Review of Literature for ICSF Study on "Climate Change and Fisheries: Perspectives from Small-scale Fishing Communities in India on Measures to Protect Life and Livelihood"

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Terms of Reference

- Aspects of climate change of relevance to Indian coastal and fishing communities. Discuss variables relevant from the perspective of climate change

- Impacts of flood, sea surge, cyclone, sea level rise, storm and other natural disasters on human settlement in coastal areas

- Impacts of climate change on fish habitats such as coral reefs, seagrass beds, etc, and distribution of fishery resources (pelagic and demersal as well as sedentary and sessile resources), and aquatic biodiversity

- Impact of climate change-induced migration on coastal and fishing communities (from fishery to fishery and from agriculture to fishery, for example)

- Existing policies, legislation and programmes to deal with issues related to climate change, especially in relation to adaptation and mitigation measures in relation to fishing communities

- Case studies of responses to climate change (these may be perceived or real) undertaken by coastal communities and the use of traditional ecological knowledge (or blending of it with modern science) in these responses.

Contents

1. Introduction – Scope of the Review

Ever since the Intergovernmental Panel on Climate Change brought out its first assessment report in 1990, and the UN Framework Convention on Climate Change was opened for signature in the 1992 UN Conference on Environment and Development (Rio Summit), climate change has been extensively studied and reported in peer reviewed journals as well as in the mass media. The detailed 'Fourth Assessment Reports' brought out in 2007 by the IPCC only intensified studies on climate change and its impacts as well as adaptation and mitigation methods.

This literature review focuses on the aspects of climate change of relevance to Indian coastal and fishing communities to enable an understanding of information available with reference to climate change impacts on their life and livelihoods, the different policies that have been put in place for adaptation/mitigation against climate change and the gaps that need to be addressed. While climate change has been recognized as of high importance to India in general, and the likely impacts of climate change on various parts of India as well as various livelihood sectors have been broadly identified[1], there is no single review that collates information from various disciplines to give a holistic perspective of climate change impacts on the small scale fishing community in India.

The review begins with an overview of the current state-of-the-art in understanding global climate change causes and consequences. The physical changes in the ocean such as sea level rise as well as the impact on weather patterns and consequent impact on coastal areas are extensively dealt with in technical literature as are ecological impacts such as those on fish habitat (e.g. coral reefs, mangroves). Less comprehensive are studies on fish stocks while reports on impact of climate change on coastal communities, which are mainly available as media reports or studies by a few NGOs. With climate change becoming an important of the agenda of many governments, a range of policies and action plans to adapt to climate change as well as mitigate climate change effects have been put in place. While some of these may be specific to the fisheries sector, many of them are general in nature but applicable to coastal communities including fishing communities.

The review then looks at the Climate Change scenario for India and the impacts of climate change on the fishery resources and the coastal community depending on fish for their livelihood in India. Action plans to adapt/mitigate climate change impacts are reviewed and a brief look is taken at the traditional knowledge especially on coping mechanisms that are available with the coastal communities. The final part consists of the available frameworks for analysing vulnerability of coastal communities to climate change and how they can be

[1] INCCA: Indian Network for Climate Change Assessment. Climate Change and India: A 4x4 Assessment. A Sectoral and Regional Analysis for 2030s. Ministry of Environment and Forests, Government of India, November 2010

used in this study to gain a better understanding of the impact of climate change on the small scale fishing sector in India.

2. Climate Change: the Basics

2.1. The Natural Greenhouse Effect

Climate is generally defined as the weather patterns over a long period of time. The earth's climate regime is an outcome of the incoming solar radiation and its interaction between the hydrosphere, lithosphere, biosphere and atmosphere. The atmosphere has a mix of various gases which play an important role in the earth's climate regions. Gases such as carbon dioxide, nitrous oxide and methane, despite their low concentrations in the atmosphere, play an important role by trapping some of the heat reflected by the earth that would otherwise escape into space. Hence these gases are also known as the Greenhouse Gases (GHG) and this phenomenon known as the natural greenhouse effect enables maintenance of the earth's average temperature about 33°C warmer than it otherwise would be. The graphic below (Figure 1) explains the process.

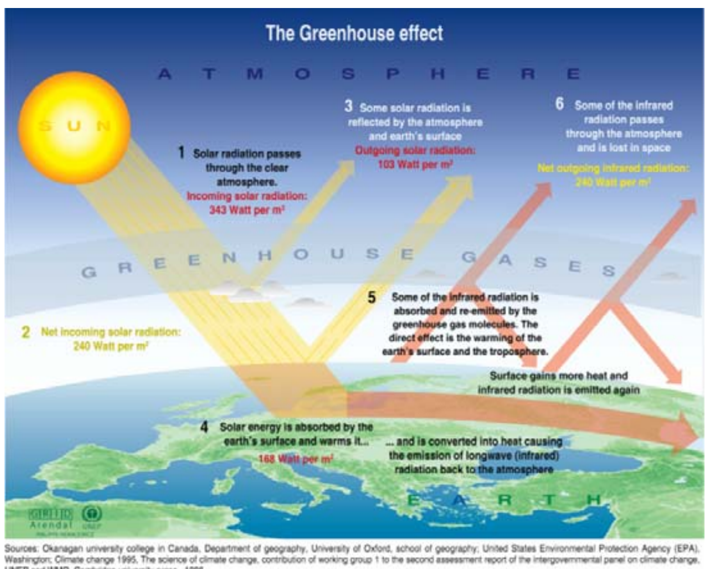

FIGURE 1: GREENHOUSE EFFECT[2]

2.2. Changing GHG Concentrations

Of the three factors that directly influence the energy balance of the earth, viz., the total energy influx on the earth (which depends on the earth's distance from the sun and on solar activity), the albedo (capacity of the earth to reflect light) and the chemical composition of the earth's surface, only the last has changed significantly as shown in Table 1:

[2] UNEP/GRID-Arendal, Greenhouse effect, *UNEP/GRID-Arendal Maps and Graphics Library*, http://maps.grida.no/go/graphic/greenhouse-effect (Accessed 18 December 2010)

GAS	Pre-1750 tropospheric concentration	Recent tropospheric concentration	GWP[3](100-yr time horizon)	Atmospheric lifetime(years)	Increased radiative forcing (W/m^2)
Concentrations in parts per million (ppm)					
Carbon dioxide (CO_2)	280	386.3	1	~ 100	1.66
Concentrations in parts per billion (ppb)					
Methane (CH_4)	700	1866/1742	25	12	0.48
Nitrous oxide (N_2O)	270	323/321	298	114	0.16
Tropospheric ozone (O_3)	25	34	n.a.	hours-days	0.35

TABLE 1: RECENT GREENHOUSE CONCENTRATIONS[4]

As can be seen, it is Carbon Dioxide that is of greatest concern in the role it plays in increasing radiative forcing[5] which translates to increased temperatures on earth.

The term 'Climate Change' is viewed slightly differently by the Intergovernmental Panel on Climate Change (IPCC)[6] and the United Nations Framework Convention on Climate Change[7]. For the IPCC, Climate Change is "*a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer*". In other words, it refers to the process without ascribing any cause for the change. On the other hand, for the UNFCCC, it is "*a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods*"[8].

The UNFCCC's focus is to consider what can be done to reduce global warming and to cope with whatever temperature increases are inevitable.

2.3. The Impacts of Global Warming

[3] GWP: Global Warming Potential
[4] Blasing, T.J. September 2010. Recent Greenhouse Concentrations (based on various sources). DOI: 10.3334/CDIAC/atg.032. http://cdiac.ornl.gov/pns/current_ghg.html accessed January 10, 2011
[5] Radiative Forcing: Change in net irradiance which is the difference between incoming solar radiation energy and outgoing radiation energy in a given climate system and is measured in Watts per square metre.
[6] www.ipcc.int
[7] www.unfccc.int
[8] UNFCCC. Article 1: Definitions

According to the IPCC's Fourth Assessment Report[9], since 1750, it is extremely likely that humans have exerted a substantial warming influence on climate and this estimated radiative forcing is likely to be at least five times greater than that due to solar irradiance changes. The report also states that the global average surface temperature has increased, especially since about 1950 with a 100-year trend of 0.74°C ± 0.18°C. The rate of warming averaged over the last 50 years (0.13°C ± 0.03°C per decade) is nearly twice that for the last 100 years. Three different global estimates all show consistent warming trends.

The atmosphere does not function in isolation. Flows of energy take place between the different spheres. It has been found by the IPCC that surface temperatures over land have warmed at a rate faster than over the oceans in both hemispheres. The ocean's heat capacity is about 1,000 times larger than that of the atmosphere, and the oceans net heat uptake since 1960 is around 20 times greater than that of the atmosphere[10] . It has been observed that over the period 1961 to 2003, global ocean temperature has risen by 0.10°C from the surface to a depth of 700 m. Heat and freshwater are transported by ocean currents. The biochemical status of the ocean plays an important role for life in the ocean waters. Warming seas also result in a rise in sea level which can have an impact on the coastal zone. The major impacts on marine ecosystems are likely to be through[11]

- ocean warming,
- increasing thermal stratification and reducing upwelling
- Sea level rise
- Increases in wave height and frequency
- Loss of sea ice
- Increased risk of diseases in marine biota
- Decreases in pH and carbonate ion concentrations of the surface oceans

Some of these may act in conjunction and have indirect impacts on fisheries. For example, climate change may slow down ocean thermohaline circulation and continental shelf "flushing and cleaning" mechanisms crucial to coastal water quality and nutrient cycling and deep-water production in more than 75% of the World's fishing grounds[12]. This may result in the formation of more dead zones.

[9] IPCC, 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[10] Levitus et al., 2005a quoted in IPCC, 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[11] Various authors cited in IPCC 2007: Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[12] Nellemann, C., Hain, S., and Alder, J. (Eds). February 2008. In Dead Water – Merging of climate change with pollution, over-harvest, and infestations in the world's fishing grounds. United Nations Environment Programme, GRID-Arendal, Norway, www.grida.no

2.4. Climate Change Impacts on Fish and Fisheries

The primary focus of this review is to generate an understanding of climate change impacts on fisheries and fishing communities, especially the small scale fishers. The effects of climate change have to be analysed from an ecological perspective (impact on fish and their habitat) as well as a socio-economic perspective (impact on fishing communities). It is therefore necessary to begin with an understanding of the potential drivers of climate change impact in oceans and coastal areas. A number of reports are already available, for example from the FAO[13] and Worldfish[14], apart from the IPCC WG reports on the impact of climate change on fish and fisheries. Many of the reports, especially with reference to vulnerability of fishers draw upon the work of Allison et al. (2005)[15]. Hence, in this review, only information that is directly relevant is summarized.

2.4.1. Ecological Perspective: Impact on the marine ecosystem

Figure 2 gives a bird's eye view of climate change and the coastal system showing the **major climate change factors, including external marine and terrestrial influences**.

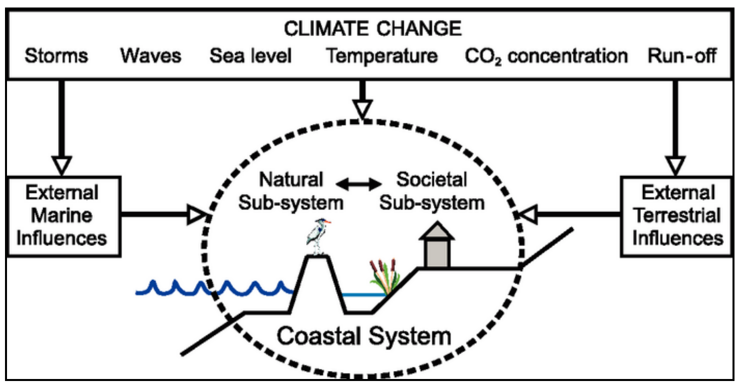

FIGURE 2: CLIMATE CHANGE AND THE COASTAL SYSTEM[16]

Sixtyeight percent of the total production of fish, crustaceans, and molluscs come from capture fisheries[17]. In other words, most fishing depends on wild populations which may also be highly migratory. The population variability of fish depends on a variety of environmental

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[13] Cochrane, K.; De Young, C.; Soto, D.; Bahri, T. (eds). Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. FAO Fisheries and Aquaculture Technical Paper. No. 530. Rome, FAO. 2009. 212p. Overeem, I. & Syvitski, J.P.M. (2009): Dynamics and Vulnerability of Delta Systems. LOICZ Reports & Studies No. 35. GKSS Research Center, Geesthacht, 54 pages.

[14] Worldfish. 2007. Fisheries and aquaculture can provide solutions to cope with climate change, Issues Brief 1701. The Worldfish Center, Penang, Malaysia.

[15] Allison, E.H., Adger, W.N., Badjeck, M.-C., Brown, K., Conway, D., Dulvy, N.K., Halls, A., Perry, A. & Reynold, J.D. 2005. Effects of climate change on sustainability of capture and enhancement fisheries important to the poor: analysis of the vulnerability and adaptability of fisher folk living in poverty. UK. Project No. R 4778J, Final Technical Report, DFID, 168 pp.

[16] Parry, M.L., O.F. Canziani, J.P. Palutikof and Co-authors 2007: Technical Summary. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 23-78.

[17] Brander, K.M., 2007. Global fish production and climate change. PNAS, 104(50): 19709–19714. www.pnas.org/cgi/doi/10.1073/pnas.0702059104

parameters which govern the supply of young stock, and feeding and predation conditions through the life cycle. Mere fertilizer addition to open water cannot increase their populations and nor can effects of environmental change or changes in fish populations be quickly observed. Fish migration creates issues of transboundary management, control and utilization, driven by natural environmental factors. In short, this means that climate change impacts could change resource access "winners" and "losers", at both community and national level[18]. The climate impact pathways on fisheries are complex and could result in various indirect effects ranging from fisheries being affected by changing water demands and availability in agriculture to funds having to be diverted from resource management to disaster relief[19].

A summary of the range of potential drivers of climate change impacts in coastal areas was provided by Parry et al (2007) for the IPCC. Table 6.2 from that report is reproduced here (Table 2).

[18] FAO, 2000. Technical Background Document From The Expert Consultation Held on 7 To 9 April 2008.
[19] FAO, 2007. Building Adaptive Capacity to Climate Change – Policies to sustain livelihoods and fisheries. Sustainable Fisheries Livelihoods Programme (SFLP)

	Climate driver (trend)	Main physical and ecosystem effects on coastal systems
1	CO_2 concentration (↑)	Increased CO_2 fertilisation; decreased seawater pH (or 'ocean acidification') negatively impacting coral reefs and other pH sensitive organisms.
2	Sea surface temperature (↑, R)	Increased stratification/changed circulation; reduced incidence of sea ice at higher latitudes; increased coral bleaching and mortality; poleward species migration; increased algal blooms
3	Sea level (↑, R)	Inundation, flood and storm damage; erosion; saltwater intrusion; rising water tables/impeded drainage; wetland loss (and change).
4	Storm intensity (↑, R)	Increased extreme water levels and wave heights; increased episodic erosion, storm damage, risk of flooding and defence failure
5	Storm frequency (?, R) Storm track (?, R)	Altered surges and storm waves and hence risk of storm damage and flooding
6	Wave climate (?, R)	Altered wave conditions, including swell; altered patterns of erosion and accretion; re-orientation of beach plan form.
7	Run-off (R)	Altered flood risk in coastal lowlands; altered water quality/salinity; altered fluvial sediment supply; altered circulation and nutrient supply

TABLE 2: MAIN CLIMATE DRIVERS FOR COASTAL SYSTEMS, THEIR TRENDS DUE TO CLIMATE CHANGE, AND THEIR MAIN PHYSICAL AND ECOSYSTEM EFFECTS.
(Trend: ↑ increase; ? uncertain; R regional variability).

While the first two drivers listed in the table above, namely CO_2 concentration and sea surface temperatures, affect fish and fish habitat, the other drivers primarily have an impact on the land space occupied by the fishing communities, though storm frequencies and intensities as well as the nutrient levels in run-off play an important ecological role. In other words, climate change makes living near water and catching or farming fish more hazardous than it is already[20].

2.5. Impact on Fisheries and Fishing Community

FAO's Fact Sheet on fisheries[21] says that climate change-related warming may result in:

- longer growing seasons and increased rates of biological processes - and often of production;
- greater risk of oxygen depletion;
- species shift to more tolerant of warmer and perhaps less-oxygenated waters;
- redeployment or re-design and relocation of coastal facilities;
- coastal cultures may need to consider the impacts of sea-level rise on facilities and the freeing of contaminants from nearby waste sites;
- changes in precipitation, freshwater flows, and lake levels;

[20] Op. cit. 14
[21] FAO. © 2005-2010. World inventory of fisheries. Variability and climate change. Issues Fact Sheets. Text by John Everett and S.M. Garcia. In: *FAO Fisheries and Aquaculture Department* [online]. Rome. Updated 27 May 2005. [Cited 17 December 2010]. http://www.fao.org/fishery/topic/13789/en#container

- introduction of new disease organisms or exotic or undesired species;
- establishment of compensating mechanisms or intervention strategies;
- a longer season for production and maintenance; and,
- modification of aquaculture systems, e.g. keeping them indoors under controlled light, may be needed more often to protect larvae from solar UV-B.

This would result in impacting four dimensions of food security, namely availability, stability, access and utilization[22]. It is very difficult to predict the impact of climate change on fisheries because of the two main uncertainties in the causal chain from global warming to fisheries, namely, the uncertainty in the impact on ocean temperatures and currents (including their magnitude and direction), and the uncertainty on the abundance and migration of fish stocks[23]. A simple causal chain relationship regarding the projected impact of climate change on marine fisheries could be as shown in Figure 3[24]:

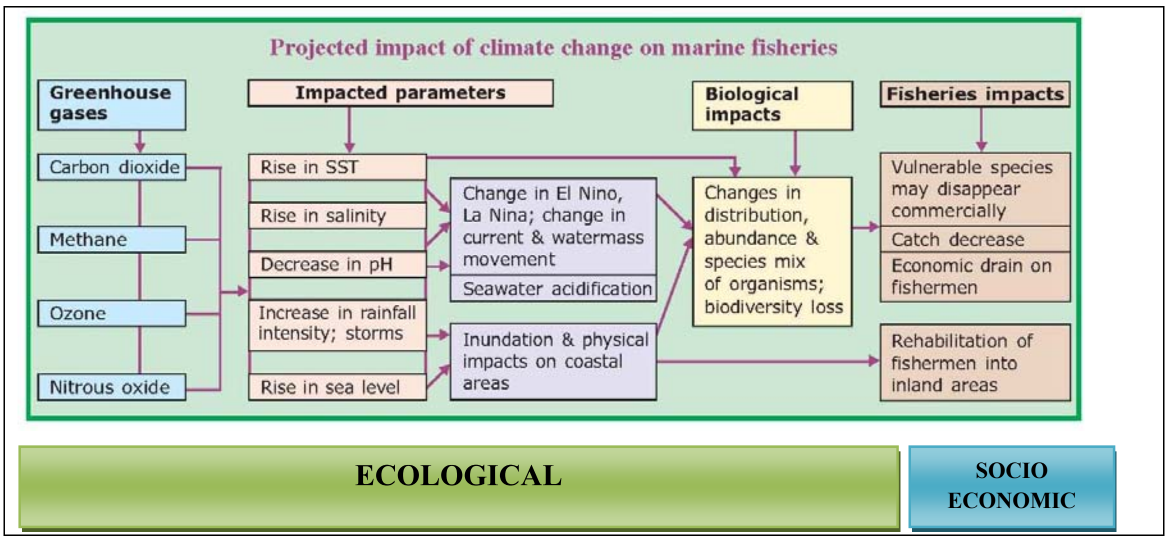

FIGURE 3: PROJECTED IMPACT OF CLIMATE CHANGE ON FISHERIES
(adapted and modified from Vivekanandan, 2006)

Another way of looking at it is using the DPSIR (Driver-Pressure-State-Impact-Response) framework. With Climate Change as the Driver, the Pressures and Impacts may be summarized as in Table 3[25]:

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[22] Op. Cit. 13

[23] Vivekanandan, E. Climate Change impacts on fisheries and aquaculture: A Global Perspective. Winter School on Impact of Climate Change on Indian Marine Fisheries, CMFRI, 2008.

[24] Vivekanandan, E., 2006. Impact of Climate Change on Marine Fisheries. CMFRI Newsletter, Oct-Dec 2006.

[25] Adapted from Table 1: Climate Change and its effect on marine fisheries and aquaculture in Vivekanandan, E., 2008. Climate Change Impacts on Fisheries and Aquaculture: A Global Perspective. Winter School on Impact of Climate Change on Indian Marine Fisheries, CMFRI, 2008.

PRESSURES	Ecological Impacts	Socio-Economic Impacts
Sea Surface Temperature	• Algal blooms, including HAB • Lowered DO, • Increase in parasites, • Change in predator numbers • Invasive Alien Species • Longer growing seasons • Shift in distribution and population sizes • Coral bleaching	• Changes in fish availability and consequent economic impacts • Marketing issues • Availability of fish preferred for consumption • Possible disease (e.g. cholera) spread
Sea Level Rise	• Increase in coastal flooding / coastal water bodies area • Change in mangrove species composition	• Inundation / loss of land • Salt water intrusion into aquifers – loss of potable water availability
Increase in frequency of storms	• Turbidity • Salinity changes	• Inundation of land • Risk to fishers (sea safety issues) • Increased cost of maintenance • Damage to craft, gear, infrastructure including houses
El-Nino Southern Oscillation (ENSO)	• Location and timing of ocean current changes, upwelling alters food supply, • coral bleaching • Change in monsoon timing	• Altered rainfall patterns • Flooding due to increase in intense precipitation events • Disease patterns and health impacts
Drought	• Salinity changes due to change in freshwater flows from rivers • Impact on mangroves	• Shortage of potable water for fishers • Heat waves and impact on health
Ocean Acidification	• Impact on shellfish and reef builders	• Loss of habitat for reef-fish, loss of hard corals which may be harvested for ornaments, handicrafts etc

TABLE 3: DPSIR APPROACH TO CLIMATE CHANGE IMPACTS ON FISHERIES

Broadly following on this, the review will look very briefly at the data on greenhouse gases and the impacted parameters in India. With respect to the biological impacts and the fisheries impacts, the literature review will be mainly on India while information on the impact on fisheries at the global level will be briefly reviewed.

