Training Resource Material

Coastal and Marine Biodiversity and Protected Area Management

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

For MPA Managers

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

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

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Summary

The module provides an overview of the concepts of climate change and natural disasters and the related risks that they pose to coastal and marine biodiversity and ecosystems. The module further explores the impacts of climate change and natural disasters on coastal livelihoods and their management options using examples and cases. The module also focuses on the very important issues of possible synergies and trade-offs between the measures taken towards climate change management, coastal and marine biodiversity conservation, coastal livelihoods and coastal disaster management.

Imprint

Training Resource Material:
Coastal and Marine Biodiversity and Protected Area Management
for MPA Managers

Module 1: An Introduction to Coastal and Marine Biodiversity
Module 2: Coastal and marine Ecosystem Services and their Value
Module 3: From Landscape to seascape
Module 4: Assessment and monitoring of coastal and marine biodiversity and relevant issues
Module 5: Sustainable Fisheries Management
Module 6: Marine and Coastal Protected Areas
Module 7: Governance, law and policies for managing coastal and marine ecosystems, biodiversity and protected areas
Module 8: Coasts, climate change, natural disasters and coastal livelihoods
Module 9: Tools for mainstreaming: impact assessment and spatial planning
Module 10: Change Management and connectedness to nature
Module 11: Communicating Coastal and Marine Biodiversity Conservation issues
Module 12: Effective management Planning of coastal and marine protected areas

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Acronyms

CBD	Convention on Biological Diversity
DRR	Disaster reduction strategies
IMO	International Meteorological Organization
IPCC	Intergovernmental Panel on Climate Change
MEA	Millennium Ecosystem Assessment
MoEFCC	Ministry of Environment, Forests & Climate Change
MPA	Marine protected area
NCSCM	National Centre for Sustainable Coastal Management
REDD	Reduced Emissions from Deforestation and Forest Degradation
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations Office for Disaster Risk Reduction

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Key messages

- 'Climate change' refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean global temperatures and/or the variability of its properties and that persist for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing factors such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use.

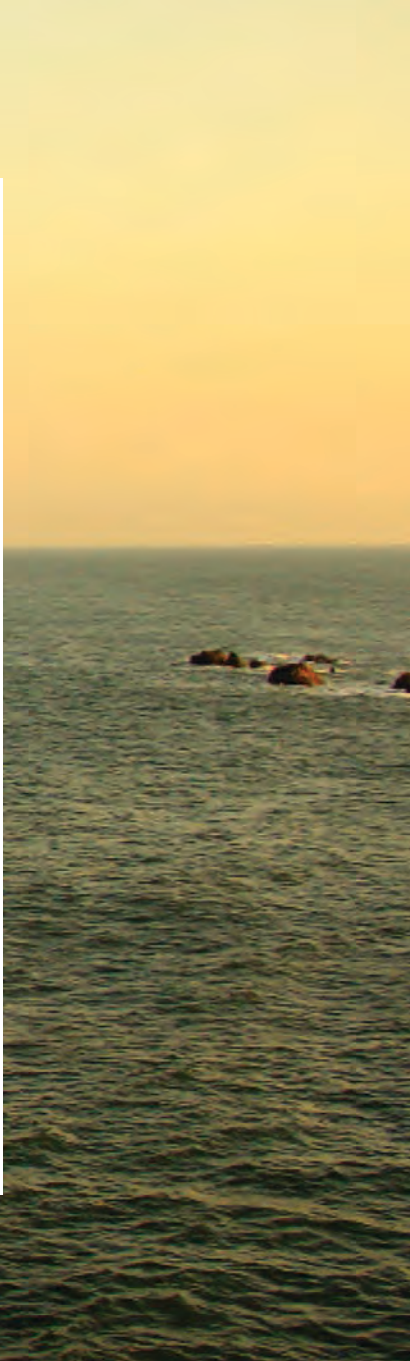
- The livelihoods of the rural poor are affected, in one way or the other, by three major factors, namely, climate change, disruption/loss of ecosystem services and disasters.

- The goal of climate change adaptation (CCA) planning is to find local or locally adapted sustainable solutions for robust and diversified livelihood options, especially in climate-sensitive sectors such as agriculture, forestry and tourism.

- Though the objective of both CCA and disaster risk reduction (DRR) measures is reducing the vulnerability of local communities, some CCA and DRR interventions may unintentionally leave people even more vulnerable than before to the impacts of natural disasters and vice versa.

- Many marine and coastal ecosystems no longer deliver the full suite of ecosystem services that humans have come to rely upon due to the existence of trade-offs between the activities of different sectors.

- Trade-offs can be minimized if the primary goal of all the activities in the marine and coastal ecosystems is maintaining a sustainable flow of ecosystem services.



8.1 What is climate change? How climate change impacts coastal and marine ecosystems

8.1.1 Basic science of climate change

The climate system is a complex, interactive system consisting of the atmosphere, land surface, snow and ice, oceans and other bodies of water, and living things. The climate system evolves in time under the influence of its own internal dynamics and due to changes in external factors. External factors include natural phenomena such as volcanic eruptions and solar variations, as well as human-induced changes in atmospheric composition.

Solar energy powers the climate system. There are three fundamental ways to change the energy balance of the Earth:

1) by changing the incoming solar energy: Incoming solar energy is changed by, for example, changes in the Earth's orbit or in the sun itself.
2) by changing the fraction of solar energy that is reflected: Changes in cloud cover, vegetation, and particles in the air, for example, can change reflected energy.
3) by altering the energy that returns to space from the Earth, for example, by changes in greenhouse gas concentrations.

Climate, in turn, responds directly to such changes, as well as indirectly, through a variety of feedback mechanisms.

So, the Earths climate is dependent upon the radiative balance of the atmosphere, which in turn depends upon the input of solar radiation and the atmospheric abundances of radiatively active trace gases (i e , greenhouse gases or GHGs), clouds and aerosols. Greenhouse gases occur naturally and are essential to the survival of humans and millions of other living things, through keeping some of the sun's warmth from reflecting back into space and making Earth livable. But it's a matter of scale. A century and a half of industrialization, including clear-felling forests and certain farming methods, has driven up quantities of GHGs in the atmosphere. The concentration of GHGs in the earth's atmosphere is directly linked to the average global temperature on Earth; The concentration has been rising steadily, and mean global temperatures along with it, since the time of the Industrial Revolution.

