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Review

Analysis of policies and programmes for tackling coastal climate risks in India

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ABSTRACT

Climate risks threaten the coastal areas all over the world. In the case of India, which has a densely populated coastline of 7516.6 km, developing effective policies and management strategies to cope with the current and future climate risks is imperative. The paper attempts to identify the major climate risks faced by coastal India through a systematic literature review between 1991 and 2022. Cyclones, Sea Level Rise, Floods, and Rainfall extremes accounted for more than 60 percent of the climate risks/issues on the Indian coast, with more pronounced incidences in the eastern coastal states than the western coastal states. We further analysed how different acts and policies associated with coastal management have addressed climate risks through a qualitative assessment of climate action plans of the Indian coastal states following the concept matrix approach. The results revealed that though a national-level policy is absent specifically for addressing coastal climate risks and adaptation, the coastal states have specific components on coastal vulnerabilities and adaptation. Further review of different states' disaster management acts, and policies emphasized the need for micro-level planning for climate-inclusive disaster management and building capacities of the concerned officials. The review of the evolution of coastal zone management in India revealed that there has been a dilution in the conservation of coastal ecosystems and reduction of no development zone under the pretext of enhancing livelihoods. The overall analysis of the national and state action plans, disaster management policies, and coastal regulation zone notifications in India shows that there is a need to include emerging climate risks in integrated planning and promote synergy amongst different sectors and institutions related to coastal governance and blue economy.

1. Introduction

Developing and modifying policies in response to emerging climate risks is necessary to minimise the loss and damage from climate change. Initially, the vulnerability to climate change was measured in terms of exposure, sensitivity and adaptive capacity (IPCC, 2007) to prioritise actions for adaptation, which now has been subsumed under the concept of climate risk, measured based on hazards, exposure and vulnerability (Pörtner et al., 2022). In the latest IPCC assessment report, risk is defined as "the potential for adverse consequences for human or ecological systems" (Pörtner et al., 2022). The definition recognises that risks can arise from both the potential impacts and the responses to climate change (Reisinger et al., 2020). The impact aspect is crafted around the interaction between hazard, vulnerability and exposure (Lavell et al., 2012), while the response aspect caters to the response risk arising from the implementation, effectiveness or outcomes of climate policies (Reisinger et al., 2020). Therefore, it is imperative to analyse how different policies related to a particular sector/site/region have evolved in response to the emerging climate risk.

The Global Climate Risk Index ranked India 7th in terms of the quantified impacts of extreme weather events linked to climate change (Eckstein et al., 2021). Meanwhile, the recent IPCC Assessment Report (Pörtner et al., 2022) has identified India, which has one-fifth of its population dependent on the coast for its livelihood, as one of the most vulnerable countries to Sea Level Rise (SLR). Around 4.1%of the economic activities in the country are dependent on marine resources, with fisheries contributing to 1.24% of the country's Gross Value Added (GVA) in the financial year 2020–2021 (Government of India, 2022;

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Ministry of Finance, Government of India, 2022). The coastal climate risks manifest as increased frequency and intensity of cyclones, coastal flooding and inundation, saltwater intrusion, and changes in the erosion accretion dynamics. These impact the ecological, social and economic activities of around 28 million Indians, especially the marginalised fisheries communities (Government of India, 2022). Moreover, the loss and damage due to climate change in India are expected to increase around 1.8% of GDP annually by 2050 (Kreienkamp and Vanhala, 2017), which necessitates a need to develop adaptation strategies based on the specific climate risks as identified in different geographical settings of the country. Therefore, identifying the emerging climate risks in the coastal areas and analysing how they are being addressed in the existing policy framework in the coastal governance context is of paramount interest.