3. Climate Change – India

3.1. GHG Emissions

India's GHG emissions are expected to stay under 4 tonnes per capita even in 2030-31, lower than the global values of 4.22 tonnes per capita in 2005[26,27] . Based on public data, Google[28] has been able to generate CO_2 emissions upto 2007 (Figure 4). According to this, while world per capita emissions were at 4.63 tons, India's per capita emission stood at 1.43 tons.

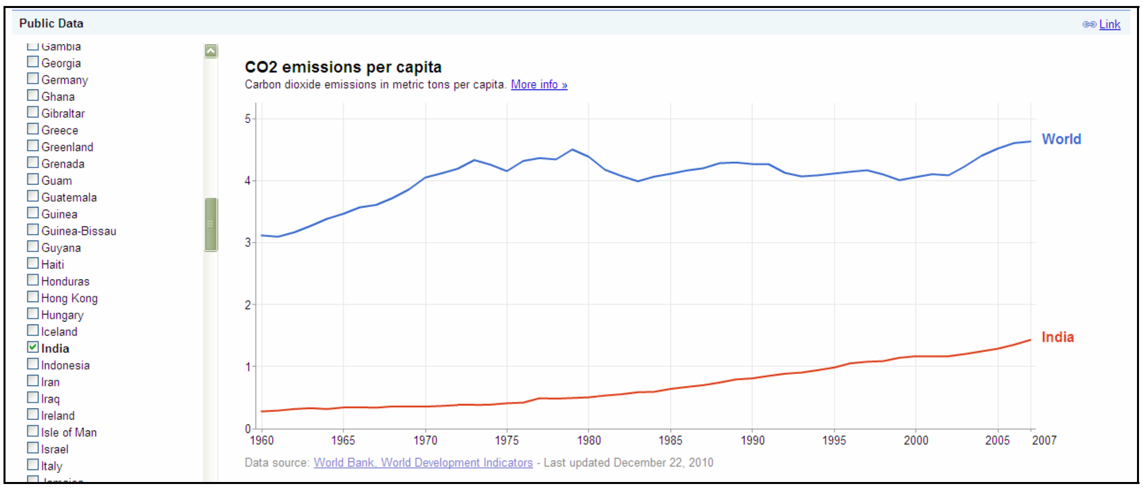

FIGURE 4: CO_2 EMISSIONS PER CAPITA

A recent assessment[29] provides information on India's emissions of the three GHG emitted from anthropogenic activities at national level from energy, industry, agriculture, waste and Land Use, Land Use Change &Forestry (LULUCF). The net Greenhouse Gas (GHG) emissions from India in 2007, that is emissions with LULUCF, were 1727.71 million tons of CO_2 equivalent (eq) of which

- CO_2 emissions were 1221.76 million tons;
- CH_4 emissions were 20.56 million tons; and
- N_2O emissions were 0.24 million tons

3.2. Climate Change Scenarios

[26] Climate Modelling Forum, 2009. India's GHG Emissions Profile: Results of five climate modelling studies. Ministry of Environment and Forests, Government of India.
[27] Sharma, S. S. Bhattacharya and A. Garg, 2006. Greenhouse gas emissions from India: A Perspective. Current Science, 90: 326-333.
[28] http://www.google.com/publicdata?ds=wb-wdi&met=en_atm_co2e_pc&tdim=true&dl=en&hl=en&q=world+co2+emissions#met=en_atm_co2e_pc&idim=country:IND&tdim=true generated on December 22, 2010
[29] INCCA 2010a. "India: Greenhouse Gas Emissions 2007". Ministry of Environment and Forests, Government of India

The 2010 INCCA Assessment[30] provides an assessment of impact of climate change in 2030s on four key sectors of the Indian economy, namely Agriculture, Water, Natural Ecosystems & Biodiversity and Health in four climate sensitive regions of India, namely the Himalayan region, the Western Ghats, the Coastal Area and the North-East Region.

Climate change impacts of highest relevance in coastal areas are with respect to sea level rise and changes in the occurrence and frequency of storms and storm surges. India's coastal zones can be divided into the Gujarat region, west coast, eastern coastal plains and the islands. There is difference between the east coast and the west coast. Fast flowing rivers in the largely mountainous west coast form estuaries and backwaters while deltas are predominant in the broad and flat plains of the east coast. The temperature in the coastal regions exceeds 30°C and has high levels of humidity receiving rainfall from both the northeast and southwest monsoons.

The climate change scenarios have been derived from a regional climate change model PRECIS (a version of HadRM3 developed by the Hadley Centre, UK) with a resolution of 50km x 50km and forced by a greenhouse gas (GHG) emission scenario emanating from A1B IPCC SRES (Special Report on Emission Scenario; IPCC, 2000)[31]. The 2030s is the average of the period between 2021 to 2050. All the changes in the 2030s are with respect to the average of the period 1961 to 1990s, also referred to as the 1970s or the baseline. With respect to surface temperatures, the model predicts[32]

§An annual mean surface temperature rise by the end of this century, ranging from 3°C to 5°C (under A2 scenario) and 2.5°C to 4°C (under B2 scenario), with the warming more pronounced in the northern parts of India.

§A20 per cent rise in all India summer monsoon rainfall and a further rise in rainfall is projected over all states except Punjab, Rajasthan and Tamil Nadu, which show a slight decrease.

3.3. Monsoon and Cyclones

India's climate regime is dominated by the two monsoons – southwest and north east monsoon. The summer or southwest monsoon is the most important feature controlling the Indian climate because 75% of the annual rainfall is received during a short span of four months (June to September)[33]. The monsoonal rainfall is not continuous. Rather, it occurs sporadically with occasional intense rainfall. Changes have been observed in the frequency

[30] Op. cit. 1

[31] Rupa Kumar, K., A.K. Sahai, K. Krishna Kumar, S.K. Patwardhan, P.K. Mishra, J.V. Revadekar, K. Kamala and G.B. Pant, 2006. High resolution climate change scenarios for India for the 21st Century. Current Science, 90: 334-345.

[32] MoEF, Government of India. State of the Environment-Report, 2009. http://moef.nic.in/downloads/home/home-SoE-Report-2009.pdf accessed December 23, 2010

[33] Attri, S.D. and A. Tyagi, 2010. Climate Profile of India. Contribution to the Indian Network for Climate Change Assessment (National Communication-II). Ministry of Environment and Forests, Government of India.

and intensity of heavy rainfall events at the expense of low rainfall events[34,35].The onset of the monsoons is also accompanied by a number of low pressure systems in the Arabian Sea as well as in the Bay of Bengal, some of which turn into deep depressions and cyclones. Nearly 7 percent of the global tropical cyclones form in the North Indian Ocean. Five to six tropical cyclones occur in the North Indian Ocean every year, with the frequency being more in the Bay of Bengal than in the Arabian Sea (a ratio of 4:1). Cyclones produced in May-June and October-November have been found to be more intense than those that develop during the monsoon months (July-September)[36]. Cyclonic storms unleash maximum destructive potential when they make landfall along the coast through violent winds, torrential rain and storm surges. The shallow depth of the Bay of Bengal and the low flat coastal terrain produce much larger storm surges and take a very heavy toll of life. The amount of damage caused by a tropical cyclone is directly related to the intensity of the storm, the duration of the storm, the angle at which it approaches the land, and the population density along the coastline. Despite warming trend noted with sea surface temperatures, a decreasing trend in the frequency and increase in intensity has been observed in the last four or five decades[37],[38]. This means that storm surges and flooding due to intense events are likely to increase over time.

3.4. Sea level rise

Sea level rise at long time scales is mainly due to thermal expansion and exchange of water between the other reservoirs (glaciers, ice caps, etc) including through anthropogenic change in land hydrology and the atmosphere. Vertical land movements such as resulting from Glacial Isostatic Adjustment (GIA), tectonics, subsidence and sedimentation influence local sea level changes. Global average sea level rose at an average rate of 1.8 mm per year over 1961 to 2003. The rate was faster over 1993 to 2003, at about 3.1 mm per year. Whether the faster rate for 1993 to 2003 reflects decadal variability or an increase in the longer-term trend is unclear. There is high confidence that the rate of observed sea-level rise increased from the 19th to the 20th century. The total 20th-century rise is estimated to be 0.17 m. Between 1993 and 2003, the sea level rose by 0.33 m with an uncertainty of ±1 mm/year[39].

Rising rates of sea level are expected to vary from 1.4-4.4 mm/yr along the East Asia coast because of regional variations. In Asia, erosion is the main process that will occur to land as sea level continues to rise. As a consequence, coast-protection structures built by humans will

[34] Krishnakumar, K. 2009. "Impact of Climate Change on India's monsoonal climate and development of high resolution climate change scenarios for India". Presentation made to the Minister, MoEF on 14 October 2009 at New Delhi. www.envfor.nic.in
[35] Op. cit. 1
[36] Frequently Asked Questions on Tropical Cyclones. http://www.imd.gov.in/section/nhac/dynamic/faq/FAQP.htm#q18 accessed January 11, 2011
[37] Niyas et al., 2009, quoted in Attri, S.D. and A. Tyagi, 2010. Climate Profile of India. Contribution to the Indian Network for Climate Change Assessment (National Communication-II). Ministry of Environment and Forests, Government of India..
[38] Ramesh Kumar, M.R. and S. Sankar, 2010. Impact of global warming on cyclonic storms over north Indian Ocean. Indian Journal of Marine Sciences, Vol. 39(4), December 2010, pp. 516-520
[39] IPCC AR4

usually be destroyed by the sea while the shoreline retreats. In some coastal areas of Asia, a 30 cm rise in sea level can result in 45 m of landward erosion[40].

According to Unnikrishnan and Shankar[41], sea-level-rise estimates for the Indian coast are between 1.06–1.75 mm yr^{-1}, with a regional average of 1.29 mm yr^{-1}, when corrected for GIA using model data. These estimates are consistent with the 1–2 mm yr^{-1} global sea-level-rise estimates reported by the IPCC. The study also showed a large trend of 5.74 mm/year for the record at Diamond Harbour (Kolkata), which is attributed partly to the subsidence of the Ganges-Brahmaputra delta. Model-based projections of global average sea level rise at the end of the 21st century (2090–2099) made for a number of climate scenarios indicate that the sea level may rise from a minimum of 0.18 m minimum to a maximum of 0.59 m. In the absence of availability of regional projections, global projections can be used as a first approximation of sea-level rise along the Indian coasts in the next few decades as well as towards the end of the 21st century. According to Han et al (2010)[42] who combined in situ and satellite observations of the Indian Ocean with climate model simulations, the sea level has decreased significantly in the south tropical Indian Ocean whereas it has increased elsewhere.

Projected inundation due to sea level rise: The east coast is considered more vulnerable due to its flat terrain and the numerous deltas. Shetye et al. 1990[43] analysed the vulnerability of regions surrounding Nagapattinam, Kochi and Paradip for a one metre rise in sea level. The estimate shows that the inundation area will be about 4.2 km^2 for a 1.0 m rise in sea level in the region surrounding Nagapattinam. But for the same sea-level rise projections, about 169 km^2 of the coastal region surrounding Kochi will be inundated and in the case of Paradip, 478 km^2 may be inundated. Thus areas with large number of creeks and backwaters are likely to be at a higher risk of inundation.

Along the east coast, studies have been done about the SLR and erosion in the Godavari delta. Because of the gentle gradient, even a small rise in sea level can result in heightened tidal ingress. A coastal vulnerability index integrating the differentially weighted rank values of the five variables: coastal geomorphology, coastal slope, shoreline change, mean spring tide range, and significant wave height, based on which the coastline was segmented into low-, moderate-, high-, and very high risk categories showed that about 43% of the 1,030-km-long AP coast is under very high-risk, followed by another 35% under high-risk if the sea

[40] Op. Cit. 16.
[41] Unnikrishnan, A.S. and D. Shankar, 2007. Are sea-level-rise trends along the coasts of the north Indian Ocean consistent with global estimates? Global Planet. Change: 57(3-4); 2007; 301-307
[42] Han, Weiqing, Gerald A. Meeh, Balaji Rajagopalan, John T. Fasullo, Aixue Hu, Jialin Lin, William G. Large, Jih-wangWang, Xiao-Wei Quan, Laurie L. Trenary, AlanWallcraft, Toshiaki Shinoda and Stephen Yeager., 2010. Patterns of Indian Ocean sea-level change in a warming climate. Nature Geoscience Letters. Published online: 11 July 2010 | doi: 10.1038/NGEO901
[43] Shetye S R, Gouveia A D and Pathak M C, (1990). Vulnerability of the Indian coastal region to damage from sea level rise, Current Science, 59, 152-156.

level rises by ~0.6 m displacing more than 1.29 million people living within 2.0 m elevation in 282 villages in the region[44].

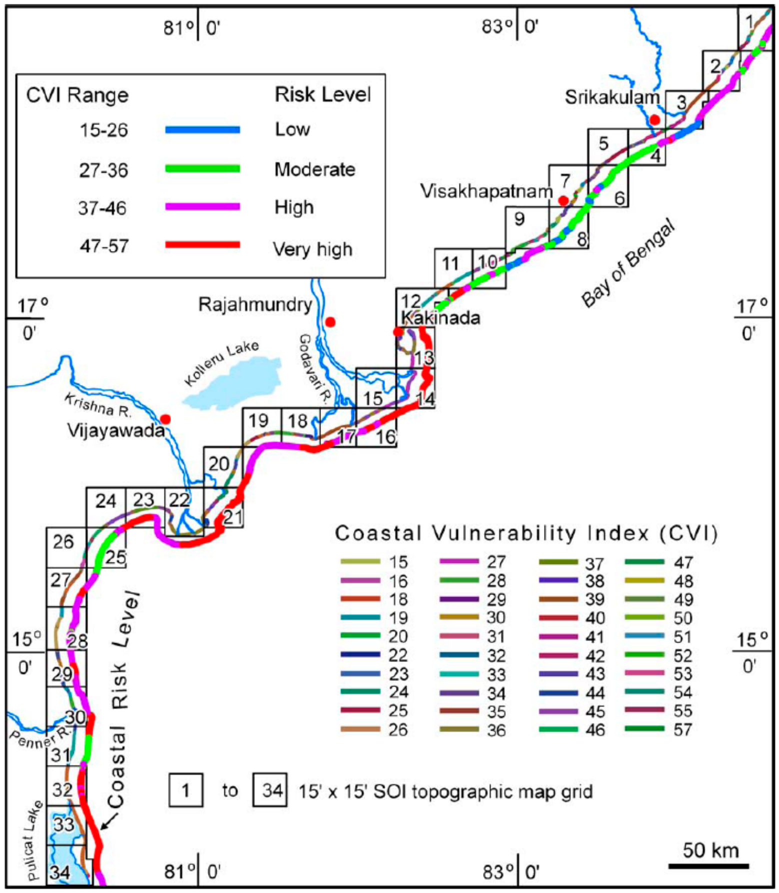

FIGURE 5: COASTAL VULNERABILITY INDEX FOR ANDHRA PRADESH
(Nageswara Rao et al., 2008)

Studies on shoreline changes for the Puducherry and Gujarat coasts are now available as part of an all India project on shoreline change[45]. A sample figure for Puducherry is given below. The land use maps and other information are available in the report. The shoreline change for Gujarat with its long coastline cannot be show in a single map and hence a map of Kachchh district is given as a sample.

[44] Nageswara Rao., K P. Subraelu, T. Venkateswara Rao, B. Hema Malini, R. Ratheesh, S. Bhattacharya, A. S. Rajawat and Ajai. (2008). Sea-level rise and coastal vulnerability: an assessment of Andhra Pradesh coast, India through remote sensing and GIS. J. Coast Conserv. 12:195–207
[45] http://ncscm.org/

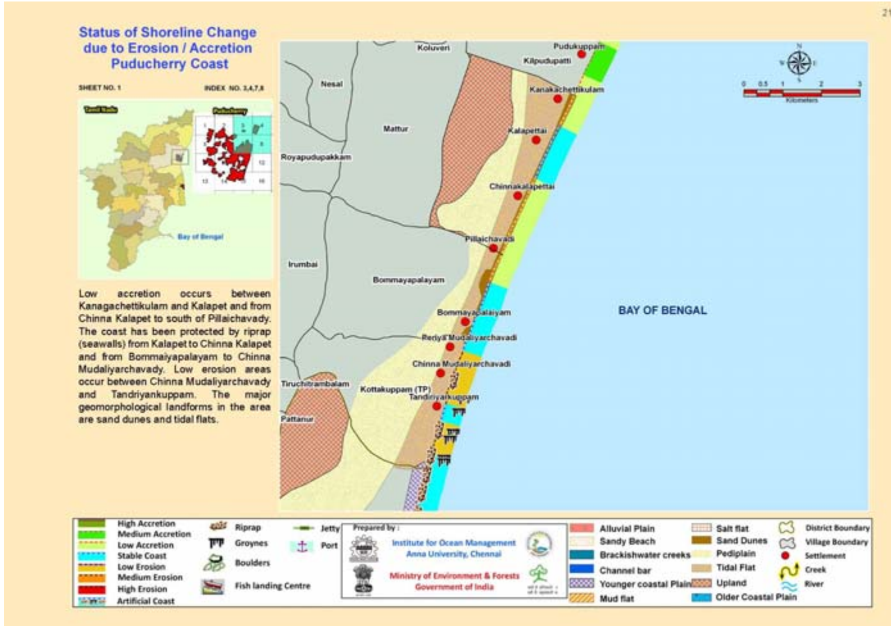

FIGURE 6: SHORELINE CHANGE ALONG PUDUCHERRY COAST[46]

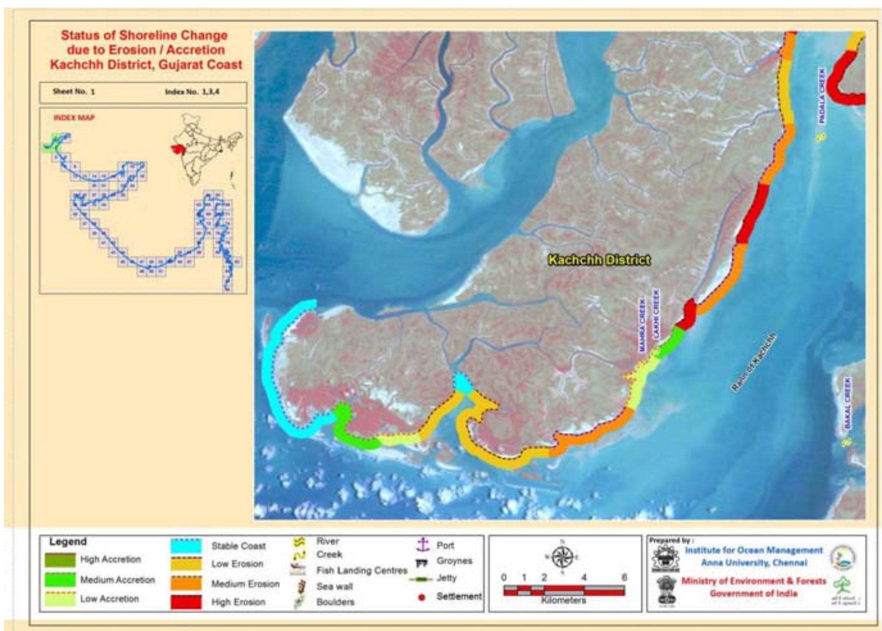

FIGURE 7: SHORELINE CHANGE IN KACHCHH DISTRICT, GUJARAT[47]

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[46]IOM, 2010. National Assessment of Shoreline Change: Puducherry. http://ncscm.org/pdf%20documents/pondy_report_web.pdf

[47] IOM, 2010. National Assessment of Shoreline Change: Gujarat. http://ncscm.org/pdf%20documents/National%20Assessment%20of%20Shoreline%20Change%20-%20Gujarat.pdf

It may be noted that the country-level estimates of urban, rural and total population and land area in a low elevation coastal zone (LECZ)[48] generated by the GRUMP project for India shows that large patches of the east coast and some areas in the west coast fall in the LECZ region and hence are vulnerable to sea level rise. The figure below shows that within many of the LECZ areas, population density is high.