One of the most common GHGs is carbon dioxide, an essential link between plants and animals. Animals produce carbon dioxide and exhale it, while plants absorb carbon dioxide during photosynthesis, store it within their material structures, and then release it when they respire. Plant material decomposes as bacteria and other organisms consume the mass, releasing more carbon dioxide back to the atmosphere. In the absence of oxygen, bacteria produce methane, the second most common GHG. Since the advent of the Industrial Revolution, in the mid 18th century, intense and inefficient burning of wood, charcoal, coal, oil, and gas, accompanied by massive land use change, has resulted in increased concentrations of GHGs in the Earth's atmosphere.

The use of artificial fertilizers, made possible by techniques developed in the late 19th century, has led to practices resulting in releases of nitrous oxide, another GHG, into air. Since the 1920s, industrial activities have applied a number of manmade carbon compounds for refrigeration, fire suppression, and other purposes some of which have been found to be very powerful GHGs (UNEP 2009).

According to the United Nations Framework Convention on Climate Change (UNFCCC), climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

In this description of climate change, the term, climate variability, refers to variations in the mean state and other statistics (such as standard deviations and statistics of extremes) of the climate on all temporal and spatial scales beyond those of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability) or variations in natural or man-made external forcing factors (external variability) (UNFCCC 2001).

According to the IPCC, climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity.

Note that the UNFCCC makes a distinction between climate change attributable to human activities that alter the atmospheric composition and climate variability attributable to natural causes.

8.1.2 Some key terms

- ***Hazard.*** It is the potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. In this report, the term ‘hazard’ usually refers to climate-related physical events or trends or their physical impacts.
- ***Exposure.*** The presence of people, livelihoods, species (or ecosystems), environmental functions, services and resources, infrastructure or economic, social or cultural assets in places and settings that could be adversely affected.
- ***Vulnerability.*** The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.
- ***Impacts.*** Effects on natural and human systems. In this report, the term ‘impacts’ is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure of the interaction of climate changes or hazardous climate events occurring within a specific time period on an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts and sea-level rises, are a subset of impacts called ‘physical impacts.’
- ***Resilience***: The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation
- ***Adaptation***: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects

8.1.3 What's the difference between climate change and global warming?

Climate change is the shift in long-term, global weather patterns due to human action; it's not exclusive to warming or cooling. Climate change includes any change resulting from different factors, like deforestation or an increase in greenhouse gases. Global warming is one type of climate change, and it refers to the increasing temperature of the surface of Earth.

"Global warming" refers to the long-term warming of the planet. Global temperature shows a well-documented rise since the early 20th century and most notably since the late 1970s. Worldwide, since 1880 the average surface temperature has gone up by about 0.8 °C (1.4 °F), relative to the mid-20th-century baseline (of 1951-1980).

"Climate change" encompasses global warming, but refers to the broader range of changes that are happening to our planet. These include rising sea levels, shrinking mountain glaciers, accelerating ice melt in Greenland, Antarctica and the Arctic, and shifts in flower/plant blooming times. These are all consequences of the warming, which is caused mainly by people burning fossil fuels and putting out heat-trapping gases into the air. The terms "global warming" and "climate change" are sometimes used interchangeably, but strictly they refer to slightly different things.

[Source: NASA http://climate.nasa.gov/faq/]

8.1.4 Climate change: Observed impacts, vulnerability and exposure

The main characteristics of climate change include rising temperatures, changes in rainfall patterns, melting of glaciers and sea ice, sea-level rises and an increased intensity and/or frequency of extreme events. These changes in physical processes have impacts on biological and socioeconomic factors such as shifts in crop-growing seasons, food production and food security, changes in disease vectors, shifting boundaries of forests and other ecosystems and extreme events such as flooding, droughts and landslides.

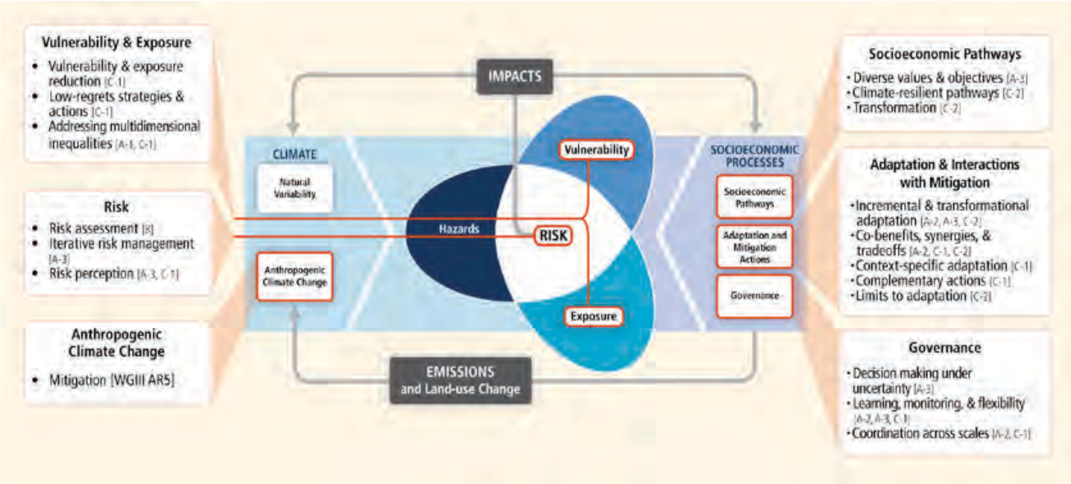


Figure 8.1 :"Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socioeconomic processes including adaptation and mitigation (right) are drivers of hazards, exposure, and vulnerability [Source: IPCC 2014]

According to the fifth report of the IPCC, in recent decades, climate change has caused impacts on natural and human systems on all continents and across the oceans.

Increasing GHGs in the atmosphere produce changes in the climate system on a range of time scales that impact the coastal physical environment. On shorter time scales, physical coastal impacts such as inundation, erosion, and coastal flooding arise from severe storm induced surges, wave overtopping, and rainfall runoff. On longer time scales, wind and wave climate change can cause changes in sediment transport at the coast and associated changes in erosion or accretion. Natural modes of climate variability, which can affect severe storm behavior and wind and wave climate, may also undergo anthropogenic changes in the future.

