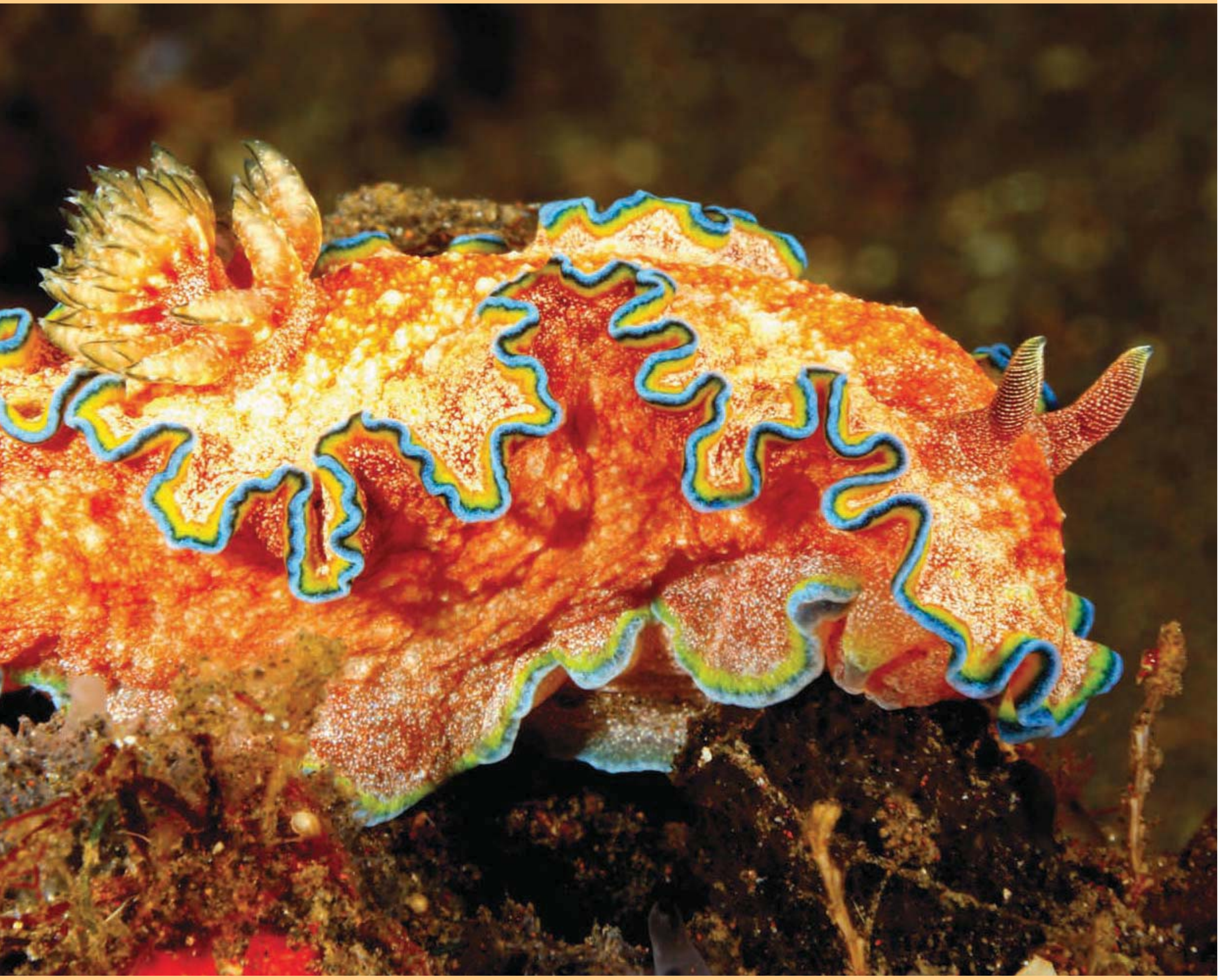
सत्यमेव जयते
Government of India

प्रकृतिः रक्षति रक्षिता
Nature Protects if She is Protected
Ministry of Environment, Forest and Climate Change

CLIMATE CHANGE AND THE VULNERABLE INDIAN COAST

R Ramesh | J R Bhatt



Publication Information

CLIMATE CHANGE AND THE VULNERABLE INDIAN COAST

Citation:
MOEFCC, (2018). *CLIMATE CHANGE AND THE VULNERABLE INDIAN COAST*
Edited by Ramesh. R, Bhatt J.R.
Ministry of Environment, Forest and Climate Change, New Delhi.

ISBN 978-93-5346-195-9

Design and production:
Majix Design, 5-2B Nat West Vijay, Pallikaranai, Chennai 600100

For further details, please contact:
Dr. R. Ramesh
National Centre for Sustainable Coastal Management
Ministry of Environment, Forest and Climate Change,
Anna University Campus, Kotturpuram,
Chennai 600025, Tamil Nadu
Phone: +91 44 2220 0606 / 2220 0950
Email: rramesh_au@yahoo.com

Dr. J R Bhatt
Scientist G,
Ministry of Environment, Forest and Climate Change
Government of India, New Delhi 110003
Tele-Fax: 011-24692593
Email: jrbhatt@nic.in

11

Impacts of climate change on the fishing and coastal communities

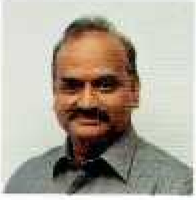
P S Swathi Lekshmi

Socio-economic Evaluation and Technology Transfer Division, ICAR-Vizhinjam Research, Centre of CMFRI, Vizhinjam, Thiruvananthapuram, Kerala, India

ABSTRACT

Climate change has a profound impact on aquatic ecosystems affecting the distribution and productivity of fisheries. Coastal communities dependent on fishery resources for their livelihood are most vulnerable to such changes. This study undertaken in the coastal districts of Karnataka, India documents the effect of climate change on the environment, fishery, social, economic and development drivers. Vulnerability indices were constructed to identify the districts which would be most affected by climate change. The study revealed that the coastal district of Udupi was the most affected with the highest vulnerability index of 0.46. Among the various drivers, development ranked foremost among the fishers perception of climate change.