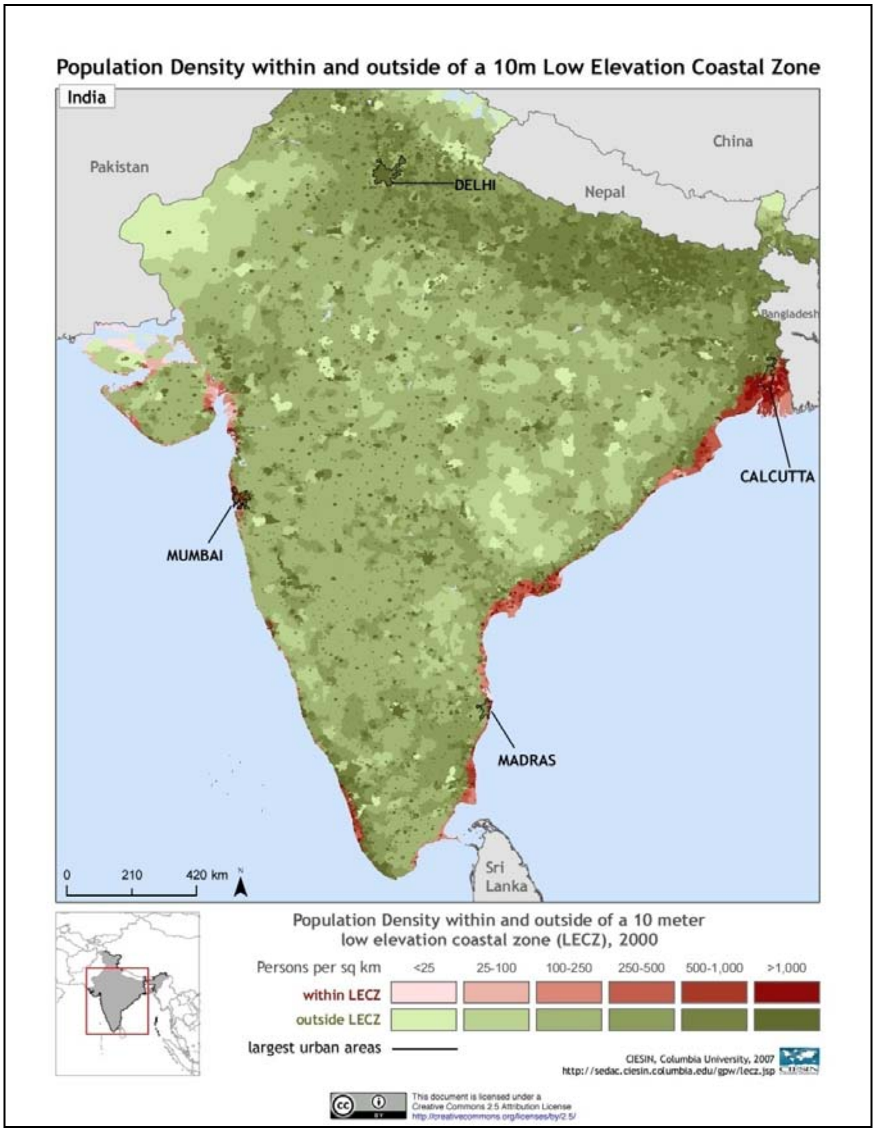

FIGURE 8: POPULATION DENSITY WITHIN AND OUTSIDE OF A 10 M LECZ, INDIA

3.5. Shoreline Change

[48] McGranahan, G., D. Balk and B. Anderson. 2007. The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. Environment & Urbanization 19(1): 17-37 (2007). International Institute for Environment and Development (IIED). http://eau.sagepub.com/cgi/content/abstract/19/1/17 (http://sedac.ciesin.columbia.edu/gpw/lecz.jsp accessed October 26, 2009)

A national shoreline assessment programme has been initiated for India as part of the activities of the National Centre for Sustainable Coastal Management (NCSCM). The study involves the usage of historical shorelines representing the following periods: 1972 (Survey of India toposheet), satellite imageries of 1990, 2000, 2006 and 2010. Multi-date shorelines have been used as input into the USGS digital shoreline analysis model to cast various transects along the chosen stretch of the coast. A distance of 500m intervals were assigned to calculate the erosion/ accretion statistics in ArcGIS 9.3 software. The results obtained were categorized into eight classes of "Zones of erosion/ accretion". The work is being carried out by the Institute for Ocean Management, Anna University Chennai and the approved maps for Gujarat and Puducherry coasts are available at the NSCSM website: http://ncscm.org/shoreline_intro.php. Though this study is not specifically related to climate change, the results of the study can be used to identify vulnerable areas along the coast.

3.6. Ocean Parameters

3.6.1. Sea Surface Temperature (SST)

Temperature is a primary factor that determines the distribution of a species since fish are poikilothermic and different species have different temperature ranges in which they survive most successfully. In the Exclusive Economic Zone (EEZ) of India, generally, the mean sea surface temperature (SST) is about 29ºC during summer (April-May), which cools down during the advancement of monsoon reaching 25ºC during August-September[49]. The temperature range in the inshore waters is 23.0 to 33.5°C in the west coast and 23.8 to 32.6 °C in the east coast[50]. An important aspect is the thermocline, a layer that separates the upper warm surface waters and the deeper cold waters. The thermocline is shallow during the southwest monsoon, moderate in summer and deeper in winter. A strong thermocline separates the pelagics and demersals successfully enabling the different species to be caught by different methods.

Prasanna Kumar et al (2009)[51] examined the signature of global warming using various data sets for the Arabian Sea region and found that the disruption in the natural decadal cycle of SST after 1995 was a manifestation of regional climate-shift. They propose that upwelling driven cooling was maintained till 1995 despite oceanic thermal inertia and increasing CO_2 concentrations but this system broke down after 1995 though it is not known yet how long this process will continue.

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[49] Laxminarayana, A., "Effect of Environment on Marine Fisheries". Winter School on Impact of Climate Change on Indian Marine Fisheries, CMFRI, 2008.
[50] CMFRI 2006. Monitoring the environmental characteristics of the inshore waters in relation to fisheries. Xth Plan in-house research project. http://cmfri.org.in/html/cmfriEnviorn01.html accessed February 9, 2011
[51] Prasanna Kumar, S., Raj P. Roshin, Jayu Narvekar, P.K. Dinesh Kumar and E. Vivekanandan, 2009. Response of the Arabian Sea to global warming and associated regional climate shift. Marine Environmental Research, 68: 217-222

The Indian National Centre for Ocean Information Services (INCOIS)[52] hosts the Indian Ocean Forecast System (INDOFOS)[53] which is capable of predicting the surface and subsurface features of the Indian Ocean well in advance. Currently, INCOIS provides forecasts of:

1. Wave height and direction
2. Sea surface currents
3. Sea surface Temperature
4. Mixed Layer Depth
5. Depth of the 20 degree isotherm (as a measure of thermocline).

Forecast information can be accessed directly from the web and is also disseminated by means of web and email to all the major stake holders in the ocean sector.

3.6.2. Salinity

Ocean salinity is another important environmental factor which changes with the monsoonal rains. The Indian subcontinent splits the Northern Indian Ocean into two distinct regions. The salinity of the Arabian Sea is much higher than that of Bay of Bengal primarily because of the large amounts of freshwater received by the Bay during the summer monsoon. Salinity values ranged between 0.4 to 37.8 ppt in the west coast and between 1.71 to 37.9 ppt in the east coast[54]. After the withdrawal of the summer monsoon, the Ganga – Brahmaputra river plume flows first along the Indian coast and then around Sri Lanka into the Arabian Sea creating a low salinity pool in the southeastern Arabian Sea (SEAS). In the same region, during the pre-monsoon months of February – April, a warm pool, known as the Arabian Sea Mini Warm Pool (ASMWP), which is distinctly warmer than the rest of the Indian Ocean, takes shape[55]. Advection of nutrients by this intrusion triggers enhanced levels of chlorophyll near the southern part of the western shelf of India and may play a role in altering the biogeochemistry of this intense hypoxic region[56].

It has been found that temperature fluctuations have an important impact on the salinity tolerance of fish species with higher temperatures having an adverse effect. Salinity and temperature together influence important physiological responses such as growth, metabolic rates and blood iron.

3.6.3. Acidification

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[52] www.incois.org

[53] http://www.incois.gov.in/Incois/indofos_main.jsp

[54] Op. cit. 50

[55] Vinayachandran, P.N. and J. Kurian., 2008. Modeling Indian Ocean Circulation: Bay of Bengal Fresh Plume and Arabian Sea Mini Warm Pool. Proceedings of the 12th Asian Congress of Fluid Mechanics, 18-21 August 2008, Daejeon, Korea. http://www.afmc.org.cn/12thacfm/IL-1.pdf accessed January 11, 2011

[56] Prasanna Kumar, S., J. Narvekar, A. Kumar, C. Shaji, P. Anand, P. Sabu, G. Rijomon, J. Josia, K.A. Jayaraj, A. Radhika, and K.K.C. Nair, 2004. Intrusion of the Bay of Bengal water into the Arabian Sea during winter monsoon and associated chemical and biological response. Geophysical Research Letters, vol.31(15), 4 pp.

Ocean acidification is the process by which the pH of the water is changed. CO_2 dissolves in the water forming carbonic acid which results in reduced pH and makes seawater corrosive to certain minerals. Between 1750 and 1994, the oceans absorbed about 42% of all emitted carbon dioxide (CO_2). As a result, the total inorganic carbon content of the oceans increased by 118 ±19 gigatons of carbon over this period and is continuing to increase. This increase in oceanic carbon content caused calcium carbonate ($CaCO_3$) to dissolve at greater depths and led to a 0.1 unit decrease in surface ocean pH from 1750–1994. The rate of decrease in pH over the last 20 years accelerated to 0.02 units per decade[57]. The global ocean average pH was 8.2 before industrialisation but ocean acidity has risen as the oceans have absorbed increased amounts of CO_2 emissions. Consequently, there has been a decrease in pH of 0.1 which, significantly, represents a 30% increase in seawater's acidity[58]. This represents a significant departure from the geochemical conditions that have existed over millions of years. The current fraction of total anthropogenic CO_2 emissions stored in the ocean appears to be about one-third of the long-term potential.[59].

The ability of marine animals, most importantly pteropod molluscs, foraminifera, and some benthic invertebrates, to produce calcareous skeletal structures is directly affected by seawater CO_2 chemistry. CO_2 influences the physiology of marine organisms as well through acid-base imbalance and reduced oxygen transport capacity[60]. Research indicates that many of the effects of ocean acidification on marine organisms and ecosystems will be variable and complex impacting developmental and adult phases differently across species depending on genetics, pre-adaptive mechanisms, and synergistic environmental factors[61].No direct studies are available in India regarding ocean acidification except to guess that increased acidification will result in the loss of reef habitat including coral reefs and oyster reefs as well as impacts on the egg and larval stages[62].

3.6.4. Primary Productivity

Primary production by phytoplankton is what the entire marine food web depends upon. The average primary productivity of west coast of India within the surface and 50m depth is $1.19 gC/m^2/day$ and it is equivalent to an annual gross production of 434 $gC/m^2/day$. The first arrival of oil sardine along the west coast coincides with the diatom bloom and migration of oil sardine is timed to coincide with two seasonal blooms of the diatom, Nitzschia oceanica. Along the southwest coast of India, the phytoplankton bloom is rich during southwest monsoon[63]. On the other hand the Bay of Bengal has been traditionally considered less

[57] IPCC 2007: Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
[58] Caldeira, K. and Wickett, M.E., 2003 Anthropogenic carbon and ocean pH. Nature, 425, 365
[59] Sabine C. L., Feely R. A., Gruber N., Key R. M., Lee K., Bullister J. L., et al. The oceanic sink for CO_2. Science 2004;305:367-371
[60] Fabry, V. J., Seibel, B. A., Feely, R. A., and Orr, J. C. 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. – ICES Journal of Marine Science, 65: 414–432.
[61] Secretariat of the Convention on Biological Diversity (2009). Scienti- c Synthesis of the Impacts of Ocean Acidification on Marine Biodiversity. Montreal, Technical Series No. 46, 61 pages.
[62] Op. cit. 49
[63] ibid

productive. Reduced salinity due to freshwater inflows and higher SST result in a strongly stratified surface layer restricting wind driven turbulence. This means that nutrients from the bottom are unable to make their way to the top[64]. Overall, chlorophyll-a concentrations in inshore waters have been found to range between 0.01 to 13.3 mg/m^3 (mean 2.52 mg/m^3) in the west coast and 0.01 to 19.5 mg/m^3 (mean 2.52 mg/m^3) in the east coast[65].

3.6.5. Ecosystem Function

Hoegh-Goldberg and Bruno (2010)[66] reviewed the effects of anthropogenic climate change on the ocean ecosystem function. The impacts of anthropogenic climate change so far include decreased ocean productivity, altered food web dynamics, and reduced abundance of habitat-forming species; shifting species distributions, and a greater incidence of disease. The problem in the case of marine ecosystems is a higher risk of sudden non-linear transformations. The authors also point out that there is little information available on the potential for large scale synergisms or antagonisms considering the multiple stressors impacting ocean ecosystems. This is especially seen in systems such as coral reefs. There is concern that the various drivers add to the complex behaviour of ecological systems, increasing the chance of triggering amplifying feedback loops and domino effects.

3.7. Impact on fish species

The impact of climate change on fish is mainly because of regime shifts. A regime is a class of physical conditions and in the case of the oceans, it refers to temperature, pH, salinity, dissolved oxygen and other parameters. These can affect the distribution and diversity of fish species as each species has evolved to fit into a relatively narrow regime. When one of the parameters changes, it can have a cascading effect on others, and eventually, on the whole ecosystem. For example, increase in temperature results in lower dissolved oxygen levels because the amount of oxygen dissolved in water varies with temperature. This means that hardier species will be able to survive better in waters of lower dissolved oxygen. Increase in temperature may also result in metabolic changes which may impact larval survival. The result may be a shift in species composition over time. Such regime shifts can occur over large temporal and spatial scales and have been related to climate forcing. Krishnakumar (2008)[67] has indicated that a number of studies in different parts of the globe have been carried out with respect to regime shifts in marine ecosystems.

Studies on the impact of climate change on fisheries (fish species, stock distribution etc) have been carried out mainly by the CMFRI, Kochi. A few studies have been carried out by other

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[64] Prasanna Kumar, S. P.M. Muraleedharan, T.G. Prasad, M. Gauns, N. Ramaiah, S.N. de Souza, S. Sardesai and M. Madhupratap. "Why is the Bay of Bengal less productive during summer monsoon compared to the Arabian Sea?" http://drs.nio.org/drs/bitstream/2264/110/1/Geophys_Res_Lett_31_L15304.pdf accessed January 11, 2011

[65] Op. cit. 50

[66] Hoegh-Goldberg, O and J.F. Bruno, 2010. The Impact of Climate Change on the World's Marine Ecosystems. Science 328, 1523 (2010); DOI: 10.1126/science.1189930

[67] Krishnakumar, P.K., 2008. Climate Change related marine ecosystem regime shifts and their impact on fisheries. Winter School on Impact of Climate Change on Indian Marine Fisheries, CMFRI, 2008.

institutions such as SDMRI, Tuticorin, and NIO, Goa; as well as a few other academic institutions but the bulk of the studies have been carried out by CMFRI.

Nearly 1570 species of finfish and about 1000 species of shellfish coexist in the same fishing ground while about 200 species constitute the commercial multispecies fishery. The abundance and distribution of stocks varies from region to region and from season to season with large pelagics like tunas being more abundant around island territories and small pelagics like sardines and mackerel supporting a fishery of considerable magnitude along the southwest and southeast coasts[68]. Pelagic fisheries constitute a little over half the total fish catch, with about 70% being fished from within the 50m depth zone. A large number of artisanal fishers depend on these underlying the importance of the low value fishes[69].

The fluctuations in abundance of the oil sardine (pelagic species) and Malabar sole (demersal species) with respect to the Malabar upwelling have been studied and it was found that fluctuations in oil sardine abundance were clearly influenced by the rainfall trends in the Southwest monsoon[70].

INCCA[71] has also reported the changing scenario with regard to marine fisheries and the impact of climate change on the availability and distribution of fish species. They point out that the lack of simulation models in the fisheries sector has meant that it has not been possible to evaluate the 2030 scenario on fisheries. Hence, much of the information on impacts of climate change on the fish sector therefore comes from the analysis of past data and its interpretation in relation to changes in weather and sea-surface temperatures in those periods.

The following responses to climate change by marine fish are discernible in the Indian seas:

(i) Extension of distributional boundary of small pelagics;
(ii) Extension of depth of occurrence; and
(iii) Phenological changes.

The report specifically deals with oil sardines, Indian mackerel and threadfin breams and the highlights of the discussion are quoted below.

The oil sardine *Sardinella longiceps* and the Indian mackerel *Rastrelliger kanagurta* are tropical coastal and small pelagic fish, forming massive fisheries (21% of marine fish catch of India). They are governed by the vagaries of ocean climatic conditions, and have high population doubling time of 15 to 24 months. The oil sardine was known for its restricted distribution between latitude 8^{o}N and 14^{o}N and longitude 75^{o}E and 77^{o}E (Malabar upwelling

[68] Srinath, M and N.G.K. Pillai, 2008. “Status of Marine Fisheries in India”. Winter School on Impact of Climate Change on Indian Marine Fisheries, CMFRI, 2008.
[69] Pillai, N.G.K. and U. Ganga, 2008. “Pelagic Fisheries of India”. Winter School on Impact of Climate Change on Indian Marine Fisheries, CMFRI, 2008.
[70] Jayaprakash, A.A., 2002. Long term trends in rainfall, sea level and solar periodicity: A case study for forecast of Malabar sole and oil sardine fishery. J Mar. Biol. Assn. India, 44: 163-175.
[71] Op. cit. 1

zone along the southwest coast of India) where the annual average sea surface temperature ranges from 27 to 29^{o}C. Until 1985, almost the entire catch of oil sardine was from the Malabar upwelling zone.

In the last two decades, however, the catches from latitude 14^{o}N - 20^{o}N are consistently increasing, contributing about 15% to the all-India oil sardine catch in the year 2006[72]. The distribution is also extending to the east coast. There has been no drop in the catch in the Malabar area and hence it may be concluded that it is a distributional <u>extension</u> and not a distributional <u>shift</u>. The coastal upwelling index (CUI) during south-west monsoon increased by nearly 50% from 1997 to 2007. This substantial increase in CUI elevated the chlorophyll a concentration during monsoon. The high concentration and increasing trend of Chlorophyll-a (Chl-a) during the monsoon resulted in increase of over 200% in annual average Chl-a concentration. The increasing CUI and Chl-a during monsoon sustained an increasing catch of oil sardine during post-monsoon season[73]. Studies have concluded that elevated SST, favourable wind (and perhaps current) and increasing CUI have induced higher chlorophyll-a concentration during southwest monsoon, which has resulted in increasing the recruitment and catches of oil sardine during post southwest monsoon season along the Kerala coast. This trend indicates that the current warming is beneficial to herbivorous small pelagics.

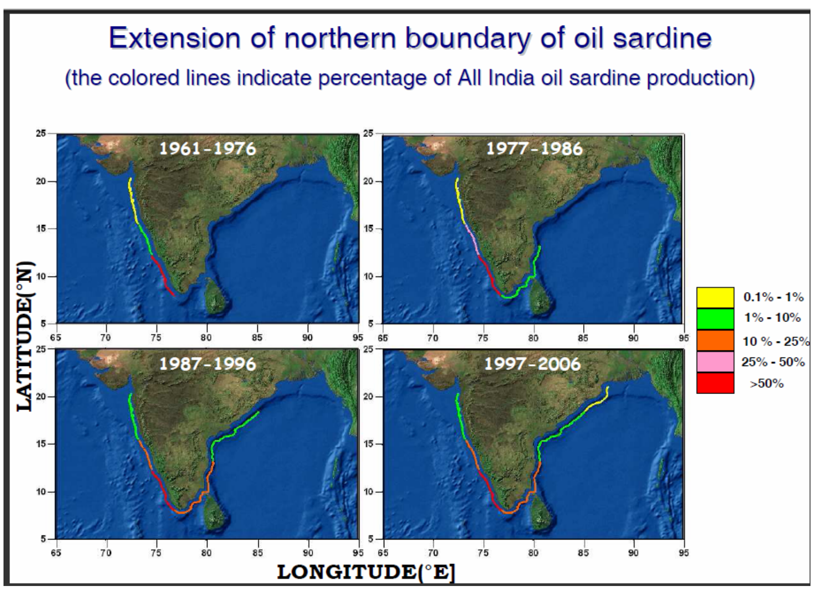

FIGURE 9: EXTENSION OF NORTHERN BOUNDARY OF OIL SARDINE (VIVEKANANDAN, 2008)[74]

[72] Op. cit. 24.
[73] Vivekanandan, E., N.G.K. Pillai, K.S. Mohamed, J. Jayasankar, V.V. Singh, Joe Kizhakudan, and R. Jeyabaskaran, 2010. Impact, adaptation and vulnerability of Indian marine fisheries to climate change. ICAR Project. CMFRI Annual Report 2009-10.
[74] Vivekanandan, E. 2008 Options on fisheries and aquaculture for coping with climate change in South Asia (presentation). International Symposium on Climate Change and Food Security in South Asia, Dhaka, 26th August 2008.

The Indian mackerel, *Rastrelliger kanagurta*, had wider distribution along the Indian coast, but the catches and abundance were predominantly along the southwest coast. It has a crucial role in marine ecosystems as a plankton feeder and as food for larger fish and also as staple sustenance and nutritional food for millions. The Indian mackerel, in addition to extension of northern boundaries, are found to descend to deeper waters in the last two decades. The fish normally occupy surface and sub-surface waters. The mackerel was conventionally caught by surface drift gillnets by artisanal fishermen.

In recent years, however, the fish is increasingly getting caught in bottom trawl nets operated by large mechanised boats at about 50 to 100 m depth. There could be two explanations for this: (i) The mackerel are being displaced from the pelagic realm due to warming of the surface waters. (ii) Global climate change models have shown that sea bottom temperatures are also increasing. The mackerel, being a tropical fish, are expanding the boundary of distribution to depths as they are able to advantageously make use of increasing temperature in the sub-surface waters. The latter explanation appears more reasonable as the catch quantities of the mackerel from the pelagic gear such as drift gillnet and ring seine are also increasing. It appears that the distribution of mackerel in the sub-surface has increased, and hence the recent trend may be a vertical extension of distribution, and not a distributional shift.

In the case of the short lived (3yrs), fast growing, highly fecund and medium sized fish - threadfin breams - *Nemipterus japonicus* and *N. Mesoprion* which are distributed along the entire Indian coast at depths ranging from 10-100m, SST appears to be playing a role in shifting of spawning activity to seasons where the temperature is around the preferred optima. Therefore in the climate change context, in the 2030s if the SST exceeds 28^{o}C during April to September, an increase in catch might take place in the comparatively cooler months of October to March. This is an example of a phenological change (change in the timing of life history events).

Deep water fishes have also been recently spotted off the west coast and this has been attributed to climate change. A main reason cited is the continuous rains after a record temperature rise in Kerala[75].

3.8. Climate Sensitive Coastal Ecosystems

In terrestrial ecosystems, biodiversity can be related to three dimensional space to permanent or semi-permanent physical structures. Such a concept breaks down in the marine ecosystem especially in the pelagic zone as waters are not stationary but become part of regional or global circulation. In addition, temporal changes that affect microscale and macrospatial distribution of organisms are more dynamic[76]. Nutrient levels are among the most important

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[75] Kishore, Kevin, 2010. Climate change affecting deep water fish species. Express Buzz, 2 Dec., 2010. http://expressbuzz.com/states/kerala/climate-change-affecting-deep-water-fish-species/227763.html

[76] Raghukumar, S and A.C. Anil, 2003. Marine biodiversity and ecosystem functioning: A perspective. Current Science, Vol. 84, No. 7, 10 April 2003

parameters that can change rapidly and cause a change in the structure of the ecosystem because they affect diversity of phytoplankton, the lowest rung of the food web in the very short term but these effects can also have a cascading long term effect. Analysis of long term data of plankton has also indicated that the marine pelagic community is responding to climate changes, but also that the level of response differs throughout the community and the seasonal cycle, leading to a mismatch between trophic levels and functional groups[77].