Ocean and atmospheric temperature change can affect species distribution with impacts on coastal biodiversity. Carbon dioxide (CO2) uptake in the ocean increases ocean acidity and reduces the saturation state of carbonate minerals, essential for shell and skeletal formation in many coastal species. Changes in freshwater input can alter coastal ocean salinity concentrations.

Coastal systems are subject to a wide range of human-related or anthropogenic drivers that interact with climate related drivers and confound efforts to attribute impacts to climate change. Some of the major terrestrially based human drivers that directly or indirectly cause changes are socio-economic development, increased river nutrients (nitrogen, phosphorous), and its impact on eutrophication and subsequent hypoxia (decreased oxygen concentration), and sedimentation.

'Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes.' Vulnerability, therefore, is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity (IPCC 2007). The lower the adaptive capacity of a system, the higher will be its vulnerability to the negative impacts of climate change.

Vulnerability is also governed by the stability and resilience of local ecosystems. The more stable and resilient an ecosystem is, the lesser vulnerable the communities will be. Therefore, protection, restoration or establishment of biologically diverse ecosystems that provide important goods and services may constitute important adaptation measures to increase the adaptive capacities of the population. Maintaining biodiversity is an important component of adaptation as biodiversity contributes to the provision of many ecosystem services.

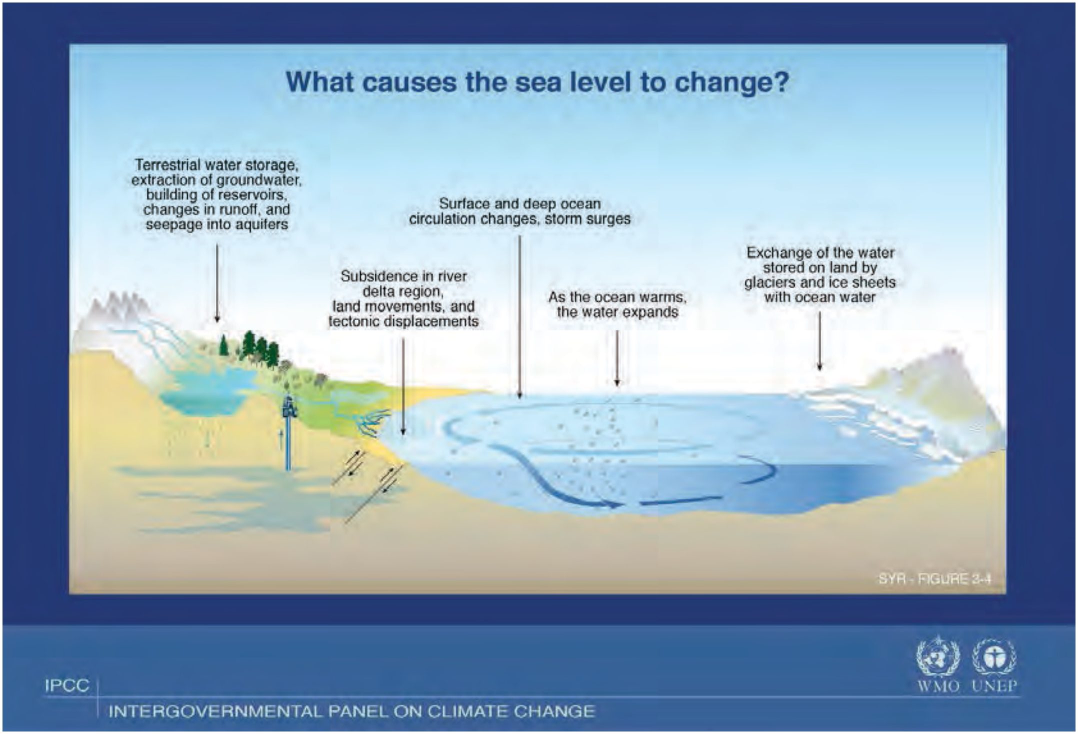


Figure 8.2 : "Causes of sea level change [Source: IPCC 2001]"

8.1.5 How does climate change affect coastal marine ecosystems?[1]

The major climate-related drivers on marine coastal ecosystems are sea level rise, ocean warming, and ocean acidification. Rising sea level impacts marine ecosystems by drowning some plants and animals as well as by inducing changes of parameters such as available light, salinity, and temperature. The impact of sea level is related mostly to the capacity of animals (e.g., corals) and plants (e.g., mangroves) to keep up with the vertical rise of the sea. Mangroves and coastal wetlands can be sensitive to these shifts and could leak some of their stored compounds, adding to the atmospheric supply of these greenhouse gases.

Warmer temperatures have direct impacts on species adjusted to specific and sometimes narrow temperature ranges. They raise the metabolism of species exposed to the higher temperatures and can be fatal to those already living at the upper end of their temperature range. Warmer temperatures cause coral bleaching, which weakens those animals and makes them vulnerable to mortality. The geographical distribution of many species of marine plants and animals shifts towards the poles in response to warmer temperatures.

When atmospheric carbon dioxide is absorbed into the ocean, it reacts to produce carbonic acid, which increases the acidity of seawater and diminishes the amount of a key building block (carbonate) used by marine 'calcifiers' such as shellfish and corals to make their shells and skeletons and may ultimately weaken or dissolve them. Ocean acidification has a number of other impacts, many of which are still poorly understood.

Coastal ecosystems are experiencing large cumulative impacts related to human activities arising from both land- and ocean-based anthropogenic drivers.

Anthropogenic drivers associated with global climate change are distributed widely and are an important component of cumulative impacts experienced by coastal ecosystems. **There is no wetland, mangrove, estuary, rocky shore, or coral reef that is not exhibiting some degree of impact. Overexploitation and habitat destruction are often the primary causes of historical changes in coastal systems leading to declines in diversity, structure, and functioning.** Further, extreme climate events generate changes to both the mean and the variance of climatic variables over ecological time scales.

1 Source: IPCC 2014a, 2014b, 2014c

Globally, **beaches and dunes have in general undergone net erosion** over the past century or longer. While some coastal systems may be able to undergo landward retreat under rising sea levels, others will experience coastal squeeze, which occurs when an eroding shoreline approaches hard, immobile structures such as seawalls or resistant natural cliffs. In these instances the beaches will narrow owing to the resulting sediment deficit and produce adverse impacts such as habitat destruction, impacting the survivability of a variety of organisms. With such a manifestation of coastal squeeze,sand dunes will ultimately be removed as the beach erodes and narrows. Extreme storms can erode and completely remove dunes, degrading land elevations and exposing them to inundation and further change if recovery does not occur before the next storm.