ABOUT THE EDITORS

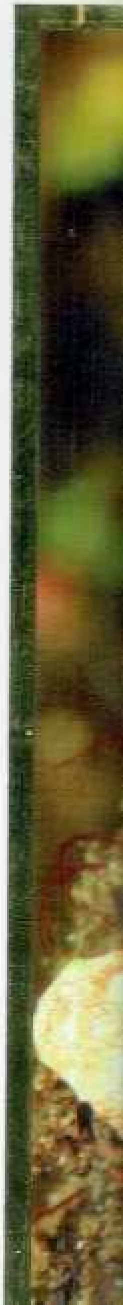


R Ramesh

Ramesh Ramachandran is director of the National Centre for Sustainable Coastal Management at the Ministry of Environment, Forest and Climate Change, Government of India. His expertise includes coastal/marine biogeochemistry, conservation of coastal/marine biodiversity, and Integrated Coastal Zone Management. He has over 135 research publications and over 100 technical reports. Among the several awards Professor Ramesh has received are the University Grants Commission UGC-Swami Pranavananda Saraswathi Award in Environmental Sciences and Ecology for the Year 2007 (awarded in February 2010). He was the chair of the Scientific Steering Committee of LOICZ (currently renamed as Future Earth Coasts), member of the Scientific Steering Committee of the Monsoon Asia Integrated Regional Study, chairman of the International Working Group on Coastal Systems on the Role of Science in International Waters Projects of UNEP-GEF, as well as being affiliated with the Bay of Bengal Large Marine Ecosystem Programme of the FAO. He is currently the chair of the Global Partnership in Nutrient Management (GPNM) of UNEP.

Dr J R Bhatt

Dr J R Bhatt is working as Scientist G in the Ministry of Environment, Forest and Climate Change, Government of India. He is the designated National Focal Point for the Intergovernmental Panel on Climate Change, Asia-Pacific Network for Global Change Research and National Communications and their Biennial Update Report under United Nations Framework Convention on Climate Change. He has represented Government of India on climate change and biodiversity-related issues both nationally and internationally.



1. Introduction

Climate Change is rapidly impacting aquatic ecosystems including marine, fresh and brackish water. Climate change plays a major role in influencing fish distribution, fish migration and also in deciding the fish productivity in various countries of the world. It will have a profound impact on humans and ecosystems during the coming decades through variations in global average temperature and rainfall. It is predicted to bring about diverse impacts with extreme weather conditions across regions like intense rainfall and flood risks while on the other side there would be extreme droughts besides higher tides, intense storms, warmer oceans and erosion along coastlines as an outcome of sea level rise. Climate change can affect lives, livelihoods and production systems posing high risk to people living in rural areas, particularly the poor. This is seen as a challenge and threat specifically to India's growing economy. Fish spawning is especially sensitive to temperature, and several species of marine fish are known to spawn only at a particular water temperature. Climatic changes are already affecting the availability, behaviour and distribution of some commercial fish. It has been observed that there is a positive relationship between the sea surface temperature and spawning activity of threadfin breams. The fish are shifting their reproductive activities to a period where the temperature is closer to their optimum. The changes in reproduction patterns will play an important role in the availability of these fish and the livelihoods and incomes of fisherfolk. One of the popular food fishes with which changes in behaviour were noticed due to climate change is the Oil Sardine, a coastal, schooling fish with a high reproductive rate (Badjeck et al., 2010). Its distribution is restricted to the Malabar region along the southwest coast; however, it plays a crucial ecological role in the ecosystem both as a plankton feeder and as food for large predators. It has economic importance in that the annual average production is 3.37 lakh tonnes which comprise 8.8 % of India's total catch. (CMFRI, 2018) It is also important in terms of food and nutritional security as it is a good source of protein, serving as a staple food for millions of coastal people. Due to the current warming of the Indian Ocean, the oil sardine has already spread to the northern and eastern boundaries of its original distribution in the Indian Ocean. Vulnerability has become the key concept of climate change. Vulnerability is the degree to which a system is susceptible to or unable to cope with adverse effects of climate change including climate variability and extremes (IPCC, 2001). Climate- related vulnerability assessments are based on the characteristics of the vulnerable system spanning over physical, economic and social factors (Gillman et al., 2008). The impacts of climate change can be addressed through adaptation and mitigation. The costs and benefits of adaptation are essentially local or national, while the costs of mitigation are essentially national whereas the benefits are global. Several international agencies, including the World Bank and the Food and Agriculture Organization (FAO, 2007) have programs to help countries and communities adapt to global warming, for example by developing policies to improve the resilience (Allison et al., 2007) of natural resources, through assessments of risk and vulnerability, by increasing awareness (Dulvy and Allison, 2009) of climate change impacts and strengthening key institutions, such as for weather forecasting and early warning systems (Gillman et al., 2008). The World Development Report 2010, shows that reducing overcapacity in fishing fleets and rebuilding fish stocks can both improve resilience to climate change and increase economic returns from marine capture fisheries by US$50 billion per year, while also reducing GHG emissions by fishing fleets. Consequently, removal of subsidies on fuel for fishing can have a double benefit by reducing emissions and overfishing. Investment in sustainable aquaculture can buffer water use in agriculture while producing food and diversifying economic activities.

Throughout the world, fisherfolk are poorly informed of climate change and its consequences that would impact the livelihood of fishers. Fishers at first instance are not aware of the terminology of climate change, but when it is explained to them by a change agent /extension worker at the field level that climate change is a significant and lasting change in the distribution of weather patterns over periods ranging from decades to millions of years, they are able to relate to various weather phenomena in which they have observed a change/departure from the normal course of events over the last few decades.

In projected climate change scenarios, the main threats to coastal populations and ecosystems are sea-level rise, the intensification of extreme weather events and ecosystem changes. (Nicholls et al., 1999). Other expected impacts are a rise of up to 3 °C on sea surface temperature, changes in precipitation and freshwater input, saltwater intrusion into soils and coastal aquifers, and ocean acidification. (Wu and Siewert, 2008) These climate alterations will have varied effects on coastal ecosystems and human populations, with a likely increase on flooding and loss of wetlands as observed by Nicholls, 2004. Flooding of populated areas and infrastructure, results in severe economic impacts and changes in the availability of natural resources, with consequences for the livelihoods of those who rely directly on them for survival, such as traditional or neo-traditional coastal populations, including fisher folk (Badjeck et al., 2010).

Fishing communities have a major role to play in the process of adaptation and mitigation of climate change effects. Fisherfolk should shoulder the responsibility that they are not only mere harvesters of fish, but they are also the guardians of these scarce resources and should be at the forefront of initiatives that support and maintain sustainable activities and facilitate coastal resource conservation and management. They should be involved in the restoration of natural barriers such as mangroves, coral reefs and seagrasses. Restoration of coastal habitats will, in the long run, increase fish productivity and aquatic biodiversity of any given area. Fisherfolk can also engage in rebuilding depleted fish stocks by strictly observing government fishing regulations which include limited entry, seasonal and area closure, mesh size limits, appropriate fishing methods, among others. They should also participate in crafting innovative gear modifications to mitigate the problems. Increasing social participation of fisherfolk in local organisations and co-operatives can promote integrated coastal resource management. Their inherent capacities and local knowledge can be used to modify and improve conventional practices supporting community adaptations to extreme conditions. In addition, they should be willing to learn to raise their awareness and help them understand how climate change will impact their daily life, livelihood productivity and well-being. By actively participating, they can access information and influence decision-making concerning development activities that may threaten their lives and resources. Collective action is also a good strategy for deterring illegal activities. Along with these are affordable communication technology/tools such as mobile phones, radios, etc. that can be used to receive up-to-date weather forecasts and storm warnings.