Over the past three decades, severe cyclonic disturbances have occurred more frequently along India's coastline, endangering the livelihoods of coastal residents (India Meteorological Department, 2021). The Okhi cyclone in 2017 caused a 46% decrease in fishing days along the Kerala coast, affecting fishermen's livelihoods (Punya et al., 2021). These cyclones also pose severe risks to agrarian livelihoods since storm surges, coastal flooding, and saltwater intrusion accompany them. By the end of the century, sea surface temperatures in the Indian Ocean are predicted to rise by 2 °C–4 °C, thereby increasing cyclone activity by 10–20% (India Meteorological Department, 2021). Marine heatwaves are on the rise in the Indian Ocean region, with a higher increase in the western part. Furthermore, the Northern Indian Ocean has been identified as one of the 17 climate change hotspots, signifying that these regions are expected to warm faster than 90% of the world's oceans (Zacharia et al., 2016), impacting the rich mangrove ecosystems (Kandasamy, 2017). Consequently, the long-term effects of climate change are anticipated to influence the marine environment, potentially affecting the sustainability of fish stocks and intensifying pressure on marine fish populations. The 2020 marine heatwave significantly impacted the fisheries industry by extensively bleaching coral and destroying seagrass and kelp forests (Saranya et al., 2022), which are crucial blue carbon sequesters. Also, the updated INDC of India has identified coastal areas as one of the most vulnerable sectors to climate change. About 66% of India's coastlines have mangroves, with a projected carbon potential of 748.17 $MtCO_2e$ by 2030. This shows that tackling climate change in coastal areas will contribute to biodiversity conservation, disaster risk reduction and climate adaptation and mitigation. It will also help meet India's commitment to the Kunming-Montreal Global Biodiversity Framework to conserve 30% of the land, inland water and ocean ecosystems by 2030.

India formulated the National Action Plan on Climate Change (NAPCC), the main strategy document for planning adaptation and mitigation to climate change for different sectors of the country (Government of India, 2008a,b). One of the principles of NAPCC is to protect the poor and vulnerable sections of society through an inclusive and sustainable development strategy sensitive to climate change. Accordingly, it has outlined eight national missions for designing and implementing multi-pronged, long-term and integrated adaptation and mitigation strategies. Notably, even though the coastal risks are rising and are affecting one-third of the country, such issues are subsumed under different missions, like the National Water Mission and the National Mission on Strategic Knowledge for Climate Change. Recently, there has been a mention of adding a coastal mission under NAPCC; however, it is still uncertain, and there are some declining trends of budget allocation for the same (Demand for grants 2023-24 Analysis, 2023). Besides NAPCC, every state prepares a State Action Plan on Climate Change (SAPCC) based on specific issues related to climate change-induced impacts. Therefore, it is important to appraise the SAPCC of nine Indian coastal states concerning their response to the emerging climate risks.

Another major regulation on the conservation and management of the Indian coast is the Coastal Regulation Zone Notification (2011), a subordinate legislation under The Environmental Protection Act (1986). It provides for the preparation of Coastal Zone Management Plans (CZMP) based on the principles of Integrated Coastal Zone Management (ICZM) (Puthucherril, 2011). The Ministry of Environment Forests & Climate Change (MOEF&CC), has been implementing the ICZM Projects in multiple phases in multiple states, with the funding of the World Bank from 2010 onwards. The provisions of the projects include reducing vulnerability to natural hazards, especially from SLR and increased frequency of cyclones and storm surges, which have major implications on the coastal areas and communities (Origin of ICZM, 2022). While the existing CRZ notification was amended many times to conserve, protect and manage coastal and marine ecosystems to ensure the livelihood security of the coastal communities, it is vital to ascertain how well they address the adaptation needs to the increasing climate risk scenario of the coast. For this, a critical analysis of how ICZM has evolved in the context of addressing coastal climate risks is essential.

While climate action plans like NAPCC and SAPCC are envisaged for adapting to existing climate risks and mitigating future climate risks, in the aftermath of a risk turning into a disaster, the disaster management plan becomes the most important guiding document for dealing with the immediate impacts. The National Disaster Management Act mandates the preparation of national, state and district-level disaster management plans, whose effectiveness depends on identifying the present and future climate risks (Disaster Management Act, 2005). So, to understand how coastal climate risk is addressed via governance instruments, identifying how they are inculcated into the disaster management scenario is also necessary.