Vegetated coastal habitats and **coastal wetlands (mangrove forests,salt marshes, seagrass meadows, and macroalgal beds) are declining globally rendering shorelines more vulnerable to erosion** due to increased sea level rise and increased wave action and leading to the loss of carbon stored in sediments. Together, the loss of coastal wetlands and seagrass meadows results in the release of 0.04 to 0.28 PgC annually from organic deposits. Recognition of the important consequences of the losses of these habitats for coastal protection and carbon burial has led to large-scale reforestation efforts in some nations (e.g., Thailand, India, Vietnam). Seagrass meadows are already under stress due to climate change, particularly where maximum temperatures already approach their physiological limit. Although elevated CO2 and ocean acidification are expected to increase productivity of vegetated coastal habitats in the future, there is limited evidence that elevated CO2 will increase seagrass survival or resistance to warming.

Coastal wetlands and seagrass meadows experience coastal squeeze in urbanized coastlines, with no opportunity to migrate inland with rising sea levels.

The primary drivers of change in lagoons and estuaries are human-related rather than climate-related drivers. Projected changes in climate-related drivers such as warming, storms,sea level, and runoff will interact with non-climate human drivers (e.g., eutrophication, damming) and will have consequences for ecosystem functioning and services of lagoons and estuaries. The projected natural impacts on deltas under changing global climate are caused mainly by extreme precipitation-induced floods and sea level rise. These will result in increased coastal flooding, decreased wetland areas, increased coastal erosion, and increased salinization of cultivated land and groundwater.

Mass coral bleaching coincided with positive temperature anomalies over the past 30 years,sometimes followed by mass mortality. Ocean warming is the primary cause of mass coral bleaching and mortality, which, together with ocean acidification, deteriorates the balance between coral reef construction and erosion. The magnitude of these effects depends on future rates of warming and acidification, with a limited moderating role owing to biological acclimation and adaptation.

Important direct effects of climate change on coastal settlements include dry-land loss due to erosion and submergence, damage of extreme events (such as wind storms, storm surges, floods, heat extremes, and droughts) on built environments, effects on health (food- and water-borne disease), effects on energy use, effects on water availability and resources, and loss of cultural heritage.

Coastal industries, their supporting infrastructure including transport (ports, roads, rail, airports), power and water supply, storm water, and sewerage are highly sensitive to a range of extreme weather and climate events including temporary and permanent flooding arising from extreme precipitation, high winds, storm surges, and sea level rise.

Climate variability and change impact both **fishers' livelihoods and fish production. Changes have occurred to the distribution of fish species** with evidence of poleward expansion of temperate species. Coastal agriculture has experienced negative impacts due mainly to increased frequency of submersion of agricultural land by saltwater inundation.

Coastal tourism continues to be highly vulnerable to weather, climate extremes, and rising sea levels with the additional sensitivity to ocean temperature and acidity for the sectors that rely on reef tourism. Developing countries and small island states within the tropics relying on coastal tourism are most vulnerable to present and future weather and climate extremes, future sea level rise, and the added impacts of coral bleaching and ocean acidification.

Damage to coral reefs has implications for several key regional services:

- **Resources**: Coral reefs account for 10 to 12% of the fish caught in tropical countries, and 20 to 25% of the fish caught by developing nations.
- **Coastal protection**: Coral reefs contribute to protecting the shoreline from the destructive action of storm surges and cyclones, sheltering the only habitable land for several island nations, habitats suitable for the establishment and maintenance of mangroves and wetlands, as well as areas for recreational activities. This role is threatened by future sea level rise, the decrease in coral cover, reduced rates of calcification, and higher rates of dissolution and bioerosion due to ocean warming and acidification
- **Tourism**: More than 100 countries benefit from the recreational value provided by their coral reefs. With coral reef bleaching or damage, the tourism industry will collapse affecting local livelihoods.

8.2 How can climate change be managed? climate change mitigation and adaptation!

Climate change is caused by increases in the concentrations of greenhouse gases in the atmosphere. There are two ways in which climate change can be managed. One is to reduce the emission of these gases (mitigation). The other way is to change or adapt our lifestyles to live with it (adaptation).

The relationship between health of coastal populations and climate change include direct linkages (e.g., floods, droughts,storm surges, and extreme temperatures) and indirect linkages (e.g., changes in the transmission of vector-, food-, and water-borne infectious diseases and increased salinization of coastal land that affects food production and freshwater supply and ecosystem health).

8.2.1 Climate change mitigation

Mitigation is a human (anthropogenic) intervention that is designed to reduce the sources of emission or enhance the sinks of greenhouse gases. This can be done through the use of energy-efficient technologies in manufacturing industry, transport and construction. Increased sequestration (capturing) of carbon dioxide by plant life can also reduce the greenhouse gas concentration in the atmosphere.

The aim of the UNFCCC was to mitigate and stabilize the emission of greenhouse gases in the atmosphere. The text of the convention reads thus:

> *The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.*[2]

The Kyoto Protocol, an instrument that was designed within the UNFCCC, set a commitment figure for emission reduction for developed countries.

At COP 21 in Paris, Parties to the UNFCCC reached a landmark agreement to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low carbon future. The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change. Read more on Paris Agreement here http://bigpicture.unfccc.int/#content-the-paris-agreemen

2 The text of the convention can be read at http://unfccc.int/files/essential_background/convention/background/application/pdf/convention_text_with_annexes_english_for_posting.pdf

Developing countries have been contributing to global mitigation efforts in several ways, such as clean development mechanism (CDM), implementation of nationally appropriate mitigation actions (NAMAs), contribute to mitigation actions in the forest sector by undertaking activities to reduce emissions from deforestation and forest degradation, conserve forest carbon stocks, implement sustainable management of forests and enhance forest carbon stocks (REDD-plus). For developed countries, mitigation policies and measures have focused mostly on the sectors with the highest emissions, such as energy and transport.

8.2.2 Climate Change Adaptation (CCA)

Coastal adaptation and risk management refer to a wide range of human activities related to the social and institutional processes of framing the adaptation problem, identifying and appraising adaptation options, implementing options, and monitoring and evaluating outcomes.

Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation.

- **Anticipatory adaptation** takes place before impacts of climate change are observed—this is also referred to as proactive adaptation.
- **Autonomous adaptation** does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems, and this is also referred to as spontaneous adaptation.
- **Planned adaptation** is the result of a deliberate policy decision based on awareness that conditions have changed or are about to change and that action is required to return to, maintain or achieve a desired state.

8.2.3 What does adaptation mean in terms of action?[3]

Identifying needs stemming from climate risks and vulnerabilities provides a foundation for selecting adaptation options. Over the years, a number of categories of options have been identified. These options include a wide range of actions that are organized into three general categories:

STRUCTURAL/PHYSICAL:

- **Engineered and built environment:** Sea walls and coastal protection structures, flood levees and culverts, water storage and pump storage, sewage works, improved drainage, beach nourishment, flood and cyclone shelters, building codes, storm and waste water management, transport and road infrastructure adaptation, floating houses, adjusting power plants and electricity grids
- **Adaptation suing technological interventions:** New crop and animal varieties, genetic techniques, traditional technologies and methods, efficient irrigation, water saving technologies, including rainwater harvesting, conservation agriculture, food storage and preservation facilities, hazard mapping and monitoring technology, early warning systems, building insulation, mechanical and passive cooling, renewable energy technologies, second-generation biofuels
- **Ecosystem-based adaptation:** Ecological restoration , including wetland and floodplain conservation and restoration, conserving biological diversity, afforestation and reforestation, conservation and replanting mangrove forest, bushfire reduction and prescribed fire, green infrastructure (e.g., shade trees, green roofs), controlling overfishing, fisheries co-management, assisted migration or managed translocation, ecological corridors, ex situ conservation and seed banks, community-based natural resource management, adaptive land use management
- **Adaptation through increasing supply of key services:** Social safety nets and social protection, food banks and distribution of food surplus, municipal services including water and sanitation, vaccination programs, essential public health services, including reproductive health services and enhanced emergency medical services, international trade

3 Source: Noble et al 2014

SOCIAL

- **Adaptation through imparting relevant education:** Awareness raising and integrating into education, gender equity in education, extension services, sharing local and traditional knowledge, including integrating into adaptation planning, participatory action research and social learning, community surveys, knowledge-sharing and learning platforms, international conferences and research networks, communication through media
- **Adaptation through enhancing the information base:** Hazard and vulnerability mapping, early warning and response systems, including health early warning systems, systematic monitoring and remote sensing, climate services, including improved forecasts, downscaling climate scenarios, longitudinal data sets, integrating indigenous climate observations, community-based adaptation plans, including community-driven slum upgrading and participatory scenario development
- **Adaptation through behavioral change:** Accommodation, household preparation and evacuation planning, retreat and migration, which has its own implications for human health and human security, soil and water conservation, livelihood diversification, changing livestock and aquaculture practices, crop-switching , changing cropping practices, patterns, and planting dates, silvicultural options, reliance on social networks

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- **Adaptation through Economic instruments:** Financial incentives including taxes and subsidies, insurance including index-based weather insurance schemes, catastrophe bonds, revolving funds, payments for ecosystem services, water tariffs, savings groups, microfinance, disaster contingency funds, cash transfers
- **Adaptation through Laws and regulations:** Land zoning laws, building standards, easements, water regulations and agreements, laws to support disaster risk reduction, laws to encourage insurance purchasing, defining property rights and land tenure security, protected areas, marine protected areas, fishing quotas, patent pools and technology transfer,

- **Government policies and programs:** National and regional adaptation plans, including mainstreaming climate change; sub-national and local adaptation plans, urban upgrading programs, municipal water management programs, disaster planning and preparedness, city-level plans, district-level plans, sector plans, which may include integrated water resource management, landscape and watershed management, integrated coastal zone management, adaptive management, ecosystem-based management, sustainable forest management, fisheries management, and community-based adaptation

Adaptation and mitigation are complementary strategies for reducing and managing the risks of climate change. Substantial emission reduction over the next few decades can reduce climate risks in the 21st century and beyond, increase prospects for effective adaptation, reduce the costs and challenges of mitigation in the longer term and contribute to climate-resilient pathways for sustainable development.

Many adaptation and mitigation options can help address climate change, but no single option is sufficient by itself. Effective implementation depends on policies and cooperation at all scales and can be enhanced through integrated responses that link adaptation and mitigation with other societal objectives.

8.2.4 How can coastal communities plan for and adapt to the impacts of climate change, in particular sea level rise?[4]

An increasing focus of coastal use planning is on precautionary measures, that is, measures taken even if the cause and effect of climate change is not established scientifically. For many regions, an important focus of coastal use planning is to use the coast as a natural system to buffer coastal communities from inundation, working with nature rather than against it.

The adaptation approaches to help coastal communities adapt to the impacts of climate change fall into three general categories:

1. **Protection of people, property, and infrastructure is a typical first response.** This includes "hard" measures such as building seawalls and other barriers, along with various measures to protect critical infrastructure. "Soft" protection measures are increasingly favored. These include enhancing coastal vegetation and other coastal management programs to reduce erosion and enhance the coast as a barrier to storm surges. [Please refer to the later section on synergies and trade-offs to understand the benefits of soft protection measures]
2. **Accommodation is a more adaptive approach involving changes to human activities and infrastructure.** These include retrofitting buildings to make them more resistant to the consequences of sea level rise, raising low-lying bridges, or increasing physical shelter capacity to handle needs caused by severe weather. Soft accommodation measures include adjustments to land use planning and insurance programs.
3. **Managed retreat involves moving away from the coast** and may be the only viable option when nothing else is possible.

   Some combination of these three approaches may be appropriate, depending on the physical realities and societal values of a particular coastal community. The choices need to be reviewed and adjusted as circumstances change over time.