2. Objectives

Against this background, it was proposed to take up a study with the following objectives:

1. To assess the vulnerability of coastal districts of Karnataka by construction of vulnerability indices.
2. To study the climate change effects with respect to environmental impact, fishery impact, social impact, and economic impact and development drivers' impact as was perceived by the fisherfolk.

3. Study Area and Methodology

An overview of coastal Karnataka

The study was carried out in coastal Karnataka. Karnataka's coastline stretches for 320 kilometres and consists of the three coastal districts namely, Uttara Kannada, Udupi and Dakshina Kannada. Of these, Uttara Kannada has 160 kilometre long coastline, Udupi district has 98 kilometres coastline, and the rest 62 kilometre length of coastline falls in Dakshina Kannada district (Figure 1). The distinct agro-climatic zones range from coastal flatlands in the west with undulating hills and valleys in the middle, and high hill ranges in the east that separates it from the peninsula. There is a narrow strip of coastal plains with varying width between the mountain and the Arabian Sea. Fourteen rivers drain into the shore waters of Karnataka. Sandbars have developed in most of the estuaries. There are 90 beaches with increasing scope for beach tourism.

The coastal zone of Karnataka hosts better developed geographical areas of the state with a high degree of economic development and high density of population. There are a total of 144 marine fishing villages with 86 fishing villages in Uttara Kannada, 41 in Udupi and 17 in Dakshina Kannada district. The occupational pressure of the region can be attributed to agricultural activities, aquaculture, fish landing and processing, port maintenance, mining for lime shells, bauxite and silica sand, cashew processing industries, rice mills and coconut oil extraction mills.

3.1 Coastal erosion

Coastal Karnataka is subject to three types of erosion, occurring along the open beaches, mouths of rivers/estuaries and the tidal reach of rivers causing considerable loss of land, vegetation and revenue. About 30 percent of the area under coastal zone is subjected to moderate soil erosion and 16 percent of the area to severe soil erosion. The annual rates of soil erosion vary from 5-15t/ha to 15-40 t/ha in moderate to severe soil erosion areas. This problem is severe in Dakshina Kannada and Udupi coasts.

3.2 Selection of the coastal district:

Among the three coastal districts of Karnataka, Udupi district was selected for the study based on secondary data such as historical data on extreme weather events, sea erosions, loss in fishing days. 46 km of the total 95 km stretch of Udupi's coastline is under critical coastal erosion (Dwarkish et al., 2009). Besides, his studies have revealed that 59 per cent of the 95 km of the shoreline of Udupi district is at very high risk due to future Sea Level Rise (SLR). In addition, secondary data collection, Participatory Rural Appraisal methods (PRA) and Rapid Rural Appraisal (RRA) methods were used for the selection of the district.

3.3 Selection of coastal villages:

Six villages of Udupi district were selected based on historical data for factors such as shoreline change, agricultural lands, wetlands, salt pans, beaches, population density, literacy rates, occupation, infrastructure and craft and gears in the fishery. The six villages selected for the study were Thenkayermal, Mattu, Kadekar, Udyavara, Paduthonse, and Maravanthe (Figure 2)

3.4 Methodology

Data was collected using well-structured interview schedules using village survey schedules for individual villages and household schedules for individual households. Data were collected from 125 households per village thus totalling to 750 households which formed the total sample for the study. Besides data collection using structured schedules, focus group discussions, freewheeling interviews and PRAs and RRAs techniques were used in the study villages in order to get greater access to the fisher communities.

The vulnerability index for each coastal district was worked out by adopting the method developed by Patnaik and Narayanan, 2005.

VI=Vulnerability index

$$VI = \left[\sum_{i-1}^{n} (AI_i)^{\alpha} \right]^{1/\alpha} \Big/ n$$

Where VI=Vulnerability index

(AI) is the average index for each source of vulnerability, n is the number of source of vulnerability and $\alpha = n$.

Accordingly, for the present study, five parameters of vulnerability namely demography, occupation, infrastructure, climate components and fishery components and their respective sub-indicators were used for the study. They were a) Demography- number of fishing villages, number of fishermen households, total fisherfolk population, literacy; b) Occupation-Full time fishermen, part-time and occasional, c) Infrastructure- kutcha houses, educational institutions, number of hospitals/ dispensaries, number of banks, number of fishermen co-operative societies, number of community centres; d) climate components- temperature, rainfall and wind velocity e) Fishery components- mechanised, motorised, non-motorized, and number of active fishermen. Since all the five parameters were in different units and scales, the methodology used in UNDP's Human Development Index (HDI) (UNDP, 2006) was used to normalise them using their functional relationship with vulnerability. When variables such as rainfall had an increasing functional relationship with vulnerability, the normalisation was done using the formula:

$$x_{ij} = \frac{X_{ij} - \underset{i}{Min}\{X_{ij}\}}{\underset{i}{Max}\{X_{ij}\} - \underset{i}{Min}\{X_{ij}\}}$$

When variables such as literacy had a decreasing functional relationship with vulnerability the normalisation was done using the formula:

$$y_{ij} = \frac{\underset{i}{Max}\{X_{ij}\} - X_{ij}}{\underset{i}{Max}\{X_{ij}\} - \underset{i}{Min}\{X_{ij}\}}$$

The perceptions of the fisherfolk towards climate change effects concerning environmental impacts, fishery impact, social impact, economic impact and development drivers impact were studied by administering a psychometric scale (Likerts summated rating technique, 1932) on a 1-5 continuum.

Figure 1: Coastal districts of Karnataka

Figure 2: Sample villages in the case study area

4. Findings and discussion

The five most important climate parameters such as Demography, Infrastructure, Occupation, Climate and Fishery were used for the construction of the vulnerability index.

