



Impact of Climate Change on Coastal Lives in India: A Socio-Economic Assessment

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Abstract

Majority of the climate change events are primarily affecting coastal areas globally. Coastal areas are facing severe impacts from climate change, especially affecting fishing communities. The Indian Ocean is experiencing more frequent cyclones due to warming sea surface temperatures, with the North Indian Ocean region being highly vulnerable which causing economic damage and disrupting fishing. Globally, climate-related disasters, particularly tropical cyclones, have led to significant economic losses over the past 50 years, with recent data indicating annual losses exceeding 200 billion USD. The Indian coast is at increased risk from tropical cyclones, directly affecting millions of coastal residents. Rising sea levels, higher than the global average, threaten fishing communities, and coastal erosion has already impacted 33.6% of coastal land. Ocean warming and shifting sea temperatures make it harder for fishermen to catch key fish species, posing another challenge on livelihood of millions. It is high time to prioritize the well-being of these coastal communities with low socioeconomic status, limited adaptive capacity, and as the primary victims of climate change impacts.

Key Words: Climate change, sea level rise, cyclone, fishing communities, livelihood

Introduction

Climate change is a global reality that has been widely debated in recent times. It has various impacts on human society and different economic sectors. Climate change effects have consequences for the socio-economic order at different levels, affecting agricultural production that depends on weather patterns, fishing sectors, food security, trade, exports and imports, etc. Countries like India, which are trying to become developed, are facing serious challenges due to the impacts of climate change on various economic sectors. In order to address the challenges posed by climate change, we need to take action to mitigate greenhouse gas emissions and adapt to the changes that are already happening. Another concern is that the climate change impacts on society as a whole, which affects the employment, income and livelihood of a large number of poor people in the developing world. The people, who rely on the primary sectors like agriculture, fisheries, livestock etc., are directly affected by the negative impacts of climate change. Some of the major events of climate change include rising sea levels, increasing sea and ocean temperatures, ocean acidification, coastal flooding, cyclones, higher temperatures, more precipitation, storms, and so on. Majority of these indicators are directly effect on coastal regions globally.

Climate change makes coastal populations highly vulnerable, as sea-level rise threatens 95% of the coastal regions worldwide in 2021. The major sea ports, which are crucial for the movement and trade of goods, are also exposed to the impacts of climate change (Dilanthi Amaratunga, 2022). India has an extensive coastline spanning more than 7,500 kilometers, with approximately 3.5% of the global population residing within 50 kilometers of this coast and these



coastal regions are especially prone to the impacts of climate change due to fast urbanization, high population densities and related economic activities such as agriculture, aquaculture, tourism, industries and trade (Aparna Roy, 2019). This paper tries to explore how climate change affects the livelihood of coastal residents.

Objectives and methods

This paper tries to explore how climate change events affect the coastal lives particularly fishermen communities across the Indian coastal region at various ways. The discussions carried out after reviewing the relevant literature in this aspect. This paper is developed based on secondary resources including various reports, journal articles, scientific reports, government reports, web based data etc. Essential statistical tools are also being used for better understanding the discussion and analysis.

Relevant literature

The South Asian countries are most vulnerable to the adverse impacts of climate change (Murari Lal, 2003), particularly the low-lying coastal areas of India are at risk due to warming of the Indian Ocean (IPCC, 2007). More than 25% of India's population resides within 50 km of the coast, which makes them vulnerable to sea level rise, extreme events, flash floods, and storm surges induced by cyclones etc., (K. Kantamaneni, 2019), and the increasing intensity of tropical cyclones (IPCC, 2007). There are about 2.6 billion people living near the coast around the Indian Ocean region. The rising sea level creates problems on population, economy, coastal infrastructures and marine ecosystems (Swapna P. et al., 2020).

The coastal area is covered by labour intensive fishery activities generally in developing countries, and more poor people in this sector are in greater vulnerability to climate change (Daniel Etongo and Lyn Arrisol, 2021). Climate change creates pressure on livelihood of fishing communities (Bimal P. Mohanty et al., 2010), and lowers the catch of fish species and productivity in the North east coast of India due to rise in temperature (Isha Das et al., 2020). The future catch of commercially valuable fishes will be reduced drastically in the Arabian Sea (Sajna Valiyakath Hussain, 2021) and the Indian oil Sardine fishes are showing declining trend continuously after 2012 particularly from the Kerala coast (CMFRI, 2019). The evidence shows that impacts of climate variability and change on aquatic ecosystems are resulting significant impacts on fisheries livelihoods (Badjeck M.C., et al., 2010). The reducing vulnerability of fisheries households relied on the proper adaptive measures comprising occupational mobility, social capital, and the reduction in over dependence on fishery resources (Selvaraj J.J. et al., (2022).