The INACCA report says that sea level rise would submerge mangroves and increase salinity of the wetlands. Increased snowmelt from the Himalayas would bring down more freshwater and reduce salinity in the case of the Sunderbans, favouring mangrove species with least tolerance to salinity. However the projected sea level rise is well within the tolerance limit of the Sunderban mangroves to adapt. This may not be true in the case of other mangroves such as Pichavaram or Muthupet in Tamil Nadu. Coral reefs are expected to undergo bleaching events due to increase in SST. While healthy reefs are expected to be able to survive this and sea level rise, degraded reefs characteristic of densely populated areas may not be able to tolerate such changes.

3.8.1. Coral Reefs

Bleaching, the whitening of corals, is due to stress-induced expulsion or death of their symbiotic protozoa, zooxanthellae, or due to the loss of pigmentation within the protozoa[78][79]. Coral bleaching is by far the most damaging event in coral reefs and is currently viewed as a major threat to the long-term health of coral reef communities[80]. Even seasonal variations in SST due to, for example, ENSO, can trigger bleaching events[81]. This study found that the Gulf of Kutch reefs showed an average of 11% bleached coral with no apparent bleaching-related mortality whereas bleached coral comprised 82% of the coral cover in lagoon reefs of Lakshadweep and 89% of the coral cover in the Gulf of Mannar reefs. Bleaching-related mortality was high –26% in Lakshadweep and 23% in Mannar. In another survey in Palk Bay, it was found that as much as 52% of the corals recovered relatively rapidly, by August, from a bleaching event that occurred April-July, 2002[82].

An attempt to project coral vulnerability in the Andaman, Nicobar, Lakshadweep, the Gulf of Mannar and the Gulf of Kachchh regions for the 21st century was made by Vivekanandan et

[77] Edwards, M and A.J. Richardson, 2004. Impact of climate change on marine pelagic phenology and trophic mismatch. Nature, 430: 881-884.
[78] Dove S.G. and O. Hoegh-Guldberg (2006). "Coral bleaching can be caused by stress. The cell physiology of coral bleaching". In Ove Hoegh-Guldberg; Jonathan T. Phinney; William Skirving; Joanie Kleypas. Coral Reefs and Climate Change: Science and Management. [Washington]: American Geophysical Union. pp. 1–18.
[79] WMO, 2010. Climate, Carbon and Coral Reefs. WMO-No. 1063.
[80] Vivekanandan, E. 2008. Vulnerability of Corals to Seawater Warming. Winter School on Impact of Climate Change on Indian Marine Fisheries, CMFRI, 2008.
[81] Arthur, R. 2000. Coral bleaching and mortality in three Indian reef regions during an El Niño southern oscillation event. Current Science, Vol. 79, NO. 12, 25 December 2000, pp1723-1729
[82] Kumaraguru, A.K., K. Jayakumar and C.M. Ramakritinan, 2003. Coral bleaching 2002 in the Palk Bay, southeast coast of India. Current Science, Vol. 85, No. 12, 25 December 2003, pp1787-1793.

al. (2009)[83]. To project the number of bleaching events, they considered the thermal threshold for bleaching, degree heating month (DHM) accumulations of the sea surface temperature (SST) hotspot anomalies, and the predicted increase in SST during this century. According to them, the annual average SST may increase by 3.0°C to 3.5°C in the Indian seas. With maximum SST in summer months rising up to 34.0°C or more, the thermal thresholds for coral bleaching in all the five regions are exceeded frequently until the middle of this century; and almost every year after 2050. The study results indicated that if there is no increase in thermal tolerance capacity, bleaching would become an annual or biannual event for almost all reef regions along the Indian coast in the next 30–50 years. The table gives an idea of the projected vulnerability of corals in the Indian seas.

Projected vulnerability of corals in the Indian seas (Vivekanandan et al., 2009)

Region	Decade in which corals may begin to decline	Decade in which reef building corals would lose dominance
Andaman	2030–2040	2050–2060
Nicobar	2020–2030	2050–2060
Lakshadweep	2020–2030	2030–2040
Gulf of Mannar	2030–2040	2050–2060

TABLE 4: PROJECTED VULNERABILITY OF CORALS IN THE INDIAN SEAS

The most recent bleaching event in Indian waters seems to have been in April-May, 2010, supposedly the worst in this decade, in the Andaman and Nicobar islands. Scientists from Marine Research Laboratory, Central Agriculture Research Institute in Port Blair and Regional Remote Sensing Centre in Nagpur, which is under the Indian Space Research Organisation (ISRO), conducted a study to assess the extent of bleaching during 2010 at selected reef sites in the islands and this was found to range from 37% to 70% in various sites[84].

The impact of dropping pH levels is also an important factor to be considered. Acidification of the ocean is likely to make corals more brittle and therefore more susceptible to damage during storms and storm surges. This would translate to loss of habitat of reef fish.

3.8.2. Mangroves

Mangroves are another important coastal ecosystem studied in the context of climate change. The composition and diversity are due a complex mix of factors. However, in general, mangroves are reported to have demonstrated considerable resilience over timescales commensurate with shoreline evolution. This notion is supported by evidence that soil accretion rates in mangrove forests are currently keeping pace with mean sea-level rise.

[83] Vivekanandan, E. M. Hussain Ali, B. Jasper and M. Rajagopalan, 2009. Vulnerability of corals to warming of the Indian seas: a projection for the 21st century. Current Science, Vol. 97, NO. 11, 10 December 2009, pp1654-1658.

[84] IANS, 2010. 2010 saw massive coral bleaching in Andamans. http://www.sify.com/news/2010-saw-massive-coral-bleaching-in-andamans-news-national-lbqpkiiiigc.html accessed January 31, 2011

Further support for their resilience comes from patterns of recovery from natural disturbances (storms, hurricanes) which coupled with key life history traits, suggest pioneer-phase characteristics[85].

Mangrove cover In India accounts for about 3% of the world's mangrove vegetation and is spread over an area of 4,639 km^2 in the coastal States/UTs of the country. Sundarbans in West Bengal accounts for a little less than half of the total area under mangroves in India. The current assessment shows that mangrove cover in the country is 4,639 km^2, which is 0.14 % of the country's total geographical area. The very dense mangrove comprises 1040 km^2 (30.29 % of mangrove cover), moderately dense mangrove is 1,659 km^2 (35.76 %), while open mangrove covers an area of 1,575 km^2 (33.95%)[86].

Mangroves in India comprise of 69 species excluding salt -marshes and other associate species. The east coast has 91% of mangrove species and the west coast has 53%. 53 species of prawns/shrimps are found in Indian mangroves of which 38 are in the east coast and 22 in the west coast. There are 91 crab species of which 67 are found in the east coast and 13 in the west coast[87]. However, it appears that proximity to mangroves, especially in the urbanizing context, does not always mean that people are aware of all the benefits of mangrove stands along the coast indicating that for protecting mangrove stands, awareness programmes as well as involving the locals in conservation is essential[88].

A study on the potential impact of climate change on mangroves in India pointed out hta the large extent of inter-tidal mudflats (about 23,620 km^2) in the country may provide a scope of adjustment and adaptation in some areas, mostly in the semi-arid region as in Gujarat. It is expected that the diversity in mangroves may improve at higher latitudes like the Gulf of Kachchh; latitudinal range extension may occur at the expense of salt marsh communities; adaptation and survival chance of mangroves in deltaic region like Sundarbans will be higher than mangroves on Andaman and Nicobar Islands[89].

3.8.3. Seagrass Beds

The major seagrass meadows in India exist along the southeast coast (Gulf of Mannar and Palk Bay) and in the lagoons of islands from Lakshadweep in the Arabian Sea to Andaman and Nicobar in the Bay of Bengal. The Seagrasses of India consist of 14 species belonging to seven genera. The main seagrasses are *Thalassia hemprichii*, *Cymodocea rotundata*, *C.*

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[85] Alongi, D.M., 2008. Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. Estuarine, Coastal and Shelf Science 76 (2008) 1e13

[86] Forest Survey of India, 2009. State of the Forest Report. http://www.fsi.org.in/sfr_2009.htm accessed January 18, 2011

[87] Kathiresan, K and N. Rajendran, 2005. Grow mangroves for protecting coral reefs! SDMRI Research Publication No. 9, 41 - 48, 2005

[88] Khan, A.S. and M. S. Ali, 2009. Mangroves Living at the Edges: A Social Survey Based on Environmental Issue. J Hum Ecol, 25(2): 75-77 (2009).

[89] Singh, H.S. 2003. Potential Impact of Climate Change on Mangroves in India. Paper submitted to the XII World Forestry Congress 2003, Quebec (Quebec) Canada. http://www.fao.org/DOCREP/ARTICLE/WFC/XII/0894-B2.HTM

serrulata, *Halodule uninervis* and *Halophila ovata*. Species such as *Syringodium isoetifolium* and *Halophila* spp. occur in patches as mixed species. The Tamil Nadu (southeast) coast harbours all 14 species, while 8 and 9 species have been reported from Lakshadweep and Andaman-Nicobar groups of islands, respectively. The mainland east coast supports more species than the west coast of India.

A paper first published in 1996 estimated that over the last decade, 90000 ha of seagrass have been lost worldwide[90]; the extent will be much higher today. However, to date, there are no documented evidences of seagrass loss due to sea level rise and historically seagrasses have adapted to rising seas. Since the rate of SLR is much higher today than it has ever been, some of the expected impacts are shoreward migration of species that are already growing at their maximum depth. Changing salinities may affect their reproduction and propagation. Increased salinities have also been associated with an increased prevalence of a highly destructive wasting disease[91]. Seagrasses are affected by natural hazards such as cyclones and earthquakes while they are under great stress from anthropogenic disturbances such as dredging, sewage disposal and increased nutrient runoff.

3.8.4. Deltas and Estuaries

Megadeltas, especially those in Asia, have been described as being at risk and low-lying deltas are especially vulnerable to sea-level rise and increasing shoreline wave action. An added threat to these deltas is sediment starvation due to upstream dams[92,93]. Tidal rivers and estuaries will become more prone to saltwater intrusion as a result of projected sea-level rise[94]. This has already been observed in the case of the Ganges delta and many other deltas in India and the world[95,96].

3.8.5. Harmful Algal Blooms

Algal blooms have profound implications for water and food safety because *vibrios* adhere to phytoplankton (algae) and zooplankton, and "red tides" bear biotoxins responsible for fish and shellfish poisoning. Furthermore nutrient-rich effluents stimulate algal growth and

[90] Short, F.T. and Sandy Wyllie-Echeverria, 1996. Natural and human-induced disturbance of seagrasses. Environmental Conservation (1996), 23: 17-27. DOI: 10.1017/S0376892900038212
[91] McKenzie, Len, 2010. Rising Seas: our oceans are changing. Seagrass-watch, Issue 42, October 2010. http://www.seagrasswatch.org/
[92] Ericson, J.P., C.J. Vorosmarty, S.L. Dingman, L.G. Ward and M. Meybeck, 2006. Effective sea-level rise and deltas: Causes of change and human dimension implications. Global and Planetary Change 50 (2006) 63–82.
[93] Overeem, I. & Syvitski, J.P.M. (2009): Dynamics and Vulnerability of Delta Systems. LOICZ Reports & Studies No. 35. GKSS Research Center, Geesthacht, 54 pages..
[94] IPCC, 2007.
[95] Millman, J.D., J.M.Broadus and F. Gable, 1989. Environmental and Economic Implications of Rising Sea Level and Subsiding Deltas: The Nile and Bengal Examples. Ambio, Vol. 18, No. 6 (1989), pp. 340-345
[96] Syvitski, James P. M., Albert J. Kettner, Irina Overeem, Eric W. H. Hutton, Mark T. Hannon, G. Robert Brakenridge, John Day, Charles Vörösmarty, Yoshiki Saito, Liviu Giosan and Robert J. Nicholls, 2009. Sinking deltas due to human activities. Nature Geoscience. Published online: 20 September 2009 | Doi: 10.1038/NGEo629

warmer sea surface temperatures shift marine ecosystems towards more toxic species[97]. Seasonal outbreaks of cholera in countries like Bangladesh were linked to algal blooms even in the 1960s but the reservoir was found only in 1991 when it was discovered that the vibrio remained as quiescent form and when conditions of temperature and nutrients become favourable, also a time for plankton bloom, the cholera bacteria come out of dormancy and become infections. Toxic species and events of toxic blooms have been reported off the Indian (especially Arabian Sea) coast[98,99]. Heavy blooms and mass mortality of fish as well as mussels were reported in September 2002 near Kozhikode, Kerala. Three successive blooms were seen and it was postulated that delayed south-west monsoon, intermittent showers followed by bright sunshine led to the blooms which were supported by upwelling and nutrient enrichment of coastal waters due to flushing by monsoonal rain[100].

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[97] Epstein, P. R., T. E. Ford, and R. R. Colwell. 1993. Health and climate change: Marine ecosystems. *The Lancet* 342: 1216-19.
[98] Alkawri, A.A.S and N. Ramaiah, 2010. Spatial-temporal variability of dinoflagellate assemblages in different salinity regimes in the West Coast of India. Harmful Algae, 9: 153-162
[99] Ramaiah, N., Jane T. Paul, Veronica Fernandes, T. Raveendran, O. Raveendran, D. Sundar, C. Revichandran, D. M. Shenoy, G.Mangesh, Siby Kurian, V.I. Gerson, D. T. Shoji, N. V.Madhu, S. Sree Kumar, P. A. Lokabharathi, S. R. Shetye, 2005. The September 2004 stench off the southern Malabar coast – A consequence of holococcolithophore bloom. Current Science, Vol. 88, No.4, 25 February 2005
[100] Mohammad, G., 2003.Algal bloom and mass mortality of fishes and mussels along the Kozhikode coast. Marine Fisheries Information Service, No. 175: January, February, March 2003

4. Studies on Climate Change (with relevance to coastal fisheries in India)

4.1. ICAR: A national network project "Impact, adaptation and vulnerability of Indian Fisheries to climate change" was carried out during the year 2006 and the salient findings are[101]

1. Southern Oscillation Index had a negative influence on Sea Surface Temperature along the northeast, southeast and northwest coasts of India. Trend of the sea surface temperature during the period 1960–2002 along the maritime states showed a significant increase. In the northeast coast sea surface temperature showed a negative correlation with total landings, demersal, cephalopod and crustacean landings resulting in low catches in the succeeding year with increase in current year SST. Along the southwest coast, the sea surface temperature revealed positive correlation with pelagic and total landings resulting in high catches in the succeeding year with increase in the current year SST. The oil sardine distribution has extended towards the northern latitudes and the catch has increased with increase in SST.
2. Mangalore coast revealed the shift of peak abundance of copepods and fish eggs and larvae towards the earlier months of the year indicating phenological changes.
3. Biodiversity shift in Hooghly estuary: The salinity regime of the estuary has changed and major portion in its middle stretch has almost changed into a freshwater zone, due to increased freshwater discharge from the Farakka barrage. The biodiversity changes reflected that a sizeable length of Hooghly Estuary has lost its estuarine characteristics. The Barrackpore stretch of the estuary is dominated by freshwater mullet *Sicamugil cascasia*. The brackishwater fish species, *Liza parsia*, *Scatophagus argus*, *Mystus gulio*, *Osteogeneiosus militaris*, *Hemiramphus gaimardi*, are no longer available in large stretches of the estuary. The plankton composition of this estuary, has changed. The once dominant marine diatoms like *Chaetoceros*, *Bacteriastrum* have been replaced by the freshwater plankton species *Scenedesmus*, *Pediastrum* and *Microcystis*.

4.2. ICAR Network Projects

A number of ICAR Network Projects have been summarized in a volume devoted to climate change and agriculture in India[102]. Only highlights from those with specific relevance to the current study are quoted below. It may be noted that studies regarding distribution of sardines as well as the spawning of threadfin breams (by the same authors) have already been discussed elsewhere in this report:

1. Sea surface temperature (SST) in the Indian seas may increase by about 3.0oC by 2100. This is likely to affect fish breeding, migration, and harvests. The

[101] Fish Production and Processing, DARE/ICAR Annual Report 2006-2007. http://www.icar.org.in/files/ar0607/05-Fisheries.pdf

[102] ICAR, 2009. Global Climate Change and Indian Agriculture: Case Studies from the ICAR Network Project. Edited by P.K. Aggarwal. Indian Council for Agricultural Research, New Delhi.

relationship of oil sardine distribution, a coastal, pelagic schooling fish, forming massive fisheries in India, with sea surface temperature was examined using data of annual oil sardine catch along each maritime state for 1961-2005. Considering the catch as a surrogate of distribution, it was found that the oil sardine has extended with time its northern and eastern boundaries of distribution. It is expected that the distribution may extend further to Gujarat and West Bengal coasts in the coming years assuming that other fishery related physical and biological parameters will not vary considerably. However, if the sea surface temperature in the southern latitudes increases beyond the physiological optimum of the fish, it is possible that the population may be driven away from the southern latitudes, which will reduce the catches along the south-west and south-east coasts in the future[103].

2. In the case of the threadfin breams, SST range of 28^{o} C and 29^{o} C may be optimum for spawners and changing SST may result in changing spawning times[104].
3. Studies indicated that in the case of coral reefs, reef-building corals are likely to disappear as dominant organisms on coral reefs between 2020 and 2040 and the reefs are likely to become remnant between 2030 and 2040 in the Lakshadweep region and between 2050 and 2060 in the Andaman and Nicobar regions; these projections were based only on increase in SST whereas the impacts maybe accelerated if acidity levels increase[105].
4. Erratic breeding and decline in fish spawn production has been noticed in the Ganga. There is also a perceptible shift in geographic distribution of the fishes of river Ganga. The warm water fish species viz., *Glossogobius giuris*, *Puntius ticto*, *Xenentodon cancila*, *Mystus vittatus*, earlier available only in the middle stretch of river Ganga, are now available in the colder stretch of the river. Both phyto and zoo plankton distribution have reduced in diversity. Extended breeding season of the Indian carp has been observed in West Bengal and this allows for breeding these fishes biannually. A prime factor influencing this trend is elevated temperature, which stimulates the endocrine glands of fish and helps in the maturation of the gonads[106].

4.3. Other Projects

[103] Vivekanandan, E., M. Rajagopalan and N.G.K. Pillai, 2009. Recent trends in sea surface temperature and its impact on oil sardine. Pp. 89-92 in "ICAR, 2009. Global Climate Change and Indian Agriculture: Case Studies from the ICAR Network Project. Edited by P.K. Aggarwal. Indian Council for Agricultural Research, New Delhi.

[104] Vivekanandan, E., M. Hussain Ali and M. Rajagopalan, 2009. Impact of rise in seawater temperature on the spawning of threadfin beams. Pp 93-96 in "ICAR, 2009. Global Climate Change and Indian Agriculture: Case Studies from the ICAR Network Project. Edited by P.K. Aggarwal. Indian Council for Agricultural Research, New Delhi.

[105] Vivekanandan, E., M. Hussain Ali and M. Rajagopalan, 2009. Vulnerability of corals to seawater warming. Pp 98-100 in "ICAR, 2009. Global Climate Change and Indian Agriculture: Case Studies from the ICAR Network Project. Edited by P.K. Aggarwal. Indian Council for Agricultural Research, New Delhi.

[106] Das, M.K., 2009. Impact of recent changes in weather on inland fisheries in India. Pp. 101-103 in "ICAR, 2009. Global Climate Change and Indian Agriculture: Case Studies from the ICAR Network Project. Edited by P.K. Aggarwal. Indian Council for Agricultural Research, New Delhi.

1. Mangroves for the Future (MFF) was established after the 2004 Indian Ocean tsunami and is headquartered in IUCN's Asia Regional Office premises in Thailand. MFF's focus in India is in the five coastal states namely; West Bengal, Orissa, Gujarat, Andhra Pradesh and Tamil Nadu which have been selected as the geographical priority areas of work. The selection is primarily based on the expanse of the mangrove cover in the states as well as extent of destruction suffered as a result of Tsunami. A number of small grants as well as one large grant (Sunderbans) have been approved. While these do not explicitly state that they are to do with climate change adaptation, they focus on resource (mangrove) identification, inventory, restoration and management etc as well as livelihood enhancement and diversification. The plan primarily is to reduce the pressure on coastal ecosystems[107].
2. Network of Aquaculture Centres in Asia-Pacific (NACA) had a case study in Andhra Pradesh, India[108]. The focus of the project was on mapping the small scale farmer's perceptions and attitudes towards climate change impacts and their adaptive capacities to address the impacts. In order to understand the perception of climate change impacts and adaptation of improved extensive shrimp farming, focus group discussion (FGD) meetings were conducted simultaneously in inland (Chinnapuram) and coastal (Gullalamoda) shrimp farming areas of the district on 3rd December 2009 and a stakeholder workshop (SW) was organized at Vijayawada on 4th December 2009. The climate change impacts identified on priority were seasonal changes, heavy rains, floods and cyclone in inland shrimp farming area and high temperature, floods, low/un-seasonal rain fall, low temperature, cyclone and low tidal amplitude in coastal shrimp farming area. The adaptation measures identified in FGDs for a particular climate change are more or less same in inland and coastal shrimp farming area. In both the cases shrimp farming has to be adapted to seasonal changes by following better management practices at farm level. In coastal areas the major adaptive measures are for high temperature as the areas near coast experiences high temperatures and for flood protection measures.

[107] Mangroves for the Future. http://www.mangrovesforthefuture.org/Countries/India.html accessed January 24, 2011

[108] Muralidhar, M., M. Kumaran, B. Muniyandi, Nigel William Abery, N.R. Umesh, Sena S.De Silva and Sirisuda Jumnongsong. 2010. Perception of climate change impacts and adaptation of shrimp farming in India: Farmer focus group discussion and stakeholder workshop Report (2nd edition). Network of Aquaculture Centers in Asia-Pacific, 75 p. www.enaca.org/aquaclimate

5. Climate Change Impact on Coastal Communities Depending on Fisheries

In India, about 12.5 lakh people are involved in active fishing in India while the postharvest sector including export and domestic marketing employs about 15 lakh and in tertiary sector there are around 2 lakh people. Among these, 71 percent of active fishers, 50 percent of secondary sector workers and 42 percent in the tertiary sector are inhabitants of coastal fishing villages. In the secondary sector, around 30 percent are women workers of which 81 percent are residents of fishing villages in the coastal belt[109].

