretic analysis of proteins. Pacific

25 Daly, J.C., Richardson, B.J. 1980. Allozyme variation between populations of baitfish species Stolephorus heterolobus and S. devisi (Pisces: Engraulidae) and Spratelloides gracilis (Pisces: Dussumieridae) from Papua New Guinea waters. Australian Journal of Marine & Freshwater Research 31: 701–711.

26 Smith, P.J. & Robertson D.A. 1981. Genetic evidence for two species of sprat (Sprattus) in New Zealand waters. Marine Biology 62: 227–233.

27 Graves, J.E., Rosenblatt, R.H 1980. Genetic relationships of the color morphs of the serranid fish Hypoplectrus unicolor. Evolution 34: 240–245.

28 Humphreys, R.L., Winans, G.A., Tagami, D.T. 1989. Synonymy and life-history of the North Pacific pelagic armourhead, Pseudopentaceros wheeleri hardy (Pisces: Pentacerotidae). Copeia 1989: 142–153.

29 Smith, P.J., McKoy, J.L., Machin, P.J. 1980. Genetic variation in the rock lobsters jasus edwardsii and Jasus novaehollandiae. New Zealand Journal of Marine & Freshwater Research 13: 549–55

1.2.2 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.

Some habitats or ecosystems have high species diversity, such as coral reefs or tropical forests. Other habitats, like high-altitude lakes or deserts, harbour lower species diversity. This is how different ecosystems have evolved over time and have their unique set of species. Species are important to carry out the functions of an ecosystem. High plant diversity in a forest ecosystem can lead to increased ecosystem productivity by more efficiently utilizing soil nutrients and water. Species-diverse ecosystems are more likely to be resilient 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. Disease spread in a diverse ecosystem is relatively low and less severe due to a proportionately lower number of hosts available for the parasite.

Figure 1: Community A

Figure 2: Community B

Gujarat is bestowed with one of the most diverse kinds of wetlands in the country including mangroves, coral reefs, beaches, mudflats, tidal flats, flood plain systems and fresh water lakes and reservoirs. And part of these is also includes the coastal areas. Gujarat has the longest coastline of about 1663km in India. Richness in the coastal biodiversity can largely be attributed to Mangroves as well. Mangroves are found throughout Tropical Asia, where they occupy more than 75,000 km2, or 40% of the world's total area of mangroves. Indonesia alone, with 42,530 km2, accounts for 23% of the world total; India (with 6,700 km2), Malaysia (with 6,424 km2), and Bangladesh (with 5,767 km2) each have over 3% of the world total. The total area under mangroves in Gujarat is 911sq.km.

Source: Stanley, 2004

1.2.3 Habitat diversity

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. Presence of variety of habitats also supports a different set of species exhibiting different genetic variations in that region/ space. For example, an area possessing a variety of marine habitats, including shallow- water sediments –

(a) continental slope sediments,

(b) cold seeps

(c) whale and wood falls, and

(d) hydrothermal vents will be able to support more species than an area with only one or two of these habitats.

Marine and coastal areas display a wide ranging habitat types, eg. estuarine, mangrove, sandy beaches, etc.

The marine environment in India consists of a variety of ecosystems occurring along the coastline which borders the Indian peninsula and encircles the two major Island groups. The Indian coastline measures 7,516 km of which the mainland part measures 5,422 km and that around the two major island groups measures 2,094 km (132 km around the Lakshadweep and 1962 km around the Andaman & Nicobar Islands. The mainland coast is divided into the West Coast and the East Coast. These two coasts are significantly different in their geomorphology. The West Coast is usually exposed with heavy surf, rocky shores and headlands while the East Coast is generally shelving with beaches, lagoons, delta and marshes. The coastal zone of India exhibits a wide range of coastal ecosystems such as estuaries, lagoons, mangroves, backwaters, salt marshes etc. A brief description of major marine ecosystems of India is given here (Saxena, 2012).

In Maharashtra, major three types of habitat were identified Rocky shore, Sandy shores and Muddy and mangrove shores which have characteristically distributed along the coastal Maharashtra. Occasionally coral are present along the coastline in small patches. Rocky Shores Rocky shores in Konkan are out crops of foot hill of Sahyadri. These are formed in between sandy shores which have characteristic “c” shape forming bays. There are about 32 rocky shores along the costal Maharashtra. Rocky shores are made up of eroded cliffs; wave cut platforms and vertical cliffs. The main feature of rocky shores of Ratnagiri is tidal pools which harbours rich diverse life in high density. Sandy Shores Sandy shores are formed by accumulation of sand particles driven by wind or water current. Sandy beaches are classified on the basis of sand structures, wave action, surf zone and the sand grain size. Mangroves and mudflats Twelve backwater regions have been identified. All of these have Mudflats and forested patches of mangrove plants and their associate vegetation. Some of these patches are old which dates back to fifties or even older.

[Source: Apte and Bhave 2010]

© Photo: Deepak Apte

1.3 What is an ecosystem?

An ecosystem is defined as a community and the interactions of living, nonliving and their environment in an area. The interaction of animals, plants and their environment is known as an "ecosystem".

An ecosystem consists of the biological community and the physical and chemical factors that make up its non-living or abiotic environment. There are many examples of ecosystems -- a pond, a forest, an estuary, a mangrove, a coral reef The boundaries are not fixed in any objective way, although sometimes they seem obvious, as with the shoreline of a small pond.

Marine Ecosystem:

The marine ecosystem is the largest ecosystem after the whole of Planet Earth because water accounts for more than 70 % of Earth's surface and of which, the marine environment (our oceans and seas) account for more than 97%.

Marine ecosystems have distinct organisms and characteristics that result from the unique combination of physical factors that create them. Marine ecosystems are a complex of habitats defined by the wide range of physical, chemical, and geological variations that are found in the sea. Habitats range from highly productive near-shore regions to the deep sea floor inhabited only by highly specialised organisms[30].

Marine ecosystems include: the abyssal plain (areas like deep sea coral, whale falls, and brine pools), polar regions such as the Antarctic and Arctic, coral reefs, the deep sea (such as the community found in the abyssal water column), hydrothermal vents, kelp forests, mangroves, the open ocean, rocky shores, salt marshes and mudflats, and sandy shores (National Geographic Society, 2015)[31].

Marine ecosystems are important to humankind both ecologically and economically, providing numerous vital goods and services, and supporting the processes that sustain the entire biosphere. Marine ecosystem services are provided at the global scale (for example. oxygen production, nutrient cycles, carbon capture through photosynthesis and carbon sequestration) and at the regional and local scales (for example stabilising coastlines, bioremediation of waste and pollutants, and a variety of aesthetic and cultural values[32]). Marine services also include several important economic benefits such as food provision and tourism[33].

30 http://www.eea.europa.eu/publications/10-messages-for-2010-2014-2/download

31 http://www.nationalgeographic.org/media/marine-ecosystem-illustrations-grades-3-5/

32 http://www.marbef.org/index.php

33 http://ec.europa.eu/environment/nature/natura2000/financing/docs/Economic_Benefits_of_Natura_2000_report.pdf


www.earthwatch.org

1.4 Three forms of biodiversity

Biological Diversity refers to the diversity of life in all its forms and at all levels of organization"4 (Hunter, 2002) emphasises on levels and forms of biodiversity. The levels of biodiversity have been already discussed in the first section. Each of the three levels, can be described further: What types of elements are there in what numbers (composition)? How are they arranged (structure)? What is their role in the system (function)?

1.4.1 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 habitats and communities distributed across the landscape.

1.4.2 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/ timescales and have a critical influence on ecosystem dynamics.

1.4.3 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 disturbances. Loss of structural and functional biodiversity (largely through habitat destruction and fragmentation) affects ecological systems and impairs their ability to continue self-maintenance.