Table 1: Vulnerability assessment of coastal districts of Karnataka

District	Demography	Infrastructure	Occupation	Climate	Fishery	Vulnerability Index (V.I)
Uttara Kannada	0.30	0.78	0.13	0.32	0.28	**0.362**
Udupi	0.30	0.84	0.56	0.35	0.25	**0.460**
Dakshina Kannada	0.32	0.69	0.22	0.29	0.57	**0.418**

The vulnerability index of the three coastal districts of Karnataka are shown in Table 1. It can be observed that, Udupi district has the highest vulnerability index of 0.460, followed by Dakshina Kannada with an index of 0.418 and Uttara Kannada with the lowest index of 0.362. Udupi district consists of 41 fishing villages. Udupi district is vulnerable to accelerated sea level rise (SLR) due to its low topography and due to its high ecological and touristic value (Dwarakish et al., 2009). Of the 41 fishing villages of Udupi district, six fishing villages namely Thenkayermal, Mattu, Kadekar, Udyavara, Paduthonse, and Maravanthe were selected for the study based on social, economic and geographical parameters. The vulnerability indices were worked out for the selected fishing villages (Figure 4). It can be inferred that the fishing village of Maravanthe had the highest V.I of 62.05 closely followed by Thenkayermal with V.I of 61.58 and Udyavara with V.I of 61.55. However, it can be observed that all the six fishing villages were more or less uniformly impacted by climate change parameters. Paduthonse had the lowest V.I of 58.89.

Figure 3: Vulnerability indices of coastal districts of Karnataka

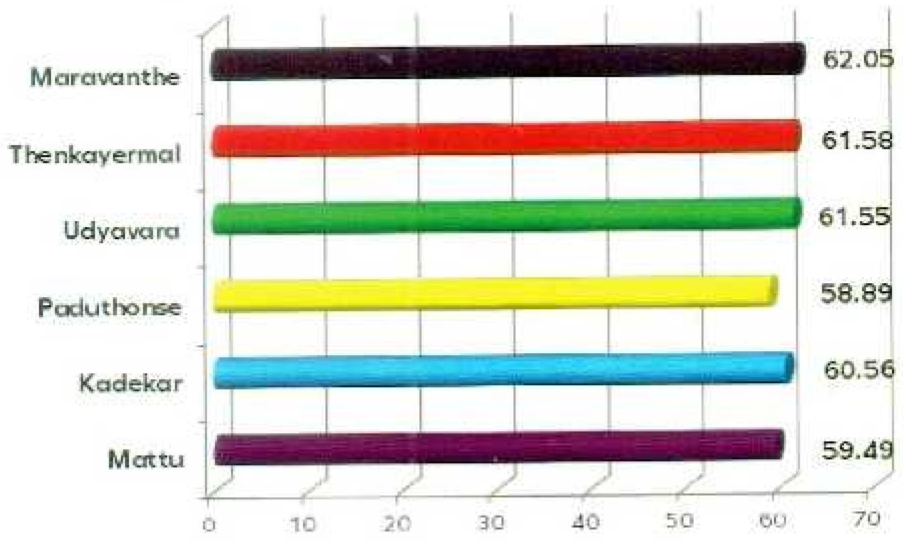


Figure 4: Vulnerability indices for fishing villages in Udupi district

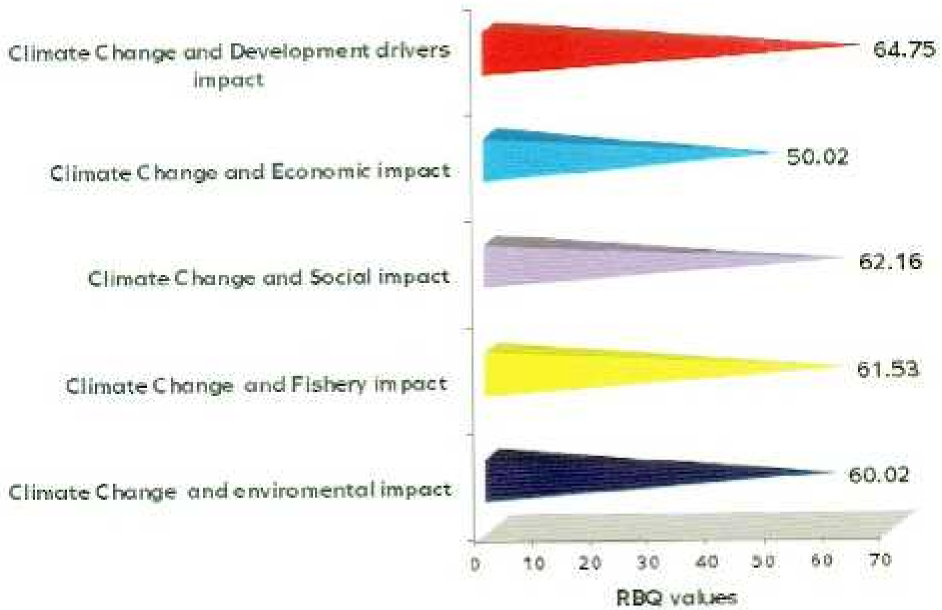


Figure 5: Climate parameter assessment of the composite villages

The climate parameter assessment of the composite villages is depicted in Figure 5. It can be observed that the parameter namely climate change and development driver ranked first (RBQ of 64.75) among fisherfolk followed by climate change and social impact (RBQ of 62.16), followed by climate change and fishery impact (RBQ of 61.53). An attribute analysis for the development drivers (Figure 6) indicated that among the development drivers such as infrastructure drivers, productivity enhancement drivers, anthropogenic drivers, ICT enabled drivers and policy support drivers, anthropogenic drivers had impacted the fisherfolk most with an RBQ value of 60.68. (Rank 1). The sample of six fishing villages undertaken for the study namely Thenkayermal, Mattu, Kadekar, Udyavara, Paduthonse, and Maravanthe had witnessed an increased influx of tourists over the years. This had led to an increase in developmental activities and impacts such as beach tourism, increased deposition of litter, plastics; and the respondents are of the perception that in the process of development, sustainability issues have been overlooked, and there has been a spurt in the anthropogenic activities over the years.

The parameter namely climate change and social impact ranked second with respect to fisherfolk perception on climate change parameters (Figure 7). Among the social impacts, the fisherfolk perceived infrastructure sensitivity as having the highest attribute. Among the resilience indicators to this attribute, it was observed that the households in the study area were highly prone to disasters and seawater inundation and coastal erosion was high in these villages.

Climate change and fishery impact ranked third in the order with a RBQ of 61.53 (Figure 8). It can be inferred from the attribute analysis that the fishery was impacted mostly by catch. The analysis on the resilience indicator to this attribute indicated that fish catch had decreased drastically over the years and effort has increased fairly and targeted groups of fishes have changed significantly.