The socio-economic impact of tropical cyclones in the coastal regions is severe particularly in the North Indian Ocean region and it might be affected the socio-economic advancement for many years (Singh O.P. et al., 2001). Medha Deshpande et al., 2021, report that the Indian Ocean is experiencing more frequent, intense and long-lasting cyclonic storms. The Arabian Sea saw a



52% increase in cyclone frequency (during 2001-2019) and a 150% rise in very severe cyclone frequency. The region also witnessed a 20% to 40% increase in cyclone intensity and a 260% increase in very severe cyclone duration. Also, the local economic environment suffers from the frequent cyclones and storms that make Indian coastline very fragile. This also influences the income of many people, particularly the members of the coastal fishing communities (Sibananda Senapati and Vijaya Gupta, 2017). The frequent cyclones in the Indian coast induce socio-economic vulnerability among the coastal lives of the country.

Cyclones have a huge impact on Indian coastal states, even though they only account for 7% of global cyclones that form in the Arabian Sea and the Bay of Bengal. The intensity and frequency of cyclones and the damage they inflict on the coastal areas of India are influenced by the geography of India and the variations in climatic conditions such as temperature, rainfall trends, humidity, etc., (K. Kantamaneni, 2022). During the last two decades (2000–2018), the frequency of very severe cyclonic storms has increased significantly (+1 event per decade) in the post-monsoon season (Krishnan R. et al., 2020). The negative impact of cyclones might be extended in between 4 and 8 months after the event (Costanza Naguib et al., 2022), and the loss from these cyclonic effects not only be measured in monetary terms it impacts other economic sectors also (Arabinda Samanta, 1997). The coastal people of western coast particularly Kerala, face grave threats from storm surge, high waves, sea erosion and extreme weather conditions. Sea erosion has made many coastal villages more prone to losing their homes and livelihoods. Many fisher families are left homeless more often due to the encroaching sea (KVA Khadar, 2021).

Discussions

Natural hazards and disasters caused by climate change have been increasing in frequency and severity, affecting millions of people. Natural disasters in 2020 affected about 100 million people, resulted in 15,082 deaths, and led to an estimated USD 190 billion of global economic losses (Jones et al. 2022). In 2022, the situation worsened, as The International Disaster Database (EM-DAT) reported 387 natural disasters worldwide, with 30,704 fatalities, 185 million people affected, and USD 223.8 billion of economic losses. In India, 2,035 human loss and USD 4.2 billion of damages has been reported in 2022 due to the monsoon floods (EM-DAT, 2023). This is the global distribution of natural hazards in the past two years. The World Meteorological Organization (WMO) estimated that natural disasters cost USD 3640.9 billion of economic losses in the last 50 years. Asian region, which incurred USD 1204 billion of damages in the past 50 years, after North America, Central America, and Caribbean region, which had USD 1657.3 billion of damages (WMO Atlas, 2021). In a single year, 2020 or 2022, economic losses reached nearly 200 billion USD globally, as compared with the economic damages in the last fifty years. This shows that the economic losses have been increasing at faster rate recently due to climate events globally.

Storms/ Tropical cyclones were the predominant among all type of natural disasters, comprising 38% of all disasters and 38% of all deaths and economic losses in the last fifty years.



WMO also indicated that developing economies suffered 71% of the consequences of natural disasters. Therefore, Asia and developing countries are more susceptible to natural disasters due to climate change. Tropical cyclones were particularly destructive, are the major cause of death and economic losses among natural disasters, posing more danger to coastal areas. India, as an Asian country with a long coastline and millions of people living and working there, is exposed to tropical cyclones and other coastal hazards. This increases the risk for these disaster-prone regions of the country.