Coastal Biodiversity – the example of Kerala state

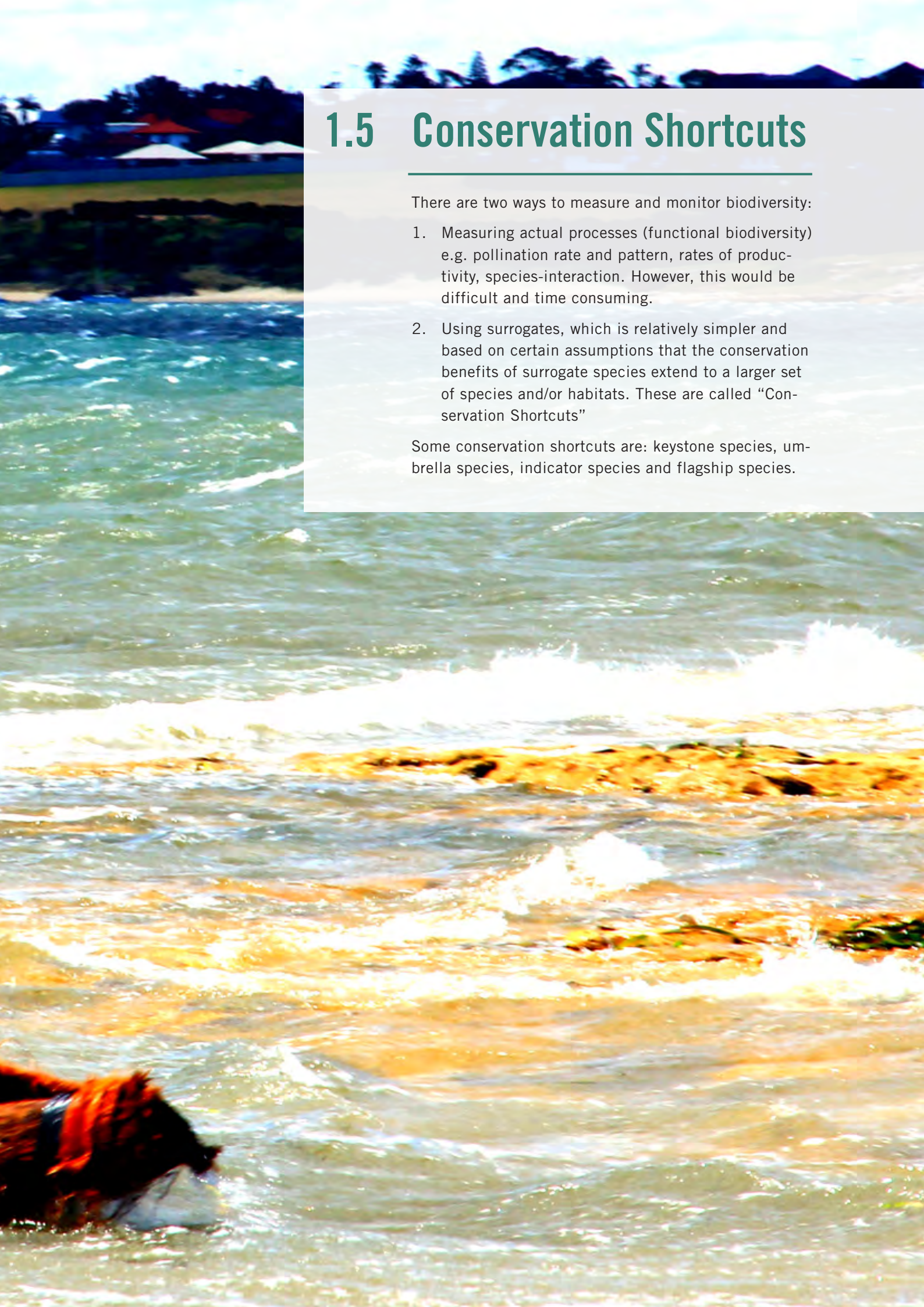
The marine biodiversity of Kerala coast is represented by over 5,000 species, including 17 species of marine mammals, 66 species of coastal and marine birds, 9 species of reptiles (turtles and sea snakes), 740 species of fish, 9 species of tunicates 64 species of echinoderms, 1,000 species of arthropods (copepods, amphipods, isopods, prawns, crabs, lobsters, etc), 250 species of molluscs, 20 species of annelids, 90 species of bryozoans, 26 species of cnidarians, 30 species of sponges, 50 species of protistans, 92 species of sea weeds, and several species of organisms in other categories. The investigations on many minor phyla occurring along the Kerala coast are far from complete (Bijukumar and Nair, 2014).

1.5 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 relatively 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"

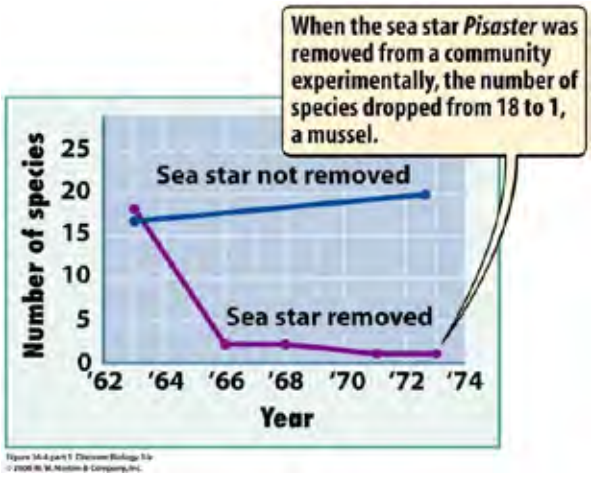
Some conservation shortcuts are: keystone species, umbrella species, indicator species and flagship species.



1.5.1 Keystone species

The term keystone species was first coined by Robert Paine (1966[34]) after extensive studies examining the interaction strengths of food webs in rocky intertidal ecosystems in the Pacific Northwest (Wagner, 2010).

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[35]: 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 starfish population will inadvertently increase the mussel population, resulting in a decline of other macro invertebrate species. The starfish is therefore the 'key-stone species' of this ecosystem, which helps in maintaining high species diversity in this intertidal community.



When talking of keystone species, it is interesting to see the relative position of other 'types' of species in the ecosystem based on their abundance and relative impacts. The figure below indicates keystone species (low abundance, high impact), rare species (low abundance, low impact), dominant species (high abundance, high impact), and common species (high abundance, low impact).

There are a number of other well-described examples where keystone species act as determinate predators. Sea otters regulate sea urchin populations, which in turn feed upon kelp and other macroalgae (Duggins 1980[36]). The otters keep the sea urchin populations in check, thus allowing enough kelp forests to remain as a habitat for a variety of other species. As a result, the entire ecosystem is kept in balance. In terrestrial environments, fire ants function as keystone predators by suppressing the numbers of individuals and species of arthropods that could be harmful to agriculture (Wagner, 2010) .

Keystone species also play important roles in many other ecosystems (Mills et al. 1993[37]). For example, hummingbirds are sometimes referred to as keystone mutualists because they influence the persistence of several plant species through pollination. On the other hand, keystone modifiers, such as the North American beaver (*Casor candensis*), determine the prevalence and activities of many other species by dramatically altering the environment. Species like the Saguaro cactus (*Carnegiea gigantea*) in desert environments and palm and fig trees in tropical forests are called keystone hosts because they provide habitat for a variety of other species. Keystone prey are species that can maintain their numbers despite being preyed upon, therefore controlling the density of a predator (Wagner, 2010) .

34 http://biology.unm.edu/jhbrown/Documents/511Readings/Paine%201966.pdf

35 http://www.csus.edu/indiv/l/loom/wk%2013/keystone%20species.jpg

36 DUGGINS, D. O. 1980. Kelp beds and sea otters: An experimental approach. Ecology 61: 447-453

37 Mills, L. S., M. Soule, and D. Doak. 1993. The keystone species concept in ecology and conservation. BioScience 43:219-224. Available from https://research.cnr.ncsu.edu/sites/millslab/wp-content/uploads/sites/13/2015/01/Mills93-Keystone.pdf

In some forest communities in tropical America, figs and a few other plants act as keystone species but in a very different manner from the starfish Pisaster. Such plants serve as keystone food resources. Figs bear fruit year-round in some of these forest communities, and a large number of birds and mammals rely heavily on this small group of plant species during the times of the year when other food resources are scarce. Without figs, many species would disappear from the community[38].

1.5.2 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. In a marine ecosystem, a turtle can be recognised as Umbrella, Indicator, Flagship and Key stone species for the kind of importance it has in an ecosystem and for the conservation benefits other species have received due to the protection of turtles.

1.5.3 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, hump- back whales and Irrawaddy dolphins.

38 Encyclopaedia Britannica Online 2015

For example in India, animals such as tigers are considered as 'indicator species' because their presence indicates that the habitat is brimming with health. If they disappear, then it means that something is very wrong. Hence there is a growing emphasis to save tigers; thereby saving tiger, country's ecological foundation such as forests, water, etc., could also be saved. Another indicator species is snow leopard. Snow leopard is extremely rare and its numbers are decreasing further. A little smaller than the common leopard, it is found at altitudes of 3,000 m. and above. The snow leopard is at the top of the food chain, just as the tiger. It indicates the health of the ecosystem because its presence means that its prey species such as hare, bharal and yak are abundant, and the prey in turn are thriving because their habitat is healthy. Similarly, frogs and toads are among the best indicators of the health of wetland habitats such as marshes and lakes. They serve the critical function of keeping insect populations in check[39].

Besides frogs and toads, crayfish also is an indicator of freshwater quality; likewise, corals as indicators of marine processes such as siltation, seawater rise and sea temperature fluctuation; peregrine falcons as an indicator of pesticide loads; or native plants as indicators for the presence and impact of alien species[40].

1.5.4 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-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.

