Overview of studies on the Impact of Climate Change on Biodiversity in India

Climate change involves temperature increases ("global warming"), sea-level rise, changes in precipitation patterns, and increased frequencies of extreme events. Each of these phenomena impact on biological diversity and is in fact threats to biodiversity all around the world.

Climate Change will aggravate the existing threats to biodiversity by disrupting delicate relationships within ecosystems. Loss of biodiversity seems to be implicit in most global warming scenarios.

In the case of vegetation, the two factors factor determinants are temperature and moisture. The structure of the world's (and India's) forests are likely to be fundamentally altered by changes in these climatic factors. While coastal and marine areas would be affected further by sea level rise, extreme weather events, and change in weather cycles (such as the monsoons).

Even a change of one degree in mean global temperatures over long periods of time is sufficient to cause changes in the distribution and composition of many plant communities . Laboratory experiments under a range of different conditions have demonstrated that changes in CO_2 levels, temperature and moisture regimes cause changes in plant growth rates and succession (IPCC 1990).

Computer models

There two types of models are commonly employed:

climate models which show how and where climate will change, and vegetation models which correlate vegetation types with climatic variables to show how forest distribution and composition might change over time.

For instance their static nature means that most models predict the migration of entire biomes in response to climate change. There have been two model used to assess impact of climate change on vegetation globally:

(i) The BIOME model is based a plan functional types characterized by a minimal set of climate thresholds.
(ii) The IMAGE model builds on the BIOME model and incorporates a model based on the interacting human population, land use, vegetation and climate . This model is useful where the land-use changes are important/significant.

Although the forecasting ability of models is constantly improving most are still relatively simple and therefore have limitations in the kinds of predictions they can make.

Both the above models have limitation when applied to India which thus limits the studies to qualitative analysis in most cases ***Deshingkar*** (1998).

Since the warming over land is projected to be lower in magnitude than that over the adjoining ocean, the land-sea thermal contrast that drives the monsoon mechanism could possibly decline. There continues to be considerable uncertainty about the impacts of aerosols on the monsoon. Infact monsoon is a major driving force and inherent factor in the ecosystem dynamics of biodiversity in India.

Impact on Forests and Vegetation

According to the IPCC (IPCC 2001), the range and abundance of plants and animals could change dramatically under changing climatic conditions, and some species are likely to be unable to adapt or migrate to new locations. Most plants and animals can tolerate only a narrow range of ambient temperature. If the temperature varies significantly from this range, normal physiological functioning breaks down.

Ravindranath and Sukumar (1996, 1998) describe the possible impacts of climate on the forests of India under 2 different scenarios.

Scenario I Green House gas forcing
Western Ghats
Ravindranath and Sukumar (1996, 1998) predict Shift in vegetation type boundaries along

- *East West Gradient* with Moist forest types expanding east ward

- *Altitudinal Gradient* with species adapting to warmer , lower elevations species migrating to higher altitudes

In a case study of the southern Indian state of Kerala, Achanta A and Kanetkar R (1996) link the precipitation effectiveness index to net primary productivity of teak plantation. Results indicate that under the climate scenarios generated by the ECHAM3 climate model, the soil moisture is likely to decline and, in turn reduce teak productivity from 5.40 m3/ha to 5.07 m3/ha. The study also shows that the productivity of moist deciduous forests could decline from 1.8 m3/ha to 1.5 m3/ha.

Montane forests
Ravindranath and Sukumar (1996, 1998) and Sukumar et al (1995) predict that the Montane forests of western ghats would change into grasslands and further in the absence of management of these grasslands it is envisaged that exotic of C3 photosynthetic type would establish themselves.

