

Rising Seas & Receding Islands

The mesmerising Maldivian island

Climate change has hit islands hard with some in danger of disappearing completely as sea levels rise. Being the most vulnerable ecosystems with regard to climate change, there is a need to frame effective adaptive and management policies specifically for the islands.

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THE world's first underwater cabinet meeting organised by the Maldivian president on 17 October 2009 was a symbolic cry for help over rising sea levels that threaten the tropical archipelago's existence. This island archipelago nation off the tip of India, best known for its mesmerising beauty and sparkling beaches, represented by 1,200 atolls, 80% of which are no more than a metre above sea level, is among the most threatened by rising seas.

In 2007, the United Nation's Intergovernmental Panel on Climate Change (IPCC) warned that a rise in sea levels of between 18 and 59 centimetres by 2100 would be enough to make the Maldives virtually uninhabitable. The economy of this Indian Ocean island nation is supported by climate-sensitive activities like fishing and tourism.

Global warming and sea level rise, if continued unabated, would affect the very existence of the nation and therefore the nation's government is developing a plan to evacuate the *entire country* to new homes in Sri Lanka, India or Australia in case of need!

The alarm bell is ticking not just for the Maldives but also for many islands across the globe. The New Moore Island of India in the Sunderbans has been consumed recently by the rising sea—even as Bangladesh was also claiming its right over it! The New Moore is not the first island to be submerged in the Sunderbans. The first inhabited island to have been submerged by the rising sea level was Lohachara. Once home to about 10,000 people, the island was submerged under the sea in 1996. The submerging of islands also results in migration of people making them "environmental refugees".

The first uninhabited island to vanish from the map due to sea level rise was the Pacific atoll nation of

Kiribati. The people of low-lying islands in Vanuatu, also in the Pacific, have been evacuated as a precaution, though the island still remains above the sea. The impacts of climate change are more pronounced in some low-lying Pacific island nations as they are slowly being submerged by the rising water levels of the Pacific Ocean. As the seas continue to swell, they will swallow whole island nations, from the Maldives to the Marshall Islands, inundate vast areas of countries from Bangladesh to Egypt, and submerge parts of a large number of coastal cities. The islands are much more vulnerable to the impacts of climate change and subsequent sea level rise.

What is Special About Island Biodiversity?

Islands encompass a diverse range of territories, differing in landform, climate and biogeography. Nearly one fourth of the world's countries are islands! With the legacy of a unique



Underwater cabinet meeting organised by the Maldivian President as a symbolic event on the impacts of climate change (left)

Lohachara Island in the Sunderbans (bottom left);

The Lakshadweep Islands—threatened! (bottom)



evolutionary history, islands are treasure troves of biodiversity. The species may become island dwellers either by drifting or by dispersal. Once they reach the islands, they are confined to small, isolated pockets, much away from the mainland. The formation of new islands and their isolation from the mainland provides many unoccupied niches for species to adapt to.

In the absence of many predators and competitors, the newly arrived species may easily get established in the new niches available. As the chances of breeding with mainland species are limited, through isolation (and with restricted gene pool), they develop into distinct species, some with highly specialized characteristics. This results in a high rate of endemism, with species restricting their distribution to localized areas. The adaptive radiation and origin of new species in the islands of Galapagos explained by Charles Darwin is well documented in science.

Compared to the mainland, islands have a disproportionately high number of endemic species. For example, 50% of endemic bird areas are found on islands. Over 90% of Hawaiian island species are endemic. In Mauritius, about half of all higher plants, mammals, birds, reptiles and amphibians are endemic, and the Seychelles has the highest level of amphibian endemism in the world. The island of Cuba is home to 18 endemic mammals, while Madagascar is home to more than 8,000 endemic species. In other words, island biodiversity is often very unique.