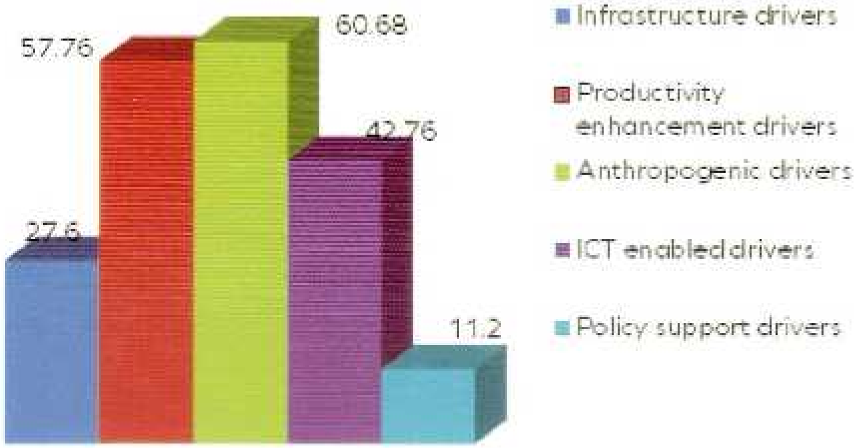


Figure 6: Attribute analysis for climate change and development drivers impact

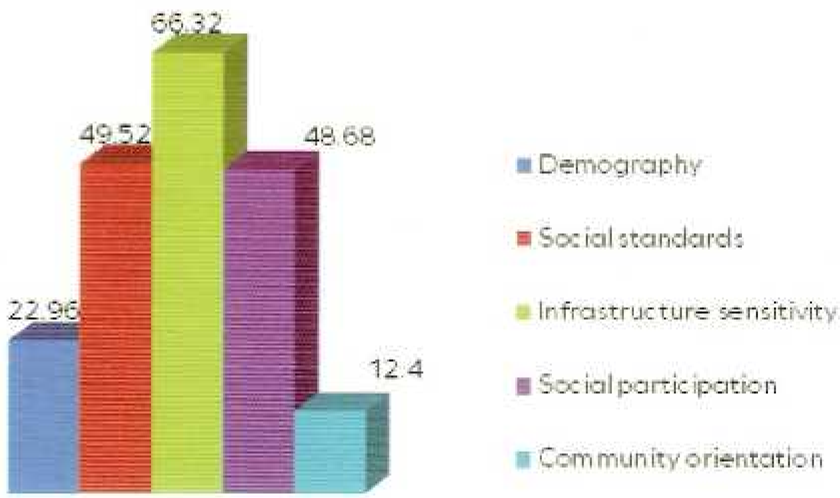


Figure 7: Attribute analysis for climate change and social impact

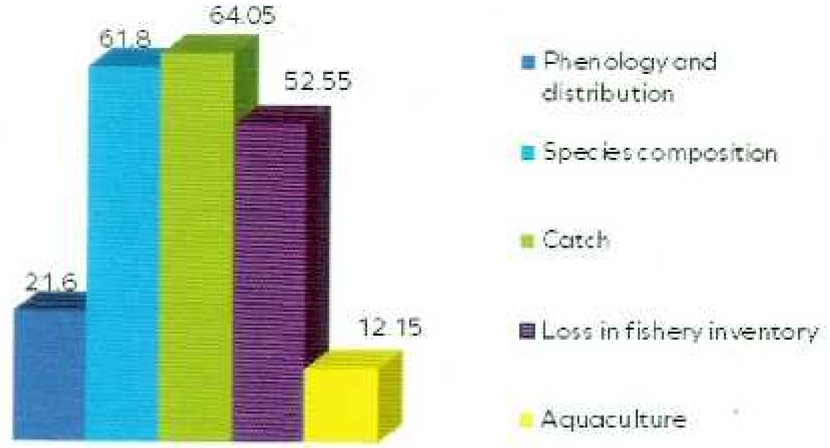


Figure 8: Attribute analysis for climate change and fishery impact

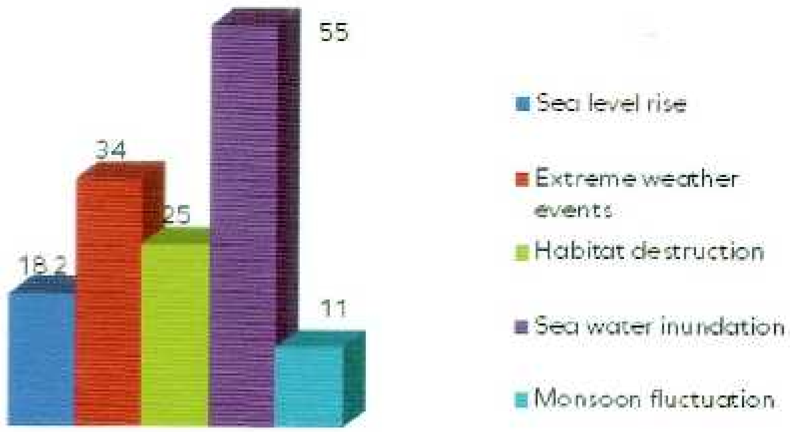


Figure 9: Attribute analysis for climate change and enviromental impact

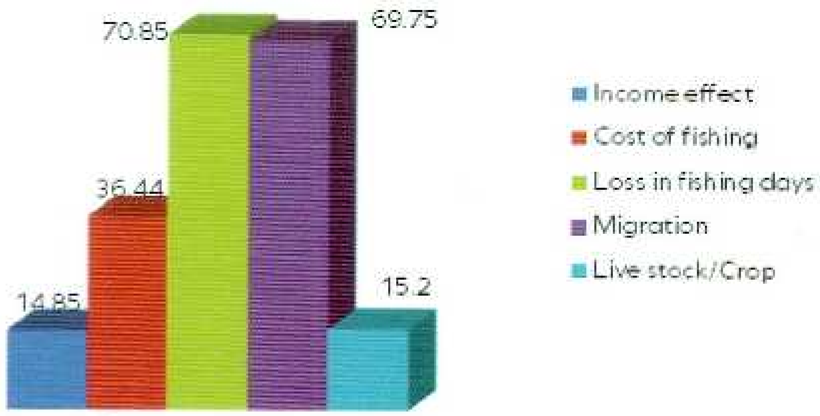


Figure 10: Attribute analysis for climate change and economic impact

Climate change and environmental impact ranked fourth with a RBQ value of 60.02. The attribute analysis for this parameter indicated that environmental parameter was highly impacted by seawater inundation followed by extreme weather events (Figure 9). Seawater inundation was high in the fishing villages of Udyavara, Paduthonse, Maravanthe and Thenkayermal.

The climate parameter assessment of the composite villages indicated that climate change and economic impact was ranked as last in order with the lowest RBQ value of 50.02. The attribute analysis for this parameter indicated that the economic parameter was highly impacted by the loss in fishing days followed by the phenomena of migration (Figure 10). Fisherfolk believes that there is a considerable economic loss due to the decrease in the number of fishing days owing to extreme weather events. Competition in fishing has increased due to the increased number of fleets over the years. Coastal Karnataka on the west coast of India has been a witness to inter-sectoral migration. There has been a shift in the occupational mobility and a steady influx of migrants from the agrarian sector of Tamil Nadu, Andhra Pradesh and Odisha to the coastal districts of Karnataka.