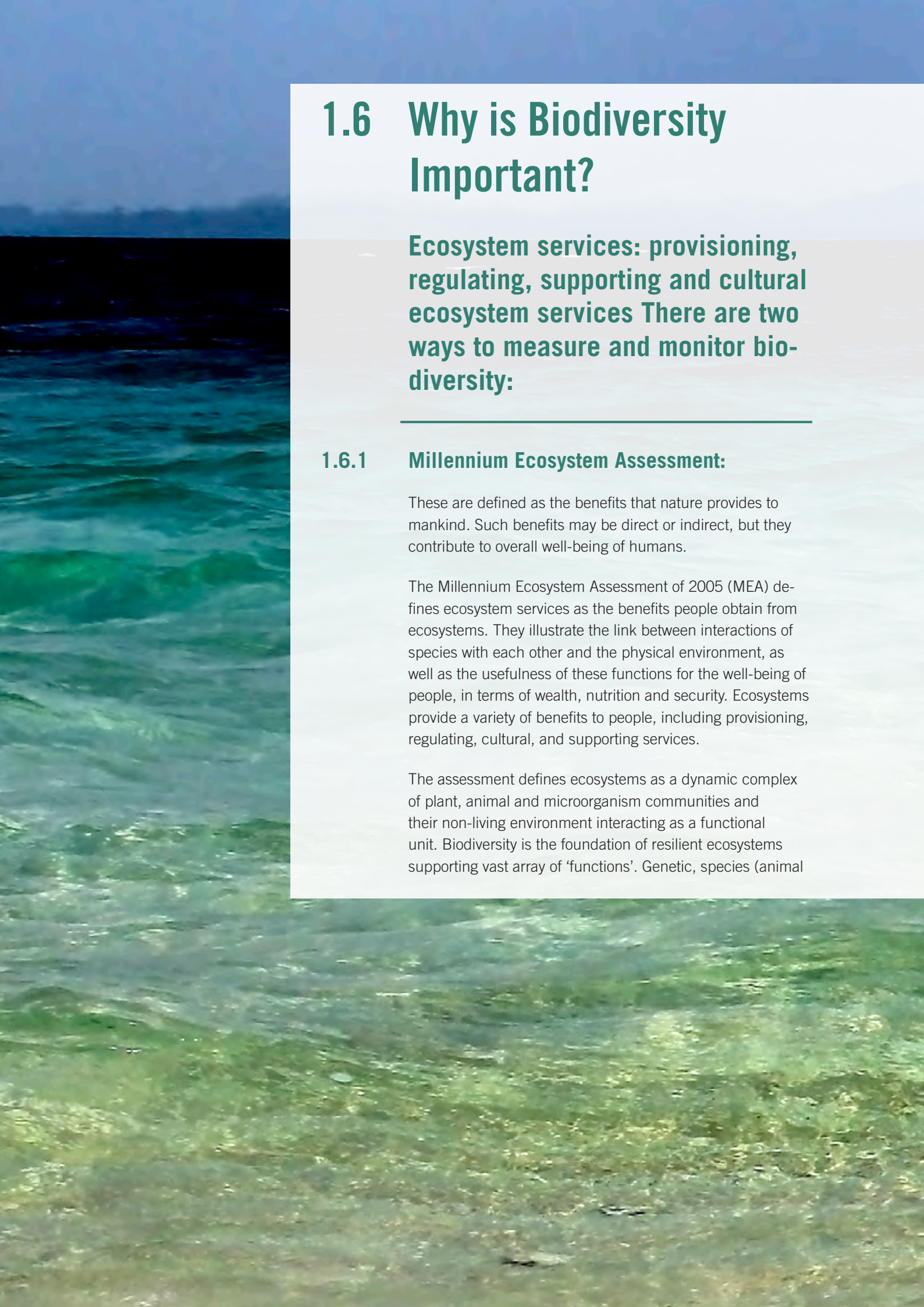
There are some species that can be both a keystone and an umbrella species such as elephants, turtles and whale sharks while other species can be a flagship species as well as a keystone species, such as tigers, turtles and mangroves. For the benefit of conservation, the term flagship species is frequently applied to what we to refer to as "charismatic mega-vertebrates" – whales, dolphins, elephants, tigers, gorillas, etc.

However, there are different views on the use of these surrogates or conservation shortcuts. The use of umbrella and flagship species as surrogates for regional biota whose spatial distributions are poorly known is a popular conservation strategy. Yet many assumptions underlying the choice of surrogate species remain untested. By using biodiversity databases containing spatial incidence data for species of concern for (i) the southern California coastal sage scrub habitat, (ii) the Columbia Plateau ecoregion, and (iii) the continental United States, we evaluate the potential effectiveness of a range of conservation surrogate schemes (e.g., big carnivores, charismatic species, keystone species, wide-ranging species), asking how many species potentially are protected by each scheme and at what cost in each habitat area. For all three databases, we find that none of the surrogate schemes we evaluated performs significantly better than do a comparable number of species randomly selected from the database.

Although some surrogate species may have considerable publicity value, based on the databases we analyzed, representing diverse taxa on three different geographic scales, we find that the utility of umbrella and flagship species as surrogates for regional biodiversity may be limited (Andelman and Fagan, 2010).

39 kidsfortigers.org

40 http://wwf.panda.org/about_our_earth/species/flagship_keystone_indicator_definition/



1.6 Why is Biodiversity Important?

Ecosystem services: provisioning, regulating, supporting and cultural ecosystem services There are two ways to measure and monitor bio-diversity:

1.6.1 Millennium Ecosystem Assessment:

These are defined as the benefits that nature provides to mankind. Such benefits may be direct or indirect, but they contribute to overall well-being of humans.

The Millennium Ecosystem Assessment of 2005 (MEA) de-fines ecosystem services as the benefits people obtain from ecosystems. They illustrate the link between interactions of species with each other and the physical environment, as well as the usefulness of these functions for the well-being of people, in terms of wealth, nutrition and security. Ecosystems provide a variety of benefits to people, including provisioning, regulating, cultural, and supporting services.

The assessment defines ecosystems as a dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit. Biodiversity is the foundation of resilient ecosystems supporting vast array of ‘functions’. Genetic, species (animal

and plant) and habitat diversity have important roles to play in the ecosystem functioning, such as: enabling the development or natural evolution of breeds and races that thrive under a variety of environmental conditions; provision of food, building materials, energy and medicines; and functions such as pollination, waste assimilation, water filtration and distribution of seeds and nutrients. Changes in biodiversity can influence all these functions (e.g. pollination, nutrient cycling) and products arising out of these (e.g. food, medicinal plants). While the variety of life and diversity of living species has an intrinsic value independent of any human concern, here, we will discuss the value in relation to human beingsi.e. ecosystem services, a concept which is the principal framework for expressing the "usefulness" of biodiversity. The concept of ecosystem services is becoming popular as a way to encourage discussion about the dependence of people on nature and what this means both socially and economically.

The Millennium Ecosystem Assessment (MEA) was a global exercise carried out to assess the ecological impact of biodiversity. In its report finalised in 2005, the MEA lists the following ecosystem services from biological diversity.

1.6.2 Provisioning services

Provisioning services are the products people obtain from ecosystems, such as food (agriculture and horticulture crops, livestock, fish), medicinal and aromatic plants and products, fuel, fibre, fresh water, gums and resins, minerals and genetic resources.

Fish (including shellfish) provides essential nutrition for three billion people and at least 50 per cent of animal protein and minerals to 400 million people in the poorest countries.

Fish (including shellfish) provides essential nutrition for

3 billion

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50 per cent

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400 million

people in the poorest countries.

The products obtained from ecosystems include:

Food. This includes the vast range of food products derived from plants, animals, and microbes.

Fibre. Materials such as wood, jute, cotton, hemp, silk, and wool.

Fuel. Wood, dung and other biological materials serve as sources of energy.

Genetic resources. This includes the genes and genetic information used for animal and plant breeding and biotechnology.

Biochemicals, natural medicines, and pharmaceuticals. Many medicines, biocides, food additives such as alginates, and biological materials are derived from ecosystems.

Ornamental resources. **Animal and plant products such as skins, shells and flowers are used** as ornaments and whole plants are used for landscaping and ornaments.

Fish (including shellfish) provides essential nutrition for

Freshwater. People obtain freshwater from ecosystems and thus the supply of freshwater can be considered a provisioning service. Freshwater in rivers is also a source of energy. Because water is required for other life to exist, however, it could also be considered a support service.

1.6.3 Regulating services

Regulating services are the benefits people obtain from regulation of ecosystem processes, including air quality maintenance, climate regulation, carbon sequestration, regulation of human diseases, plant pest and disease control, water purification, natural hazard and disaster risk reduction (mitigating the threat from landslides, floods and even tsunamis), pollination etc. The benefits obtained from regulation of ecosystem processes include:

Air quality regulation. Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality;

Climate regulation. Ecosystems influence climate both locally and globally. For example, at a local scale, changes in land cover can affect both temperature and precipitation. At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases.

Water regulation. The timing and magnitude of runoff, flooding and aquifer recharge can be strongly influenced by changes in land cover, including in particular, alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas.

Erosion regulation. Vegetative cover plays an important role in soil retention and the prevention of landslides.

Water purification and waste treatment. Ecosystems can be a source of

Disease regulation. Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes.

Pest regulation. Ecosystem changes affect the prevalence of crop and livestock pests and diseases.

Pollination. Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators.

55%
of atmospheric carbon emanating from living organisms is captured by marine organisms, and of this between

50-71%
is captured by the ocean's vegetated habitats (e.g. mangroves, salt marshes, seagrasses) which cover less than

0.5%
of the seabed.

Natural hazard regulation. The presence of coastal ecosystems such as mangroves and coral reefs can reduce the damage caused by hurricanes or large waves.

There are a number of coastal ecosystems depending on the local coastal geomorphology and patterns of winds, waves and tides. Some of the important coastal ecosystems are mangroves, coastal lagoons, estuaries, tidal flats and sandy beaches on the landward side; and coral reefs, seagrass beds and submerged rocky patches in the sea. Each ecosystem provides different services with varying levels of importance from our (human) point of view. The importance of the different services may vary according to the local community as well. Describing the environment in terms of ecosystem services helps in translating the complexity of the environment into a series of functions that can be readily understood, and also provide a better understanding of what is being gained or lost when resource exploitation or development takes place (Beaumont et al., 2007[41]).