In a specific study of Montane Forests of Western Ghats (Sukumar et al 1995), the predicted higher levels of Co2 and lower frost incidence (due to increased temperature) is expected to favor C3 vegetation vegetation. Thus in the montane evergreen forests of the westerns ghats they predict expansion to grasslands with further replacement of C4 grass and herbs by C3 types

They list pioneer colonizers of grasslands and ecotones (eg. . Rhododendron nilagiricium, Rhodomyrtus tomentotosus, etc.) and species with better dispersal abilities could be favored

Due to the reduced frost and enhanced photosynthetic Fast growing species like Wattles and eucalyptus also would be enabled to spread to grassland areas (where they are now absent) out beating slower grower forest trees and shrub species. The scenario also predicts establishment of C3 Plants in these grasslands.

Species at risk Nilgiri Thar
Ravindranath and Sukumar (1998) At the species level , highlight that one vertebrate that is almost certainly affected in the absence of conservation & management measures is the Nilgiri Thar which is endemic to the montane grasslands of the western ghats.

Central Forest Belt
The resultant increase of dry season length would increase the risk of forest fires in most and dry deciduous forests of India.

Central Indian forest which are mostly in most and dry deciduous forsts may be exposed to increased rainfall and soil moisture from the south west monsoon and be transformed to moister vegetation types. In the moister belt the sal characteristic could replace teak in the drier belt.

North West India
Ravindranath and Sukumar (1996, 1998) There is no significant changes envisaged in the Forest of North West India .

In a study conducted by the Stockholm Environment Institute in collaboration with TERI, Deshingkar P, Bradley P N, Chadwick M J, Leach G (1996) apply the BIOME model to project future climate-induced shifts in geographical location and changes in area under different forest types in the north Indian state of Himachal Pradesh.

The overall prediction is that certain biomes namely Evergreen Warm Mixed Forests and Taiga - are likely to show a marked expansion regardless of degree of climate change. Likewise Tundra and Wooded Tundra will probably shrink in the future under all possible scenarios. But the mix of trees is likely to be different than at present due to the additional influence of biotic factors. Some economically and socially important species such as Deodar Cedar and the oaks will almost certainly decline due to the interaction of climatic and biotic factors. At the same time resilient species such as Blue Pine and Chir

Pine, which may not be particularly useful for fulfilling the day to day needs of people, may increase in numbers as various changes eliminate competing species

North East India

For the North East of the India the scenario is not very clear. Ravindranath and Sukumar (1996, 1998) speculate that since the since the regions is receives very high rainfall, small changes in rainfall may not have any consequence on the vegetation . The increase of temperature may result in shift of lower altitude tropical and sub-tropical forests to higher altitude forests this contraction or dying of some of the temperate vegetation types.
The practice of slash and burn cultivation in this region, however, may override climate related change.

Ravindranath and Sukumar (1998) summarized that the increased rainfall and soil moisture coupled with increasing CO2 could stimulate productivity in tropical forests there by increasing levels of (alpha) diversity.

Scenario II GHG and Sulphate Aerosol forcing

The second scenario of Ravindranath and Sukumar (1998), involving a more modest increase in temperature and a decrease in precipitation in central and northern India, could have adverse effects on forests. The strength of the monsoon is also expected to decline (declining as we move further north). In this model no significant change is to be expected for southern India but has a major impact on central and northern India

In central India a shift from moister to drier types is expected with drier teak forests replacing the moister sal forest . Similar trends of lower magnitude may be observed in Northern India

Ravindranath and Sukumar (1998) conclude that in both the cases species extinction and decline of biodiversity is expected. This depends of the rate of change of climate and time available for species to adapt.

General Trends*(CSE 2001 a , b)

Ecosystems that cannot move northwards at a rate dictated by global warming will be most at risk. These include glacial ecosystems, coral reefs and atolls, forests, Himalayan systems.

Mountain ecosystems are projected to shift to higher elevations, although the rate of vegetation change is expected to be slow and the success with which they colonise new habitats will be constrained by local geographical features. For species that are already at their maximum altitude, this is not an option and extinction seems a distinct possibility.

Even more evolved forms of plants and animals that seem to be able to exist in wider climatic ranges need long periods of time to adapt to variations. If change is rapid, they will not be able to adapt, and will die out.

Slow-moving species could lose out to weeds and pests that can move or adapt quickly. Plant and animal pests will be affected in the same way as human disease vectors.