The study on climate change and vulnerability indicated that climate change and development driver ranked first among fisherfolk. The coastal district of Udupi has been impacted the most with the highest vulnerability index of 0.46. The low lying nature of Udupi coastal zone coupled with significant land reclamation investments and extensive industrial, commercial, residential and tourism activity emphasises that ecological and socio-economic systems are currently facing tremendous pressure due to rapid industrialisation urbanisation and economic development. Fifty- nine percent of Udupi's shoreline is classified as being at very high risk due to future Sea Level Rise. This implies that the population living presently in these areas would be displaced. There is an urgent need for incorporating the elevation levels for new settlement areas under the town planning acts so that human life and property are saved from natural hazards/vulnerabilities.

It was observed during the study that the awareness of the fishers about climate change was relatively low. Widespread awareness campaigns on climate change is vital. The options available for protection of Udupi coast from future sea level rise could be dune afforestation, mangrove restoration and management, periodic beach nourishment and building seawalls and groynes. Long term measures should focus on planned and regulated urban development, institutional building and involvement of local fisherfolk for disaster preparedness and creation of awareness on a large scale.

5. Adaptation and mitigation strategies to combat Climate Change in Udupi district

A total of 95 km of the shoreline is ranked in the study area, out of which 59% of the mapped shoreline is classified as being at very high risk due to future Sea Level Rise. The percentage of high and moderate risk is only 11%, and the remaining 30% of the shoreline is under the low- risk category. It is clear that the Udupi coast is highly vulnerable for future SLR, and the different LU/LC features under the direct risk of flooding include coastal villages, agricultural land, wetland, salt pans, aquaculture ponds, link roads, beaches and coastal dunes. This implies that the population living presently in these areas would be displaced.

The options available for the protection of the Udupi coast from future SLR could be dune afforestation, mangrove restoration and management, periodic beach nourishment and building seawalls and groins. The construction of seawalls is costly, and hence it would be used only for some settlements at high risk of inundation. The performance of properly constructed and maintained seawalls along the undivided Dakshina Kannada coast is satisfactory. The integrated coastal zone management plan, though active in India, is still not fully functional. It must emphasise more on building regulations, urban growth planning, development of institutional capacity, involvement of local community, increasing public awareness and should be based on long-term sustainable developmental programmes.

Adaptive capacity is the ability or potential of a system to respond successfully to climate variability and change and includes adjustments in both behaviour and resources and technologies. The presence of adaptive capacity is prerequisite for the design and implementation of effective adaptation strategies to reduce the likelihood and the intensity of harmful consequences accruing from climate change. (Brooks et al., 2005) Adaptive capacity also enables sectors and institutions to take advantage of opportunities or benefits from climate change, such as a longer growing season or increased potential for tourism.

Much of the current understanding of adaptive capacity comes from vulnerability assessments. Even if vulnerability indices do not explicitly include determinants of adaptive capacity, the indicators selected often provide important insights on the factors, processes and structures that promote or constrain adaptive capacity (Ericson et al., 2006). One clear result from research on vulnerability and adaptive capacity is that some dimensions of adaptive capacity are generic, while others are specific to particular climate change impacts. Generic indicators include factors such as education, income and health. Vulnerability is operationalised for the present study as the extent to which fisherfolk are affected by or unable to withstand the harmful effects of Climate Change.

Technology can potentially play an important role in adapting to climate change. Strategies which can be adopted by fisherfolk could include estuarine cage farming, resorting to diversified livelihoods, use of solar dryers for drying of fish, since rainfall and temperature no longer follow set patterns of occurrence. Other tactics could be efficient cooling systems, improved seeds, desalination technologies, and other engineering solutions represent some of the options that can lead to improved outcomes and increased coping under conditions of climate change. Technological adaptations and innovations are developed through research programmes undertaken by governments and by the private sector (Smit and Skinner, 2002). Innovation, which refers to anything perceived as new or the revival of old ones in response to new conditions, is an important aspect of adaptation, particularly under uncertain future climate system (Bass, 2005). All climate change issues cannot be addressed by technological innovations. For example high wind speed, changing water currents, sea level rise can reduce the number of fishing days in a year leading to low income of the fisherfolk.

In the climate change context, the term 'mainstreaming' has been used to refer to the incorporation of climate change vulnerabilities or adaptation plans into some government schemes such as water management, disaster preparedness and emergency planning or land-use planning (Agrawala, 2005). Actions that promote adaptation include integration of climate information into environmental data sets, vulnerability or hazard assessments, broad development strategies, macro policies, sector policies, institutional or organisational structures, or in development project design and implementation (Burton and Aalst, 1999). By implementing mainstreaming initiatives, it is argued that adaptation to climate change will become an integral part of other well-established programmes, particularly sustainable development planning.

6. Measures for coastal adaptation to climate change

- An effective early warning communication and response system can reduce death and destruction
- Hazard awareness education and personal hazard experience are important contributors to reducing community vulnerability
- Many factors reduce the ability or willingness of people to flee an impending disaster, including the warning time, access and egress routes, and their perceived need to protect property, pets and possessions
- Coastal landforms (coral reefs, barrier islands) and wetland ecosystems (mangroves, marshes) provide a natural first line of protection from storm surges and flooding, despite divergent views about the extent to which they reduce destruction

- Recurrent events reduce the resilience of natural and artificial defences
- In the aftermath of extreme events, additional trauma occurs in terms of dispossession and mental health
- Uncoordinated and poorly regulated construction has accentuated vulnerability
- Effective disaster prevention and response rely on strong governance and institutions, as well as adequate public preparedness

This assessment shows that the level of knowledge is not consistent with the potential severity of the problem of climate change and coastal zones. Establishing better baselines of actual coastal changes, including local factors and sea-level rise, and the climate and non-climate drivers, through additional observations and expanded monitoring would better establish the causal links between climate and coastal change which tend to remain inferred rather than observed and support model development.