The North Indian Ocean comprises the Arabian Sea and the Bay of Bengal, which surround the Indian Peninsula. The value of damage due to tropical cyclones, a prominent natural disaster, over the coastal regions of the country is estimated at 85.24 billion USD for the period 2000 to 2023. The damage for each five-year period from 2000 to 2023 is shown in Figure 1. During 2000-2004, it was 0.61 billion USD, and it then increased to 22.45 billion USD in the next five years. During 2010-2014, it came down to 8.22 billion USD, and then it increased again to 25.24 billion USD. The highest damage value is in the 2020-2023 period, estimated at 28.72 billion USD (Figure 1). It is noted that the damage has increased significantly after 2020, which is visible in the 2020-2023 period. It increased to 28.72 billion USD in just four years (2020-2023). This indicates that damage due to tropical cyclonic storms in the North Indian Ocean has been increasing at a much higher level in recent years.

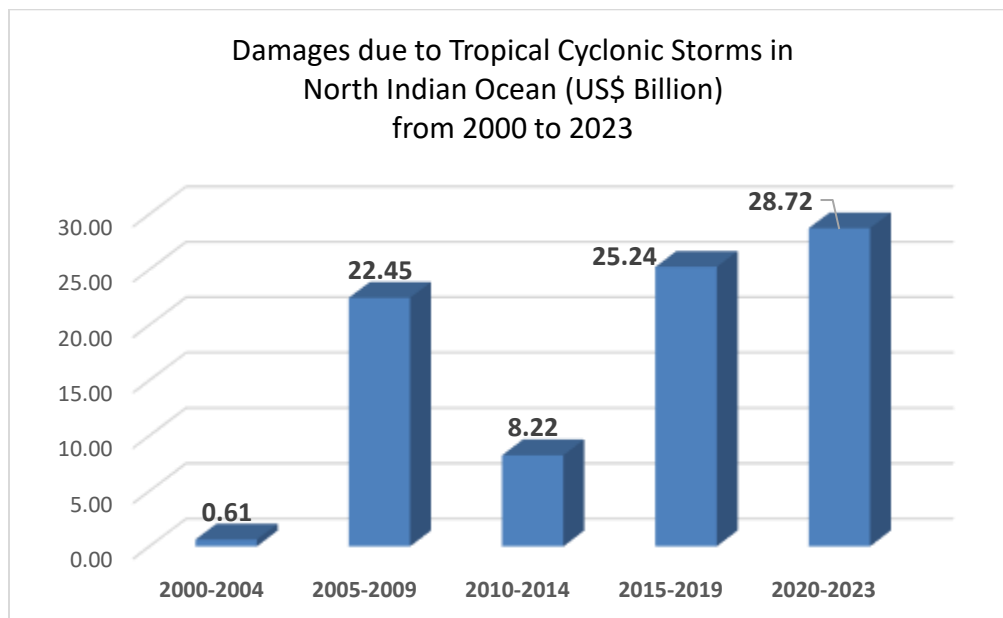


Figure: Damage value due to Tropical Cyclonic Storms in North Indian Ocean from 2000 to 2023 (in USD Billion)

Source: Calculated from various IMD reports and from Web series data,
https://en.wikipedia.org/wiki/North_Indian_Ocean_tropical_cyclone

The Indian vulnerability to hazard scenario is changing rapidly since the last three decades, with the increasing intensity of cyclones (Jublee Mazumdar & Saikat Kumar Paul, 2016).



Historically east coast of India covered by Bay of Bengal experiences about 4 to 5 cyclones every year and faces a higher risk and vulnerability from the storm surge and the coastal flooding than the West coast (Bishnupriya Sahoo and Prasad K. Bhaskaran, 2019).

The super cyclone that hit Orissa in 1999 with winds faster than 250 km per hour caused enormous damage and led to a significant loss of human lives. It was the most severe cyclone of the century. The areas most directly in its path, where the cyclone hit the hardest, saw the collapse of 3.5 lakhs houses and partial collapse of 2.5 lakhs more. The cyclone affected 120 blocks across 14 districts, causing damage to a total of 1.9 million houses. Over six villages were completely wiped out, and 59 villages suffered partial destruction. Alongside heavy rainfall lasting over two days, there were also tidal waves and sea intrusion. This super cyclone affected 14 districts, displacing 2.5 million people and rendering agricultural land unsuitable for farming due to increased saltiness. Additionally, more than 200,000 livestock perished due to the cyclone (Kalsi S.R., 2006). Very Severe Cyclonic Storm Ockhi devastated in Sri Lanka, Maldives and south west coast of India from 29th November to 6th December 2017. This cyclone was more intense in the south part of the Kerala state and it caused to change coastal morphology at great extent (Princy, J.R., et al., 2023).