The direct impact of climate related events on coastal communities include sea level rise and extreme events due to hydro-meteorological hazards. There are a few studies related to sea level rise in coastal areas. There are a number of scattered studies on the impact of climate related hazards in coastal areas. Many of the studies are subsequent to major disasters in coastal areas such as the 1999 supercyclone that struck Orissa on the east coast, the Mumbai deluge in 2005 and various flood related events. While such events are not necessarily pointers to climate change, their impacts provides an idea of what kind of situations may arise due to extreme events that have been forecast as a consequence of climate change.

5.1. Sea Level Rise, changes in tidal penetration and coastal erosion

An increase in MSL will affect the waves, currents and bottom pressure in the near shore region. In general, an increase in mean water depth will be accompanied by increase in mean wave height and hence, larger waves and stronger littoral drift. Historical records show how hydrometerological hazards raise sea levels, leading to floods onshore. Satellite imagery has shown that standing waters persisted even 11 days after a cyclone crossed the coast along the Krishna delta[110]. Table 5 gives an idea of the extent to which coastal land has been inundated by storm surges in extreme hydro-meterological events. These have caused extensive damage to housing, coastal farm land and infrastructure apart from damaging coastal livelihoods. This is a matter of concern because the intensity extreme events may increase with climate change and hence the future impacts may be higher.

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[109] Sathiadas, R and Sangeetha K. Pratap, 2009. Employment Scenario and Labour Migration in Marine Fisheries. Asian Fisheries Science 22 (2009): 713-727

[110] Mascarenhas, A. 2004. Oceanographic validity of buffer zones for the east coast of India: A hydrometeorological perspective. Current Science, Vol. 86, No. 3, 10 February 2004

Period	Coast affected	Maximum wind speed (km/h)	Maximum surge height (m)	Hinterland inundation (km)
October 1737	Hoogly river, West Bengal	272	12.1	100
May 1823	Balasore, Orissa	–	–	10
November 1867	East of Calcutta, West Bengal	60	1.8	–
October 1942	Medinipur, West Bengal	–	5.0	40
October 1949	Masulipatnam–Kakinada, Andhra Pradesh	137	4.5	15
November 1952	Nagapatnam, Tamil Nadu	88	1.2	8
October 1955	Kalingapatnam, Andhra Pradesh	111	1.5	–
November 1955	Rajamadam, Tamil Nadu	193	4.5	16
December 1955	Tanjore, Tamil Nadu	200	5.0	3–8
October 1963	Cuddalore, Tamil Nadu	139	6.0	–
December 1964	Rameshwaram, Tamil Nadu	278	6.0	–
October 1971	Paradip, Orissa	170	6.0	10–25
November 1973	North of Paradip, Orissa	137	4.5	–
August 1974	Contai, West Bengal	139	3.0	–
September 1976	Contai, West Bengal	160	3.0	–
November 1977	Nizampatnam, Andhra Pradesh	193	5.0	8–15
November 1977	Divi–Machilipatnam, Andhra Pradesh	120	5.0	12
November 1978	Ramanathpuram, Andhra Pradesh	204	5.0	–
May 1979	South of Ongole, Andhra Pradesh	160	3.6	–
November 1989	Near Kavali, southern Andhra Pradesh	222	4.0	1–2
May 1990	Nellore, Andhra Pradesh	102	5.0	16
November 1991	Karaikal, Tamil Nadu	89	–	< 1
November 1992	Tuticorin, Tamil Nadu	113	1.0	–
December 1993	Karaikal, Tamil Nadu	133	4.0	2
October 1999	Paradip/Balasore, Orissa	252	9.0	35

TABLE 5: LOCATION, MAXIMUM WIND SPEED, OBSERVED HEIGHT OF ASSOCIATED STORM SURGES AND ACTUAL INLAND PENETRATION OF SEA WATER DURING SOME SEVERE TROPICAL CYCLONIC EVENTS THAT AFFECTED THE EAST COAST OF INDIA
(compiled from various references by Mascarenhas, 2004)

In many places in Kerala, the land behind the beach is much lower than the mean sea level and hence tidal waves of higher than normal heights can gush inland causing flooding of the houses, roads, agricultural land, wells etc. Such an occurrence was reported in October 1987[111]and again in 2005[112]. Dinesh Kumar (2008)[113] looked at the impact of sea level rise on the coast and coastal structures in the Kochi, Kerala area and found that there would be permanent inundation of low lying areas with accelerated beach erosion and greater frequency of flooding events. Higher water levels would also reduce coastal drainage gradients, promote saltwater intrusion and even force water tables in certain areas to rise to the surface.

There are about 2643 fishing villages along the Indian coast of which 458 are within 100m of the High Tide Line, of which the largest number (200) are in Kerala. The population in these 458 fishing villages is around 1 million[114]. A study in Orissa and Andhra Pradesh based on stakeholder interviews and survey of ten coastal fishing villages was carried out. Dimension Indices (DI) and vulnerability Indices (VI) were worked out by considering 31 factors under 7 dimensions on a seven-point scale (1-7). Among the villages considered, Gokarkuda in Ganjam district of Orissa was the most vulnerable (VI: 0.53) and BCV Palem in Andhra Pradesh was the least vulnerable (VI: 0.16). Among the dimensions of vulnerability, the

[111] Mathew, K.J., N.S. Kurup, V. Chandrika, G. Balakrishnan and K. Gopalakrishna Pillai, Tidal waves cause damages to coastal villages in Kerala. Marine Fisheries Information Service, No. 77, November 1987.
[112] Satish Babu, personal communication
[113] Dinesh Kumar, P.K., 2008. Climate Change Vulnerability: Local Perspectives. Winter School on Impact of Climate Change on Indian Marine Fisheries, CMFRI, 2008.
[114] CMFRI Research Highlights 2007-2008

demography, food security and habitat induced maximum vulnerability to climate change with average index above 0.50 was observed[115].

About 75 coastal fishing villages of Maharashtra are located within 100 m from the high tide line[116]. To find out the vulnerability of these fishing villages to sea level rise, validation of available primary data from vulnerable fishing villages along Maharashtra coast was completed by ground truthing by using GPS. Three scenarios for SLR are being used to generate maps to identify the most vulnerable of the villages.

In south Gujarat, Danti in Valsad district has been facing the encroaching sea for many years. It was very severe in 1986 compared with earlier occurrences in 1968 and 1976. In Udwada village, continuous erosion has forced people inland by over 100 m[117]. A recent study says that Danti village has moved back three kilometres in the last twenty years. Only the poorest remain at the edge of the village with the sea wall for protection. Their wells are now in the sea and they need to buy potable water as the groundwater is saline[118].

An issue that came up in the national public hearing on climate change in coastal communities was the impact on livelihood activities due to reduction of space for post harvest facilities due to erosion of coastal stretches[119,120].

5.2. Changes in frequency of cyclones, flooding and other natural hazards

5.2.1. Impact of natural hazards on coastal populations

Orissa on the east coast frequently experiences floods and cyclones and one would expect a reasonable degree of preparedness amongst the people. However, it appears that large numbers were unprepared resulting in the 1999 super-cyclone killing over 10,000 people, though other estimates put a much higher figure for the casualties. A study reported that interviews with some of those who survived pointed to the fact that all had received warnings but that the information provided was inadequate to help them determine whether they were personally at risk. As a result, many took no or inappropriate action[121]. At that time, there was little coordination between different agencies and the communication and weak links between the IMD (which issues warnings) and the administration and its public response systems. The

[115] CMFRI Annual Report 2006-07. ICAR (National Network Project of NRM Division): Impact, adaptation and vulnerability of Indian Fisheries to climate change.
[116] Climate Change. DARE/ICAR Annual Report 2009-2010. http://www.icar.org.in/files/reports/icar-dare-annual-reports/2009-10/Climate-Change.pdf
[117] Lipton, A.P., S.G Raje and M. Chellappa, 1987. Sea Erosion threat to coastal fishing villages of Valsad District, Gujarat. Marine Fisheries Information Service, No. 76, October 1987.
[118] Bunsha, D., 2007. Gone with the waves. Frontline, Volume 24 - Issue 14, Jul. 14-27, 2007. http://www.flonnet.com/fl2414/stories/20070727000206600.htm
[119] Press Release, Sneha, Nagapattinam.
[120] Gupta, D. 2009. Exiled. http://www.tehelka.com/story_main43.asp?filename=Ne141109exiled.asp
[121] Thomalla, F and H. Schmuck, 2004. “We All Knew That A Cyclone Was Coming”: Disaster Preparedness and The Cyclone of 1999 In Orissa, India. EVA Working Paper No. 8, DINAS-COAST Working Paper No. 13, Potsdam Institute for Climate Impact Research, Potsdam, Germany.

higher figures of casualties could also be related to the fact that the region sees a number of migrants from West Bengal and Bangladesh who are not registered with authorities[122].

Mumbai experienced a very high rainfall of 944mm within a period of 18 hours on 26th July 2005[123]. The monsoon season started off erratically with some deficiency in rainfall. The situation changed after 21 July 2005 with unusually heavy rains lashing the coastal districts. Suburban Mumbai and Thane experienced a deluge on 26th July. The downpour flooded a number of other areas and soon after the floods receded, the release of water from the Koyna and Ujani dams flooded many areas[124]. In Mumbai, it was a case of urban flash flooding because of poor drainage as many natural drains have been constructed across, paved areas have increased resulting in slower and lower percolation as well as faster runoff, and flow in drains impeded because of the presence of solids including plastics[125]. A study on the economic impacts of climate change for Mumbai considered costs due to dislocation due to extreme events, material damage to low lying areas, mortality costs due to extreme flooding, disability-adjusted-life-years (DALY) due to diseases, building foundation damages (due to water stagnation) and tourism losses to be 34 trillion Rupees (34×10^{12}) by 2050; with the last two making up more than half of that amount[126].

A recent study on the economic impact due to sea level rise on the infrastructure on the Tamil Nadu coast showed that a one metre rise in average sea level would permanently inundate about 1091 km^2 along the Tamil Nadu coast but the total area at risk would be nearly six times as much. The study estimates the total replacement value of infrastructure (ports, power plants and major roads) impacted by sea level rise to be between Rs. 47,418 and Rs. 53,554 crores (in 2010 terms). The present value of wetlands (estimated in terms of foregone ecosystem services through 2050) impacted by sea level rise is estimated to be between Rs. 3,583 and Rs. 14,608 crores. By far the largest impact will be on the land at risk, whose market value is estimated to be between Rs. 3,17,661 and Rs. 61,15,471 crores. In comparison, Tamil Nadu's annual Gross Domestic Product is estimated to be around Rs. 2,50,000 crores, indicating that very significant value is at risk along the coast due to climate change impacts from sea level rise alone[127].

5.3. Health issues related to climate change

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[122] IMM, 2001: Learning Lessons from the Cyclone: A Study of DFID's Support for Post-Cyclone Livelihoods Rehabilitation in Orissa, India. IMM Ltd, The Innovation Centre, University of Exeter, UK.

[123] Attri, S.D. and A.Tyagi, 2010. Climate Profile of India. Met Monograph No. Environmental Meteorology-01/2010. IMD, MoES, New Delhi.

[124] Govt of Maharashtra, 2005. Maharashtra Floods 2005. http://mdmu.maharashtra.gov.in/pdf/Flood/statusreport.pdf

[125] Gupta, K., Urban Flooding: Vulnerability, Preparedness and Mitigation. Presentation at the University of South Australia. http://www.icewarm.com.au/userfiles/File/ICEWARM_Adelaide%20290506.pdf

[126] Kumar, R., P. Jawale and S. Tandon., 2008. Economic impact of climate change on Mumbai, India. Regional Health Forum – Volume 12, Number 1, 2008. http://www.searo.who.int/LinkFiles/Regional_Health_Forum_Volume_12_No_1_Economic_impact_of.pdf

[127] Byravan, S, Sudhir Chella Rajan and Rajesh Rangarajan, 2010. Sea Level Rise: impact on major infrastructure, ecosystems and land along the Tamil Nadu coast. Centre for Development Finance (CDF), IFMR and Humanities and Social Sciences, IIT Madras. http://ifmr-cdf.in/pg/groups/3650/climate-change-sea-level-rise&type=Initiative&int=3650

Six aspects that connect climate change to adverse health outcomes have been considered by the University College London (UCL) - Lancet Commission as the major obstacles to effective adaptation: changing patterns of disease and mortality, food, water and sanitation, shelter and human settlements, extreme events, and population and migration[128]. According to the commission, vulnerability of poor populations will be caused by greater exposure and sensitivity to climate changes and reduced adaptive capacity and called for a public health movement that is multidisciplinary and multisectoral, and that leads to coordinated thinking and action across governments, international agencies, NGOs, and academic institutions. In India too, research on correlating climate change and health is limited to studies on the spread of malaria and indications are that malaria may penetrate elevations above 1800 meters and some coastal areas[129, 130].

Incidences of other vector borne diseases such as dengue and water borne diseases like diarrhoea are also likely to increase. A recent TV programme on the status of houses (in Pazhayar) constructed after the 2004 tsunami showed residents complaining of a variety of sicknesses, mainly water borne, because of water stagnation due to poor drainage. This could be an indicator of problems in the future if there are bouts of intense rainfall in poorly drained areas. Discussions with coastal residents on impacts of climate change also indicated that poor nutrition is an increasing problem due to various reasons such as non-availability of healthy fish and the increasing junk-food culture and reduced consumption of traditional foods[131].

5.4. Gender and climate change

Women bear a disproportionate burden of climate change consequences including impact on food security (higher prices of groceries), livelihoods (loss of beach spaces used for auctioning, fish drying), water resources (shortage, access), increased burden of care giving (family illnesses due to greater exposure to vector borne diseases). In addition, it is expected that existing gender issues related to differentiated access to resources and occupational change in markets, distribution and processing, where women currently play a significant role, may be heightened under conditions of stress and increased competition for resources and jobs stemming from climate change[132,133] . In the case of large scale migration from inundated areas, it is mostly the men who migrate and leave women-headed households to

[128] Costello, Anthony, Mustafa Abbas, Adriana Allen, Sarah Ball, Sarah Bell, Richard Bellamy, Sharon Friel, Nora Groce, Anne Johnson, Maria Kett, Maria Lee, Caren Levy, Mark Maslin, David McCoy, Bill McGuire, Hugh Montgomery, David Napier, Christina Pagel, Jinesh Patel, Jose Antonio Puppim de Oliveira, Nanneke Redclift, Hannah Rees, Daniel Rogger, Joanne Scott, Judith Stephenson, John Twigg, Jonathan Wolff , Craig Patterson, 2009. Managing the health effects of climate change. Lancet 2009; 373: 1693–733

[129] Op. cit. 1

[130] WHO, 2007. Country Report India. Workshop On Climate Change And Health In South East And East Asian Countries, 2-5 July 2007, Kuala Lumpur, Malaysia. http://www.whoindia.org/LinkFiles/Health_&_Environment_Country_report_Climate_Change_KL_Workshop.pdf

[131] The Fisherfolk and Farmers at Gulf of Mannar, Ramanathapuram District, Tamil Nadu (Report by Dakshin Foundation) Community Charter on Climate Crisis: Outcome on an Indiawide participatory initiative. 2010.

[132] Op. cit. 18

[133] Padmanabhan, Geeta. Distress Call. http://www.hindu.com/mp/2009/12/07/stories/2009120750120200.htm

cope, which means that women need to put in extra effort to manage their homes and families[134]. The way forward, therefore is to[135]:

- Recognize that women are more vulnerable in climate change driven scenarios
- Understand and address gender-specific natural resource use pattern
- Identify women's particular skills and capacities that lend themselves to mitigation and adaptation
- Increase women's participation in decision-making at all levels in climate change mitigation and adaptation

[134] Parikh, J. 2009 Gender: The Ignored Other Half. In "Climate Change – Perspectives from India" http://www.undp.org.in/content/pub/ClimateChange/UNDP_Climate_Change.pdf.
[135] Parikh, J.2007. Is Climate Change a Gender Issue? Brief based on a draft paper "Mainstreaming Gender into Climate Change Policies". UNDP, India

6. Climate Change Impact on Fishery related Livelihoods

6.1. CC impact on fish catch

A variety of craft and gear combinations are used to harvest fish by the small scale sector. The combinations vary seasonally as well as regionally. The introductions of different gear have also had an influence on the marine fish production. An appraisal of the craft-gear combinations of the different states in India was done by Pillai et al in 2000[136]. They point out that traditional gears like beach seines have reduced in numbers because of the advent of purse seines and mechanized trawling along the coast while gillnets comprise 40% of the traditional gears with sardine gillnets retaining its efficiency for more than five decades accounting for nearly 90% of the sardine catch along the east coast. In the late nineteen fifties, nylon twines and monofilaments began to replace the cotton twines and coir ropes resulting in increased durability and operational efficiency of fishing gear. Replacement of the prawn net by the trammel net, increase in number of purse-seines and ring-seines and reduction in mesh size are seen, the latter resulting in the large quantities of juveniles being caught[137].

Currently, the data sets that are collected are with respect to the fish (species), assemblages (pelagic, demersals etc) and major gears (multi day trawl, purse seine etc.) contributing to the catch, available state-wise[138,139]. These data sets need to be consolidated and analysed with respect to temporal and spatial changes in catch quantity and composition as well as gear types and numbers. As noted in an earlier section, a change in the distribution of certain fish species has been observed with increased catch in places where that fish (oil sardines) did not earlier form a significant proportion. This indicates that there may be an increased demand for the gear that is used to catch that fish but for this, it is not clear if updated datasets are available. In places where the catch exceeds local demand, if there is persistence in the quantities caught, unless there a build up of transportation and marketing network, this may not translate into profitable ventures for the local fishers. No studies appear to have focused on this aspect yet.

6.2. Migration within the sector – change in craft, gear, fishing methods, grounds

[136] Pillai, P.K. Mahadevan, G. Balakrishnan, V. Philipose and V. Rajendran, 2000. An appraisal of the marine fishing craft and gear of the Indian coast. Pp 190-221 in Marine Fisheries Research and Management (Eds: G..N. Pillai and N.G. Menon), CMFRI, Kochi.
[137] Sathiadas, R. 1997. Socio-economic structural changes in the marine fisheries sector of India and coastal zone management. Proc Sem. Coast. Manag., 1997: 79-89.
[138] CMFRI Annual Report 2009-10. CMFRI, Kochi. www.cmfri.org.in
[139] CMFRI, Estimated Marine Fish Landings in tonnes. http://cmfri.org.in/html/cmfriDATA01.html

Labour migration in the fisheries sector does not yet seem to have climate related influences as much as because of mechanization, availability of better gadgets[140,141], localized reduction in catch and such reasons. A clear shift in employment pattern towards mechanised and motorized sectors can also be observed[142]. Active fishers in the mechanised segment have increased from 24 percent in 1980-81 to 35 percent in 2004-05 and motorized segment from 17 percent in 1997-98 to 32 percent in 2004-05. The share of active fishers in the non-mechanised segment decreased from 75 percent in 1980-81 to 34 percent in 2004-05[143]. Increase capital investments have resulted in a number of active fishermen moving towards the mechanized sector as labour. The unemployed labourer in the traditional non-mechanized sector has largely migrated to the capital intensive mechanized sector which results in the increase in disguised unemployment[144]. In the study on Thoothoor (Kanyakumari) shark fishermen[145], it was found that causes for large scale migration among these fisherfolk include high demand for shark in the international market coupled with its earning potential, accessibility to landing points, and berthing facilities and better price realization.

In the PRA exercises regarding climate change[146], fishers from Rochumanagar in Kanyakumari said that after 1978 when there was a storm, there were high winds and rough seas that made it difficult for country boats to be used; subsequently there was a wave of mechanization in the eighties, since their village had no anchoring points, trawlers had to be moored elsewhere and hence the fishers (and their families) migrated. They said that migration affected education of children, and no finances were available for their higher education. Similar statements were made by others who participated in the exercises from other places.

6.3. Implications for trade

Few studies appear to be available regarding the trade in fisheries despite the fact that about 40% of the global production enters international trade and fish are an important source of foreign currency to many developing countries[147]. An information note[148] from the ICTSD in 2009 notes that trade policy can play an important role in promoting economic diversification

[140] Sathiadas, R., 2006 Socio-economic scenario of marine fisheries in India – an overview. Sustain Fish. B.M. Kurup and K. Ravindran (Eds) School of Industrial Fisheries, Cochin University of Science and Technology, Cochin 682016.
[141] Op. cit. 109
[142] Sathiadas, R., 2006 Socio-economic scenario of marine fisheries in India – an overview. Sustain Fish. B.M. Kurup and K. Ravindran (Eds) School of Industrial Fisheries, Cochin University of Science and Technology, Cochin 682016.
[143] Op. cit. 109
[144] Sathiadas, R., 2006 Socio-economic scenario of marine fisheries in India – an overview. Sustain Fish. B.M. Kurup and K. Ravindran (Eds) School of Industrial Fisheries, Cochin University of Science and Technology, Cochin 682016.
[145] Op. cit. 109
[146] Op. cit. 131
[147] Op. cit. 18.
[148] ICTSD, 2009. Climate Change and Fisheries: Policy, Trade and Sustainable Development Issues. Information Note Number 15, October 2009.

in the fisheries sector and that appropriately designed trade policies and rules can contribute to reforming economic distortions, such as harmful subsidies, that encourage overcapacity and overfishing. Market access may become difficult in areas affected by frequent flooding or the catch may be unfit due to bacterial or viral contamination.