PROVISIONING (products obtained from the ecosystem)

REGULATING (benefits available from the regulation of ecosystem processes)

CULTURAL (non-material benefits that people obtain from ecosystems)

SUPPORTING: (services that are necessary for the other three but do not yield direct benefit to humans)

41 Beaumont N.J., Austen M.C., Atkins J.P., Burdon D., Degraer S., Dentinho T.P., Derous S., Holm P., Horton T., van Ierland E., Marboe A.H., Starkey D.J., Townsend M. Zarzycki T. 2007. Identification, definition and quantification of goods and services provided by marine biodiversity: implications for the ecosystem approach. Marine Pollution Bulletin, 54, 253–265

1.6.4 Cultural services

Cultural services are the nonmaterial benefits people obtain from ecosystems such as spiritual enrichment, religious and cultural value (sacred sites), knowledge systems, educational values, aesthetic values, social relations (in urban green spaces), and recreation and ecotourism. Spiritual and religious value refers to religious bonds to sacred landscapes, groves and species (Butler, 2006[42]) which is often connected to different religions. For example, the Khecheopalri Lake in Sikkim in northeast India, is considered to be sacred both by Buddhists and the Hindus of Sikkim. The World Heritage Convention acknowledges ecosystem services provided by cultural landscapes.

These are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, including:

Cultural diversity. The diversity of ecosystems is one factor influencing the diversity of cultures.

Spiritual and religious values. Many religions attach spiritual and religious values to ecosystems or their components.

Knowledge systems (traditional and formal). Ecosystems influence the types of knowledge systems developed by different cultures.

Educational values. Ecosystems and their components and processes provide the basis for both formal and informal education in many societies.

Inspiration. Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising.

Aesthetic values. Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, scenic drives, and the selection of housing locations.

Social relations. Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies.

Sense of place. Many people value the "sense of place" that is associated with recognised features of their environment, including aspects of the ecosystem.

Cultural heritage values. Many societies place high value on the maintenance of either historically important landscapes ('cultural landscapes') or culturally significant species.

Recreation and ecotourism. People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.

1.6.5 Supporting services

Supporting services are those that are necessary for the production of all other ecosystem services, such as biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of the habitat. A very prominent example for this type of service is the value of an intact forest in the vicinity of agriculture fields, which provides soil nutrients and maintains soil productivity of the agriculture field.

42 Butler, C. D., Oluoch-Kosura, W. (2006): Linking Future Ecosystem Services and Future Human Well-being. Ecology and Society Vol 11/1, art.30; 16 p. (http://www.ecologyandsociety.org/vol11/iss1/art30/).

A quick overview of various ecosystem services along with examples and the relative importance in terms of contribution by various coastal and marine ecosystems. The classification in the first column is adapted from Beaumont et al, 2007.

SERVICE	EXAMPLES	ECOSYSTEMS								
Provisioning services: Goods and products obtained from ecosystems		Mangroves	Coral reefs	Seagrass beds	Coastal lagoons	Submerged rocks	Tidal flats	Salt marshes	Sandy beaches	Estuaries
Food	Fish, shellfish	H	H	M	M		L			H
	Seaweed		L			H				
	Non Timber Forest Products (NTFP)	H								
Raw materials	Timber, firewood, charcoal	H								
	Alginates, carrageenan, various pharmaceuticals from seaweed		L				H			
	Biochemicals, natural medicines, pharmaceuticals									
	Construction material (coral blocks)		M							
Others	Freshwater	M			M					
	Genetic resources	H	H	L	M	L				M
Regulating services										
Gas and climate regulation	Regulation of local air quality	H								
	Regulation of global climate	H	M	M	L			M		
Disturbance prevention (flood and storm protection, erosion control)	Reduction of wave energy reaching coastline; control of storm surge, wind break	H	H	M			M	M	H	
Bioremediation of waste	Water purification and waste treatment	H		M	M		H	H	M	H
Cultural services										
Leisure and eecreation	Recreation and ecotourism	H	H	L	L		M	L	H	
Cultural heritage and identity	Ethical and spiritual values	H	H						M	
Cognitive values	Education and inspirational values	H	H				H		H	
Existence values	Existence – present and potential future benefits	H	H	H	H	M	M	M	H	
Supporting services										
Biologically mediated habitat	Habitat	H	H	M	M	L	L			
Nutrient cycling	Nutrient cycling	H	H	H	H		M	M		
	Carbon sequestration	H	H	H	L			H		
Life Support	Primary production	H	L	H	H	M	L	M		
	Water cycling	H			M			L	L	

1.7 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.

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.

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

1.7.1 Freshwater regions

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 (Gupta, 2005). 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).

India has about 4% of world's freshwater resources ranking it among the top ten water rich countries. Despite this, according to the Working Group II report of the Fourth Assessment of the Intergovernmental Panel on Climate Change, India is designated a 'water stressed region' with current utilisable freshwater standing at 1122 cubic meter (cu m) per year and per capita compared to international limiting standards of 1700 cu m.

There are different types of freshwater regions. The following sections describe the characteristics of these regions.

1.7.1.1 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 organisms 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 limnetic zone into the profundal zone. The fauna are heterotrophs, meaning that they eat dead organisms and use oxygen for cellular respiration.

India is house to some of the most beautiful lakes of the world, some natural, others artificial. They are there in the high Himalayas under the ice sheath, in the virgin northeast, semi-arid deserts of Rajasthan, coastal zones, or in metros, small towns and villages. In India, lakes serve as source of water for drinking, agriculture, and even industries. It acts as sewage absorbers, flood cushions and recharge zones for groundwater aquifers. It is an ecosystem where a variety of birds and animals breed; pisciculture, and aquaculture thrive leading to a source of income for people. Lake tourism is an immensely profiting sector. In India, there are urban and rural lakes along with natural water bodies that are important to the local population as an important source / basis of their livelihood.

1.7.1.2 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.

India's river system is large and well watered. Twelve major river with a number of smaller rivers and streams. Seven major rivers make the river system of India. The Ganges-Brahmaputra and the Indus systems are the largest as they drain almost half of the country carrying more than 40% of the utilisable surface water. All major rivers of India originate from one of the three main watersheds - a) The Himalaya and the Karakoram ranges, b) Vindhya and Satpura ranges and Chotanagpur plateau in central India and c) Sahyadri or Western Ghats in western India. Over 70% of India's rivers drain into the Bay of Bengal, mostly as part of the Ganges-Brahmaputra system. The Arabian Sea receives 20% of the total drainage from the Indus and other rivers. The remaining 10% drains into interior basins and natural lakes (Sources: NIH, 2015 and India-WRIS Wiki 2014).

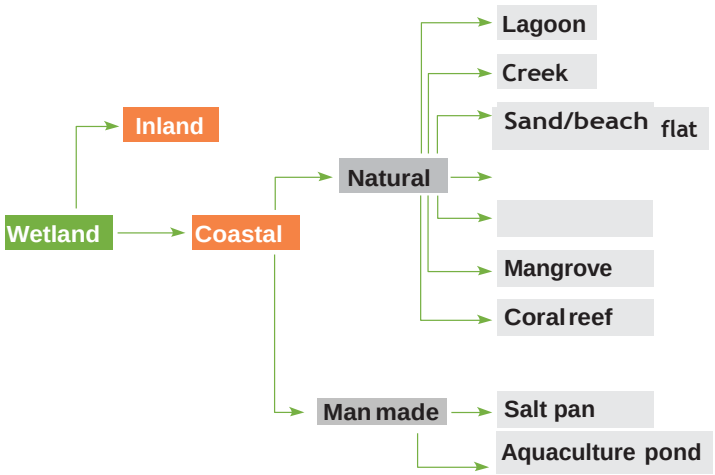
1.7.1.3 Wetlands

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 ecosystems 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.

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. In fact with the exception of bogs, fens and typical salt marshes, Wetlands in India occupy 58.2 million ha, including areas under wet paddy cultivation (Directory of Indian Wetlands) Prasad et al., 2004

Fig 1: Classification of Wetlands in India



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

Gosabara wetland area is located in Porbandar district in the Saurashtra region of Gujarat, which covers an area of 2,316 km^2 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 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 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.


ચાંદની

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.

Coastal Wetlands Categories and their extent in India

Wetland Category	Number of Wetlands	Total Wetland area	% of 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 Centre (ISRO), Ahmedabad, India, 310p.

1.7.2 Coastal and Marine regions

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.

Coastal

1.7.2.1 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.

Indian mangrove vegetation covers about 6,749 km^2 . The entire mangrove habitats are situated in three zones: (1) East Coast, about 4700km^2 , (2) West Coast, about 850 km^2 , and (3) Andaman and Nicobar Islands about 1190 km^2 These zones have been further categorized into Deltaic, Coastal, and Island habitats. It is estimated that worldwide 48 to 90 species of mangroves exist, India with rich mangrove species diversity inhabits 82 species of mangroves are present in India Areas under mangrove vegetation (sq.km) mapped in different scales using satellite data shows that West Bengal has highest mangrove cover of 1838.4 sq.km followed by Gujarat 1012.9 sq.km (Marale & Mishra 2011).

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 22º15' and 21º30' North and 88º10' and 89º51' 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 maximum mangrove cover in the country followed by Gujarat and the Andaman and Nicobar Islands. The Ministry of Environment, Forest and Climate Change (MoEFCC) 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 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 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. 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[43]. 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[44].