The post disasters effect cannot be limited in the coast; it might be affected in other economic scenarios. Cyclones cause soil salinity to rise in the coastal regions of West Bengal due to storm-surge inundations. This has long-term economic effects on the region's agriculture. The losses from this are almost unquantifiable in monetary terms (Arabinda Samanta, 1997). The human impact of cyclones is usually assessed by counting the deaths and the financial losses. However, this is not providing the whole picture and the actual impact is much more than that. It creates stress, anxiety and psychological trauma among the coastal residents particularly those who depending upon the sea resources for their livelihood. The post cyclonic effect in the socio-economic life of the people has to be taken into consideration.

The increasing warming of the Indian Ocean is making tropical cyclones more common, which is directly impacting the lives of fishers. The formation of depressions, deep depressions, and cyclones in the ocean is increasing due to climate change, which is causing fishermen to lose working days. Table 1 show that the various storms occurred during the period of 2000 to 2023. There are 159 deep depressions and 101 cyclonic storms have been reported during this period. All these are worse affect the coastal areas and the nearby regions particularly, the people who are depending upon the sea resources. In between 2016 to 2020 a higher number of such events have been registered. It clearly shows that the occurrences of cyclonic events are increasing recent years. The number of these events is increasing at an alarming rate in the North Indian Ocean, affecting millions of people who rely on the sea for their livelihood. Cyclonic storms such as Taukte, Yaas, Gulab, Shaheen and Jawad hit India in 2021, reducing the number of fishing days significantly. The fishing days declined sharply due to the adverse impact of these storms that occurred in May, September, October and December (Gopalakrishnan A., 2021). Fishers are being restricted from fishing during these times, which is directly impacting their employment, income, and livelihood.



Fishing communities are historically marginalized and have low socio-economic indicators. Climate change is creating even more stress on their lives and property.

Table 1: Tropical Cyclones in the North Indian Ocean from 2000 to 2023

Period	D	DD	CS	SCS	VSCS	ESCS	SuCS
2000-2005	49	37	23	11	5	4	0
2006-2010	49	33	20	10	6	5	1
2011-2015	45	31	16	9	8	5	0
2016-2020	55	37	27	18	14	5	2
2021	10	6	5	3	2	1	0
2022	15	7	3	2	0	0	0
2023	10	8	7	5	4	3	0
Total	233	159	101	58	39	23	3

Source: Calculated from various IMD reports (Reports on cyclonic disturbances over North Indian Ocean-various years)

D: Depression, DD: Deep depression, CS: Cyclonic Storm, SCS: Severe Cyclonic Storm, VSCS: Very Severe Cyclonic Storm, ESCS: Extremely Severe Cyclonic Storm, SuCS: Super Cyclonic Storm etc., are given in cyclone manual published by IMD (2003).

Sea level rise and coastal flooding is another threat to the coastal lives. The global sea level rise is imposing threat to the millions of people who are settled in the low lying coastal areas. India, having long coast line and densely populated, considered as one of the most vulnerable countries to faster sea level rise in the world. Indian Ocean to face much higher sea-level increases than the global average due to Indo Pacific warm pool and create more pressure on the coastal people (UNEP, 2010). The WMO's report 'State of the Global Climate 2021', states that from 1993 to 2002, the mean globally sea level increased by 2.1 mm year. However, the rise was faster averaging 4.5 mm per year, from 2013 to 2021. The accelerated melting of land ice is the primary cause of this trend. A larger portion of the Indian coastline will experience sea level rise than the average worldwide. Sea levels are rising 2.5 mm per year faster in the southwest of the Indian Ocean than on average around the world.