6.4. Gender and fisheries

Fisherwomen play an important role in the marketing and processing activities. According to Kohli and Dube (2003)[149], the participation of women in fisheries activities in the coastal states of Gujarat, Maharashtra, Goa, Kerala, TN and AP generally involves fish drying, fish processing, fish loading and unloading, retail marketing and net mending. While marketing is dominated by females (MF ratio (Male Female ratio) of 2.8), labour in the secondary sector is done by men (MF ratio of 0.4). Curing /processing and peeling are undertaken by women (MF ratio of 3.1 and 3.4, respectively). Male female participation in secondary sector is almost equal denoted by the ratio of 0.9. Of the fisher population engaged in secondary sector, women accounted for 48 percent of the work force in marketing, curing/processing and peeling sectors[150]. The existence of a large number of intermediaries because of the unorganized nature of the fish marketing system results in the reduction of the share of the fishermen in the consumer's price. In India, women Self Help Groups (SHG) have helped in the empowerment of women by enabling them to avail financial assistance (microfinance) for socio economic improvement. Such activities include mussel, oyster and seaweed farming, dry and fresh fish marketing, fish processing (pickles) etc[151].

In recent times, there has been increasing 'masculinisation' of fisheries[152] with traditional women vendors and processors losing out to middlemen because of the increasing capital costs that are forcing boat owners to rely on middlemen -traders for credit. Women who were processing excess catch as dry/salted fish began losing out when ice availability (brought in by trader middlemen) enabled keeping the fish fresh for longer periods[153]. Thus women are losing their access to fish to high-value export markets, due to their poor access to capital and weak organization. In a recent workshop[154], participants pointed out that vulnerability to climate change was looked at mainly from an ecological perspective which actually subsumes and overtakes the awareness of women's political vulnerability, and the way in which existing power relations impact women's vulnerability. An aspect that is likely to be

[149] Kohli, M.P.S and K. Dube, 2003. Women in Fisheries: An Indian Scenario. In Proceedings of National Workshop on Best Practices in micro-finance programmes in support of women in coastal fishing communities and poverty alleviation (1-4 July 2003).
[150] Op. cit. 109
[151] Mohite, S.A. and A.S. Mohite, 2009. Scope of women Self Help Group (SHGs) and Co-operative Societies in Fishery Sector of India. Fishing Chimes, 29: 177-180
[152] Salagrama, V, 2007. Assessing opportunities for livelihood enhancement and diversification in coastal fishing communities of southern India: Draft. www.icsf.net
[153] Salagrama, V., 2000. Small scale fisheries in India: Does it exist anymore? Bay of Bengal News, March 2000.
[154] ICSF, 2010. Recasting the Net: Defining a gender agenda for sustaining life and livelihood in fishing communities. Proceedings of the workshop. http://icsf.net/icsf2006/jspFiles/wif/wifWorkshop/english/proceedings.jsp

importance, but not yet studied, is how change in species composition due to climate change will affect fish drying and curing activities. Considering that this is one aspect where marketing of pelagic fish is done mostly by women in rural areas, studies are required to see whether there has been any change in their activities and if there has been loss of livelihood due to this particular aspect.

6.5. Climate induced migration to and from fisheries

Traditionally, Indian fishermen have migrated along the coast, but in recent years, the trend seems to have intensified with resources getting depleted in inshore waters. Migration could be of entire fishing units or just the crew; this is usually a response of fish workers to secure their livelihood[155,156]. However, migration with specific reference to climate change is what was looked for in this part of the report.

6.5.1. Entry of non fishers into the sector

There do not yet appear to be reliable data on the move of non-fishers to the fishing sector except with reference to increased mechanization when traditional fishers were unable to invest and this brought in investors from other communities[157]. In Chilika lake, Orissa, it was only when shrimp farming became lucrative that the fishermen population went up. This has been attributed to the fact that the non-fisher caste that had hitherto looked upon fishing as an 'unclean' operation were drawn to prawn when it became a marketable and profitable commodity[158].

6.5.2. Exit to other vocations

In most cases, diversification into non-fisheries related livelihoods and exit to other vocations is limited[159]. In recent times, especially after the 2004 Indian Ocean tsunami, a number of initiatives have been made to enable fishers move out of the sector if they choose to do so. This has been done by enabling training of youth from the fishing community in various other vocations. An example is the Gulf of Mannar Biosphere Trust which provides revolving trust funds through self help groups for women not only for pursuing fishery related activities such as dry fish vending but also for palm crafts, goat rearing and mat making, among other things. Also, funds for vocational training in government polytechnics and accredited community colleges are provided to enable fisher youth for non-fishery related activities to enable them to move out of the sector[160]. There are also many who prefer to move to shore

[155] ICSF, 2003. Rural Poverty among Coastal Fishers: Profile and Possible Interventions. A report to IFAD
[156] Op. cit. 152
[157] Vivekanandan, V., C.M.Muralidharan and M. Subba Rao, 1997. A Study of the Marine Fisheries of Andhra Pradesh. Unpublished Report.
[158] Pattanaik, S. 2007. Conservation of Environment and Protection of Marginalized Fishing Communities of Lake Chilika in Orissa, India. J. Hum. Ecol., 22(4): 291-302 (2007)
[159] FAO/UNTRS, FERAL 2008. Co-management and Livelihood Enhancement Planning in Coastal Artisanal Fisheries. Report submitted to FAO/UNTRS.
[160] GOMBRT GEF Project Output V-A. www.gombrt.org

based regular-paying jobs as watchmen or security guards as the returns on investment if they continue fishing does not allow them to sustain their families[161]. In some places, due to migration of the men to other places, a sizeable proportion of the household income comes from women's earnings in agriculture, port operations, the hotel industry, household labour, construction and plantation work[162].

6.5.3. Migration and climate refugees

Two distinct drivers of migration in the climate change context are **climate processes** such as sea level rise salinisation of agricultural land, desertification and growing water scarcity, and **climate events** such as flooding, storms and glacial lake outburst floods[163]. Climate induced migration is likely to be a cross border problem for India with large numbers displaced from climate change hot-spots including Bangladesh, Myanmar and Sri Lanka migrating to India[164], [165]. In all these places, since the most vulnerable communities will be those with maximum exposure to the stress and least capacity to cope, such as those dependent on subsistence fishing, they will be the first to experience 'tipping points' in their life systems; and as larger numbers of such people will cross these points resulting in mass migration of entire villages[166]. Forced migration linked to climate changes has been reported mainly from the Sunderbans where migration has been forced upon the local communities in some areas due to increasing saline intrusion that has resulted in non-availability of potable water[167]. In such cases, it may be more pertinent to call such migrants as climate refugees as there is little hope for them to return to their homes in the future.

[161] Sridhar, L., 2002. Fishing in troubled waters. http://www.indiatogether.org/opinions/lalisri/ls1202.htm accessed January 31, 2011.
[162] Salagarama, V., 2003. Poverty, Food Insecurity and Vulnerability in Coastal Fishing Communities of Orissa. Final Report of the ICM Case Study in Orissa, Feb-Jun 2003. ICM, Kakinada.
[163] Brown, O., 2007. Climate change and forced migration: Observations, projections and implications. A background paper for the 2007 Human Development Report.
[164] TERI, 2009. Climate Induced Migration and its Security Implications for India's neighbourhood. Discussion paper prepared for the 15th CoP, UNFCCC, Copenhagen, 2009. www.teriin.org
[165] Rajan, S.C.2008. Blue Alert: Climate Migrants in South Asia, Estimates and Solutions – A report by Greenpeace. www.greenpeaceindia.org
[166] Byravan, S and S.C. Rajan, 2009. The Social Impacts of Climate Change in South Asia. JMRI (2009) Vol 5 No 3: 134-149.
[167] Sengupta, S. and Prakash Rao, 2003. Sunderban Delta. Adverse Impacts of Climate Change - Perception and Responses of Local Community. UNFCCC Expert Workshop on Local Coping Strategies for Adaptation 12-13 November 2003, New Delhi.

7. Current Methods to deal with Climate Change (for Coastal (Fishing) Communities)

Adaptation and Mitigation are the two major methods by which climate change issues are tackled at various levels. A number of studies are available that have analysed vulnerability to climate change for different scenarios and suggested appropriate responses. Strategies already exist for coping with various conditions in the small scale fisheries sector and a number of these have been documented. These vary from switching between rice farming, livestock rearing and fisheries as well as supplementing incomes by working as watchmen, shopkeepers etc[168]. Adaptation strategies will require to be context and location specific, and to consider both short term and long term impacts[169].

7.1. Adaptation

This has been defined in various ways. An analysis on what adaptation can be refers to a number of sources where adaptation in the climate change context has been discussed[170]. Thus, for some, adaptation refers to the "adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts"; while for others, the term refers to changes in "processes, practices, or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate". Adaptation involves adjustments to decrease the vulnerability of communities and regions to climate change and variability.

Adaptation can be defined as either autonomous or planned, although in practice, both strategies are often interconnected[171]:

- Autonomous adaptation depends on underlying systems that enable people and organisations to take advantage of opportunities available in the new environment, or constrain their ability to shift livelihood strategies as conditions evolve.
- . Planned adaptation depends on the ability to:
    - proactively identify, and respond to, emerging constraints and opportunities;
    - enable autonomous adaptation processes by supporting the development of flexible, resilient, and accessible social and physical infrastructure systems; and
    - establish social protection systems capable of ameliorating the impact of climate change on vulnerable groups.

[168] Op. cit. 19
[169] Op. Cit. 13
[170] Huq, S., A. Rahman, M. Konate, Y. Sokona and H. Reid, 2003. Mainstreaming adaptation to climate change in Least Developed Countries (LDCs). International Institute for Environment and Development. http://www.iied.org
[171] Ahmed, S and E. Fajber. Engendering adaptation to climate change variability in Gujarat, India. Gender & Development Vol. 17, No. 1, March 2009. DOI: 10.1080/13552070802696896

The latter may be anticipatory or reactive. They can be short or long term, localized or widespread. Table 6 below gives the various types and forms of adaptations.

Bases for characterising and differentiating adaptation to climate change (Smit *et al*., 1999)			
General differentiating	Examples of terms used		
concept of attribute			
Purposefulness	Autonomous		Planned
	Spontaneous		Purposeful
	Automatic	Vs.	Intentional
	Natural		Policy
	Passive		Active
	Strategic		
Timing	Anticipatory		Responsive
	Proactive	Vs.	Reactive
Temporal Scope	Short Term		Long term
	Tactical	Vs.	Strategic
	Instantaneous		Cumulative
Spatial scope	Localised	Vs.	Widespread
Function/Effects	Retreat, accommodate, protect, prevent, tolerate, spread, change, restore.		
Form	Structural, legal, institutional, regulatory, financial, technological		
Performance	Cost, effectiveness, efficiency, implementability, equity		

TABLE 6: DIFFERENT FORMS OF ADAPTATION[172]

The greatest difficulty is in identifying the right kind of adaptation for each sector and each community. Adaptations have costs, and it is necessary to identify hidden costs to ensure that adaptation for one community does not become a danger for another community. A case in example is sea walls or other protective structures to protect coastal communities from erosion. However, a sea wall that is not properly designed may result in the protection of one community while resulting in erosion of a neighbouring community as has been seen in many villages along the east coast.

Community based adaptation (CBA) is described as a tool to help millions of poor people who are at greatest risk from climate change. Some of the important lessons learned from the field are[173]:

- Outsiders need to gain trust of the community. It would be better to begin dialogues with trusted local intermediaries (NGO, govt bodies) before moving on to the communities themselves
- Communities need explanations of scientific texts in their own language, in formats they can understand

[172] Smit et al., 1999 quoted in Page 18 of Huq, S., A. Rahman, M. Konate, Y. Sokona and H. Reid, 2003. Mainstreaming adaptation to climate change in Least Developed Countries (LDCs). International Institute for Environment and Development. http://www.iied.org

[173] Huq, S and H. Reid, 2007. Community Based Adaptation: An IIED Briefing. www.iied.org

- After understanding the community's indigenous capacities, knowledge and practices on coping with past climate change (including climate related hazards), identification of appropriate adaptations should begin
- Adaptation projects look largely like any other development project except for the inputs that have gone into the project formulation. It is not what the community is doing but why and with what knowledge.
- Adaptation is a classic case of learning-by-doing.

Adaptation to climate change by integrating aquaculture and agriculture has been suggested as this can help farmers cope with drought while boosting profits and improving nutrition. Also suggested is that fisheries management move from trying to maximise yield to increasing adaptive capacity[174].

The following table provides examples of potential adaptation measures in fisheries[175]. Suggested adaptation measures for aquaculture as well as post harvest practices have also been suggested.

Impact of climate change on fisheries	**Potential adaptation measures**	**Responsibility**	**Reactive/ Anticipatory**
Reduced yield	Access higher value markets/shifting targeted species	Public/private	Either
	Increase effort or fishing power*	Private	Either
	Reduce costs to increase efficiency	Private	Either
	Diversify livelihoods	Private	Either
	Exit the fishery	Private	Either
Increased variability of yield	Diversify livelihood portfolio	Private	Either
	Design insurance schemes	Public	Anticipatory
Change in distribution of fisheries	Migration of fishing effort/strategies and processing/distribution facilities	Private/public	Either
Reduced profitability	Exit the fishery	Private	Either
Vulnerability of infrastructure and communities to flooding, sea level and surges	Add new or improved physical defences	Private/public	Anticipatory
	Managed retreat/accommodation	Private/public	Either
	Rehabilitate infrastructure, design disaster response	Private/public	Reactive
	Integrate coastal management	Public	Anticipatory
	Set up early warning systems, education	Public/private	Anticipatory
Increased dangers of fishing	Set up weather warning system	Public	Anticipatory
	Invest in improved vessel stability/safety/communications	Private	Anticipatory
Influx of new fishers	Support existing local management institutions, diversify livelihoods.	Public	Either

* May risk exacerbating overexploitation.

TABLE 7: POTENTIAL ADAPTATION MEASURES IN FISHERIES

[174] Worldfish. 2007. Fisheries and aquaculture can provide solutions to cope with climate change, Issues Brief 1701. The Worldfish Center, Penang, Malaysia.
[175] Op. cit. 18.

7.2. Mitigation

Mitigation involves human interventions to reduce the emissions of greenhouse gases by sources or enhance their removal from the atmosphere by "sinks". A "sink" refers to forests, vegetation or soils that can reabsorb CO2. Carbon dioxide is the largest contributing gas to the greenhouse effect. Currently mitigation methods are towards efforts in reducing greenhouse gas, especially CO_2, concentrations in the atmosphere. Market mechanisms introduced under the Kyoto protocol include Clean Development Mechanism (CDM) which includes emissions control and enhance sinks through afforestation or reforestation, Joint Implementation by funding projects with economies in transition and Emissions Trading[176].

With specific reference to fisheries, policy support for the following has been suggested to enable working towards adaptation/mitigation goals[177]:

- raising awareness of the impacts of climate change, to ensure that the special risks to the fishery sector are understood and used to plan national climate change responses, including setting of mitigation targets through mechanisms such as the Kyoto Protocol;
- reducing fuel subsidies granted to fishing fleets, to encourage energy efficiency and assist towards reducing overcapitalization in fisheries;
- supporting the use of static-gear - pots, traps, longlines and gillnets, which uses less fuel than active gear such as trawls and seines - and therefore emits less CO_2;
- restoring mangroves and protecting coral reefs, which will contribute to CO_2 absorption, coastal protection, fisheries and livelihoods;
- managing aquaculture to optimize carbon retention, reduce energy use and minimize impacts on mangroves and other important habitats; and
- raising awareness through seafood campaigns, reducing food miles, and promoting corporate social responsibility in the commercial sector

There are a few examples of ongoing mitigation programmes in the fisheries sector. In Sri Lanka, the Nagenahiru Foundation has launched a number of programmes with the participation of the community aimed towards climate change mitigation. In one programme, instead of kerosene lamps, the foundation has introduced solar powered LED lamp systems for prawn catching. It is expected to save foreign exchange spent on importing kerosene which amounts to 60,000 litres a year. In another programme, the kerosene lamps are by CFL lighting systems which are affordable and user-friendly[178].

[176] UNFCCC, 2009. Fact Sheet: The need for mitigation. http://unfccc.int/files/press/backgrounders/application/pdf/press_factsh_mitigation.pdf accessed January 29, 2011
[177] Op. cit. 19
[178] Nagenahiru Climate Change Mitigation. http://www.nagenahiru.org/projects/climate_change.html accessed February 8, 2011

7.3. The Cancun Adaptation Framework

At the Cancun Climate Change Conference in December 2010, Parties established the Cancun Adaptation Framework with the objective of enhancing action on adaptation, including through international cooperation and coherent consideration of matters relating to adaptation under the Convention. The draft decision (CP-16) on the Outcome of the work of the Ad Hoc Working Group on long-term Cooperative Action under the Convention says that there is a collective commitment by developed countries to provide new and additional resources, including forestry and investments through international institutions, approaching USD 30 billion for the period 2010–2012, with a balanced allocation between adaptation and mitigation[179].

7.4. Global Financing Mechanisms

At the global level, the Special Climate Change Fund (SCCF) was established under the Convention in 2001 to finance projects relating to: adaptation; technology transfer and capacity building; energy, transport, industry, agriculture, forestry and waste management; and economic diversification. This fund should complement other funding mechanisms for the implementation of the Convention.

Funding for adaptation is provided through the financial mechanism of the Convention, currently operated by the Global Environment Facility (GEF) and the Adaptation Fund Board (AFB). Funding opportunities include:

- The GEF Trust Fund, including support for vulnerability and adaptation assessments as part of national communications;
- The Least Developed Countries Fund (LDCF) under the Convention;
- The Special Climate Change Fund (SCCF) under the Convention;
- The Adaptation Fund (AF) under the Kyoto Protocol and managed by the AFB.

The Global Environment Facility (GEF), as an operating entity of the financial mechanism, has been entrusted to operate the SCCF. In 2004, the GEF Council approved a programming document which provides the operational basis for funding activities under the SCCF[180]. The latest document about this effort is dated 9 June 2010 and merely says that with regard to the Assessment of the Special Climate Change Fund, the Subsidiary Body for Implementation agreed to conclude its consideration of issues under this sub-item at its thirty-third session in December 2010.

[179] UNFCCC,
[180] The Special Climate Change Fund. http://unfccc.int/cooperation_and_support/financial_mechanism/special_climate_change_fund/items/3657.php accessed January 29, 2011

A detailed analysis by sectors was prepared for a background paper by GEF. The paper on agriculture, forestry and fisheries by B.A. McCarl[181] discusses investment costs for climate adaptation focusing on the year 2030. Two development scenarios are considered. One is the "Business-As-Usual" (BAU) scenario assumes a population of about 8 billion and a per capita income of USD 15000 in 2030 (in 2000 USD). The second scenario has a lower per capita income of USD 12000. A point to be noted is that adaptations are not to climate change alone and it is virtually impossible to untangle the climate change component. Also, while the report deals with the three sectors of agriculture, forestry and fisheries it is limited in its inability to fully separate these sectors. According to the author, a range of adaptation actions have been identified, but the extent of these needed cannot be fully linked to climate change. Many adaptation actions, however, have commonly been used and involve research, extension and infrastructure investments. These estimates amount to

- US$520 billion or $260 per new person for a BAU scenario without climate change largely due to large efforts needed to deal with advances in population. this adds
- An added US$12.9 billion without mitigation when climate change is considered and
- An added US$ 11.3 billion when mitigated climate change is considered relative to the no climate change baseline.

Nicholls[182] used the DIVA global impact and adaptation model to explore selected impacts (land loss costs, coastal flood costs and number of people flooded) and the costs of two adaptation policies (beach nourishment and sea dike construction). These are applied in a standard way around all the world's coasts using benefit-cost criteria. Flooding dominates both the adaptation costs and the damage costs. The author says that in DIVA, the costs of proactive adaptation are up to 37% greater 39 than reactive adaptation, but in practice, a proactive strategic approach will almost certainly be cheaper, especially in the longer term. While the absolute investments estimated by DIVA are large, at up to $22 billion per year, they are sums that present investment in coastal adaptation suggests could be feasibly mobilised if desired.

7.5. Policies

7.5.1. National Action Plan on Climate Change

[181] McCarl, B.A., 2007. Adaptation Options for Agriculture, Forestry and Fisheries. A Report to the UNFCCC Secretariat Financial and Technical Support Division. http://unfccc.int/files/cooperation_and_support/financial_mechanism/application/pdf/mccarl.pdf accessed January 29, 2011

[182] Nicholls, R.J., 2007. Adaptation Options for Coastal Areas and Infrastructure: An Analysis for 2030. Report to the UNFCCC, Bonn. http://unfccc.int/files/cooperation_and_support/financial_mechanism/application/pdf/nicholls..pdf accessed January 29, 2011

India had agreed to adopt regional DRR measures under the Delhi Declaration (2007)[183]. The Declaration said with specific reference to climate change that all stakeholders should be encourage to address the long term disastrous impact of climate change and effective steps should be taken under the principle of common but differentiated responsibilities to integrate disaster risk reduction with climate change adaptation initiatives at all levels in accordance with the UNFCCC and Kyoto Protocol. In June 2008 the Prime Minister of India released the "National Action Plan on Climate Change" (NAPCC)[184], which laid out principles to protect the poor through inclusive sustainable development and stressed inclusion of civil society and PPP in the development process. Eight National Missions form the core of the National Action Plan, representing multi-pronged, long-term and integrated strategies for achieving key goals in the context of climate change. They are:

1. National Solar Mission
2. National Mission for Enhanced Energy Efficiency
3. National Mission on Sustainable Habitat
4. National Water Mission
5. National Mission for sustaining the Himalayan Ecosystem
6. National Mission for a "Green India"
7. National Mission for Sustainable Agriculture
8. National Mission on Strategic Knowledge for Climate Change
    a. *will have on its research agenda* - socio-economic impacts of climate change including impact on health, demography, migration patterns and livelihoods of coastal communities.

State governments have been asked to prepare action plans. A National Consultation Workshop on Preparation of State Level Strategy and Action Plan on Climate Change was held in New Delhi on August 9, 2010[185]. Even before this, two state governments alone have gone ahead with state level plans on climate change. Gujarat established a separate Department for Climate Change in February 2009 and 39 clean energy initiatives of energy and petrochemicals, urban transportation, forest and environment, rural development and industrial and mines as well as studies on global warming impacts have been proposed. Orissa has a climate action plan dated June 2006 with a long list of proposed activities with a multidisciplinary integrated and coordinated convergence approach.