4 [Source: IPCC 2014]

Community-based adaptation measures

[Source: IPCC 2014] [Please refer to the original document for cross-references in this table]

Impact	Type of option	Measures	Brief description	References
Increased salinity	New and diversified livelihoods	Saline-tolerant crop cultivation	Farmer production of saline-tolerant multi-vegetable varieties and non-rice crops	Ahmed (2010); Rabbani et al. (2013)
	New and diversified livelihoods	Keora nursery	Mangrove fruit production to develop local female entrepreneurship	Ahmed (2010)
	New and diversified livelihoods	Crab fattening	Collection, rearing, and feeding of crabs for 15 days to increase local market value	Pouliotte et al. (2009)
	Structural	Homestead protection	Houses constructed on raised foundations to mitigate salinity ingress	Ayers and Forsyth (2009)
Flooding/ inundation	Socio-technical	Disaster management committees	Multi-community stakeholder committees established to discuss disaster preparedness and response on a monthly basis	Ahammad (2011)
	Socio-technical	Early flood warning systems	Established systems converted into a language and format understood by local communities; warning dissemination through community radio services	Ahmed (2005); Saroar and Routray (2010)
	New and diversified livelihoods	Aquaculture: cage and integrated approaches	Small-scale fish culture in cages on submerged agriculture land; aquaculture integrated with other livelihood practices	Pomeroy et al. (2006); Pouliotte et al. (2009); Khan et al. (2012)
	New and diversified livelihoods	Embankment cropping	Growing different vegetable varieties around heightened shrimp enclosures/coastal polders for productive use of fallow land	Ahmed (2010)
	New and diversified livelihoods	Hydroponics	Cultivating vegetables and other crops on floating gardens	Ayers and Forsyth (2009); Ahmed (2010); Dev (2013)
Cyclones/ storm surges	Structural/hard	Homestead reinforcement	Low-cost retrofitting to strengthen existing household structures, especially roofs; strict implementation of building codes	Sales (2009); Ahmed (2010)
	Structural/soft	Homestead ecosystem protection	Plantation of specific fruit trees around homestead area	Haq et al. (2012)
	Structural/hard	Underground bunker construction	Underground bunker established, providing protected storage space for valuable community assets	Raihan et al. (2010)
Sea level rise	Institutional	Risk insurance mechanisms	Farmers educated on comprehensive risk insurance, focusing on sea level rise and coastal agriculture	Khan et al. (2012)
Multi-coastal impacts	Institutional	Integrating climate change into education	Formal and informal teacher training and curriculum development on climate change, vulnerability, and risk management	Ahmed (2010)
	Institutional	Integrated coastal zone management (ICZM) plan	ICZM plan development at local institutional level, including land and sea use zoning for ecosystem conservation	Sales (2009)
	Structural/soft	Restoration, regeneration and management of coastal habitats	Community-led reforestation and afforestation of mangrove plantations, including integration of aquaculture and farming to increase household income levels	Rawlani and Sovacool, (2011); Sovacool et al. (2012)
	Institutional	Community participation in local government decision-making	Active female participation in local government planning and budgeting processes to facilitate delivery of priority coastal adaptation needs	Faulkner and Ali (2012)
	Institutional/ socio-technical	Improved research and knowledge management	Establishment of research centers; community-based monitoring of changes in coastal areas	Sales (2009); Rawlani and Sovacool (2011)

Coastal adaptation, Coastal Zone Management and Disaster Risk Reduction:

The issues for coastal adaptation are not radically different from issues encountered within the framework of "Coastal Zone Management (CZM)" or also termed "Integrated Coastal Zone Management. Integrated coastal zone management is a long-term, institutionalized and iterative process that promotes the integration of coastal activities, relevant policymakers, practitioners, and scientists across coastal sectors, space and organizations with a view to use coastal resources in a sustainable way; and thus it provides an enabling environment for coastal adaptation practice. **The major difference between the two is that coastal adaptation means coping with greater uncertainty, longer time frames in planning (beyond 30 years), and long-term commitments inherent to climate change.**

Much of the observed adaptation practice deals with the coastal hazards of erosion and flooding. Efforts are also being made to integrate climate change adaptation into Disaster Risk Reduction (DRR) frameworks, and adaptation practice is likely to move forward as climate change adaptation (CCA) converges with disaster risk reduction. In the next section, an overview of the disaster risk reduction is provided.

Videos of report of the Intergovernmental Panel on Climate Change

https://www.youtube.com/watch?v=6yiTZm0y1YA (Climate Change 2013: The Physical Science Basis)

https://www.youtube.com/watch?v=jMIFBJYpSgM (Climate Change 2014: Impacts, Adaptation, and Vulnerability)

https://www.youtube.com/watch?v=gDcGz1iVm6U (Climate Change 2014: Mitigation of Climate Change)

8.3 Disaster and risk reduction

8.3.1 Basics of Disaster risk reduction

India's National Policy on Disaster Management (2009) defines 'disaster' as **'a catastrophe, mishap, calamity or grave occurrence from natural or man-made causes, which is beyond the coping capacity of the affected community'**

With growing populations and infrastructure, the world's exposure to natural hazards is witnessing a steep increase. This is particularly true as the fastest population growth is in coastal areas (with greater exposure to floods, storms and tidal waves). To make matters worse, any land remaining available for urban growth is generally risk prone, for instance, floodplains or steep slopes subject to landslides. The accompanying graph shows a steep increase in the frequency of disasters in recent years.

This raises several questions.

- Is the increase due to a significant improvement in access to information?
- What part does population growth and infrastructure development play?
- Is climate change behind the increasing frequency of natural hazards?

There are many reasons for the escalation in the frequency of disasters, such as new settlement patterns, population growth, increased rural-to-urban migration, emerging poverty levels and trends, the impact of development processes, new forms of vulnerabilities related to technological and industrial developments, emergence of virulent biological threats, ecological degradation, phenomena such as El Niño/La Niña, climate change and the potential for rising sea levels, affecting the patterns and intensity of hydro-meteorological hazards.