The mean sea level rise combined with the effects of storm surges creates extreme sea level rise. This phenomenon is increasing in the Indian coastal region (Sreeraj P. et al., 2022). The north Indian Ocean areas facing the most danger high sea levels, rising very fast (~5.0 mm/year) at Hiron Point, which is part of the Ganga–Brahmaputra delta. This shows that the sinking of the delta is a big factor in the changes in the sea level extremes, along with the changes in the average sea level (Unnikrishnan A.S., Antony, C., 2022). In Kerala, the south west state of India is facing these issues, especially, southern part of the state. A study of Sreeraj P. et al., 2022 has identified a 2–3-fold increase in extreme sea level occurrence, with higher risk along the Arabian Sea coastline and the Indian Ocean Islands. The mean sea level rise and intense tropical cyclones are the major contributor of the extreme sea level occurrences. As the extreme sea level rises, the coastal areas of the Indian Ocean face more frequent and severe coastal flooding. This is a big problem for the



adaptation to climate change of the almost 2.6 billion people who live in the Indian Ocean region (Sreeraj P. et al., 2022).

According to a recent technical report from the National Centre for Coastal Research (NCCR), a division of the Union Ministry of Earth Sciences, coastal erosion is increasing in the east and west coast of the country. Based on the report 33.6 percent of India's coastline has been eroded by the sea. Moreover, 27 percent of the coastline has been expanded. The West Bengal is especially vulnerable to erosion, with 60 percent of its coastline being impacted. This is followed by Puducherry at 56 percent, Kerala at 46.4 percent and Tamil Nadu at 42.7 percent (Table 2). The coastal area faces a significant and concerning threat from both coastal flooding and erosion. In Kerala, for instance, 46% of the coastal region is at risk of erosion. The coastal area faces a significant and concerning threat from both coastal flooding and erosion. The total coastal erosion is estimated as 2318.31 km in the North Indian Ocean region, which means 33.6 % of the coastal area has been disappeared. This poses a serious and threatening challenge among the fishermen at great extent. The people lose their properties, land and other assets due to these climatic events.

Table 2: Coastal erosion in India

Sl. No.	State	Coast Length (in km)	Erosion	
			Km	%
1	Gujarat	1945.6	537.5	27.6
2	Daman&Diu	31.83	11.02	34.6
3	Maharashtra	739.57	188.26	25.5
4	Goa	139.64	26.82	19.2
5	Karnataka	313.02	74.34	23.7
6	Kerala	592.96	275.33	46.4
7	Tamil Nadu	991.47	422.94	42.7
8	Puducherry	41.66	23.42	56.2
9	Andhra Pradesh	1027.58	294.89	28.7
10	Odisha	549.5	140.72	25.6
11	West Bengal	534.35	323.07	60.5
	Total	6907.18	2318.31	33.6

Source: National Assessment of Shoreline changes along Indian coast-Vol-2- West coast, (2022). NCCR, Government of India

Ocean warming and Sea Surface Temperature (SST) is one of the serious climate change effect which face by the fishermen. The warming sea affects the movement of fish stocks particularly from the sea shore. The fisher folk in Odisha coast are unable to catch fish due to warming seas, the situation is going to more badly due to El Niño events. The impact of warming sea further affect the livelihood of fishing communities in Odisha at great extent (Senapati



A.,2023). Marine heat waves and high ocean temperatures lead to habitat loss through coral bleaching, sea grass thinning, and kelp forest loss, which has a negative impact on the fishing sector. The food web of small fishes relies on phytoplankton, which are important algae. However, the western coast has seen a worrying drop of up to 20% in marine phytoplankton over the last six decades due to the rising temperatures of the ocean. Roxy M.K.et al., (2015) found that this decline was even more severe in the last 16 years, reaching up to 30% in this area. The ocean warming is increasing globally; Indian Ocean is a major region for that. This warming ocean is caused to generate frequent cyclones. Increasing SST is a major threat to the fishing communities. This will cause to decrease the availability of fish species having more economic significance. In Kerala coast Indian Oil Sardine fish species are decreasing one third compared to previous decade as per the studies of CMFRI. The studies show that economic important fish species are disappearing from the sea shores which are migrating to cooler places. Therefore fishermen are unable to catch these fish species which affect the livelihood of fishermen and induce poverty among them. Warming condition of the sea is being affected the distribution and diversity of fish stocks. Extreme weather events like storms, floods and drought will damage fish species. Some tropical fish stocks may face regional extinction. Some others may move towards higher latitudes (Bay of Bengal News, 2008).