Current government expenditure in India on adaptation to climate variability, as shown in Figure 9, exceeds 2.6% of the GOP, with agriculture, water resources, health and sanitation, forests, coastal zone infrastructure and extreme weather events, being specific areas of concern.

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[183] Delhi Declaration on Disaster Risk Reduction in Asia 2007. Second Asian Ministerial Conference on Disaster Risk Reduction, New Delhi, 7 – 8 November 2007.

[184] Government of India, National action on climate change. Prime Minister's Council on Climate Change. http://moef.nic.in/modules/about-the-ministry/CCD/NAP_E.pdf

[185] MoEF, 2010. National Consultation Workshop on State Action Plans on Climate Change, http://moef.nic.in/modules/others/?f=sapcc-workshop

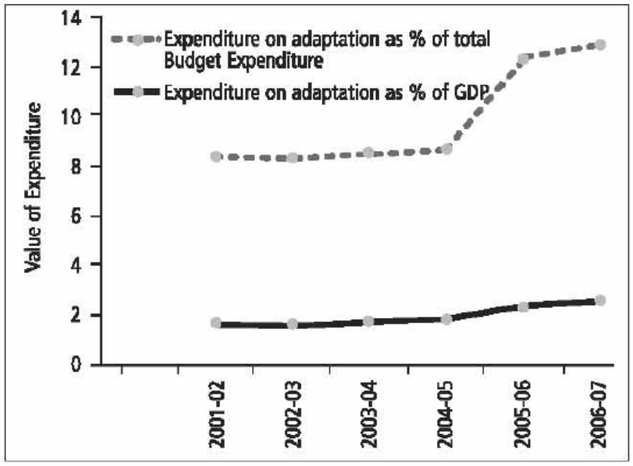

FIGURE 9: EXPENDITURE ON ADAPTATION PROGRAMMES IN INDIA (NAPCC)

According to the document, in the coastal regions, existing adaptation measures include the restrictions in the development in the 200-500 m zone from the HTL which aims at protecting coastal ecosystems and prevent their exploitation while simultaneously addressing concerns of coastal population and their livelihood. Coast-related programmes will focus on two elements, namely (1) coastal protection and (2) early warning systems. Priority areas on coastal zones include:

- Development of a regional ocean modelling system especially in the Bay of Bengal and the Arabian Sea
- High-resolution coupled ocean-atmosphere variability studies in tropical oceans, in particular the Indian Ocean
- Development of a high-resolution storm surge model for coastal regions
- Development of salinity-tolerant crop cultivars
- Community awareness on coastal disasters and necessary action; plantation and regeneration of mangroves
- Timely forecasting, cyclone and flood warning systems
- Enhanced plantation and regeneration of mangroves and coastal forests

The document says that development and poverty eradication would be the best form of adaptation to climate change. It also says that climate change impacts would be particularly severe on women as they would add to the deprivations already faced by women. However, this does not appear in the assessments or mechanisms that could support people to adapt[186].

7.5.2. National Environment Policy 2006[187]

India's National Environment Policy of 2006 refers to the issue of climate change affecting many areas and sectors. Specifically with reference to the coastal zone, it is pointed out that

[186] Op. cit. 171

[187] MoEF, 2006. National Environment Policy. http://www.envfor.nic.in/nep/nep2006e.pdf

while currently there are many causes for the degradation of coastal resources including pollution from industries and settlements and overexploitation of natural resources, in future, sea level rise may have additional adverse impacts. For this, coastal management plans as well as infrastructure planning and construction norms are to be taken up. With respect to mitigation of climate change, India's policies for sustainable development, by way of promotion of energy efficiency, appropriate mix of fuels and primary energy sources including nuclear, hydro and renewable sources, energy pricing, pollution abatement, afforestation, mass transport, besides differentially higher growth rates of less energy intensive services sectors as compared to manufacturing, results in a relatively GHG benign growth path.

7.5.3. Fisheries Policy[188]

In India, Marine fisheries within the territorial waters are the subject of maritime states whereas fisheries beyond this limit within the EEZ fall in the jurisdiction of Central Government. The Central Government besides playing an advisory role also provides funding support to the States/Union Territories for implementation of Central Sector and Centrally Sponsored Schemes. The policy objectives of the Marine Fishing Policy of 2004 are: (1) to augment marine fish production of the country up to the sustainable level in a responsible manner so as to boost export of sea food from the country and also to increase per capita fish protein intake of the masses, (2) to ensure socioeconomic security of the artisanal fishermen whose livelihood solely depends on this vocation. (3) to ensure sustainable development of marine fisheries with due concern for ecological integrity and bio–diversity. No specific mention of climate change or its impact on fisheries is made in the policy. The policy interestingly advocates against the motorisation of the entire traditional craft fleet as that would result in exertion of fishing pressure in a limited area. This particular policy can be seen to have important ramification with respect to climate change mitigation as it can bring down the carbon footprint of the sector.

7.5.4. National Disaster Management Policy 2009[189]

Section 5.1.7 states that “there are definite indications that climate change would increase the frequency and intensity of natural disasters like cyclones, floods and droughts in the coming years. In order to meet these challenges in a sustained and effective manner, synergies in our approach and strategies for climate change adaptation and disaster risk reduction shall be encouraged and promoted”.

[188] Government of India, 2004. Comprehensive Marine Fishing Policy. Ministry of Agriculture, Department of Animal Husbandry & Dairying New Delhi
[189] NDMA, 2009. National Disaster Management Policy, 2009. www.ndma.gov.in

The National Disaster Management Authority (NDMA) has released a number of guidelines and is formulating action plans for preventing and mitigating impacts due to various natural hazards. Guidelines for flood, drought and cyclone management (directly relevant to climate change) are available. The UNDP is also pursuing an action plan for capacity building for disaster preparedness and post-disaster recovery. The National Cyclone Risk Mitigation Project[190] aims to strengthen cyclone warning systems by improving last mile connectivity, improved infrastructure (cyclone shelters, bridges, roads), shelterbelt planting, coastal embankments to prevent saline ingress as well as community response systems by capacity building of the first responders in an emergency.

7.6. Legislation

7.6.1. CRZ 2011 and Island Protection Zone Regulation 2011[191]

On 6th January 2011, the CRZ 2011 and the IPZ 2011 were notified in the official gazette replacing the 1991 CRZ Notification. In essence similar to the 1991 notification, the CRZ 2011 has some important changes in its perspective. The preamble to the CRZ 2011 states that it is to enable sustainable development in coastal areas "based on scientific principles taking into account the dangers of natural hazards in the coastal areas, sea level rise due to global warming...". As part of the preparation of coastal zone plans, a ''hazard line' is to be mapped by MoEF through Survey of India (SoI) all along the coastline of the country and the hazard line shall be demarcated taking into account, tide, waves, sea level rise and shoreline changes. For the purpose of depicting the flooding due to tides, waves and sea level rise in the next fifty and hundred years, the contour mapping of the coastline shall be carried out at 0.5m interval normally upto 7 km from HTL on the landward side, and the shoreline changes shall be demarcated based on historical data by comparing the previous satellite imageries with the recent satellite imageries; and Mapping of the hazard line shall be carried out in 1:25,000 scale for macro level planning and 1:10,000 scale or cadastral scale for micro level mapping.

7.7. Adaptation Programmes

Coastal communities are increasingly affected by the impacts of hydro-meteorological hazards and climate change related studies so far generally are agreed that they are on the rise. A large number of people living along the coast belong to the category of illiterate, unskilled and resource-poor fishing, farming and landless labour. To reduce their vulnerability to frequent disaster events, the Chennai based M.S. Swaminathan Research Foundation has developed a biovillage paradigm and rural knowledge centres for

[190] National Cyclone Risk Mitigation Project http://ncrmp.gov.in
[191] CRZ 2011. Ministry of Environment and Forests, Government of India. http://moef.nic.in/downloads/public-information/CRZ-Notification-2011.pdf

ecotechnological and knowledge empowerment of the coastal communities at risk. The rural communities are given training and helped to develop capacity to adopt ecotechnologies for market-driven eco-enterprises. The modern information and communication based rural knowledge centres largely operated by trained semi-literate young women provide time- and locale-specific information on weather, crop and animal husbandry, market trends and prices for local communities, healthcare, transport, education, etc. to the local communities. The ecotechnologies and time- and locale-specific information content development are need-based and chosen in a 'bottom-up' manner[192].

Strengthening livelihoods is increasingly seen as a critical strategy for supporting adaptation. Studies by Practical Action in different countries amongst the poor has demonstrated strong consensus that holistic, livelihoods thinking is relevant to understanding and addressing disaster and climate change impacts[193]. WORLP, a partnership between the Government of Orissa and the UK's Department for International Development (DFID), started in 2000 and is still on-going. It has had a substantial impact on poverty, with a 30 per cent reduction in the number of poor households recorded in the project districts. The five successful strategies of the project are: empowering of the poor, building human capacity, building institutions for the poor, providing access to resources and managing natural resources[194].

Vivekanandan[195] has suggested a number of adaptive mechanisms for the fishing community. They include suitable energy-efficient craft-gear combinations with emphasis on static gear and focus on post harvest practices. He has also suggested promoting carbon sequestering such as by mass cultivation of agents such as seaweeds and the cultivation of halophytes such as Salicornia in coastal areas. Artificial reefs with multipurpose usage such as surfing, fish aggregation as well as coastal protection would help combat rough seas due to climate change. He also suggests fiscal mechanisms ranging from incentives to reduce the carbon footprint of the sector to self-protection of stakeholders. The Integrated Mangrove Fishery Farming System promoted by MSSRF[196] enables growing of mangroves along the inner and outer bunds of ponds. On top of the bunds, halophytes such as Sesuvium or Salicornia can be cultivated. Fish can be grown in the water spread area. The mangrove plants, when they grow as trees in about 4 to 5 years, will act as a bioshield. They also provide necessary nutrients and feed to fish/crab/prawn growing in the pond.

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[192] Kesavan, P.C. and M.S. Swaminathan, 2006. Managing Extreme Natural Disasters in Coastal Areas. Phil. Trans. R. Soc. A (2006) 364, 2191–2216; doi:10.1098/rsta.2006.1822; Published online 27 June 2006.

[193] Integrating approaches: Sustainable livelihoods, disaster risk reduction and climate change adaptation. Briefing Paper and report of a seminar organized by Practical Action, UK and funded by the Economic and Social Research Council. http://practicalaction.org/reducing-vulnerability/integrating-approaches-seminar

[194] Everett, B. Learning from a livelihoods project. In Integrating approaches: Sustainable livelihoods, disaster risk reduction and climate change adaptation. Briefing Paper and report of a seminar organized by Practical Action, UK and funded by the Economic and Social Research Council. http://practicalaction.org/reducing-vulnerability/integrating-approaches-seminar

[195] Vivekanandan, E. 2008 Options on fisheries and aquaculture for coping with climate change in South Asia (presentation). In "Climate Change and Food Security in South Asia 2011, Part 6, 359-376, DOI: 10.1007/978-90-481-9516-9_21

[196] MSSRF, 2010. Integrated Mangrove Fishery Farming System: Strengthening the resilience of coastal communities. MSSRF, Chennai.

In the Sunderban delta area, increasing saline intrusion is a major problem. Some of the adaptation strategies that have been tried by the local communities include the construction of mud barrages around the islands to protect from saline intrusion and mangrove reforestation. However, they appear to be hampered by the lack of finance and proper institutional mechanisms[197].

A study in Gujarat describes various climate change related adaptations that have been executed. The following example deals with the way in which water scarcity in a coastal area was addressed[198]. The Kachchh region experiences frequent droughts and it was found that while there was a steady increase in the community's dependence on the government for drought relief. There was, however, no mitigation of the effects of droughts. Along term drought proofing programme with focus on water related and livelihood related initiatives is being carried out by local NGOs and coordinated by Kachchh Nav Nirman Abhiyan. The former included construction of dams by the villagers after discussion. It was found that initially, women were more motivated but after a while, most village members participated and became more confident about long term drought proofing rather than short term drought relief by the government. Some of the lessons learnt for climate change micro adaptation from the project include[199]:

- The right information to the community,
- Involvement of the community in the process is linked to the ownership of the adaptation actions,
- Institutionalization at local government development plan is a definite challenge,
- Coordination among NGO, local government, and academic is crucial,
- Continued efforts and people's participation can overrule political pressure

In many cases, adaptation responses to climate change appear to be ad hoc and short term and could be inadequate in the long term. Sea walls and other coastal structures are a case in point. Concern is also there about existing protective mechanisms such as mangroves being destroyed because of 'development' activities[200], inappropriate construction of seawalls that led to the abandonment of turtle nesting sites[201] or due to incomplete understanding of the

[197] Op. Cit. 167.
[198] Shaw, Rajib, S.V.R.K. Prabhakar and A. Fujieda, 2005. Community level climate change adaptation and policy issues: Inter-linkages of environment, poverty and livelihoods: A case study from Gujarat, India. Report Submitted to United Nations University as a part of the Forum for Globally Integrated Environmental Assessment Modeling (GLEAM). Kyoto University Graduate School of Global Environmental Studies, March 2005. http://info.worldbank.org/etools/docs/library/230308/Session%202/Session%202%20Reading%202.doc
[199] Shaw, Rajib. 2005. Lessons Learned from Community Level Climate Change Adaptation: Case Studies of India and Vietnam. Consultation Meeting on Proactive Micro-Adaptation: Implications for International Climate Change Negotiations and Sustainable Development. http://www.iedm.ges.kyoto-u.ac.jp/publication/workshop/2005/29.pdf
[200] Janakarajan, S., 2007. Challenges and Prospects for Adaptation: Climate Change and Disaster Risk Reduction in Coastal Tamilnadu. Chapter 9 in "Working with the Winds of Change: Towards strategies for responding to the risks associated with climate change and other hazards" Second Edition (Edited by M. Moench and A. Dixit). ISET. http://climate-transitions.org/climate/node/777
[201] Balachandran, S. ,P. Sathiyaselvam & P. Dhakshinamoorthy, 2009. Rescue of a leatherback turtle (Dermochelys coriacea) at Manakudi beach, Kanniyakumari District, Tamil Nadu, and the need for an awareness campaign. Indian Ocean Turtle Newsletter No. 10, July 2009.

usage/role of certain systems as in the case of post-tsunami mass plantation of Casuarinas as bioshields (a good idea) in sand dune areas near Mahabalipuram which were actually turtle nesting sites (a point not considered) resulted in an outcry by environmentalists and the removal of the plants upto 45m from the HTL[202].

The UNFCC Compendium[203] on methods and tools to evaluate impacts of, and vulnerability and adaptation to, climate change is designed to assist Parties and other potential users in selecting the most appropriate methodology for assessments of impacts and vulnerability, and preparing for adaptation to climate change. In addition, a database of case studies on various coping mechanisms has also been put together[204].

7.8. Mitigation Programmes

7.8.1. Change in fuel:

A study of boats using LPG in Kerala found that the LPG units required only Rs 95 towards fuel cost per hour compared to Rs 253 in kerosene operated fishing units. The mean LPG consumption was found to be 12.46$\pm$ 4.29 kg[205].

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[202] Subramanean, J. and M. Vikram Reddy, 2010. Effect of casuarina (Casuarina equisetifolia) plantation on the sand skink (Eutropis bibronii Gray 1839) population. Current Science, Vol. 98, No. 5, 10 March 2010. http://www.ias.ac.in/currsci/10mar2010/604.pdf

[203] UNFCCC Compendium on methods and tools to evaluate impacts of, and vulnerability and adaptation to, climate change http://unfccc.int/adaptation/nairobi_workprogramme/knowledge_resources_and_publications/items/5457.php

[204] UNFCCC Database on Coping Strategies http://maindb.unfccc.int/public/adaptation/

[205] Riyas, K.V. and M. Harikrishnan, 2009. Studies on the use of Liquified Petroleum Gas as alternate fuel in motorized fishing units. Abstract of the paper presented at the 'National Seminar on Conservation and Sustainability of Coastal Living Resources of India, 1-9 December 2009, Cochin. – paper from CUSAT

8. Coastal Ecosystems as Carbon Sinks

Carbon capture mechanisms are of increasing interest. Carbon capture and storage (CCS), alternatively referred to as carbon capture and sequestration, is a means of mitigating the contribution of fossil fuel emissions to global warming, based on capturing carbon dioxide (CO_2) from large point sources such as fossil fuel power plants, and storing it in such a way that it does not enter the atmosphere. It can also be used to describe the scrubbing of CO_2 from ambient air as a geoengineering technique[206]. Out of all the biological carbon captured in the world, over half (55%) is captured by marine living organisms hence it is called blue carbon[207]. Carbon stores in seagrass beds and coastal wetlands—including coastal peats, tidal freshwater wetlands, salt marshes and mangroves—are vast, unaccounted natural carbon sinks, especially over multi-century time scales[208]. Methane production by various coastal wetlands does happen but as a net GHG sink, salt marshes, seagrass beds and estuarine forests are considered high, while mangroves are rated low to high depending on the salinity[209]. There is evidence that degradation of coastal ecosystems such as sea grasses and mangroves releases considerable GHG, enough in some cases to warrant inclusion into the national GHG budgets. Conserving such coastal habitats may enable their better functioning as carbon sinks. Current carbon prices could be sufficient for benefits of management and preservation of coastal wetlands to outweigh the opportunity costs of wetland-uses such as low-to-average income shrimp farming. This case is strengthened if environmental externalities of short term, highly profitable but unsustainable wetland uses are accounted for in cost-benefit analysis.

India has 3% of the global mangroves and 5% of Asian mangroves but the role of mangroves in carbon budget is not understood due to dearth of data. An assessment of global mangrove primary production from the literature results in a conservative estimate of ~ 218 ± 72 Tg C a^{-1} [210].India has 4445 km^2 of mangroves and the annual organic carbon burial is estimated at = 0.617855 Tg C. 1698 km2 of salt marsh vegetation exist along the Indian coast and their annual carbon burial rate is estimated at 0.256398 Tg C. Seagrasses cover 1391 km2 and contribute to the burial of 0.115453 Tg C annually. Examination of soil carbon in relation to depth in Vellar estuary (Cauvery delta, Tamil Nadu, India) indicated that burial rates were much higher in the case of luxuriant mangroves. The carbon stock in the sediment was found

[206] Carbon Capture and Storage, Wikipedia. http://en.wikipedia.org/wiki/Carbon_capture_and_storage accessed January 24, 2011
[207] Blue Carbon - The Role of Healthy Oceans in Binding Carbon. www.grida.no
[208] Capturing and Conserving Natural Coastal Carbon: Building mitigation, advancing adaptation. 2010. World Bank, IUCN, ESA PWA
[209] ibid.
[210] Bouillon, Steven, Alberto V. Borges,Edward Castaneda-Moya, Karen Diele, Thorsten Dittmar, Norman C. Duke, Erik Kristensen, Shing Y. Lee, Cyril Marchand, Jack J. Middelburg, Victor H. Rivera-Monroy, Thomas J. Smith III, and Robert R. Twilley, 2008. Mangrove production and carbon sinks: A revision of global budget estimates. Global Biogeochemical Cycles, Vol. 22, GB2013, doi:10.1029/2007GB003052.

to increase with age as shown in field studies in artificially developed mangrove ecosystems[211].

[211] Kathiresan, K. Carbon Cycling in Mangrove Ecosystems. From the presentation made at the Deltas Workshop, Chennai, December 2009. In Deltas: Coastal Vulnerability and Management. Report of a workshop held at Chennai, India during 7-11 December, 2009 edited by Ramesh Ramachandran, Purvaja Ramachandran, Ahana Lakshmi, Anjan Datta and Hartwig Kremer. IOM, Anna University Chennai.

9. Carbon Footprint of Fisheries

Activities that contribute to the carbon footprint of fisheries include capture operations, transport, processing and storage. A vessels carbon footprint is the emission of Greenhouse gases (measured in kilos or tonnes of CO_2) from fossil fuels during the building, use and disposal of a vessel[212]. A large proportion of the small scale sector is boat based fisheries using motorized vessels. The subsector's fuel: CO_2 emissions ratio has been estimated at around 3 teragrams of CO_2 per million tonnes of fuel used. Fuel efficiency is defined primarily by motor, propulsion and gear characteristics, but is substantially affected by fisheries management and practice[213].

It is useful to note that currently aviation and shipping lie outside any emissions trading scheme. As the vast majority of fisheries operations are entirely reliant on fossil fuels, they are vulnerable to any decrease in the availability or increase in the price of fuel[214]. This is also important in the context of fuel subsidies and efforts to ensure that efficiency of engines as well as fisheries is improved.

A WWF study on the carbon footprint of tuna fisheries in the Philippines indicated that fishery fleet fuel consumption is typically the largest contributor to overall carbon footprint. Purse seine fishing gives the lowest carbon footprint per kilogram of landed catch, while long line gear has the largest footprint[215]. The other major contributors to the overall carbon footprint are cannery operations and transportation by air. Cold storage, on the other hand, has a relatively minor contribution.

The diesel provided for fishing boats in India is supposed to have higher sulphur levels[216] and hence the emissions of sulphur oxides and black carbon are likely to be higher. Carbon footprint: it is estimated that annual CO_2 emission of marine fishing boats in India was 3 mn tonnes during 2005-07. It was found that the mechanized boats emitted 1.67 tonnes of CO_2 per tonne of fish catch, and motorized boats with outboard engine emitted 0.48 t CO_2 per t of fish catch. Among the mechanized craft trawlers emitted more CO_2 than the gillnetters and dolnetters. Based on the data available on the number and size of fishing boats in India in the past years, it is estimated that CO_2 emission per tonne of fish caught has increased by 64% in a period of 25 years[217]. Data were collected on the diesel consumption of about 1332 mechanized boats and 631 motorized boats in the major fishing harbours along the east and west coasts of India. Initial estimates indicate that the fossil fuel consumption by marine

[212] Seafish. 2009. Fishing vessel fuel emissions. www.seafish.org
[213] Op. cit. 18
[214] Daw, Tim ., W. Neil Adger, Katrina Brown and Marie-Caroline Badjeck, 2008. Review of climate change and capture fisheries. Report for FAO High-Level Conference on
World Food Security and the Challenges of Climate Change and Bioenergy 3-5th June 2008.
[215] Tan, R. R. and A.B. Culaba, 2009. Estimating the Carbon Footprint of Tuna Fisheries.
http://assets.panda.org/downloads/estimating_the_carbon_footprint_of_tuna_fisheries_9may2009.pdf
[216] Rao, K.V.B.M. 2010 Personal communication.
[217] CMFRI Annual Report, 2008-09

fishing boats is around 1200 million litres per year and CO_2 emission by the marine fishing sector is around 2.4 million tonnes per year[218].