Rural and tribal communities all over India are dependent on biological resources for food, fuel, shelter and medicine. If there are shifts or movements in ecosystem affecting the biodiversity of a region, the people living in those areas will be deeply affected.

Climate Change and Bird Migration (WWF, 2002)

A new WWF report, Climate Change Threats to Migratory Birds, identifies 15 of these critical habitats that are seriously threatened by global warming, and predicts the most threatened migratory birds to be shorebirds, ducks and geese.

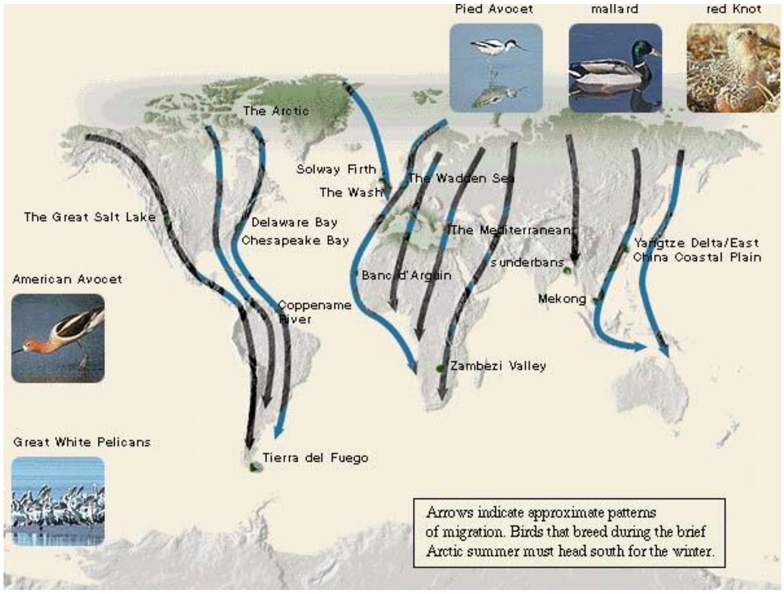
For most migratory birds, the weather and the availability of food along the migratory route, are two critical factors for the success of their long and arduous journey.If birds don't have access to food sources at staging points along their routes, they are not able to complete their migrations.. If any of these so-called "critical" sites are lost or altered, the whole balance of the migratory process can be thrown off.

In India only the Sunderbans is anyway listed which is one of the most vulnerable habitat and biodiversity in India. Using the above arguments all the Bird Areas with large no. of migratory birds would be have reduced number of birds.

http://www.panda.org/resources/publications/climate/migration/migration.html

Bird Areas and Migration –The Sunderbans : one of the 15 critical bird areas most threatened by climate change

Similarly, increases in the frequency of dry spells and local droughts may decrease populations. For example, drought-related decreases in the density and persistence of Green Leaf Warblers have been recorded on their wintering grounds in the Western Ghats of south India (Katti and Price, 1996).



Impacts on coastal zones

GLOBAL sea level has risen between 10-25 centimetres (cm) during the 20th century due to thermal expansion of the oceans, and melting of Antarctic and Arctic glaciers.

The rate of sea-level rise during the 20th century was about 10 times higher than the average rate during the last 3,000 years.India has a low-lying densely populated coastline extending about 6500 km. UNEP (1989) identifies India among the 27 countries t hat were most vulnerable to sea level rise.

Coastal erosion will increase substantially, endangering natural protective features such as sand dunes, mangroves, and barrier islands, and exacerbating flood risk. Many coastal communities depend on fisheries and these will be damaged. (CSE 2001, 2001)

JNU (1993) shows that in the absence of protection, a one-meter sea level rise on the Indian coastline is likely to affect a total area of 5763 km2**. *This would logically also imply severe loss of biodiversity and salinization of soil. The succession will follow would be very different (but lower) biodiversity due to the increased salinity***

The dominant cost, as indicated in Table 1 is land loss, which accounts for 83% of all damages. The extent of vulnerability, however, depends on physical exposure.