The impacts and vulnerability of climate change have been studied across ecosystems in the country, especially the terrestrial ecosystems (Pandey et al., 2017; Patasaraiya et al., 2021; Yadava and Sinha, 2022; Singh et al., 2022; Devi et al., 2023), and the coastal ecosystems (Zacharia et al., 2016; Koya et al., 2017; Nazneen et al., 2022; Ramachandran et al., 2023). However, no systematic effort has been made to identify coastal climate risks, which is a prerequisite for designing any policy response. Therefore, the major research question we intend to address is how India's key major policy frameworks (ICZM, NAPCC & SAPCC, State Disaster Plans) have evolved to tackle new emerging coastal climate risks. Our hypothesis is that the new climate risks have not been adequately addressed in the existing policy frameworks.

Building on this rationale, the current paper is aimed with an objective to understand and identify the manifestation of climate risk on the Indian coast in the past three decades through a systematic literature review and analyse the existing coastal governance instruments towards addressing these emerging risks. This, in turn, will help to strengthen the policy response to emerging coastal climate risks.

2. Methodology

Our framing of this paper is from a policy response aspect to emerging coastal climate risks in India. With this view, we used "coastal climate risk" as a keyword for the systematic literature review, and not "hazard", even though hazard is an intrinsic component of climate risk. A systematic literature review is carried out to identify the type of climate risk studied across India. Since the coasts experience multiple kinds of hazards, the articles on risks are invariably linked to hazards. This paper uses the systematic literature review technique to identify the emerging coastal climate risk and analyse the existing policy frameworks for reducing the related loss and damage.

2.1. Study area

India has a coastline of around 7500 km spread across nine states and four union territories, and action plans on climate change are available at the state level. Therefore, the current analysis focuses only on the nine coastal states. A brief profile of the coastal states is provided in Appendix A (Table S1).

2.2. Overview of methodology

To achieve the objectives, a systematic literature review was carried out with the sole purpose of identifying how climate risk is researched across the coastal states in India. Furthermore, the NAPCC and SAPCC were analysed in the context of the identified climate risks. In the next step, the disaster management acts and policies were analysed to find how coastal climate risks have been incorporated into them. Following this, a detailed narrative review of the three notifications on coastal regulation zones was undertaken to understand how these notifications have evolved over the years in the context of climate risk. The overview of the methodology is given in Fig. 1.

2.3. Systematic literature review for mapping the coastal climate risks in India

A systematic literature review is a thorough and rigorous research approach for identifying, evaluating, and synthesising all available information on a research topic. It entails a methodical and structured strategy for finding, choosing, evaluating, and analysing relevant academic articles, reports, and other sources of information from different databases and publications (Petticrew and Robert, 2006). Systematic reviews are increasingly used in climate change research (Hoque et al., 2017; Bisaro et al., 2018; Mallette et al., 2021; Predragovic et al., 2023). In the present study, we have done a systematic review of the past 30 years to map out the climate risks in the coastal regions of India.

A preliminary scoping review was conducted to identify relevant terms to develop the search string. The final search string used in the literature search was "coastal climate risk and India," with at least "climate" OR "risk" and "coastal India" as the exact phrases in the article. On July 27, 2023, a search on the Google Scholar database produced 1540 results. The date delimitations were set from 1991 to 2022 as this timespan covers the earliest and latest Coastal Regulation Zone Notifications (1991and 2019), after which the number of papers for screening came down to 1510. Only English, peer-reviewed articles, and book chapters pertaining to the Indian coastline were included in the database filters. After title and abstract screening of 1510 articles, only 64 articles were retained. The retained papers contained documentation of different types of coastal climate risks in India, their impacts, assessments, etc. Most of the excluded publications at this stage focused on health problems in coastal regions or non-coastal studies (such as health, agriculture, etc.). The processes and steps of the systematic literature review are further explained through the PRISMA flowchart (Fig. 2.). A full-text scan of 64 articles was done using the inclusion and exclusion criteria and relevance screening (see Appendix A, Table S2). Finally, 35 articles were chosen for an intensive review.

A concept matrix was used to document the specific research question, i.e., mapping of coastal risks in India. It provides an organised visual representation of how the different articles address specific aspects of the research question. The matrix included authors, year of publication and journal, types of coastal risks addressed in the study, the geographical area and major conclusions drawn (Appendix B).