- Improving predictive capacity for future coastal change due to climate and other drivers, through field observations, experiments and model development. A particular challenge will be understanding thresholds under multiple drivers of change. Developing a better understanding of the adaptation of the human systems in the coastal zone. At the simplest level, this could be an inventory of assets at risk, but much more could be done in terms of deepening our understanding of the qualitative trends and issues of adaptive capacity.
- Improving impact and vulnerability assessments within an integrated assessment framework that includes natural-human sub-system interactions. This requires a robust inter-disciplinary approach and the targeting of the most vulnerable areas, such as populated mega deltas and deltas, small islands and coastal cities. Improving systems of coastal planning and zoning and institutions that can enforce regulations for clearer coastal governance is required in many countries.
- Developing methods for identification and prioritisation of coastal adaptation options. The effectiveness and efficiency of adaptation interventions need to be considered, including immediate benefits and the longer term goal of sustainable development
- Developing and expanding networks to share knowledge and experience on climate change and coastal management among coastal scientists and practitioners

7. Increasing human utilisation of the coastal zone

Although not all coasts of the world are inhabited, very few of them are devoid of human influence (Buddemeier et al., 2002). Utilisation of the coast increased dramatically during the 20th century, a trend that seems certain to continue through the 21st century. The increasing population density harboured by many of the world's deltas, barrier islands and estuaries has led to the unprecedented conversion of natural coastal landscapes to agriculture, aquaculture, silviculture, as well as for commercial and residential uses (Wu et al., 2009). It has been assessed that 23% of the world's population lives both within 100 km distance of the coast and <100 m above sea level, and population densities in coastal regions are about thrice higher than the global average (Small and Nicholls, 2003). The attractiveness of the coast has resulted in disproportionately rapid expansion of economic activity, settlements, urban centres and tourist resorts. Migration of people to coastal regions is common in both developed and developing nations. Sixty percent of the world's 39 metropolises with a population of over 5 million are located within 100 km of the coast, including 12 of the world's 16 cities with populations greater than 10 million. Rapid urbanisation has many consequences: for example, enlargement of natural coastal inlets and dredging of waterways for navigation, port facilities, and pipelines exacerbate saltwater intrusion into surface and ground waters. Instances of Increasing shoreline retreat and dangers arising from occurrence of floods in coastal cities in Thailand (Durongdej, 2001, Saito, 2001), India, (Mohanti, 2000), Vietnam (Thanh et al., 2004) and the United States (Scavia et al., 2002) have been attributed to degradation of coastal ecosystems by human activities.

The direct impacts of anthropogenic activities on the coastal zone have been more conspicuous over the last century than impacts that could be directly attributed to observed changes in the climate (Scavia et al., 2002, Lotze et al., 2006). The major direct impacts include drainage of coastal wetlands, deforestation and reclamation, and discharge of sewage, fertilisers and contaminants into coastal waters. Extractive activities include sand mining and hydrocarbon production, harvest of fisheries and other living resources, introductions of invasive species and construction of seawalls and other structures. Engineering structures, such as damming, channelisation and diversions of coastal waterways harden the coast, change circulation patterns and alter freshwater, sediment and nutrient delivery. Natural systems are often affected and changed directly or indirectly by soft engineering mechanisms, such as beach nourishment, and for dune construction (Nordstorm, 2000; Hamm and Stive, 2002). Human activities often disrupt ecosystem services on the coast. For example, tropical and subtropical mangrove forests and temperate saltmarshes provide goods and services (they accumulate and transform nutrients, attenuate waves and storms, bind sediments and support rich ecological communities), which are reduced by large-scale ecosystem conversion for agriculture, industrial and urban development, and aquaculture.

8. Conservation and development of mangroves

The coastal zone in Karnataka contains habitats and ecosystems, such as estuaries, mangroves and coral reefs, which have a definite role in the maintenance of ecological balance and economic vitality of the coastal region. The diversity and distribution of mangroves along the Karnataka coast indicate the sensitivity to various environmental changes. Increasing anthropogenic pressures in the form of conversion of habitats or pollution are mainly responsible for the decline in species- level diversity of mangroves and coral reefs along the coast. To overcome such problem, it is essential to formulate an action plan for replanting of mangrove in the area where they have disappeared. Also to be taken up in conjunction with protection of mangroves is the restoration of patches of biodiversity-rich habitats in the coastal, riverine and deltaic belt. The Karnataka State Coastal Zone Management Authority can:

- Develop a viable concept for replanting in terms of extent, timeframe, implementation, monitoring etc. in consultation with competent research institutes
- Ensure local communities' participation to protect mangroves
- Promote awareness on the importance of mangrove ecosystems
- Removal of encroachments posing a threat to mangrove ecosystems
- Re-plantation plan to rejuvenate the mangrove ecosystem

The stakeholders would be the Karnataka State Coastal Zone Management Authority, Karnataka Biodiversity Board, the Department of Agriculture, Panchayat Raj Institutions and local non-governmental organisations. It is essential to impart knowledge on mangrove protection to different groups of coastal population. The awareness /user-interaction should be conducted in different regions during different times of the year. Further, skill training programme on mangrove nursery and using of Information and communication tools improves the desired level of awareness.

References

"World Bank. 2010: Development and Climate Change. Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/4387 License: CC BY 3.0 IGO."

Adger, W. N., Hughes, T. P., Folke, C., Carpenter, S. R., & Rockström, J. (2005). Social-Ecological Resilience to Coastal Disasters. Science, 309, 1036-1039.

Agrawala, S, (2005). Putting Climate Change in the development main stream- Introduction and Framework. Bridge over Troubled Waters: Linking Climate Change and Development, OECD, Paris 23-24.

Allison, E.H., Andrew, N.L., & Oliver, J. (2007). "Enhancing the resilience of inland fisheries and aquaculture systems to climate change". Journal of Semi-Arid Tropical Agricultural Research 4 (1).

Badjeck, M-C., Allison, E. H., Halls, A. S., & Dulvy, N. K. (2010). Impacts of climate variability and change on fishery-based livelihoods. Marine Policy, 34, (3), 375-383.

Bass, B. (2005). Measuring the adaptation deficit. Discussion on Keynote Paper. Climate Change and the adaptation deficit. Climate Change: Building the a, 34-36.

Brooks, N., Adger, W.N., & Kelly, P.M., (2005). The determinants of Vulnerability and Adaptive Capacity at the national level and the implications for adaptation. Global Environment Change, 15(2), 151-163.

Buddemeier, R.W, S.V.Smith, D.P.Swaaney and C.J.Crossland, (2002). The Role of the Coastal Ocean in the disturbed and undisturbed Nutrient and Carbon Cycles. LOICZ Reports and Studies Series, 24, 84.

Burton, I., & Van Aalst., M. (1999). Look before you Leap. A Risk Management Approach for Incorporating Climate Change Adaptation in World Bank Operations. Final Draft, prepared for the Climate Change Team, World Bank, Washington, District of Columbia, 57.

Dulvy, N., & Allison, E. (2009). "A place at the table?" Nature Reports Climate Change (906), 68.