Table 1 Effect of 1–m sea-level rise on coastal area and population

Coastal area (million hectares)				Population (million hectares)		
State/Union territory	**Total**	**Inundated**	**Percentage**	**Total**	**Affected**	**Percentage**
Andhra Pradesh	27.504	0.055	0.19	66.36	0.617	0.93
Goa	0.37	0.016	4.34	1.17	0.085	7.25
Gujarat	19.602	0.181	0.92	41.17	0.441	1.07
Karnataka	19.179	0.029	0.15	44.81	0.25	0.56
Kerala	3.886	0.012	0.3	29.08	0.454	1.56
Maharashtra	30.771	0.041	0.13	78.75	1.376	1.75
Orissa	15.571	0.048	0.31	31.51	0.555	1.76
Tamil Nadu	13.006	0.067	0.52	55.64	1.621	2.91
West Bengal	8.875	0.122	1.38	67.98	1.6	2.35
Union territory						
Andaman and Nicobar Islands	0.825	0.006	0.72	0	0	0
India	**139.594**	**0.571**	**0.41**	**416.74**	**7.1**	**1.68**

Note: Coastal area and population are based on the 1981 and 1991 census

Source: JNU. 1993

Table 2 Impact of 1-m sea-level rise on coastal districts (billion 1990 rupees) (4.5% rate of growth, 5% discount rate)

Coastal areas	Economic impact	Value of anticipation	Cost of protection
Mumbai	2287	1061	0.76
Goa	81	36.5	1.42
Balasore	3.6	1.3	1.25

Source: TERI. 1996

In a case study of the Orissa and West Bengal region, IPCC (IPCC, 2001) estimates that in the absence of protection, a one metre sea level rise will inundate an area of 170,000 ha

The Rann of Kutch in India supports one of the largest Greater Flamingo colonies in Asia. With sea-level rise, these salt marshes and mudflats are likely to be submerged (Bandyopadhyay, 1993), which would result in decreased habitat for breeding flamingoes and lesser floricans. In addition, about 2,000 Indian wild asses in the Rann of Kutch could lose their only habitat in India to rising sea level.

Global warming is already contributing to the decline of mangrove forests. Mangroves protect the shoreline, provide wood and fuel. They are also breeding sites for birds, and act as nurseries for fish. At places where urban development and industries are destroying mangroves, the problems caused by sea level rise and thermal stress will be particularly acute there.

Coastal Wetlands

Salt-water intrusion from sea level rise will damage fresh water ecosystems. Loss of coastal wetlands will result in resident and migrating species having to shift their habitats.

Sunderbans – A lose –lose situation

The increased water flow from melting of glaciers and weather) as well as sea level rise make the Sunderbans one the most of the area in India likely to be lost. These coastal mangrove forests provide habitat for species such as Bengal tigers, Indian otters, spotted deer, wild boars, estuarine crocodiles, fiddler crabs, mud crabs, three marine lizard species, and five marine turtle species. With a 1-m rise in sea level, the Sundarbans are likely to disappear, which may spell the demise of the tiger and a large loss of wildlife, useful biodiversity and lifestyle. (Smith et al., 1998).

A rise in sea surface temperatures may be accompanied by an increase in tropical cyclone intensities. According to IPCC, the intensity may go up by 10-20 per cent in the event of a 2-4°C increase in sea surface temperature leading to storm surges along the eastern coast of India. These extreme weather events such cyclones will cause biodiversity loss as seen in Orissa cyclone.

Impacts on Marine Biodiversity

In coastal seas around the Maldives, Sri Lanka, the Andaman Islands of India, and Japan, reef community structure has switched from dominance by fast-growing branching species to monopolization by the more physically rigorous and slow-growing massive corals (Wilkinson, 1998).

Sea level rise will affect many regions of India, but the Andaman and Nicobar Islands and the coral atolls of the Lakshadweep archipelago are most vulnerable. According to a report on the impacts of climate change on India by the Asian Development Bank (ADB 1994), the entire population of Lakshadweep is at peril.