Lakshadweep is the tiniest Union Territory of India and this archipelago consists of 36 coral islands, 12 atolls, three reefs and five submerged banks. Only 10 of these islands namely, Agatti, Amini, Andrott, Bitra, Chetlat, Kadmat, Kalpeni, Kavaratti, Kiltan and Minicoy are inhabited. Both inhabited and uninhabited islands are rich in biodiversity. Similarly, the Andaman and Nicobar islands include

572 islands in the territory, of which only approximately 38 are permanently inhabited. Andaman and Nicobar Islands are blessed with unique tropical rainforests, made of a mixed flora with elements from Indian, Myanmar, Malaysian and endemic floral strains. So far, these Islands are home to about 2,200 varieties of plants, out of which 200 are endemic. In addition to these, a wide spectrum of uninhabited islands is there in association with the Gulf of Mannar and the Sunderbans.

Islands are rich in ecosystem diversity too, as within islands we may come across mountain forests to coastal wetlands. These ecosystems provide food, fresh water, wood, fibre, medicines, fuel, tools and other important raw materials, in addition to aesthetic, spiritual, educational and recreational values. In fact, the livelihood and economic stability of the islands depend on its biodiversity.

Think about corals and mangroves that border island ecosystems. These



Vanuatu Island



Kiribati Island

unique ecosystems provide a wide array of ecosystem services, including defence against natural disasters, support to recycling of nutrients, and regulation of microclimate. They also act as homes and nursery grounds of hundreds of marine species. Above all, biodiversity of islands not only supports the economy and food security of the islands but also determines the livelihood and cultural identity of 600 million island-dwelling people across the world.

Coral reefs provide an estimated US\$ 375 billion per year in goods and services to the world. This includes support for marine fisheries, which provide the principal protein source for many island populations. The Lakshadweep is a coral island. Coral reef ecosystems around Indian islands are home to hundreds of marine ornamental fishes. United Nations Environment Programme (UNEP) estimated the value of coral reefs as between US\$100,000 to US\$600,000 per square kilometre a year!

Vulnerability of Islands

Each island ecosystem is unique in its biological character and therefore even slight changes in environmental conditions may drastically impact biodiversity and life of human species inhabiting there. These ecosystems are fragile, often comprising species that have evolved in the absence of aggressive competitors, diseases or predators. Though they are more biodiverse than mainland regions and the degree of endemism is high, the small size of populations and separation restricts movement and gene flow, limiting the ability for recolonization following catastrophic events. Many of the islands are thickly populated and there are pressures from human developmental activities,

including tourism. Conversely, remote islands did not receive popular attention, though the impacts are severe.

Over the past century, island biodiversity has been subject to intense pressure from anthropogenic interventions in the form of habitat destruction, introduction of invasive alien species, over-exploitation, and more importantly pollution and climate change. Of the 724 recorded animal extinctions in the last 400 years, about half were island species! We have the classical example of Dodo in the islands of Mauritius as a symbol of extinction.

The impacts of climate change and related events are much more effervescent in islands than any other

Rich biodiversity in the Lakshadweep Islands



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ecosystem in the world. The most significant impacts of climate change are sea level and sea-surface temperature (SST) rise. Because most small islands are low lying and have a large exposure of coasts in relation to landmass, as well as a high concentration of population in coastal zones, islands are extremely vulnerable to sea-level rise. Experts

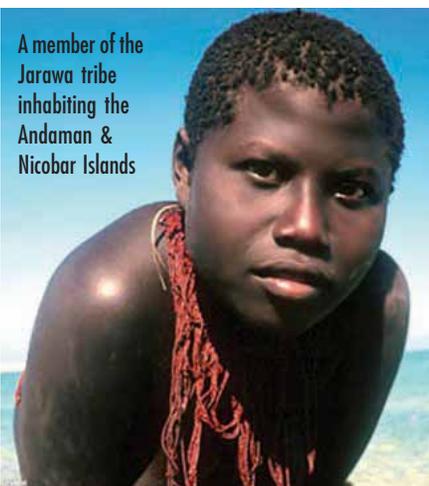
predict that average sea level could rise by as much as 21 centimetres by 2025 and 66 centimetres by 2100, may lead to inundation, storm surge or shoreline erosion, with the potential to destroy island economies.