Conclusion

Coastal areas are experiencing various impacts due to climate change. The severity of these events differs across regions, but they are significantly affecting fishing communities. The warming of the ocean and sea surface temperatures (SST) are leading to cyclonic events in the Indian Ocean. These cyclonic events are becoming more frequent. The North Indian Ocean region is particularly susceptible to cyclones, with the occurrence increasing each year. In the Bay of Bengal alone, around 4 to 5 cyclones occur annually, which restricts fishing activities due to cyclonic storms and deep depressions. Between 2016 and 2020, the North Indian Ocean experienced a critical tropical cyclone season that caused approximately 40.68 billion USD in damages. This resulted in a decrease in fishing days. Over the last 50 years, climate-related natural disasters have led to an economic loss of 3640.9 billion USD globally. Among these, tropical cyclones have been particularly devastating. Recent statistics indicate that climatic disasters are causing over 200 billion USD in economic losses worldwide within a single year. This highlights the increasing frequency of climate-related disasters and their rising costs.

The Indian coast has become vulnerable to tropical cyclones, directly affecting millions of coastal people. The accelerated rise in sea levels, exceeding the global average, poses a direct threat to fishing communities. Coastal erosion is severe, with 33.6% of coastal land already eroded. The increasing ocean warming and SST further endanger fishermen's livelihoods as key fish species migrate to different areas, making them harder to catch. All these climate events are directly impacting the lives of coastal people, many of whom belong to marginalized fishing communities with low socioeconomic indicators and limited adaptive capacity. Coastal



communities, historically marginalized, the majority of climate disasters are primarily affecting them. These coastal people have low level of adaptive capacity and higher level of vulnerability.

Given this severe situation, it is imperative to prioritize these coastal communities. The fishing sector significantly contributes to GDP and food security, making it crucial to protect and support those engaged in fishing. Effective adaptive and mitigation measures need to be implemented to address these challenges and ensure the well-being of coastal residents.

Future research

Further in-depth study is needed to assess the impacts of climate change events in each socio-economic indicator among the coastal residents particularly fishermen communities. As far as the adaptive measures are concerned, the historical backwardness and capacity of these people to cope with such measures has to be taken into account in the future research to formulate proper measures to face challenges of climate change.

Reference

1. Aparna Roy (2019). Making India's Coastal Infrastructure Climate-Resilient: Challenges and Opportunities, *Occasional Paper No. 207*, August 2019, Observer Research Foundation.
2. Arabinda Samanta (1997). Cyclone Hazards and Community Response in Coastal West Bengal: An Anthro-Historical Perspective. *Economic and Political Weekly*, Vol. 32, No. 38 (Sep. 20-26, 1997), pp. 2424-2428
3. Bay of Bengal News (2008). Impact of Climate Change on Indian Marine Fisheries. March-June, 2008, https://www.bobpigo.org/html_site/bbn/march-june08/March-June2008-Pages32-37.pdf
4. Bimal P. Mohanty, Sasmita Mohanty, Jyanendra K. Sahoo and Anil P. Sharma (2010). Climate change: impacts on fisheries and aquaculture In *Climate change and variability* (Ed.) Suzanne Simard. <https://www.intechopen.com/chapters/11440> , accessed on 15-08-2023
5. Bishnupriya Sahoo and Prasad K. Bhaskaran, (2019). Prediction of storm surge and coastal inundation using Artificial Neural Network—A case study for 1999 Odisha Super Cyclone. *Weather and Climate Extremes*, Volume 23, March 2019, <https://www.sciencedirect.com/science/article/pii/S2212094718301695> , accessed on 08-08-2023
6. Central Marine Fisheries Research Institute, <http://eprints.cmfri.org.in/13281/>
7. Costanza Naguib, Martino Pelli, David Poirier, Jeanne Tschopp (2022). The impact of cyclones on local economic growth: Evidence from local projections. *Economics Letters*, Volume 220, <https://www.sciencedirect.com/science/article/pii/S0165176522003457#fn3>, accessed on 08-08-2023