Durongdej, S. (2001). Land Use Changes in Coastal areas of Thailand. Proceedings of the APN/SURVAS/LUICZ Joint Conference on Coastal Impacts of Climate Change and Adaptation in the Asia-Pacific Region, 14-16 Nov 2000, Kobe, Japan. Asia Pacific Network for Global Change Research. 113-117.

Dwarakish, G. S., Vinay, S. A., Natesan, U., Asano, T., Kakinuma, T., Venkataramana, K. & Babita, M. K. (2009). Coastal vulnerability assessment of the future sea level rise in Udupi coastal zone of Karnataka state, west coast of India. Ocean & Coastal Management, 52(9), 467-478.

Ericson, J. P., Vörösmarty, C. J., Dingman, S. L., Ward, L. G., & Meybeck, M. (2006). Effective sea-level rise and deltas: causes of change and human dimension implications. Global and Planetary Change, 50(1-2), 63-82.

FAO (2007) Building adaptive capacity to climate change. Policies to sustain livelihoods and fisheries.

Fussel, H.M., & Klein, R.J.T. (2006). Climate change vulnerability assessments: an evolution of conceptual thinking. Climatic Change, 75(3), 301-329

Gilman, E. L., Ellison, J., Duke, N. C., & Field, C. (2008). Threats to mangroves from climate change. Climate Change and adaptation options: A review. Aquatic Botany, 89(2), 237-250.

Hamm, L., & Stive, M.J.F. (2002). Shore nourishment in Europe. Coastal Engineering, 47, 79-263.

India's Marine Fish Landings increase by 5.6% in 2017. http://www.cmfri.org.in/news/ marine fish landings in India increase by 5.6%%in 2017/Accessed 19, August 2018.

IPCC (2001a Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK Cambridge University Press. ISBN 0521807670.

https://www.ipcc.ch/publications_and_data/ ar4/wg2/en/ ch17s17-3.html

Likert, R. (1932). "A Technique for the Measurement of Attitudes". Archives of Psychology 140, 1–55.

Lotze, H. K., Lenihan, H. S., Bourque, B. J., Bradbury, R. H., Cooke, R. G., Kay, M. C., & Jackson, J. B. (2006). Depletion, degradation, and recovery potential of estuaries and coastal seas. Science, 312(5781), 1806-1809.

Mohanti, M. (2000). Unprecedented Super cyclone in the Orissa Coast of the Bay of Bengal, India. Co-geoenviornment Newsletter, Commission on Geological Sciences for Environmental Planning of the International Union on Geological Sciences,16,11-13.

Nicholls, R. J. (2004). Coastal flooding and wetland loss in the 21st century: changes under the SRES climate and socio-economic scenarios. Global Environmental Change, 14, 69-86.

Nicholls, R. J., Hoozemans, F. M. J. & Marchand, M. (1999). Increasing flood risk and wetland losses due to global sea-level rise: regional and global analyses. Global Environmental Change, 9, S69-S87.

Nicholls, R. J., Wong, P. P., Burkett, V. R., Codignotto, J., Hay, J. E., McLean, R. F., Ragoonaden, S. & Woodroffe, C. D. (2007). Coastal systems and low-lying areas. Pp.315- 356.

Nordstorm, K.F. (2000). Beaches and Dunes of Developed Coasts. Cambridge University Press 338 pp

Parry M. L., Canziani, O. F., Palutikof, J. P., Van der Linden, P. J. & Hanson, C. E. (Eds.). (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, 982 p.

Patnaik and Narayanan. (2005). Quantitative Assessment of Vulnerability to Climate Change, computation of Vulnerability Indices, ICRISAT, Manual.

Saito, Y. (2001). Deltas in Southeast and East Asia: their evolution and current problems. In: Proceedings of the APN / SURVAS /L OICZ. Joint Conference on Coastal Impacts of Climate Change and Adaptation in the Asia-Pacific Region,14-16 November,2000,Kobe,Japan, Asia Pacific Network for Global Change Research, 185-191.

Scavia, D, J.C.Field, D.F.Boesch, R.W.Buddemeier, V.Burkett, D.R.Cayan, M. Fogarty, M.A.Harwell, R.W.Howarth, C.Mason, D.J.Reed, T.C.Royer, A.H.Sallenger and J.G.Titus, (2002). Climate Change impacts on US Coastal and Marine Ecosystems. Estuaries, 25,149-164.

Small, C & R.J.Nicholls, (2003). A global analysis of human settlement in Coastal Zones. Journal of Coastal Research, 19,584-599.

Smit, B. & M.W. Skinner, (2002). Adaptation options in agriculture to climate change: A typology. Mitigation Adapt. Strategies Global Change, 7, 85-114.

SRES climate and socio-economic scenarios. Global Environmental Change 14, 69–86.

Sterr, H, Klein, R, & Reese, S. (2000). Climatic Change Zones: an overview on the State of the art of regional and local vulnerability assessments. FEEM working paper series 38.

Thanh, T.D., Y.Saito, D.V.Huy, V.L.Nguyen, T.K.O.Oanh & M.Tateishi, (2004). Regimes of human and Climate impacts on Coastal Changes in Vietnam. Regional Environmental Change, 4, 49-62.

The World Bank Climate Change Adaptation website.

U.S.Government, cited 2006.The federal response to Hurricane Katrina. Lessons learned. 228pp (Accessed 13.04.07:http:/www.whitehouse.gov/reports/katrina-lessons –learned.pdf.)

UNDP, (2006), Human Development Report, United Nations Development Program, Available at: http://hdr.undp.org/hdr2006/statistics.

UNOCHA, (2005).Regional Workshop on Lessons learned and Best Practices of Disasters. United Nations, Economic Commission for Latin America and the Caribbean. (ECLAC), 111.

Williams, M.J, R.Coles & J.H.Primavera, (2007). A lesson from Cyclone Larry: An untold story of the success of good coastal planning.Estuar.Coastal Shelf.71, 364-367.

Wisner, B.Cited (2006). Monsoon, market and miscalculation. The political ecology of Mumbai's July 2005 Floods.6pp. (Accessed 13.04.07:http://www.Jan2006.doc)

World Bank (2006) Aquaculture: Changing the Face of the Waters: Meeting the Promise and Challenge of Sustainable Aquaculture

Wu, S Y.R.Najar & J.Siewert. (2009).Potential impacts of Sea level Rise on the Mid and Upper Atlantic region of the United States. Climatic Change, 95, 121-138.

Wu, S., Najjar, R., & Siewert, J. (2008). Potential impacts of sea-level rise on the Mid and Upper Atlantic Region of the United States. Climatic Change, 95, 121–138DOI 10.1007/s10584-008-9522-x

Zhang, K., Douglas, B. C., & Leatherman, S. P. (2004). Global Warming and Coastal Erosion.