Climate change is expected to cause serious degradation of the coastal environment and natural resources on which poor rural people depend. Higher rates of erosion and coastal land loss are expected in many islands as a consequence of the projected increase in sea level. Pacific Islands are shown to be mainly vulnerable to coastal flooding and decreased extent of coastal vegetated wetlands. There is also a detectable influence on marine and terrestrial pathogens, such as coral diseases and oyster pathogens. Low-lying islands as well as states and atolls are likely to experience increased sea flooding, inundation and salinization as a direct consequence of sea level rise.

Sea-level rise will also cause increased salinity due to encroachment

of the sea and saltwater intrusion into freshwater lenses, contributing to an increasing shortage of water supply and loss of agricultural land. Water stresses caused by climate change will have terrific impacts on poor rural people reliant on water resources for their livelihoods. Ocean warming, frequent tropical cyclones, flash floods and droughts are likely to have dramatic impact on food production system in islands. This would also affect export of agricultural produce from many island nations.

Fisheries contribute significantly to the economy and rural poor livelihood on many islands. As fishing is the major occupation of many island people, the socio-economic implications of fisheries loss would be severe and this may trigger other anthropogenic stresses such as over-fishing. For example, more intense tropical cyclones and rise in sea surface temperature will negatively impact inshore fisheries and food supply,

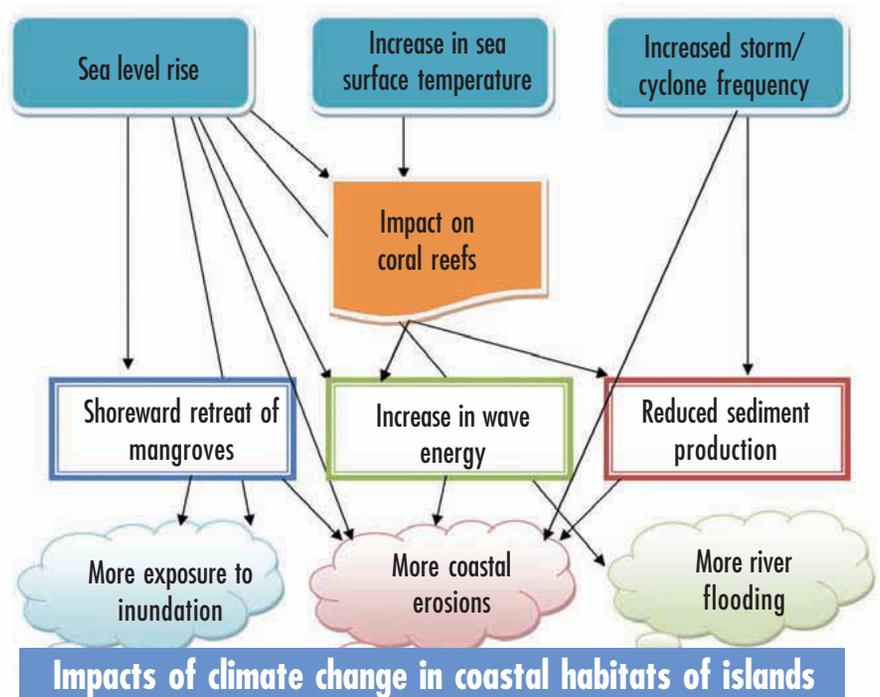


A member of the Jarawa tribe inhabiting the Andaman & Nicobar Islands

A rise in temperature causes coral bleaching, which negatively affects fishes.

especially in rural areas. Not all effects of climate change on agriculture are expected to be negative. For example, increased temperatures in high-latitude islands are likely to make conditions more suitable for agriculture and provide opportunities to enhance resilience of local food systems.