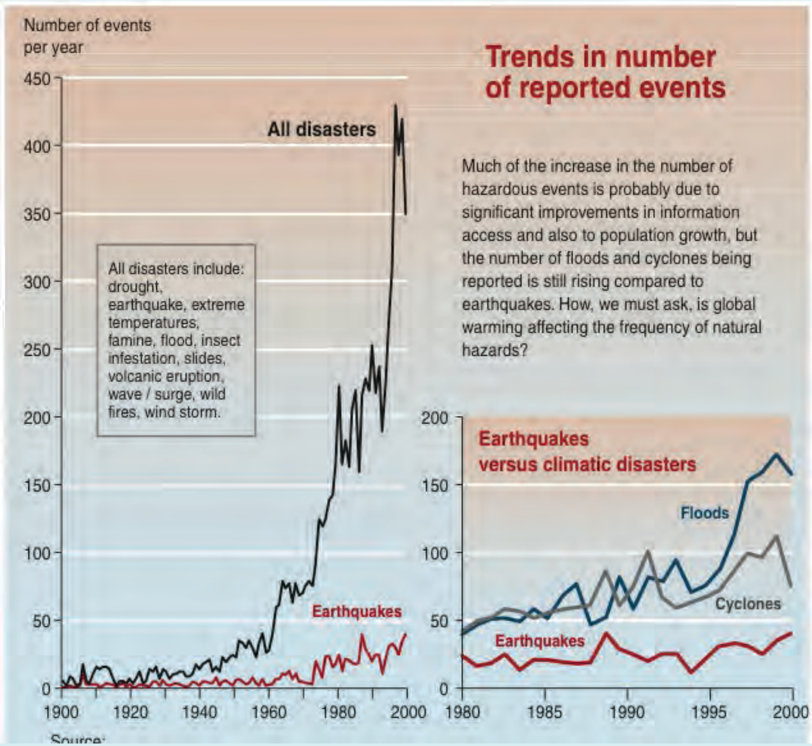

Figure 8.3 : Trends in natural disasters (Source: Centre for Research on the Epidemiology of Disasters[5])

Emerging trends in disaster impacts, hazards and vulnerability patterns

- More than 90 per cent of natural disaster-related deaths are in developing countries.
- The global trend is of fewer deaths but higher economic losses due to disasters.
- Hazards and vulnerability are constantly shaped by dynamic and complex socioeconomic and ecological processes and get compounded by stresses within individual societies.

5 Source: Centre for Research on the Epidemiology of Disasters http://www.cred.be/

8.3.2 Types of natural and non-natural disasters

Disasters are often classified according to their causes (natural vs human-made) and speed of onset (sudden vs slow)

Classification by cause

Natural disasters. These types of disasters are caused by biological, geological, seismic, hydrologic or meteorological conditions or processes in the natural environment, e.g., cyclones, earthquakes, tsunami, floods, urban floods, landslides, heat waves and volcanic eruptions.

Human-made disasters. These are Nuclear and Radiological Emergency, biological disasters and chemical disasters.

Classification by speed of onset

Sudden onset. The disaster happens with little or no warning, and there is minimal time to prepare, for example, an earthquake, a tsunami, a cyclone, a volcanic eruption.

Slow onset. These adverse events are slow to develop: first, the situation develops; the second level is an emergency; the third level is a disaster. Examples are droughts, civil strife and epidemics.

8.3.3 The disaster continuum and the context of coastal and marine biodiversity conservation

Disaster management can be defined as the body of policy and administrative decisions and operational activities that pertain to the various stages of a disaster at all levels. There are three key stages of activity in disaster management.

1. BEFORE A DISASTER STRIKES (PRE-DISASTER)

Activities taken to reduce human and property losses caused by the hazard and ensure that these losses are also minimized when the disaster strikes. Risk reduction activities are taken up in this stage. They are termed mitigation and preparedness activities.

Stable and healthy coastal and marine habitats such as mangroves, coral reefs and sea grasses are key in ensuring the pre-disaster mitigation and preparedness activities against coastal disasters.

2. DURING A DISASTER (DISASTER OCCURRENCE)

Activities taken to ensure that the needs of affected people are met and suffering is minimized. Activities carried out during this stage are called emergency response activities.

3. AFTER A DISASTER (POST-DISASTER)

Activities undertaken for early recovery and efforts undertaken to ensure that the earlier vulnerable conditions do not prevail again. These are called response and recovery activities.

8.3.4 Urbanization and disasters

- One out of every two people now lives in a city. This proportion will go on rising—by 2030, 5 billion of the planet's expected 8.1 billion population will be urban.
- One in three of the urban population lives in marginal settlements or crowded slums with inadequate access to clean water, sanitation, schools, transport and other public services. This is relevant for many of our Tier 1 and Tier 2 cities.
- One city dweller in four lives in absolute poverty. By 2030, two-thirds of humankind will live in cities and 3 billion in slums.
- Eight of the 10 most populous cities on the planet are vulnerable to earthquakes. Six of the 10 are vulnerable to floods, storm surges and tsunamis.
- Issues in land-use planning, enforcement of building codes and faulty construction standards put millions at risk.
- By 2015, 33 cities had at least 8 million residents. Of these, 21 are in coastal areas and are particularly vulnerable to meteorological hazards driven by climate change, e.g., Dhaka, Shanghai, Manila, Jakarta and Mumbai.
- Cities with weak governance and small- and medium-sized urban areas are more vulnerable to disasters as they have weaker capacities to manage urban growth, deforestation and destruction of coastal systems.

"Climate Change, Coastal Urbanization, and Water: A Recipe for Disaster" - By Geoffrey Scott

https://www.youtube.com/watch?v=oOkjaMOIeWO

8.4 Climate change and disaster risk: How they relate to coastal and marine biodiversity and coastal livelihoods

8.4.1 Sustainable Coastal Livelihoods

A livelihood is sustainable that can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets and provide sustainable livelihood opportunities for the next generation and that contributes net benefits to other livelihoods at the local and global levels and in the short and long term (Chambers and Conway 1991). This translates into a two-way relationship between livelihoods and the ecosystem.

A livelihood is environmentally sustainable when the natural resources and ecosystem services are being utilized for livelihood activities at a rate and in a manner that do not pose any threats to the natural ecosystems and the ecosystem services. A livelihood is socially sustainable when it is able to cope with stress and shocks and retain its ability to continue and improve (Chambers and Conway 1991). There is a need to include the impacts of stresses and shocks or disasters and the coping capacities of human communities in the conceptual planning of livelihood sustainability.

Climate-related hazards affect the lives of poor people directly through impacts on livelihoods, reductions in fish catch or destruction of homes and coastal defenses leaving them further vulnerable to the next disaster. The livelihoods of the coastal population are, therefore, closely affected, in one or the other way, by three major factors, viz, climate change, disruption/loss of ecosystem services and disasters.

Therefore, adapting to climate change and maintaining ecosystem services, is of high relevance for protecting the livelihood security of communities in coastal areas and the overall well-being of such areas.