8. Daniel Etongo and Lyn Arrisol,(2021). Vulnerability of fishery-based livelihoods to climate variability and change in a tropical island: insights from small-scale fishers in Seychelles. *Discover Sustainability*, 2:48, <https://doi.org/10.1007/s43621-021-00057-4>
9. Dilanthi Amaratunga, (2022). How does climate change affect coastal regions?. *Land Journal*, <https://ww3.rics.org/uk/en/journals/land-journal/how-does-climate-change-affect-coastal-regions-.html>
10. Gopalakrishnan A. (2021). Marine Fish Landings in India 2021. Central Marine Fisheries Research Institute, Kochi
11. https://en.wikipedia.org/wiki/North_Indian_Ocean_tropical_cyclone
<https://www.sciencedirect.com/science/article/abs/pii/S0308597X09001237?via%3Dihub>, accessed on 25-08-2023
12. India Meteorological Department, Ministry of Earth Sciences, Government of India, <https://mausam.imd.gov.in/>
13. India Meteorological Department. (2023). Various Reports on cyclonic disturbances over North Indian Ocean. Ministry of Earth Sciences, Government of India.
14. IPCC, (2007). Climate Change 2007 Synthesis Report. Intergovernmental Panel on Climate Change, https://www.ipcc.ch/site/assets/uploads/2018/02/ar4_syr_full_report.pdf, accessed on 15-08-2023
15. Isha Das et al.,(2020).Effects of climate change and management policies on marine fisheries productivity in the north-east coast of India. *Science of The Total Environment*, Vol. 724, <https://www.sciencedirect.com/science/article/abs/pii/S0048969720315953>, accessed on 25-08-2023
16. Jones, R.L., Guha-Sapir, D. & Tubeuf, S. (2022). Human and economic impacts of natural disasters: can we trust the global data?. *Sci Data* **9**, 572
<https://doi.org/10.1038/s41597-022-01667-x>
17. Jublee Mazumdar & Saikat Kumar Paul, (2016). Socioeconomic and infrastructural vulnerability indices for cyclones in the eastern coastal states of India. *Nat Hazards* **82**, 1621–1643 <https://doi.org/10.1007/s11069-016-2261-9>
18. Kalsi S.R., (2006). Orissa super cyclone – A Synopsis. India Meteorological Department, *MAUSAM*, 57, 1 (January 2006), 1-20.
19. Khadar KVA (2021). How climate change is taking a toll on livelihoods of small-scale fishers in Kerala. MongaBay e-News, <https://india.mongabay.com/2021/08/how-climate-change-is-taking-a-toll-on-livelihoods-of-small-scale-fishers-in-kerala/>, accessed on 25-08-2023
20. Komali Kantamaneni et al., (2019). A Systematic Review of Coastal Vulnerability Assessment Studies along Andhra Pradesh, India: A Critical Evaluation of Data Gathering, Risk Levels and Mitigation Strategies. *Water*, 11, 393