The rise in sea temperature causes coral bleaching, which negatively affects fishes, sponges, giant clams, molluscs and other sea creatures, whose survival depends on reefs. As a result, the food security and economies of islands, which are largely dependent on marine ecosystems, will be negatively affected. The El Niño event of 1998 resulted in massive bleaching and mortality of corals in the Lakshadweep, and subsequent loss of structure, and significant alterations



of fish communities. The coral bleaching events are now frequently reported from seas around Lakshadweep as well as Andaman and Nicobar islands due to increase in SST. The food security of the Lakshadweep islands is not hit because of this

phenomenon primarily due to dependence of people on tuna, a pelagic fish caught abundantly in waters around the islands.

A report issued by the World Wildlife Fund for Nature (WWF) argues that Australia's Great Barrier

Coral Bleaching

Corals are marine animals included in class Anthozoa and phylum Cnidaria. These organisms, producing hard exoskeleton of calcium carbonate, are represented by a colony of genetically similar flower-like structures called polyps. Over many generations the colony secretes a skeleton that is characteristic of the species. Huge deposits of these skeletons over long periods of history may give rise to coral reefs. Each polyp is typically only a few millimetres in diameter and has a skeleton cup, tentacles with stinging cells, a mouth and a stomach. The tiny tentacles snatch at passing plankton for food.

Many corals form a symbiotic relationship with a class of algae, zooxanthellae, of the genus *Symbiodinium*. Typically a polyp harbours one species of algae. Via photosynthesis, these provide energy for the coral, and aid in calcification. The algae benefit from a safe environment, and consume the carbon dioxide and nitrogenous waste produced by the polyp. Due to the strain the algae can put on the polyp, stress on the coral often drives the coral to eject the algae. Mass ejections are known as coral bleaching, because the algae contribute to coral's brown colouration; other colours, however, are due to host coral pigments, such as green fluorescent protein (GFP).



Bleached massive coral in Tamil Nadu coast (left); Bleached branching coral in Tamil Nadu coast (right). (Image Courtesy: SDMRI)

they commonly lose 60-90% of their zooxanthellae and each zooxanthella may lose 50-80% of its photosynthetic pigments. The bleached coral can recover, but only if cooler water temperatures return and the algae are able to grow again. Without the zooxanthellae, the coral slowly starves to death.

Apart from heat stress, other causes of coral bleaching may include: (i) increased exposure to ultraviolet (UV) radiation; (ii) large amounts of storm water from heavy rains flooding the reef; (iii) exposure of coral to certain chemicals or diseases; (iv) sediments such as sand or dirt covering the coral; and (v) excess nutrients such as ammonia and nitrate from fertilisers and household products entering the reef ecosystem.

Rising water temperatures block the photosynthetic reaction that converts carbon dioxide into sugar. This results in a build-up of products that poison the zooxanthellae. To save itself, the coral spits out the zooxanthellae and some of its own tissue, leaving the coral a bleached white. This phenomenon is often referred to as coral bleaching.

Most reef-building corals normally contain around 1-5 x 10⁶ zooxanthellae per square cm of live surface tissue and 2-10 pg of chlorophyll per zooxanthella. When corals bleach

The government of India has recently prepared the National Climate Change Action Plan that identifies a roadmap for energy efficiency and sustainable development.

Reef, the largest of its kind in the world, could lose 95% of its living coral by 2050 should ocean temperatures increase by the 1.5 degrees Celsius projected by climate scientists. This is due to the phenomena of coral bleaching and ocean acidification. As oceans absorb more amount of carbon dioxide, more carbonic acid is formed, resulting in ocean acidification. Animals with hard exoskeleton such as diatoms, corals and molluscs, may fall prey to ocean acidification as their skeleton may become weak very fast. If global temperatures increase by 2 °C, corals may not be able to adapt quickly enough physiologically or genetically. It has been estimated that, in order to counter the threat of ocean acidification through global warming, a reduction of up to 40% of current emissions is needed, and up to 95% by 2050.