43 http.www//assets.panda.org/downloads/wwfparksbro.pdf)

44 Smith, J.B., A. Rahman, and M.Q. Mirza. 1998. Considering Adaptation to Climate Change in the Sustainable Development of Bangladesh. Report to The World Bank by Stratus Consulting Inc.,Boulder, CO.

1.7.2.2 Tidal mudflats

The Indian coastline has extensive mud flats covering an area of more than 38,000 km^2 . 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 mud flats have a total area of about 22300 km^2 , 90% of which are located in the state of Gujarat in the north-west of the country. The vegetated category is also in large part situated in this area i.e. 4353 km2 out of a total of about 5073 km2 (Marale & Mishra 2011).

1.7.1.3 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. There are 8 major lagoons on the East Coast and 9 on the West Coast. Major lagoons on the East Coast are 1. Bende, 2. Chilka, 3. Gulf of Mannar, 4. Muthupet, 5. Muthukadu, 6. Nizampatnam, 7. Pennar and 8. Pulicat. Lagoons on the West Coast are 1. Asthamudi, 2. Ettikulum, 3. Lagoons of Bombay Coast, 4. Lagoons of Lakshadweep atolls, 5. Paravur, 6. Murukumpuzha, 7. Talapady, 8. Veli and 9. Vembanad. Lagoon ecosystems are also getting adversely affected by the urbanization, industrialization and aquaculture activities in the same ways as estuarine ecosystems (Saxena, 2012).

Lagoons:

Lagoons are shallow water bodies separated from larger water bodies by barrier islands or reefs. 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.

Some examples of lagoons in India are Chilika in Odisha, Pulicat in Tamil Nadu, Vembanad Lake in Kerala and atoll lagoons of Lakshadweep.

1.7.2.4 Estuaries[45]

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.

Oceans and major seas cover 70.8 per cent 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 ecosystems 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.

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. There are 14 major estuaries on the East Coast and 16 on the West Coast. Major East Coast estuaries are Adyar, Agniyar, Corum, Edaiyur, Ennire, Godavari, Hoogly, Kallar, Kavery, Kollidam, Krishna, Rushikulya, Uppanar and Vellar. The major West Coast estuaries are Asthamudi, Amba, Beypore, Gangolli, Kali, Kaninamkulam, Korapuzha, Madovi, Mahi, Mahim, Netravathi and Gurupur, Pavenje, Periyaar, Vembanad and Zurai. The total estimated

45 Source: Saxena, 2012

area under the estuaries in India is approximately 2 million ha (Qasim & Sengupta, 1984)[46]. 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).

Marine

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.

1.7.2.5 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 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, 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.

46 Qasim, S. Z. and Sengupta, R. 1982. Marine Environment. In:State of the Environment, Some Aspects. Pp29. (Mimeo)

1.7.2.6 Coral reefs

Coral reefs are widely distributed in warm shallow waters. 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).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.

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 protection 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. [Source: NCSCM Special Publication: Lagoons, Lives and Livelihood]

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. 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 2012)

1.8 The story of Seagrasses and Dugong

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. [Source: NCSCM 2012]

Higher water temperatures resulting from climate change will affect growth, reproduction and general metabo- lism of seagrasses, while increased acidity will affect their productivity. 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. [Savarkar 2013]

Dugongs

Dugongs (*Dugong dugon* Müller, 1776), also known as sea cows, are herbivorous marine mammals belonging to the family Dugongidae and order Sirenia. It is one of the four surviving species in the order Sirenia, and it is the only existing species of herbivorous mammal that lives exclusively in the sea, including Indian waters.

The dugong *(Dugong dugon)* is a grey brown animal that looks a bit like a cross between a seal and a whale. It has a powerful fluked tail and small front flippers, which act like paddles to stabilise it when it swims. The forelimbs are also used for scratching, mouth-cleaning and supporting the body when resting on the bottom. The movement of a dugong is often slow and graceful. It measures 2-4 metres in length and weighs up to 400 kg. An air-breathing mammal, totally adapted to life in the sea, the dugong spends much of its time grazing on seagrasses. It is for this reason that it is often called a sea cow.

Dugongs are shy, secretive animals that are very difficult to approach. They have poor eyesight, but their hearing is sharp. Even though the external ear opening is tiny, their large internal ears enable them to hear well, both on the surface and under water. Dugongs are capable of staying submerged for six minutes or more. They must surface regularly, albeit for only 1–2 seconds at a time[47]. They are hard to see as they can take a breath by exposing only the nostrils, which are placed on the top of their snout.

They are distributed in the Indo-Pacific region and their diet consists mostly of seagrasses of the genera Cymodocea, Halophila, Thalassia and Halodule[48].

Breeding behaviour

Dugongs can live for about 70 years. They breed very slowly, and females start breeding when they are aged between 10 and 17 years. Breeding occurs throughout the year, and peak months for birth vary geographically. The exact length of gestation is unknown, but it is presumed to be about 12–14 months (Marsh, 1986)[49]. Single calves are the norm and twins are rare. Parturition takes place in shallow water, and newborn calves are able to swim immediately to the surface for their first breath of air.

Feeding behaviour

The dugongs are the only strictly marine herbivores and feed mainly on seagrasses. If the seagrass is short, they root at the bottom, eating rhizomes, stems and leaves, and cause sediments to cloud the water. If the seagrass is tall, they just strip the leaves from the stems.

Seagrass has low nutritional value, and so dugongs must consume vast amounts. In captivity, they eat 20 to 30 kg a day.

Habitat use and movement

Dugongs inhabit shallow tropical coastal waters and are more strictly marine thanare manatees. Since their main source of food is seagrasses, by and large theirhabitat mirrors that of seagrasses. Thus, they are shallow-water animals feeding in waters just a few metres deep. Long-distance migration of dugongs is unknown, butsome daily and seasonal movements do occur in some populations. The tides, watertemperature and food abundance are probably the main factors involved in these movements.

Economic and cultural significance

Traditionally dugongs were hunted by some tribes in the Andaman andNicobar Islands, fishermen and local people in Tamil Nadu and Sri Lanka. However,currently, due to their low abundance, dugongs are not the target species forhunting in most of these areas. The Onge, on Little Andaman, use bones of dugongs(tusks, rib bones, pelvic/pectoral girdles) as ornaments.

47 Anderson, P.K. (1981). Dugong behaviour: observations, extrapolations and speculations. Pp. 91–111 in Marsh, H. (ed.) The dugong. Proceedings of a Seminar/Workshop held at James Cook University of North Queensland 8–13 May 1979. Department of Zoology, James Cook University of North Queensland : Townsville. Dugong
Anderson, P.K. (1981). The behaviour of the dugong (Dugong dugon) in relation to conservation and management. Bulletin of Marine Science 31: 640–47. Dugong

48 Marsh, H., Eros, C, Corkeron, P., and Breen, B. 1999. A conservation strategy for Dugongs: implications of Australian Research. Marine and Freshwater Research 50, 979-90.
Marsh, H., Penrose, H., Eros, C., and Hugues, J. 2002. The Dugong (Dugong dugon)Status Reports and Action Plans for Countries and Territories in its Range. Final Report, United Nations Environment Programme, Nairobi, Kenya.

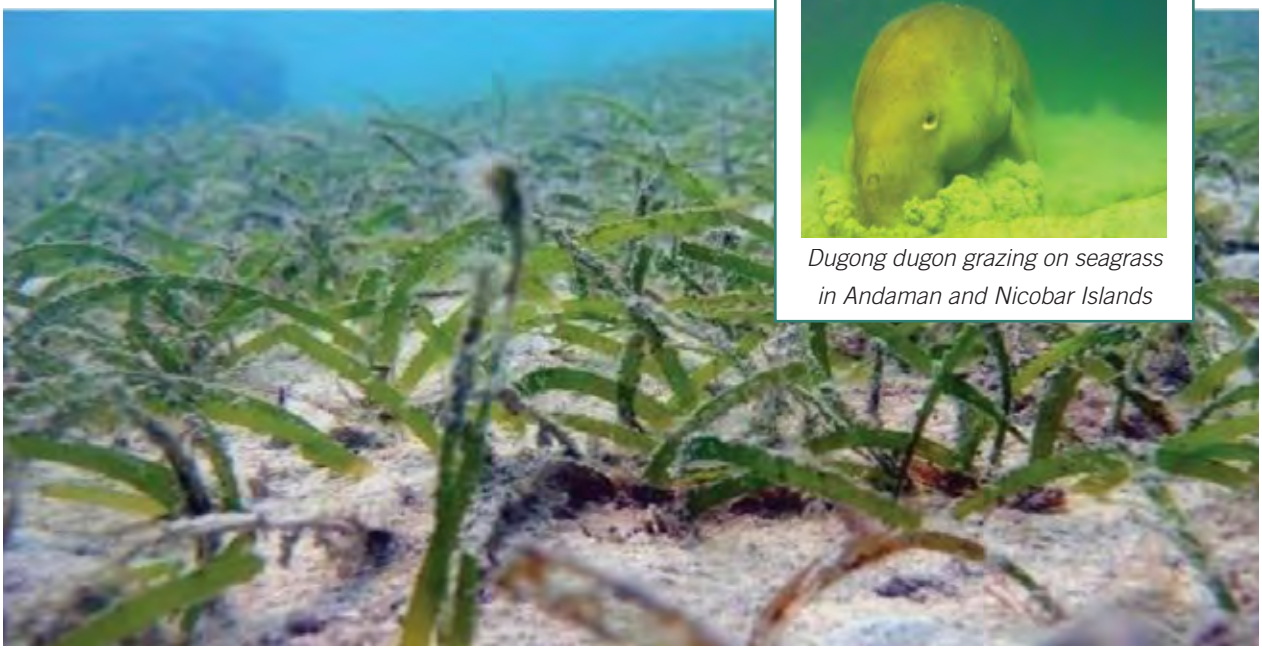
49 Marsh, H. (1986). Development of aerial survey methodology and results of aerial surveys for dugongsin the Northern and Central Sections of the Great Barrier Reef Marine Park. Great Barrier Reef Mar. Park Auth., Townsville, unpubl. rep

This number and the range of the dugong are believed to be continuously declining. Several reasons have been attributed to the decline in the dugong population, including seagrass habitat loss and degradation, gill netting, disease, water pollutants, indigenous use and poaching. Restricted to the inshore waters due to their dependence on seagrass beds, dugongs remain vulnerable to hunting, boat strikes and habitat disturbances . Additionally, incidental entanglement in gill nets has been identified as one of the prime causes of the decline of the dugong population in all the sub-regions of its current distribution, which extends across the waters of 37 countries (Marsh et al, 2002)[50].