2.4. Review of coastal management in the context of climate risks

Policies and regulations at the national and state levels linked to climate change and coastal management are important tools to address emerging climate coastal risks. In this context, an assessment of the existing NAPCC and SAPCC is essential to understand the extent of inclusion of climate risk and ICZM into them. The concept matrix approach (Klopper et al., 2007) was employed to capture the inclusion of different concepts pertaining to climate risk, ICZM, adaptation and mitigation with a specific focus on coastal areas in the existing state action plans on climate change. Since climate risk management is inextricably linked with disaster management, the current National Disaster Management Policies, along with the coastal state's disaster management plans, were also reviewed to gain a deeper understanding of these linkages. Furthermore, a review of the Coastal Regulation Zone notifications (1991, 2011 and 2019) was undertaken to understand the climate responsiveness of Coastal Zone management in India.

3. Results

Worldwide, Studies have addressed how climate risk affects coastal zone management (Phillips et al., 2018; Powell et al., 2019). Since climatic extremes are not avertable, identifying and understanding them is vital in the adaptation planning and sustainable management of coastal resources and infrastructure. This becomes relevant for India as the country has a diverse coast with sandy shores, estuaries, cliffs, lagoons, etc., leading to differing degrees of exposure and susceptibility to different climate hazards. This section details the major climate risks coastal India faces as identified through a systematic literature review and how different acts and policies associated with coastal management have addressed them.

3.1. Coastal climate risks in India

In the past thirty years, there has been a consistent increase in publications on climate risk in coastal India. The systematic review identified a total of nine climate-related risks like cyclones, rainfall and temperature extremes, coastal inundation, flood, saltwater intrusion, shoreline changes, drought, and sea surface temperature across the coastal states in India, with a varying number of studies in different states on different risks (Fig. 3.). Cyclones, SLR, Flood and Rainfall extremes accounted for more than 60% of the climate risks addressed in the literature. The number of articles in the last decade was evidently higher than in the previous two decades. The sudden interest over the last ten years could be attributed to the sudden increase in the frequency of climate extremes in coastal India, like the Nilofer cyclone (2014), Kerala floods (2018), and the Amphan cyclone (2020). A higher number of studies were on the East Coast rather than the West Coast, which can be attributed to the historical incidences of cyclones on the East Coast (Saini et al., 2020). The maximum number of articles addressed climate risk issues in West Bengal, a state on the East Coast. Cyclone risk is the most widely researched risk in coastal areas (Rao et al., 2015; Ghosh et al., 2016; Ali et al., 2021; Shah et al., 2021), followed by rainfall extremes and shoreline changes (Lakshmi et al., 2021; Natarajan et al., 2021; Parthasarathy et al., 2022).

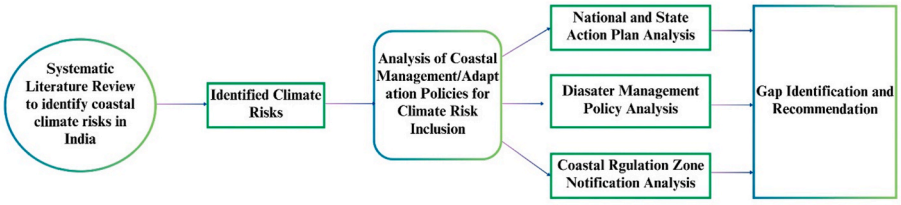

Fig. 1. Methodology flowchart.