8.4.2 Synergies and trade-offs between climate change, disaster risk, coastal and marine biodiversity and coastal livelihoods[6]

Despite the wealth of coastal adaptation activities, meeting the multiple goals of coastal adaptation, improving governance, accounting for the most vulnerable populations and sectors and fully integrating consideration of natural ecosystems is still largely aspirational. Meanwhile, development continues in high-risk coastal areas, coastal ecosystems continue to degrade in many regions, coastal freshwater resources are being overexploited in many highly populated areas, and vulnerability to coastal disasters grows.

Though the objective of both CCA and DRR is reducing the vulnerability of local communities, some CCA and DRR interventions may unintentionally leave people even more vulnerable than before to the impacts of natural disasters.

This is not because of a lack of understanding of the interlinkages between climate change and disasters. **The challenge, however, lies in identifying the activities and strategies that may be mutually beneficial (interlinkages) or may diminish the efforts of the other sectors (trade-offs) in a particular context.** There are well established studies on analysing synergies and trade-offs between various measures in the coastal areas, some of which are highlighted below:

- Many coastal zone-based activities and various coastal management strategies involve emissions of Green House Gases. Reduction or cessation of some of them may have positive implications for both mitigation and adaptation. For example, limiting offshore oil production may not only lead to reduction in GHG emissions, but also a reduced risk of oil spills, and a reduction of stresses on the marine/coastal ecosystems, as well as public health. This may result in reduced vulnerability that is positive for adaptation. However, this measure would increase the vulnerability of countries whose economies are highly dependent on oil extraction.

6 Source: Adapted from Khera (2012)

- While most of the disaster risk reduction activities are synergistic with the objectives of coastal adaptation and the livelihoods of coastal communities, there are certain activities with trade-offs, such as shelterbelt plantation on the shoreline with the tree species Casuarina (*Casuarina equisetifolia*) for cyclone protection (NDMA 2008), which reportedly has adverse effects on the nesting of sea turtles by causing beaches to shrink (Balu 2008). Ironically, it has also not been possible so far to establish the effectiveness of thin shelterbelt plantations as bio-shields (Forbes & Broadhead 2007). This example supports the need to build scenarios of ecosystem service trade-offs, which will help prioritize activities on the basis of their impacts on ecosystem services.
- Trade-offs can be seen with the adaptation options, such as **modification of land use for coastal agricultural practices and aquaculture, which may lead to habitat loss and degradation, spread of invasive alien species and coastal pollution**—changes that may result in loss of fisheries, affecting local livelihoods and ultimately leaving the coastal communities even more vulnerable to the negative impacts of climate change and natural disasters than before. Such adaptation options may compromise biodiversity and ecosystem stability in the long term and not only increase the risk of disasters but also diminishes the livelihood opportunities of the coastal population, making them further vulnerable to climate change.
- **Some protective hard infrastructure raised as CCA options (such as seawalls, floodgates, tidal barriers and saltwater-intrusion barriers) have been reported to be ineffective in extending protection, rather enhancing the risk of natural disasters and contributing to habitat loss due to coastal squeeze (Knogge et al 2004; Rochelle-Newall et al 2005)**. Such CCA strategies, termed ‘mal-adaptation’ (Burton 1996), may compromise biodiversity and the stability of an ecosystem in the long term and not only increase the risk of disasters but also diminish the livelihood opportunities of the population and make it more vulnerable to climate change.

8.4.3 The root cause: Trade-offs between different ecosystem services
[Source: Khera, 2013]

Stable and diverse ecosystems provide multiple services, which interact in multiple ways. This makes the ecosystem services relate to each other either negatively or positively. Some ecosystem services co-vary positively (an increase in one service means another also increases), and others co-vary negatively **(an increase in one service means another decreases). Focusing on one ecosystem service in isolation from the possible impacts on other critical services provided by the same ecosystem leads to a situation of conflict and management failure** (Elmqvist et al 2011).

Many marine and coastal ecosystems no longer deliver the full suite of ecosystem services that humans have come to rely upon (Mengerink et al 2009) due to the existence of trade-offs between the activities of different sectors. Trade-offs can be minimized if the primary goal of all the activities in the marine and coastal ecosystems is maintaining a sustainable flow of ecosystem services (MEA 2005).

Marine and coastal ecosystems around the world are experiencing an increasing demand for their diverse ecosystem services, which are required for different sectors such as fisheries, tourism, biodiversity conservation, CCA, DRR and so on. The viability of many activities of these sectors is dependent on the services provided by the same ecosystem. In such situations, progress toward one objective, such as increasing fish production, has often been at the cost of other objectives, such as conserving biological diversity or improving water quality (MEA 2005), and this is known as a ‘trade-off’. These trade-offs exist even within the ‘green sector.’

There are many potential synergies between disaster risk reduction, coastal marine biodiversity conservation and climate change adaptation that can contribute to social, economic, and environmental sustainability and a resilient future. Though there is no single approach, framework, or pathway to achieve this, reducing vulnerability has been identified as one of the most important prerequisite for a resilient and sustainable future.

Identifying the drivers of hazard and vulnerability is key to effective action for reducing vulnerability. This can be done best where local and scientific knowledge is combined and the local capacity is developed. Key drivers of hazard and vulnerability in the coastal areas include loss of coastal and marine habitats and species loss leading to declined ecosystem services.

Adopting an ecosystem approach in the overall development planning can be one of the solution. Conservation of ecosystems and biodiversity provides multiple benefits in the long run and keeping "ecosystem services" as the primary goal of interventions affecting coastal and marine ecosystems, will minimize the trade-offs between the actions of various sectors.

The Ocean is exposed to a range of stresses that may or may not be related to climate change. Non-climate stress factors such as pollution, eutrophication (too many nutrients), habitat destruction, invasive species, destructive fishing, and over-exploitation of marine resources increase the vulnerability to climate change. Reducing the impact of these non-climate factors and building ecological resilience through ecosystem-based approaches to the management of coastal and marine environment, may pay dividends in terms of reducing and delaying the effects of climate change

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Further resources

BBC Planet Ocean https://www.youtube.com/watch?v=eH1s9GCqPKo

OCEAN + TV https://www.youtube.com/channel/UCbpNymvg7GecYuUQk2BvG2A

Concerned Citizens Commission Report: 'Mumbai Marooned'; also National Geographic channel documentary, https://www.youtube.com/watch?v=uvIuroTz8Gw

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https://www.youtube.com/watch?v=6yiTZm0y1YA