Status of regional conservation measures

Assessed as vulnerable by the International Union for Conservation of Nature (IUCN), the dugong is considered to be facing a high riskof extinction in the wild. In India, dugongs are protected under Schedule-I of the Wildlife (Protection) Act, 1972 (WPA), which makes hunting, killing and capture of dugongs and buying and selling dugong meat punishable by imprisonment. The Government of India is a signatory to Convention on International Trade in Endangered Species (CITES), and dugongs are listed in Appendix-I of CITES, which prevents international trade in the species. At present, a few dugong habitats fall within the existing protected area network, for example, the Gulf of Kachchh Marine Protected Area (22°34° N, 69°40° E), Gulf of Mannar Marine NationalPark (9°07° N, 79°36° E) and Mahatma Gandhi Marine National Park (11°34° N, 92°39° E).In April 2008, the Government of India signed the Memorandum of Understanding (MoU)on the Conservation and Management of Dugongs and their Habitats throughout their Range [United Nations Environmental Program – Convention on Migratory Species (UNEP-CMS) Dugong MoU] to strengthen the protection and management of dugongs and their habitats in Indian waters with the support ofthe international community. The UNEP-CMS Dugong MoU, which has 11 range states todate as signatories (Australia, Eritrea, France, Madagascar, Myanmar, the UnitedArab Emirates, the United Republic of Tanzania, India, the Comoros, Kenya and the Philippines), provides a platform for coordinating conservation and management throughout the dugong's extensive range to ensure its long-term survival.Dugong is one of the eight critically endangered species identified by the Ministry ofEnvironment and Forests, Government of India, under the species recovery component of the Integrated Development of Wildlife Habitats (CSS-IDWH), a centrally sponsored scheme. Additionally, a Task Force for Conservation of Dugongs was constituted to ensure implementation of the UNEP-CMS Dugong MoU in India and to prepare an action plan aimed at increasing dugong numbers and preventing degradation of its habitat. Seagrasses provide a habitat for Dugong dugon, the only herbivorous marine mammal. Because of their growth pattern, they also provide exceptional habitats for a wide variety of marine organisms, both plant and animals.

50 Marsh, H., Penrose, H., Eros, C. and Hugues, J. (2002).'Dugong Status Report and Action Plans for Countries and Territories'. Early Warning and Assessment Report Series. UNEP/DEWA/RS.02-1. 162 pp.



Seagrass meadow

Dugong dugon grazing on seagrass in Andaman and Nicobar Islands

1.9 Key coastal and marine species

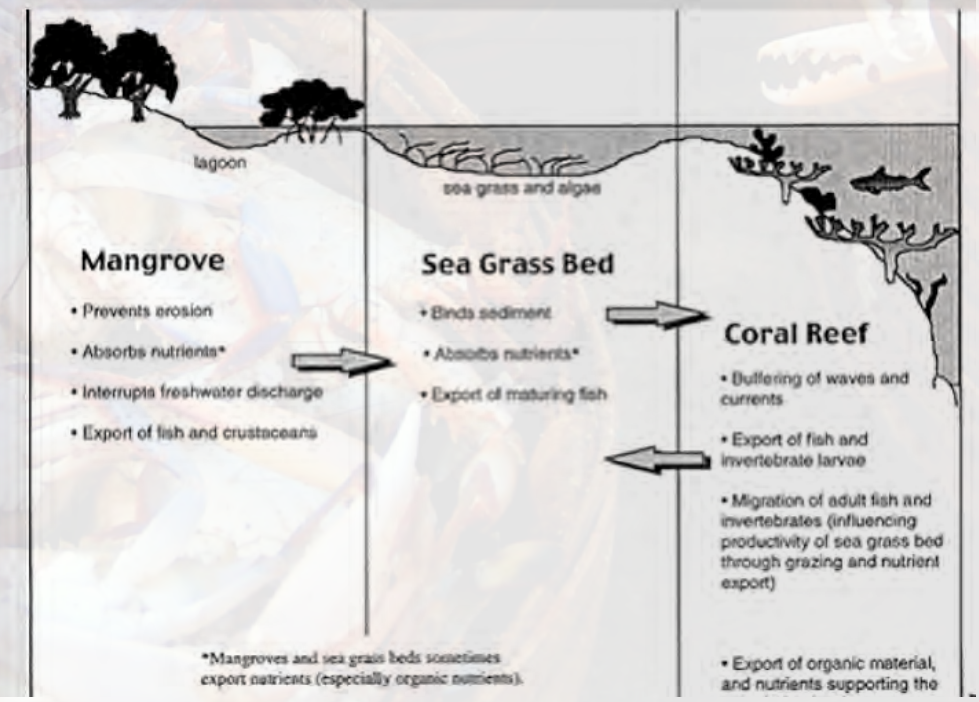
The faunal diversity of India—terrestrial, freshwater, brackish water and marine—is represented by 92,037 species, of which 2,577 belong to Protista and 89,460 to Animalia, including 31 phyla of invertebrates and chordates. These numbers account for 7.50 per cent of the total in the world. Among these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

India has 919 species of plants and animals that are globally threatened[51].

1.9.1 Marine Algae[52]

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

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



Source: NCSCM Special Publication: Lagoons, Lives and Livelihood

51 http://www.iucnredlist.org/documents/ summarystatistics/2011_2_RL_Stats_Table5.Pdf

52 Source: Venkataraman K, Wafar M (2005) Coastal and marine biodiversity of India. Ind J Mar Sci 34: 57–75

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. 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.

1.9.2 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 fishes in the coastal and marine ecosystems of India of which

154 species belong to the Chondricthyes (cartilaginous fish) family, and more than 2,275 species belong to the Actinopterigii (bony fishes) family. The annual average landings of the Indian Chondrichthyes is 33,442 tonnes, of which, 15,537 tonnes come from the east coast and 17,605 tonnes come from the west coast and the rest come from the Andaman and Nicobar, and Lakshadeep Islands (Marale and Mishra, 2011).

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). Cryptic and nocturnal species that are confined primarily to caverns and reef crevices during daylight periods constitute another 20 per cent.

1.9.3 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 affinis* 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), Testudines (turtles and tortoises) and Squamata (lizards and snakes). The diversified climate, varying vegetation and different types of soil in the country form a wide range of biotopes that support a highly diversified reptilian fauna (Aengals et al 2011).

A total of 32 species of marine reptile have been reported from Indian seas, including 26 species of sea snake, five species of sea turtles and the saltwater crocodile. Among the turtles, the five species are: leatherback sea turtle- a rare species; green turtle; Olive Ridley; hawksbill; and the loggerhead turtle.

Amphiprion ocellaris Cuvier,1830

Pterois antennata (Bloch,1787)

Crocodylus porosus Schneider, 1801

Dermochelys coriacea (Vandelli, 1761)

1.9.4 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, which is representative a wide ranging orders (BNHS/ENVIS, 2011). The below mentioned list indicates some key marine bird families along with their orders.

Procellariiformes

- Procellariidae storm petrels and Shearwater

Pelecaniformes

- Sulidae boobies
- Phalacrocoracidae cormorants
- Fregatidae frigatebirds

Phoenicopteriformes

- Flamingos Phoenicopteridae

Falconiformes

- White-bellied sea eagle, Haliaeetus leucogaster
- Pallas's fish eagle, Haliaeetus leucoryphus

Charadriiformes

- Laridae gulls
- Sternidae terns
- Stercorariidae Skua
- Scolopacidae Phalarope

Podicipediformes

- Podicipedidae Grebe

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.

Pelagic seabirds: Terns, waders, sandpipers, oyster catchers, turnstones, plovers, egrets and herons. pelicans and flamingos have been recorded in the Gulf of Kachchh. Birds of prey, including ospreys and sea eagles, are likewise occasional visitors to the marine region. A total of 123 species of waterfowl and 85 species of terrestrial birds were reported from the Gulf of Kachchh Marine Park area in 2002.

Waterfowl that have moderately large populations in Kachchh are the lesser flamingo, kentish plover, ruff, crab plover, black-tailed godwit and avocet.