Warming may also contribute to increase in occurrence of coral diseases. A host of new coral diseases including black band disease, white band disease and skeletal eroding band, are now reported frequently from the world's oceans.

The majority of the world's turtles have environmental sex determination, which means the sex of sea turtle hatchlings is temperature dependent. Warmer temperatures increase the number of female sea turtles at the expense of males. When the sea turtles deposit eggs on the beach, the eggs are subject to changes in beach conditions—temperature, moisture, and oxygen availability. The incubation temperature of the eggs during the first trimester of development determines the sex of the hatchling. It has been found that eggs incubated above a pivotal temperature of about 30°C develop into females and those below about 30°C develop into males.

Some scientists are now suggesting that global climate change has the potential to eliminate the production of male turtle offspring if mean global temperatures increase by

Defining Islands

An island, strictly speaking, is a piece of land surrounded by water. The Millennium Ecosystem Assessment (MA), a research programme supported by the United Nations, defines islands as “lands isolated by surrounding water and with a high proportion of coast to hinterland”. This definition stipulates that they must be populated, separated from the mainland by a distance of at least two kilometres, and measure between 0.15 square kilometres and the size of Greenland (2.2 million square kilometres).

Islands located within seas can be categorized in many ways, including by their area. Based on altitude, islands are classified into high and low-lying islands. The islands are also classified into inhabited and uninhabited; classification is also made based on the density of population. They are also grouped as continental (land areas that used to be connected to the mainland) or oceanic (those that rose from the sea as a result of coral deposits, volcanic activity or tectonic forces) islands.

By a combination of the size of the land area, and political and demographic criteria, islands are grouped into the Small Island Developing States. Countries known collectively as Small Island Developing States (SIDS) have in common their smallness and insularity that often also indicates their vulnerability. These small island and low-lying coastal countries are subject to structural vulnerability that affects their productivity, development and cooperation policies. Since SIDS were identified as a special group during the 1992 Earth Summit, a number of internationally agreed development goals have been formulated to address SIDS vulnerabilities and to build resistance and sustainability. Currently 52 states in the Caribbean, the Pacific, and Africa, Indian Ocean, Mediterranean and South China Sea are included in this category.

An archipelago is a chain or cluster of islands that are formed tectonically. It is now used to generally refer to any island group or, sometimes, to a sea containing a large number of scattered islands. Archipelagos are usually found isolated in bodies of water; less commonly, a large land mass may neighbour them. The five largest modern countries that are mainly archipelagos are Japan, the Philippines, New Zealand, the United Kingdom and Indonesia. The largest archipelago in the world, by size, is Indonesia. Australia is geographically considered a continent, not an island, although in the past it was considered an island country for tourism purposes. It is sometimes still considered an island country.

4°C, and increases of less than 2°C may dramatically skew the male-female sex ratios. Global warming, therefore, will have impacts on sea turtle populations, majority of which prefer calm and pristine beaches around islands to nest.

The islands are also well known for their human diversity and cultural diversity. For example, the Andaman group of islands are inhabited by four Negrito tribes, viz., the Great Andamanese, Onge, Jarawa and Sentinalese and the Nicobar group of islands by two Mongoloid tribes, viz., Nicobarese and Shompens. Recent molecular genetic studies revealed the presence of these tribes in India around 60,000 years ago! As life of these island people depends fully on the health of the forest ecosystems and fishing, climate change events could make their lives more miserable.

Decline in resources have been documented by the island communities. Women in the Cook Islands have noticed a scarcity of pupu shells which are used by them for making local

handicrafts and this is linked to warming of seas. The indigenous people of northern Europe, Sami people, observed changes in species composition in traditional reindeer grazing lands, which reduce sufficient quantity of food for the reindeer populations. They depend on the reindeer for food, clothing and other artifacts.