21. Komali Kantamaneni et al., (2022).Appraisal of climate change and cyclone trends in Indian coastal states: a systematic approach towards climate action. *Arabian Journal of Geosciences*, 15: 814
22. Krishnan R., J. Sanjay, Chellappan Gnanaseelan, Milind Mujumdar, Ashwini Kulkarni, Supriyo Chakraborty (2020). Assessment of Climate Change over the Indian Region, A Report of the Ministry of Earth Sciences (MoES), Government of India. Springer Open, <https://link.springer.com/book/10.1007/978-981-15-4327-2> accessed on 08-08-2023
23. Marie-Caroline Badjeck, Edward H. Allison, Ashley S. Halls, Nicholas K. Dulvy (2010). Impacts of climate variability and change on fishery-based livelihoods, *Marine policy*, Volume 34, Issue 3,
24. Medha Deshpande et al., (2021). Changing status of tropical cyclones over the north Indian Ocean. *Climate Dynamics*, 57(3),
<https://link.springer.com/article/10.1007/s00382-021-05880-z#citeas> , accessed on 25-08-2023
25. Murari Lal, (2003).Global Climate Change-India's Monsoon and its Variability. *Journal of Environmental Studies and Policy* (JESP), V6 (1), June 2003, pp. 1-34
26. National Centre for Coastal Research (NCCR), a division of the Union Ministry of Earth Sciences, Government of India, <https://nccr.gov.in/?q=technical-report>
27. Princy, J.R., et al. (2023). Non-monsoonal Coastal Erosion Due to the Tropical Cyclone (OCKHI) and Its Impacts Along Thiruvananthapuram Coast, Southwest Coast of India – A Geospatial Approach. In: Jayaraju, N., Sreenivasulu, G., Madakka, M., Manjulatha, M. (eds) Coasts, Estuaries and Lakes. Springer, Cham. https://doi.org/10.1007/978-3-031-21644-2_29
28. Roxy M.K.et al., (2015). A reduction in marine primary productivity driven by rapid warming over the tropical Indian Ocean. *Geophysical Research Letters*, 43(2), pp. 826-833.http://www.rocksea.org/bin/research/roxy_phytoplankton_indian_ocean_warming_gr1_2015.pdf, accessed on 20-08-2023
29. Sajna Valiyakath Hussain (2021).Impact of climate change on the fishery of Indian mackerel (*Rastrelliger kanagurta*) along the Kerala coast off the southeastern Arabian Sea. *Regional Studies in Marine Science*, Volume 44,
<https://www.sciencedirect.com/science/article/abs/pii/S2352485521001651>, accessed on 25-08-2023
30. Selvaraj J.J., Daniel Guerrero, Maria Alejandra Cifuentes-Ossa, Ángela Inés Guzmán Alvis (2022). The economic vulnerability of fishing households to climate change in the south Pacific region of Colombia.*Heliyon*, Vol.8:5,
<https://www.sciencedirect.com/science/article/pii/S2405844022007137> , accessed on 25-08-2023
31. Senapati A., (2023). Odisha's fish stocks are depleting, courtesy warming seas; here's how. Down To Earth E-News, <https://www.downtoearth.org.in/news/climate->



- change/odisha-s-fish-stocks-are-depleting-courtesy-warming-seas-here-s-how-89139
accessed on 24-08-2023
32. Sibananda Senapati and Vijaya Gupta,(2017). Socio-economic vulnerability due to climate change: Deriving indicators for fishing communities in Mumbai. *Marine Policy*, Vol.76, Pp.90-97,
<https://www.sciencedirect.com/science/article/abs/pii/S0308597X16307515>, accessed on 08-08-2023
 33. Singh O.P., Tariq Masood Ali Khan, Shahibur rahman shovon (2001). Has the frequency of intense tropical cyclones increased in the north Indian Ocean?,
 34. Sreeraj P. et al., (2022). Extreme sea level rise along the Indian Ocean coastline: observations and 21st century projections. *Environmental Research Letters*, 17,
<https://iopscience.iop.org/article/10.1088/1748-9326/ac97f5/pdf>, accessed on 24-08-2023.
 35. Swapna P. et al., (2020). Sea Level Rise. In (Ed.) R. Krishnan et al. *Assessment of Climate Change over the Indian Region*, A Report of the Ministry of Earth Sciences (MoES), Government of India. Springer Open
https://link.springer.com/chapter/10.1007/978-981-15-4327-2_9
 36. The International Disaster Database of The Centre for Research on the Epidemiology of Disasters (CRED), <https://public.emdat.be/>, accessed on 20-08-2023
 37. UNEP (2010). Sea-level Rise in the Indian Ocean Differs by Region and Low-lying Pacific Reef Islands can Grow or Shrink in Size Depending on Conditions. Global Environmental Alert Service,
https://na.unep.net/geas/getUNEPPageWithArticleIDScript.php?article_id=56, accessed on 24-08-2023.
 38. Unnikrishnan, A.S., and Antony, C. (2022). Changes in Extreme Sea-Level in the North Indian Ocean. In: Unnikrishnan, A., Tangang, F., Durrheim, R.J. (eds) *Extreme Natural Events*. Springer, Singapore. https://doi.org/10.1007/978-981-19-2511-5_10
 39. World Meteorological Organization (2021). WMO Atlas of mortality and economic losses from weather, climate and water extremes (1970–2019). United Nations,
https://unfccc.int/documents/306865?gclid=Cj0KCQjw3JanBhCPARIsAJpXTx4RhXBn1y5rWKGgt0abE0GHMSA0fMhsy4bnZKLoGVim_LB52VGk9c4aAnY0EALw_wcB
 40. World Meteorological Organization (2022). State of the Global Climate 2021.WMO No.1290, <https://library.wmo.int/records/item/56300-state-of-the-global-climate-2021>