A total of 187 species were recorded from the Gulf of Mannar Marine National Park during 1985–1988, of which 84 were aquatic and the remaining terrestrial.

Some common 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 *Icthyophaga ichthyaetus*

This bird of pray 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 is a small gull which breeds in the high plateaus of central Asiafrom 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 coasts.

http://bnhsenvis.nic.in/Database/MarineBirdsIndia_837.aspx


Photo by: Dr. Neeraj Khera

1.9.5 Marine mammals

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, th order Carnivora containshe pinnipeds (sealions, walrusesand seals), the polar bear *(Ursus maritimus),* and the two otters (*Enhydra lutris* and *Lontra feline*)

There are some 120 species of marine mammal 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. One species belonging to the order Sirenia, namely the dugong, and 30 species of cetaceans, including dolphins, whales and porpoises, are found in the waters of the Indian subcontinent. In size they range from the relatively small Finless Porpoise to the largest animal ever to have lived on Earth, the Blue Whale.

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.

1.10 Coastal and marine ecosystems in India : A statistical overview

According to the Indian naval hydrographical charts, the mainland coast consists of the following:

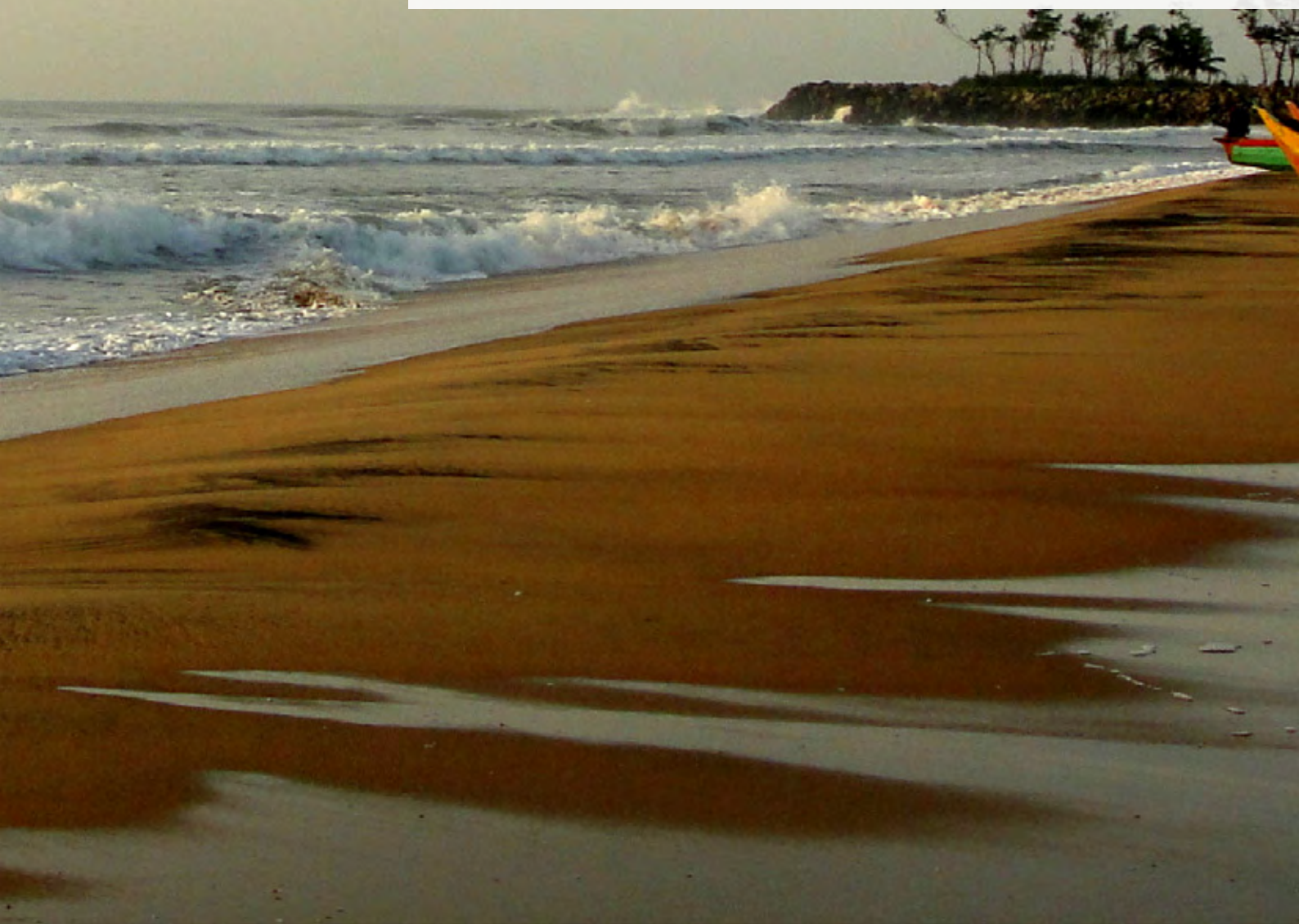
43 per cent - sandy beaches;

11 per cent - rocky coast including cliffs; and

46 per cent - mudflats or marshy coast.

Among the notable coastal features of India are the marshy Rann of Kachchh, in western India, and the alluvial Sundarbans Delta, to the east (which India shares with Bangladesh).

India has two archipelagoes: (1) the Lakshadweep, coral atolls off India's southwestern coast; and (2) the Andaman and Nicobar Islands, a volcanic chain of islands in the Andaman Sea.



According to the Zoological Survey of India, the Indian Ocean accounts for:

29 per cent of the global ocean area;

13 per cent of marine organic carbon synthesis; 10 per cent of capture fisheries;

90 per cent of culture fisheries; 30 per cent of coral reefs;

10 per cent of the mangroves; and

it has 246 estuaries draining a hinterland greater than 2,000 sq km, besides coastal lagoons and backwaters.

Being landlocked in the north, and with the largest portion of it lying in the tropics, the Indian Ocean is a region of high biodiversity, with one of the countries in the region, India, rated as being one of the mega-biodiversity centres of the world.

In the current context of international trade and intellectual property regimes, it is important for all of the Indian Ocean countries to understand their marine biodiversity.

The dissimilarities between the west and east coasts of India are remarkable. The west coast is generally exposed, with heavy surf and rocky shores and headlands, whereas the east coast is generally shelving, with beaches, lagoons, deltas and marshes. The west coast is a region of intense upwelling, associated with the southwest monsoon (May–September), whereas the east coast experiences only a weak upwelling, associated with the northeast monsoon (October–January), resulting in marked differences in hydrographic regimes, productivity patterns and qualitative and quantitative composition of fisheries.

India is one among 12 mega-biodiversity countries and 25 biodiversity hotspots of the richest and highly endangered eco-regions of the world.

All the islands on the east coast are continental islands, whereas the major island formations in the west coast are oceanic atolls.

According to the Zoological Survey of India13, the current inventory of coastal and marine biodiversity of India indicates that a total of 17,795 species from the faunal and floral communities have been reported from the seas around India.

The data reveal that India contributes 6.75 per cent to the global marine biodiversity.

1.11 What are the differences between the terrestrial and 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. Populations in the marine realm have been found to be genetically more homogenous and therefore, effective population sizes are larger. Dispersal and response to local events such as pollution or rising temperatures elicits faster response in the case of marine organisms.

Degradation and destruction are 'visible' in terrestrial ecosystems whereas they may not be in the case of the marine realm. Only relatively recently property rights have been introduced in the marine realm (till now considered largely open-access) whereas they are well entrenched on land. Defining borders and patrolling them is much easier on land than on water.

According to Convention on Biological Diversity (CBD) Aichi Target 11, protected areas should be integrated into the wider landscape and seascape, and relevant sectors, bearing in mind the importance of complementarity and spatial configuration. Here landscape refers broadly to terrestrial ecosystems whereas seascapes refer to marine ecosystems. Wider landscape and seascape includes the array of land and water uses, management practices, policies and contexts that have an impact within and beyond protected areas, and that limit or enhance protected area connectivity and the maintenance of biodiversity. The methods of managing terrestrial ecosystems cannot be directly applied to marine ecosystems because of a number of causes. These can be examined under the following broad contexts:

1.11.1 Ecological context

The fundamental difference between marine and terrestrial areas is the aquatic medium in which all marine organisms live. Water being denser than air (800 times), organisms may be neutrally buoyant, have specialised floatation devices (e.g. swim bladder of fish) or have surface area to volume ratio to increase buoyancy. The buoyancy of water offsets the effect of gravity which is why the largest animal on earth is a whale, an inhabitant of the marine realm. Terrestrial plants such as trees have to invest large resources in support structures (e.g. wood) whereas aquatic plants invest in fewer resources for support.

Plants, primarily the multicellular flowering forms, are the dominant primary producers on land, releasing oxygen through the process of photosynthesis. On land, plants are mostly sessile, rooted to the ground for their lifetime. In the marine realm, the microscopic unicellular phytoplankton are the dominant primary producers. These drift along with winds and waves, forming blooms where conditions (especially availability of nutrients) are favourable. Thus, on land, the ecosystems can be described as being more internally controlled by the dominant organisms (trees) whereas the organisms of the marine realm are subject to the physics of the surrounding medium, water.