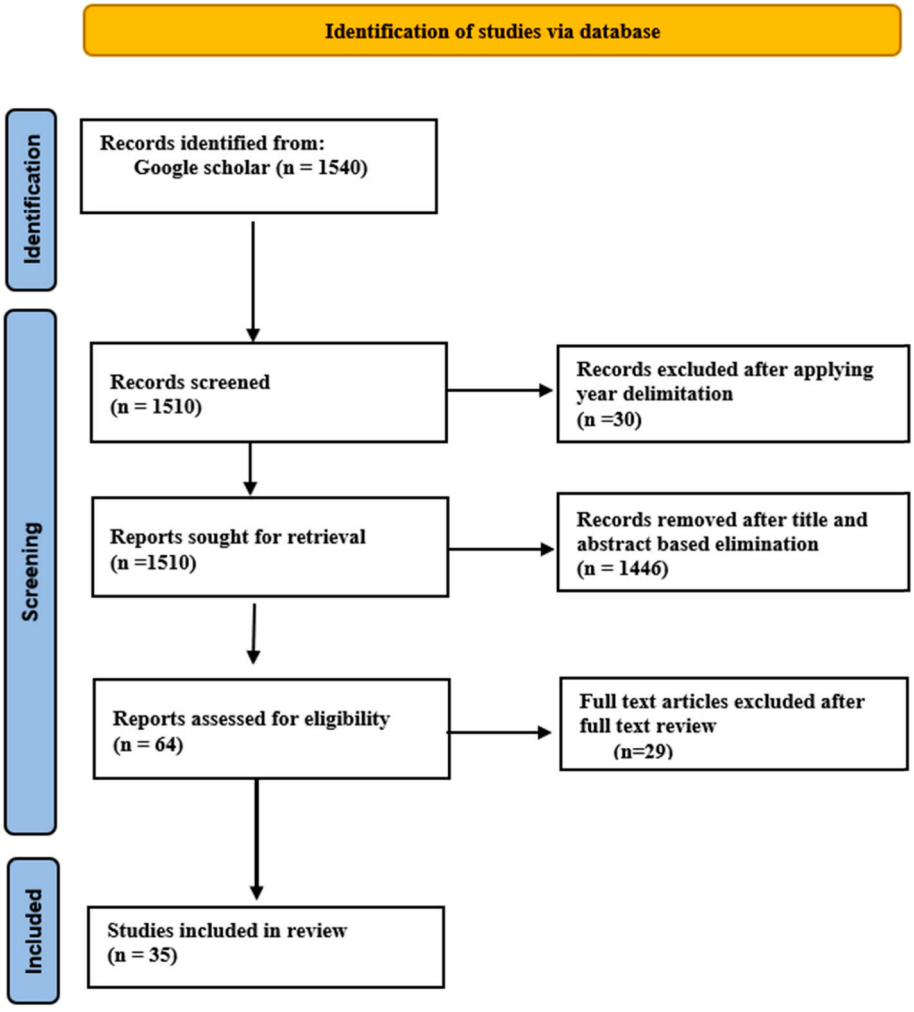

Fig. 2. PRISMA flowchart detailing the steps followed in the selection of studies in the systematic literature review.

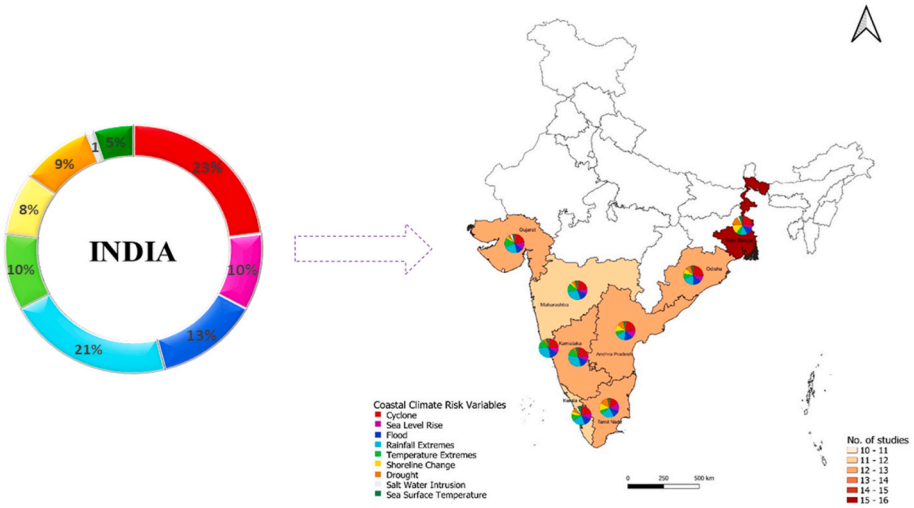

Fig. 3. Distribution of coastal climate risks in India addressed in reviewed literature (Note: Temperature extreme is representing the air temperature extremes).