The increase in atmospheric CO_2 concentration (resulting in higher $CaCO_3$ concentrations in seawater) and consequent rise in sea surface temperature (SST) is likely to have serious damaging effects on reef accretion and associated biodiversity. (IPCC 2001)

Unlike many terrestrial ecosystems, coral reef ecosystems appear to be directly threatened by globally increasing atmospheric carbon dioxide. The calcification rates of corals, coralline algae, and coral-algal communities depend on calcium carbonate available in surrounding seawater, and is expected to be reduced by rising atmospheric carbon dioxide.

Though coral reefs in these areas will most likely be able to keep up with the rise in sea level, they probably will not survive a rise in sea temperature. With the loss of coral a series of other marine biodiversity will be lost due to the symbiotic relations between corals and plankton.

The marine ecosystem is far less studied than the terrestrial ecosystem. Indian coral reefs have not received enough attention due to the lack of field research on the same. (Arthur, 2000).

Arthur (2000) studied the extent of coral mortality in India Reefs during the El-Nino Soutthern Oscillations (ENSO) in May 1998 . This perhaps the only study closest to studying the impacts of increased SST.

These studies have also indicated that the lakshwadeep's natural threats are less than Andaman, but is more vulnerable to climate phenomena such as the El Nino and global warming than the Andaman & Nicobar.

According to the climate change impacts map, Global Warming: Early Warning Signs map (http://www.climatehotmap.org). The map illustrates global climate change indicators or "hot spots" such as sea-level rise, melting glaciers, heat waves, floods, and shifting plant and animal ranges.

One of the indicators of climate change in south asia is coral reef bleaching in the Indian Ocean which is complied from four other sources namely ISRS (1998), NOAA (1999), Wilkinson et al (1999), World Conservation Monitoring Centre (1998).

However there are no modeling scenarios or predictions for the scale and details of the impact at all. One of the reasons for this is lack of field research and lack of understanding of the community ecology of the reefs in India. Though one may not be able predict or model the dynamics of the impacts based on current information,, their vulnerability to climate change is not disputed globally as illustrated by Guldberg (----)

The Impact of climate change on fish stocks in India is not known at all, although there are some theories that suggest that fish catch in the India ocean did decline during the 1998 El- Nino event (Sridhar, 2002)

Shanmuganandan, *(*http://www.olympus.net/IAPSO/abstracts/IG-01/IG01-09.htm*)* identified the possible effects of climate change which are the reduction of fished and non-fished species, removal of organisms attached to sea floor and changes in food webs, including increased populations of other species.

Commented [MK1]:

Wetland and Riverine Ecosystems

Available records suggest that Gangotri glacier is retreating by about 30 m yr^{-1}. A warming is likely to increase melting far more rapidly than accumulation (IPCC 2001). As reported in IPCC (1998), glacial melt is expected to increase under changed climate conditions, which would lead to increased summer flows in some river systems for a few decades, followed by a reduction in flow as the glaciers disappear.

According to Worldwatch, (www.wordwortch.org) about 2,000 glaciers in the eastern Himalaya have completely disappeared in the last century. The Pindari glacier is receding at a rate of 13 metre a year while the Gangotri glacier is retreating at an annual rate of 30 metre. Warming is likely to increase the melting far more rapidly than accumulation of snow.

According to the GSI (1999) and Kulkarni et al (2002), Glaciers in the Himalayas are retreating at an average rate of 50 feet (15 m) per year, consistent with the rapid warming recorded at Himalayan climate stations since the 1970s. Winter stream flow for the Baspa glacier basin has increased 75% since 1966 and local winter temperatures have warmed, suggesting increased glacier melting in winter.

The Dokriani Barnak Glacier retreated 66 ft (20.1 m) in 1998 despite a severe winter. The Gangorti Glacier is retreating 98 ft (29.9 m) per year. At this rate scientists predict the loss of all central and eastern Himalayan glaciers by 2035. Science (1998)

Glacial melt is expected to increase under changed climatic conditions which will lead to an increase in summer flows in some river systems for a few decades followed by a reduction in flow as glaciers disappear. As the rate of glacier melting gets higher, flash floods can be expected.