Marine systems are highly dynamic, tightly connected through a network of surface and deep-water currents whose stratifications are broken by upwelling that create vertical and horizontal heterogeneity. Consequently, the wide range of physical, chemical and geological variations that are found in the sea have given rise to a complex of marine habitats that range from highly productive near-shore ecosystems to the ocean deeps that are inhabited only by specialised organisms.

Aquatic environments are richer in nutrients than equivalent terrestrial ecosystems and hence able to support more life. However, while light and oxygen can be limiting factors in the aquatic environment, they are seldom so on land. The aquatic realm is relatively more stable than the terrestrial realm with smaller fluctuations in temperature and other variables. Since they live in water, aquatic organisms are seldom exposed to desiccation while terrestrial organisms are often exposed to desiccation. This is important considering the fact a large proportion of an organism's body is made up of water.

Perhaps the most important ecological point that needs to be considered in managing marine ecosystems is that terrestrial ecosystems have discrete boundaries while in the case of marine ecosystems, the boundaries are relatively open; which is why it may be said that while the sea unites, land divides. This issue of boundaries is important in the context of migration of organisms and in the dispersal of organisms in various life stages. This has probably resulted in relatively lower genetic variation between populations and therefore larger effective population sizes. Apart

from migration in search of food, marine organisms migrate as the local conditions change; the rate of response to environmental variability is much faster in the case of marine ecosystems compared to terrestrial ecosystems. The boundary issue is also relevant with respect to habitat fragmentation – the sensitivity to habitat fragmentation is much lower in the case of marine ecosystems.

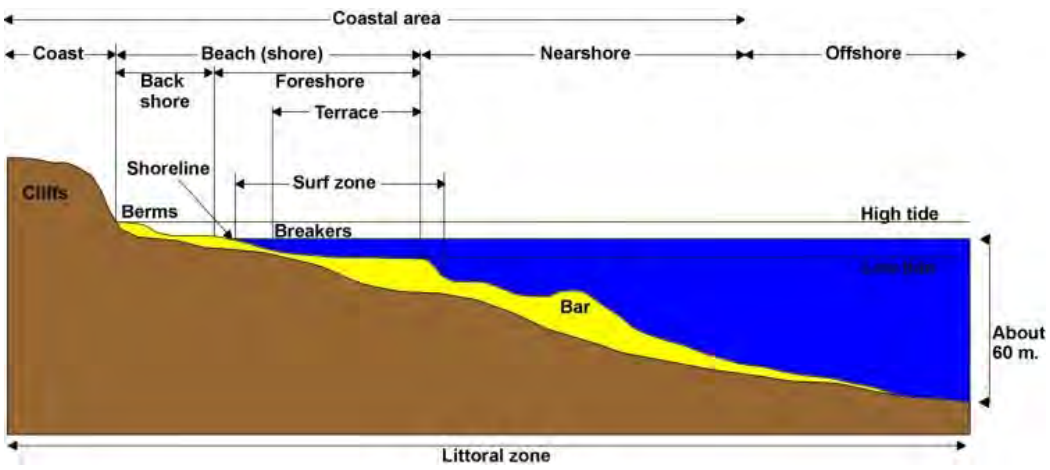
There is also a difference in the rate and importance of anthropogenic pressures. Habitat destruction in the case of terrestrial ecosystems is widespread whereas it is localised in the case of the marine realm (estuaries, coral reefs etc.). More importantly, in the case of terrestrial ecosystems, habitat destruction is 'visible' as in the cutting down of trees in a forest whereas while bottom trawling may devastate the benthic habitat of marine ecosystems, it may not be visible unless someone dives in the area as humans do not live in water and therefore cannot be aware of change in habitat.

1.11.2 Socio-economic context

In the socio-economics context, the different kinds of property rights become relevant in understanding the difference between marine and terrestrial ecosystems. On land, property rights are reasonably clear: private, public (state) and common property. In contrast, coastal waters and many coastal spaces such as beaches have always been considered open access which means that restricting natural resource based activities such as fishing, sea- weed collection and shell collection can be difficult as it will affect thousands of livelihoods.

At the international level, it was only after the United Nations Convention on the Law of the Sea (UNCLOS) that nations have acted to establish ownership of the seabed and overlying waters by the declaration of territorial waters and Exclusive Economic Zone (EEZ). While the onus of conservation of living marine resources in the EEZ vests with the coastal state, Section 2 of Part VII of UNCLOS broadly states that states should cooperate with one another in the conservation and management of living marine resources in the high seas. Most recently (2011), the Global Environment Facility (GEF) project on Areas Beyond National Jurisdiction (ABNJ) was developed to promotes efficient and sustainable management of fisheries resources and biodiversity conservation in the ABNJ, considered as the world's last global commons.

More than a third of the world's population lives in coastal areas and small islands that make up just over 4 per cent of earth's total land area. Fisheries and fish products provide direct employment to 38 million people. Coastal tourism is one of the fastest growing sectors of global tourism and provides employment for many people generating local incomes. 90 per cent of world trade is through sea shipping.



Marine ecosystems have been important as providers of food for millennia, especially for those living in coastal areas. While the proportion of farmed food with respect to wild-caught food is very high in the case of terrestrial ecosystems, it is capture fisheries that dominate production from the marine environment. In terrestrial environments, it is primary producers and herbivores, the first two levels in a food chain/web that are farmed and consumed, whereas in the case of food from the sea, it is the carnivores or organisms at higher levels in the food chain that are harvested and consumed. Depletion at the higher trophic levels can have a cascading effect on the food chain and food web. This can be considered as the second relevant point of difference between marine and terrestrial ecosystems from a socio-economics context.

1.11.3 Political and security context

Land borders are geographical features such as rivers, seas, mountains and other formations that present natural obstacles to communication and transport. Existing political borders are often a formalisation of these historical, natural obstacles. While some borders (between countries) are open and completely unguarded (e.g. inter-state borders within the Schengen area in Europe), most borders between countries are fully or partially controlled and may be crossed legally only at designated check points. Deliberate (human) movement of plants and animals across borders may be prohibited (in the case of endangered species) and is otherwise usually restricted with quarantine requirements. However, migratory movement of plants or animals (in which a significant proportion of the members of the entire population or any geographically separate part of the population cyclically and predictably crosses one or more national jurisdictional boundaries) is historically unrestricted and also the subject of the Convention on Migratory Species.

With respect to maritime boundaries, under UNCLOS, a coastal state is entitled to a territorial sea not exceeding 12 nautical miles measured from its baselines. Within its territorial sea, the coastal state exercises sovereignty, including over its resources. Subject to the provisions of the convention, ships of all states enjoy the right of innocent passage through the territorial sea. The convention also grants a coastal state the right to establish a contiguous zone not extending beyond 24 nautical miles from the baselines. Within its contiguous zone, the coastal state may exercise the control necessary to prevent and punish infringement of customs, fiscal, immigration or sanitary laws and regulations that have occurred within its territory or territorial waters and to control, in specified circumstances, the trafficking of archaeological and historical objects.

In addition, a coastal state may establish an exclusive economic zone not extending beyond 200 nautical miles from its baselines, where the coastal state has sovereign rights for, inter alia, marine scientific research and protection and preservation of the marine environment. When two or more coastal states share a sea or ocean, usually bilateral/ multilateral treaties are executed to resolve border disputes.

On land, hunting in border areas can be controlled: hunters chasing their prey may be stopped by clearly demarcated natural or artificial borders which allow their prey to move away but clearly indicate the limit of human movement. On the other hand, fishing may involve chasing fish even across maritime borders as there may not be visible indicators of such borders and the fish are swimming underwater, out of sight. Similarly, since a reserve demarcated in the ocean realm, unlike that demarcated on land, may not have visible boundaries, hence, trespass (human) may happen.

Thus, there is considerable difference in costs in demarcating and monitoring in terrestrial and marine systems in terms of their borders. It is easier to fix boundaries of terrestrial systems and ensure their visibility by, for example, using fences and monitor them by patrolling. In contrast, it is much more difficult to demarcate boundaries of marine ecosystems and make the boundaries visible. The costs of patrolling seas/ocean and enforcing regulations are higher than that for terrestrial ecosystems.

Food for thought:

- What is biodiversity? What are differences between genetic , species and habitat biodiversity?

- Discuss coastal and marine biodiversity with your family, friends and neighbors. What do they think about coastal and marine biodiversity conservation?

- Why do you and they think it is important/ not important?

- Which examples of your local environment (coastal & marine) come to your mind that clearly show the relevance of concepts presented in this module? Are there examples around us, where we can clearly see the relevance of concepts presented in this module?

- When you think of biodiversity in relation to your city/locality, what ecosystem functions come to your mind? What do you think would be the risks of loosing them?

- Are conservation shortcuts efficient in conserving biodiversity at all levels and in all the forms? If yes, where are the examples?

- Are there any flagship or keystone species in your area that you know of?

- What are ecosystem services? Can we come up with one example in each category (provisioning, regulating, cultural and supporting) from our surrounding ecosystem?

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Further Resources

BBC Human Planet ep 1 of 8 Oceans pt 14 HD nature documentary
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The Effects of Fishing on Species and Genetic diversity
ftp://ftp.fao.org/fi/document/reykjavik/ pdf/14kenchington_v6_final.PDF

Umbrellas and flagships: Efficient conservation surrogates or expensive mistakes?
http://www.pnas.org/content/97/11/5954.long

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