[218] Vivekanandan, E. M. Rajagopalan, N. G. K. Pillai, K. S. Mohamed, J. Jayasankar, P.K. Krishnakumar, K. Vijayakumaran, H.M. Kasim, Joe Kizhakudan and V.V.Singh, 2008. Impact, adaptation and vulnerability of Indian marine fisheries to climate change. ICAR Network Project, CMFRI Annual Report, 2007-08.

10. Indigenous / Traditional Knowledge – Responses to Climate Change – Case Studies

Article 8(j) of the CBD states that contracting Parties must *'respect, preserve and maintain the knowledge, innovations and practices of indigenous and local communities'*. Today, local and indigenous knowledge is widely recognized as a key element in biodiversity conservation. A body of knowledge has been built up on indigenous knowledge with respect to fisheries but most of it deals with the management of fisheries – and for the fishers, it is actually 'a way of life that evolves continuously to address changes in fisheries and fishers'[219]. This localized knowledge is essential with the constant changes in the marine ecosystems due to a variety of causes including climate change because this knowledge is seen as critical to the recovery of our marine ecosystems and the communities that depend on them. Fishers' knowledge, often anecdotal in nature, may often be the only source of information on the history of changes in local ecosystems and on their contemporary state that is of sufficiently fine scale to help us design ways to protect stock remnants and critical habitats[220].

Indigenous Knowledge (IK) or Traditional Ecological Knowledge (TEK) of fishermen in India has to do with activities that help them to plan their fishing operations such as forecasting rains (by observing the production, movement and colour of clouds and the intensity of winds), prediction of winds (direction, speed) to enable them to navigate, colour of the sea and current flows in different seasons. These help them to decide on what kind of nets to use as they are able to predict what kind of fish would abound under a particular combination of circumstances[221,222].

The following conclusions were drawn from interviews with fishermen from Maharashtra, Kerala and Tamil Nadu on their indigenous technical knowledge regarding climate change:

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[219] Haggan, Nigel, Barbara Neis and Ian G. Baird, 2007. Introduction: Putting fishers' knowledge to work. In "Fishers' Knowledge in Fisheries Science and Management (Edited by Nigel Haggan, Barbara Neis and Ian G). Baird Coastal Management Sourcebooks 4, UNESCO Publishing, Paris, France.
[220] Johannes, R.E. and B. Neis, 2007. The value of Anecdote. In "Fishers' Knowledge in Fisheries Science and Management (Edited by Nigel Haggan, Barbara Neis and Ian G). Baird Coastal Management Sourcebooks 4, UNESCO Publishing, Paris, France.
[221] Santanam, R. Traditional Ecological Knowledge of Tamilnadu (India) Fishermen www.ser.org/files/ppt/Ramasamy%20Santhanam%20PPT.pdf
[222] Swathi Lekshmi, P.S. and A.P. Dinesh Babu, 2009. Indigenous Technical Knowledge and ancient proverbs of the coastal fisherfolk of Kerala and their implications. Indian J of Traditional Knowledge. Vol 8(2): 296-297

• Marine fishermen have heard about climate change, but are confused with annual climatic variability and climate change.

• The perceptions on climate change and adaptation options differ between fishermen of different states.

• They believe that reduction in fish catch in recent years is essentially due to juvenile exploitation, habitat destruction and overfishing.

• Fishermen attach maximum importance to wind direction and speed as the drivers of fish abundance and availability, followed by rainfall and temperature. They believe that direction as well as speed of wind and temperature have changed over the last 20 years, which will have adverse impact on fisheries.

• Sea erosion in Kerala and Tamil Nadu, cyclones in Maharashtra and Tamil Nadu and sea status off Maharashtra are perceived as major safety concerns.

• In the event of cyclones and sea erosion, fishermen of Tamil Nadu prefer temporary exit from their villages; their counterparts in Kerala prefer temporary exit as well as permanent rehabilitations to interior dwellings.

• A large majority of fishermen listen to and follow daily weather bulletins in the media. They are prepared to take weather related insurance if the premium is within their capacity.

• Fishermen believe that fish catches will decline in future. However, they do not want to leave the profession, but want their children employed in government jobs.

Indigenous Technical Knowledge (ITK) of fishermen on climate change, CMFRI Annual Report, 2010[223]

[223] Op. Cit. 73.

11.Vulnerability Analysis

Climate change is one of the many factors that are making fishing and fishing communities more vulnerable in socio-economic terms. The ecological impacts of climate change translate to availability of fish, not only as a consumable commodity but also as a marketable one. Fish constitutes a significant component of the GDP of a number of countries apart from the employment and food security provided especially to the poorest section. An important question therefore is where do climate change impacts on fisheries have greatest social and economic significance. From the survey of literature done so far, it appears that the climate change – fisheries issue is complex with extensive ramifications and to understand this, vulnerability at various levels needs to be understood, from global to local levels.

The most comprehensive study of the vulnerability of national economies to the impacts of climate change with specific focus on the fisheries sector is the 2008 report spearheaded by the Worldfish Center[224]. They found that the vulnerability was due to combined effect of predicted warming, the relative importance of fisheries to national economies and diets, and limited societal capacity to adapt to potential impacts and opportunities.

Vulnerability is a 'set of conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of a community to the impact of hazards[225]. Disasters are regarded as a function of hazards and vulnerability. Vulnerability can be physical, social or attitudinal[226]. Most assessment frameworks follow a similar principle of participatory vulnerability analysis using a set of indicators for which data may be collected through surveys for quantitative assessment with supportive qualitative assessments done using free-form narratives, discussions and other methods.

Kavi Kumar (2010)[227] points out that vulnerability can be assessed using a 'starting point' or 'end point' where the key difference between the two is in terms of assessing the adaptive capacity. Adaptation responses need to be relevant to the local community to be effective and also need to be seen as a continuum of processes.

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[224] Allison, Edward H., Allison L. Perry, Marie-Caroline Badjeck, W. Neil Adger, Katrina Brown, Declan Conway, Ashley S. Halls, Graham M. Pilling, John D. Reynolds, Neil L. Andrew & Nicholas K. Dulvy, 2008. Vulnerability of national economies to the impacts of climate change on fisheries. Fish and Fisheries, 10: 173–196. doi: 10.1111/j.1467-2979.2008.00310.x

[225] Hyogo Framework of Action, www.unisdr.org

[226] Ahmed, S and D. Mustafa. 2007. Understanding Vulnerability, building capacity: Concepts, Approaches and Insights. Chapter 4 in "Working with the Winds of Change: Towards strategies for responding to the risks associated with climate change and other hazards" Second Edition (Edited by M. Moench and A. Dixit). ISET. http://climate-transitions.org/climate/

[227] Kavi Kumar, K.S., 2010. Climate Change and Adaptation. Dissemination Paper-10. Centre for Excellence in Environmental Economics, Madras School of Economics, Chennai.

Patwardhan (2006)[228] has analysed the exposure effects framework in the context of climate change and table 3 from this paper is reproduced below (Table 8) with suggestions (mine, in blue) for adapting this in the context of Climate Change and the Small Scale fishing community. This is largely in the context of physical vulnerability.

Process	Coastal change equivalence
Exposure	Sea level rise, change in sediment budget, change in storm statistics Sea level rise, change in storm statistics
Effects	Change in beach width, altered structural damage from extreme events, intrusion of salt water into a coastal aquifer. Conditioned on local geomorphology, sediment budgets and other physical characteristics Change in beach width, intrusion of water into coastal aquifer, coastal settlements
Perception and valuation	Changes in recreational benefits, property loss from extreme events, or an increase in water supply costs. Loss of beach space for beaching craft, landing fish, mending nets, drying fish, living space for communities close to the HTL These costs and benefits are conditioned on the resources at risk (amount and character of built property, population), on the existing regulatory and financial context such as availability of flood insurance, and on mitigative and adaptive policy actions Moving away would require higher transport investment, loss of fishing time, loss of 'spotting' fish by observing sea colour change etc., increased financial outlay for changing fishing practices...

TABLE 8: EXPOSURE-EFFECTS FRAMEWORK IN THE CONTEXT OF COASTAL CHANGE (adapted and modified from Patwardhan, 2006)

The exposure-effects (risk assessment) framework is the same that has been adapted successfully for other situations including exposure to chemicals. A similar exercise could be carried out for other processes related to climate change's various impacts on fisheries.

A Vulnerability Index[229] has been constructed based on the approach used to calculation of the Human Development Index (HDI) for the assessment of vulnerability, and an Adaptive efficiency Tool has been developed for adaptation. The development of these involves examining existing tools, adding improvisations and incorporating local factors. This development has been carried out in the context of coastal zones. Two frameworks were used in the development of the Vulnerability Index. The Livelihood Vulnerability and Adaptation Framework identified livelihoods likely to be affected by climate related uncertainties, which include rainfall, temperature, sea level changes and precipitation. The quantification of vulnerability involved a study of settlements, food, health, ecosystems and water, which

[228] Patwardhan, A., 2006. Assessing vulnerability to climate change: The link between objectives and assessment. Current Science, Vol. 90, No. 3, 10 February 2006

[229] Narayanan, K., D. Parthasarathy and Unmesh Patnaik, Tools for Assessing Vulnerability and Adaptation. Proceedings of the International Workshop on Vulnerability and Adaptation to Climate Change: From Practice to Policy. Organized by Winrock International on May 11-12, 2006, New Delhi, India. http://www.basic-project.net/

provides a sensitivity indicator. Coping and adaptive indicators are derived from the economy, human resources and environment. These may be used with national baseline estimates and projections of sectoral – indicators. This methodology has been used mainly for agricultural communities in coastal areas. A modified set of variables for the fisheries sector has been proposed by Sathiadas (2008)[230]:

Sector/system	Variables needed for scenario
General	Population growth, economic growth (GDP, exports, employment etc)
Coastal zones	Population density and occupancy in CRZ Demographic structure Socioeconomic variables: Investments Land use Housing patterns Coping mechanisms for disasters Adaptation capacity (economic, technological, institutional)
Climatic Vulnerability	Variance in annual rainfall Increase in sea level and displacement ENSO (El Nino Southern Oscillations) Incidence of natural hazards
Human health	Food and water accessibility Health care Adaptation capacity (economic, technological, institutional)
Fishing	Use of common property resources Fishing (practice and intensity) Fish production and potential (Bio physical and economic estimations) Adaptation capacity (economic, technological, institutional)

TABLE 9: VARIABLES FOR CONSTRUCTING VULNERABILITY INDEX[231]

A number of studies have looked at the climate change impacts on coastal/fishing communities. Most of them follow a similar framework of participatory assessments and the development of different kinds of vulnerability indices. A few of these case studies have been cited highlighting some of the methods followed.

In the nationwide project "Community Charter on Climate Crisis" [232] which covered 12 locations in 5 ecosystems and 20 communities chosen from different corners of India, a set of participatory tools were used. These were:

- Problem Tree: enabled people to collectively analyse their climate-related problems, and sort them into "root causes" and their "manifestations".
- Resource Mapping: helped them to plot their forests, farms, pastoral and fishing resources
- Time Line: the reason why the communities were saying what they were saying
- Problem solving matrices which mirrored the hopes and strengths they still had in great measure

[230] Sathiadas, R., 2008. "Economic concepts and applications with special reference to climate change". Winter School on Impact of Climate Change on Indian Marine Fisheries, CMFRI, 2008.
[231] Sathiadas, R., 2008. "Economic concepts and applications with special reference to climate change". Winter School on Impact of Climate Change on Indian Marine Fisheries, CMFRI, 2008.
[232] People's Coalition on Climate Change, 2010. Community Charter on Climate Crisis: Outcome on an Indiawide participatory initiative.

The fishing and coastal communities that participated were represented by people from the Gulf of Mannar, Chilika lagoon in Orissa and Sunderbans in West Bengal. The participants discussed not only problems that whose causes were likely to be climate change but also other reasons by approaching issues such as fish catch and water availability, charting changes through time and analysing the causes.

The NACA[233] project focused on coastal and inland shrimp farmers in Andhra Pradesh. The methodology used was to have a number of focus group discussions (FGD) and a stakeholder workshop. In the FGD, a cross section of farmers varying in age, experience in farming and owning farms of different sizes from different societies of the study area participated in the FGD meeting. The FGDs were conducted in Telugu (local language) and English with translations between the two languages. FGD meeting process involved the discussions among the sub-groups and the ideas were posted on the cards. For the stakeholder workshop, key stakeholders, individuals and organizations were characterised based on their understanding on CC issues and impact on shrimp farming, adaptive capacity and interests in implementing them. Primary stakeholders are those ultimately affected, either positively or negatively by CC actions. Secondary stakeholders are the ‘intermediaries’, that is, persons or organizations who are indirectly affected by the CC actions. The tasks of all the identified stakeholders related to shrimp farming and climate change such as the role they play in shrimp farming sector, financial, technical and research support, natural resources and aquaculture policy management, and collection/ maintenance/ dissemination of data were analysed. According to the report, the use of participatory processes such as facilitated semi-structured focus group discussion and facilitated stakeholder workshop was a novel technique for the shrimp farmers and stakeholders in Andhra Pradesh. It helped in understanding the perceptions, vulnerability, and adaptability to climate change on small scale shrimp farmers.

Initial insights from an ongoing programme on disaster risk reduction and adaptation to climate change in South Asia have been brought out in a book, “Working with the Winds of Change” [234]. The studies being undertaken in India, Pakistan and Bangladesh follow a similar methodology. In India, the study areas are coastal Tamil Nadu and coastal Gujarat. The broad methodologies followed in the studies available were:

- Situational analysis:
    - Identification of threat(s), understand who is vulnerable, how they are coping
    - Tools used: historical profiles, transects, seasonality calendars, community mapping, hazard mapping
- Analysis of causes
    - Analyses of different causes of vulnerability, prioritization of vulnerable groups
    - Tools used: FGD, Ranking matrix

[233] Op. Cit. 108

[234] Mench, M and A. Dixit, 2007. Working with the winds of change: Toward Strategies for Responding to the Risks Associated with Climate Change and other Hazards. Second Edition. ProVention Consortium; Institute for Social and Environmental Transition-International; Institute for Social and Environmental Transition-Nepal http://climate-transitions.org/climate/node/777

- Assessing capacities
    - Assess different individual/ community capacities to cope or adapt in given social, institutional and governance context
    - Tools used: Venn Diagram, FGD, Shared Learning Dialogues

A case study of climate change impacts and DRR techniques in Tamil Nadu[235] was carried out in the coastal district of Cuddalore where the basic livelihoods are fishing and agriculture. The methodology used included initial secondary data collection from various governmental and non-governmental sources, literature collection, time-series data collected from the Indian Meteorological Department, a series of shared learning dialogues at village, mid- and state levels, ranking potential costs and benefits of strategies to reduce risks as perceived by communities, etc.

Phase 1 of ISET's approach to vulnerability assessment in coastal Gujarat[236] (2006- 2007) began with participatory assessments of vulnerability, drawing on various frameworks for assessing the three dimensions of vulnerability - physical, social, and attitudinal. Information/data was collected through participatory exercises, often with women and men separately, such as historical time-lines of disasters or seasonality calendars to identify monthly variations in food, water, and livelihood security. The Vulnerability Capacity Index (VCI), a simple quantitative vulnerability index based on 11 'drivers of vulnerability is being developed. Scores are attached to the different indicators, and the three dimensions of vulnerability are then weighed to come up with a composite score. The index is not comprehensive; it is, rather, indicative.

Material Vulnerability Weightage: 35%	Institutional Vulnerability Weightage: 50%	Attitudinal Vulnerability Weightage: 15%
• Income source – local/non-local, land or non-land based • Educational attainment, particularly for women • Assets – fungibles • Exposure to risk – distance from river, coast, landslide zone	• Social networks • Extra-local kinship ties – response at times of adversity • Infrastructure – access to roads, water, sanitation, electricity, health services, communication • Proportion of dependents in household • Reliability of early warning systems • Belonging to the disadvantaged – caste, religious or ethnic minority	• Sense of empowerment, derived from: • Access to leadership at different levels – community, regional, national • Knowledge about potential hazards
Source: Drawn from Mustafa and Ahmed 2008.		

TABLE 10: INDICATORS OF VULNERABILITY AT THE RURAL HOUSEHOLD LEVEL (ILLUSTRATIVE)

Some of the points noted by the researchers include the need for conceptual tools to be simple and manageable with practical indicators that can be used by communities to gather data, enhancing social networks as fall-back mechanisms for women, gender-sensitive extension

[235] Op. cit. 199
[236] Op. cit. 171

systems that provide capacity building and the need to identify and validate women's priority needs in a disaster situation and strengthening their participation in disaster governance.

Going by the premise that while, in general, vulnerability to extreme events is usually addressed on a macro scale (districts), relative vulnerability of micro units may be more useful to a policy maker, Das (2009) [237] defines the vulnerability index as the probability of facing non-zero deaths due to severe cyclones and calculate the indexes from a cyclone impact (human casualty) function using both Logit and Poisson specifications. Based on human casualty in the 1999 super cyclone in Orissa, villages established in the mangrove habitat areas after cutting down the forest and the ones with a higher percentage of marginal workers were found to be more vulnerable while those with mangrove vegetation behind them and situated near a big river were seen as being less vulnerable.

As mentioned in an earlier section, a key issue that needs to be avoided in the implementation of adaptation/mitigation programmes is executing projects that result in greater vulnerability of the addressed populace. Since the World Bank and such institutions undertake large, expensive, multi component projects, a screening tool that includes climate risks in development projects at the design stage has been developed. ADAPT[238] is a screening and design tool intended for project developers, field staff, multilateral organizations and NGOs and is not a community level tool for decision making. It provides a quick, initial check of potential issues that might arise in design or implementation of project that is climate sensitive. It guides project developers to appropriate knowledge and experience. It also, generates a database of local experts, who are familiar with the project activity and raises awareness of risks due to climate change. It offers suggestions to make the project more robust.

[237] Das, S. 2009. Addressing Coastal Vulnerability at the Village Level: The Role of Socio-economic and Physical Factors. Institute of Economic Growth, University of Delhi Enclave, North Campus, Delhi – 110 007, India. Working Paper Series No. E/295/2009. www.iegindia.org
[238] Iqbal, F.Y., 2006. Assessment and Design for Adaptation (ADAPT): a prototype tool. Proceedings of the International Workshop on Vulnerability and Adaptation to Climate Change: From Practice to Policy. Organized by Winrock International on May 11-12, 2006, New Delhi, India. http://www.basic-project.net/

12. Perceived Gaps

Climate change studies with respect to fisheries can be looked at from the ecological aspects and the socio-economic aspects (Figure 3). In the following sections, a brief look at the major gaps perceived on the basis of the literature review undertaken is provided.

12.1. Ecological Aspects

There are 1570 species of finfishes and about 1000 species of shellfishes coexisting in the same fishing ground in India and the multispecies Indian fishery comprises of over 200 commercially important finfish and shellfish species[239]. The oil sardine Sardinella longiceps was the largest contributor to the marine fish resources during 2009 accounting for 12.4% followed by penaeid shrimps forming 8.9% of the total catch[240]. The report also mentions that while Indian mackerel, catfish and threadfin breams registered an increase in catch, there was a decline of 20% in the cephalopod catch. There are also no studies talking about the change in catch composition and relating that to climate change. However, studies related to climate change appear to have focused only on the oil sardines, mackerel and threadfin breams, only three of the 200 or so commercially important fish and shellfish species. While studies on coral bleaching events are reported, no specific studies linking fish species reduction/loss to such bleaching events appear to have been done. Carbon sequestration abilities of coastal ecosystems such as seagrass and mangroves needs to be explored.

12.2. Socio-economic aspects

According to recent reports, there are 2643 coastal fishing villages in India. Only a small percentage of these have been studied for vulnerability – mostly with respect to shoreline change. There are other aspects that need to be studied in greater detail and a few of these include:

- Impact of changes in catch composition on people with focus on Fish processors (especially women dry-fish processors), traders
- Changes in craft-gear composition – as a response to the change in catch composition
- Carbon footprint of fish harvest with different gears
- Impacts of provision of hazard-resilient housing (e.g. post tsunami housing schemes in Tamil Nadu) and other Disaster Risk Reduction schemes including capacity building on the welfare of fisherfolk (increased adaptation?)
- International and national markets (glut and dropping prices of some species)
- Fish disease as well as bacterial/viral infections and transmission due to higher temperatures
- Types of mitigation strategies that can be pursued by the small scale fishing sector (e.g. move towards CNG as fuel, increased efficiency of engines), the subsidies and support that would be required; other clean energy alternatives

[239] Op. cit. 68
[240] CMFRI, 2010. Annual Report. www.cmfri.org.in

- Improved early warning systems (from natural hazards such as cyclones) not only for those on land but also for those in the sea; as well as sea safety practices
- Salinization of groundwater due to seawater intrusion and hence, water collection systems for improving potable water availability as well as bioshields to prevent such intrusions
- Nutrition and health as well as disease transmission due to elevated temperatures, water borne diseases due to water stagnation.

While there are dozens of documents relating to climate change, the literature review showed that the studies are scattered and not comprehensive enough. Also, while studies on the natural sciences aspects are reasonably extensive, the social science component is weak; in fact this is even reflected in the NATCOM composition[241]. Assessing vulnerability or deciding on adaptation strategies with climate change alone in mind is difficult. They have to be integrated with the overall development agenda.

[241] Kavi Kumar, K.S., Priya Shyamsundar and A. Arivudai Nambi, The Economics of Climate Change Adaptation in India – Research and Policy Challenges Ahead. Summary of discussions at the brain-storming workshop on the Economics of Climate Change Adaptation during 12-13 February 2010 at the MSE, Chennai.