Adaptation and Mitigation

Though the developed countries contribute more towards climate change, the impacts of climate change are much more effervescent in developing countries, including the islands. The geographical location of the countries of Asia, Africa, Latin America and Small Island states, located in tropical and subtropical regions are most likely to be affected by climate-change impacts. There is ongoing political and public debate on a global scale regarding actions to be taken to reduce or reverse future warming or to adapt to its expected consequences.

The first uninhabited island to vanish from the map due to sea level rise was the Pacific atoll nation of Kiribati. The people of low-lying islands in Vanuatu, also in the Pacific, have been evacuated as a precaution, though the island still remains above the sea.



To counter the impacts of climate change, scientists, conservationists and policy makers are now envisaging combining mitigation efforts with climate adaptation measures and strategies. Adaptation refers to all those responses to climate change that may be used to reduce vulnerability or susceptibility to harm or damage potential. For fighting climate change, we need elaborate high quality data and information on climate, and on environmental, ecological and social systems affected by climate changes.

The adaptation and mitigation measures cannot always be led by governments. There should be partnerships with communities, individuals, and the private sector to frame effective measures to reduce the impact of climate change on islands. We have very little studies, including modeling to realize the impact of climate change on our own islands. We need strong databases to study the impact of climate change, specifically on islands. We need separate packages for adaptation and mitigation in islands, including community based adaptation measures such as co-management of coastal areas.

Community-based programmes, such as vector control, water conservation, coastal management, or mangrove/coral restoration will need the support of government and nongovernmental organizations. There should also be programmes for finding out alternative employment schemes for the island dwellers. Public awareness and discussion forums involving community representatives could help convey information about the impacts of climate change and gain consensus on the adaptation options. The large student power available in the country can also be used for this purpose. Some adaptation measures will need to rely on government

interventions. These include early warning systems and disaster mitigation programmes, improvements in primary health care, and coastal protection in town areas.

There should be synergies between climate mitigation strategies and development policies in areas such as energy efficiency, fuel substitution, renewables, afforestation, and land and waste management. The afforestation activities in islands not only help increasing ground water discharge, but also reduce pressure on natural ecosystems such as forests. The mitigation in islands also includes ensuring health to coral reef and mangrove ecosystems surrounding it. There should also be alternative employment opportunities for the island inhabitants.

The government of India has recently prepared the National Climate Change Action Plan that identifies a roadmap for energy efficiency and sustainable development. It also talks about coordinating national strategic pathways for assessment, adaptation and mitigation of climate change. India is a Party to the United Nations Framework Convention on Climate Change. The National Inventory Management System (NIMS), formed under the Ministry of Environment and Forests, plans to generate a comprehensive knowledge base on scientific issues related to climate change for informed decision making and mitigation. Identification of vulnerabilities and hence risks associated with climate change at state level, agro-ecological zones and agro-climatic zones enables the development of adaptation frameworks at these levels for a target sector or for the associated vulnerabilities.

The planning should not be for temporary economic gains and

support, but for sustainability in future as well. For example, sea walls are built along the coastal areas to protect settlements against coastal erosion and storms. However, sea walls do not solve the underlying cause of erosion and may cause further problems downstream. Strategic replanting of mangroves might be a more efficient solution to guard against periodic inundation.

For the islands, even though the threat of climate change is not imminent, there should be a "precautionary approach". These include better management of resources including biodiversity, coastal habitats, land, and water, and measures such as disease/vector control and making sustainable development plans based on the carrying capacity of the islands. For example, the Lakshadweep and Andaman and Nicobar Islands of India are important tourism destinations and therefore we need to plan tourism development based on the resource availability and carrying capacity of the islands. Acting now would definitely reduce vulnerability to extremes of climate change and reducing the magnitude of the damage.

Considering the fact that the islands are the most vulnerable ecosystems with regard to climate change we need to frame effective adaptive and management policies specifically for the islands. Therefore, in all development and planning activities climate change should form the major agenda, as the underlying principle is "precaution is better than cure".

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