River deltas will see incursion of salt water as sea levels rise affecting agriculture. The floods will also see submergence of forest areas and land thus resulting in loss of biodiversity.

Local Knowledge and Climate Change

Despite the undertainity in the rate and extent of the impact of climate change on biodiversity, there is seems to be a scope for local knowledge to augment the current research in climate change. Especially in the local specific context of biodiversity / ecological indicators

This is perhaps the most underrated aspects and perhaps even rejected by most climate scientist

Riedlinger and Berkes (2000), make a case in the context of indigenous communities in the Canadian artic. This is mainly in the context of the use of **traditional knowledge** (i) as local scale expertise; (ii) as a source of **climate** history and baseline data; (iii) in formulating research questions and hypotheses; (iv) as insight into impacts and adaptation in communities; and (v) for long term, community-based monitoring.

The Canadian artic project provides a basis for exploring value judgments involved in defining vulnerability, changing roles for indigenous knowledge and indigenous knowledge holders in vulnerability studies, and new perspectives on participatory research and capacity building in climate change.

With India being a large store house of local knowledge, there is need to investigate this in the context of prediction of weather or micro-climate as well as adaptation measures. T

Climate Change Research and Biodiversity – Limitations~~, and~~ Conclusion and Recommendations

Milind and Sagar (1999) assess the north -south divide in climate change science using India as a case study. The paper also analyzes how climate change research and analysis is performed in India, a major lesser-industrialized country and explores the factors that play a role in shaping the capability of India to perform, and respond to, climate-change analyses.

Climate Change Impact studies in India (as well as most of the world) suffer from few inherent limitations:

- Lack of reliable regional climate change scenarios and information about changes in weather variability and seasonality
- Lack of long-term ecological data sets
- Major gaps in current scientific understanding of community and population ecology
- The difficulty of differentiating climate change impacts from other stress related environmental degradation.

As result most of the current information and studies are could be termed as qualitative assessments and analysis. As result most studies are restricted modeling change in vegetation types and not further on to specific impacts on ecosystems, ecological functions species and biodiversity.

Climate Change, Ecological, Biological Research and Biodiversity Conservation

Climate change is too often seen by those responsible for biological research, conservation and even policy makers as a future problem that is currently insignificant in comparison to more immediate pressures.

This results in the development of national conservation strategies that will sometimes be in place for decades, but which have not taken future environmental changes, such as demographics or climate, into account.

All research in the natural and allied sciences should take start taking into account climate, temperature moisture, when studying species , community and population ecology. The gradual shift in recent years from structurally based, species oriented conservation to an approach rooted in preserving ecological processes and complexity will require increased attention to the climate issue if it is to be successful.

Climate Change Mitigation and its impacts on biodiversity

- The ~~longterm~~long-term goals of ecosystem management will be impossible to achieve if climate change is not considered. Of critical importance is the confluence of interests between the proponents of ecosystem management and those advocating climate change adaptation strategies.

- There is a need that strengthen linkages between the teams/focal points within the Ministry of Environment & Forest dealing with the CBD and UNFCC.

Conservation plans must include precautions against climate change

Climate change can be used by conservationists as another argument for sound environmental management. In the language of government policymakers, the maintenance of ecosystem integrity becomes a `no regrets' strategy.

- Conduct training and capacity building on studies of the impact of climate change on biodiversity to various stakeholders .
- The ministry should also promote a coordinated review and study on the likely impact of climate change on biodiversity.
- The Ministry of Environment & Forests should develop an action plan for determining vulnerability and adaptation of ecological systems to climate change
- There is a need for the MOEF to develop guidelines and criteria for conservation & management measures/activities that will promote ecosystem resilience to climate change
- Document and augment research on the use of traditional knowledge in climate change, local indicators as well as local adaptation strategies.

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