3.2. Addressal of climate risk in national and state action plans on climate change

The Government of India initiated the NAPCC in 2008 as a comprehensive plan to deal with climate change. The initial strategy included eight missions, each one focusing on a different component of climate change, namely, the National Solar Mission, National Mission for Enhanced Energy Efficiency, National Mission on Sustainable Habitat, National Water Mission, National Mission for Sustaining the Himalayan Ecosystem, National Mission for a Green India National

Mission for Sustainable Agriculture and National Mission on Strategic Knowledge for Climate Change (Government of India, 2008a,b). Since climate change is a dynamic issue, the NAPCC is a living document subject to revision based on new and rising challenges. The plans to add a new mission to address the effects of climate change on the coast, the National Coastal Mission (NCM), is proposed (Pti, 2020; Mohan, 2022). While there has been a mention of budgetary allocations for NCM in the past six years, there has been constant underutilisation of funds over the years (Demand for grants 2023-24 Analysis, 2023). While the NAPCC doesn't feature coastal area-specific plans, the SAPCC of all nine coastal states has specific components on coastal vulnerability and adaptation (Table 1).

Except for two states, Maharashtra and West Bengal, all the other states have come up with a second version of SAPCC (TERI, 2014; Government of West Bengal, 2021). In the case of Andhra Pradesh, though a new SAPCC was initiated, only the old SAPCC was available online, which has been used in the analysis. Out of the new SAPCCs, only Gujarat, Kerala and Odisha followed the latest vulnerability assessment framework of IPCC (Government of Odisha, 2021; Government of Gujarat, 2021; DoECC, 2022). Most vulnerability assessments are generally carried out at district levels, except for Goa, which has the latest plan. Though all the documents mention SLR in varying degrees, the state of Tamil Nadu has projected future SLR for the state (Government of Tamil Nadu, 2021) Department of Environment and Climate Change, 2021). Some states focussed on developing adaptation strategies based on specific sectoral adaptation plans (Government of Karnataka, 2021; Government of Tamil Nadu, 2021). The Odisha state has specific programmes delineated under coastal and disaster risk management (State Action Plan For Climate Change For The State Of Goa, 2023). Managing mangroves is one of the most important adaptation strategies identified in all SAPCCs (Table 1). Climate risk is either mentioned or detailed in all the documents. Except for Goa and Maharashtra, all the other states had a coastal area-specific adaptation strategy (Goa State Biodiversity, 2023). The geographical diversity of the states resulted in varying degrees of preparedness across them.

3.3. Inclusion of climate risks in disaster management planning in coastal India

Until the early 2000s, relief and rescue efforts were the cornerstone of India's disaster management strategy (Jha et al., 2016). After the Odisha Super Cyclone in 1999 and the Indian Ocean Tsunami in 2004, the need for early preparedness became clear, and intentional measures were taken to create a national framework integrating economic, environmental, and general developmental issues for an effective response to catastrophes (Gupta, 2018). Since meteorological and climatological risks constitute a significant part of disaster risks, the National Disaster Management Plan (2016) has added Climate Change Risk Management as a new and sixth thematic area for disaster risk management in the responsibility framework. The National Disaster Management Policy (2009) outlines the mitigation/reduction/severity of disaster risk and consequences as one of the major aspects of disaster management (National Disaster Management Authority, 2009). Additionally, developing contemporary forecasting and early warning systems backed by responsive and failsafe communication with information technology support has been added as one of the objectives. The policy identifies the need for synergy between climate change adaptation and Disaster Risk Reduction (DRR) at national, state and local levels to tackle the increasing climate risks in the country. To achieve this, an in-depth knowledge of local climate risk is essential, which can feed into developing climate-inclusive disaster management plans. The latest disaster management plans of the majority of the coastal states also stress the need for developing the capacity of different departments and local bodies to achieve this (Andhra Pradesh State Disaster Management

Table 1
Analysis of climate risk in state action plan on climate change (SAPCC) of coastal states in India.

State	Gujarat	Maharashtra	Goa	Karnataka	Kerala	Tamil Nadu	Andhra Pradesh	Odisha	West Bengal
Year of publication	2021	2014	2023	2021	2022	2021	2012	2021	2017
Climate vulnerability assessment									
Framework	IPCC 2014	IPCC, 2007	Not specified	IPCC 2014	IPCC 2014	IPCC, 2007	IPCC, 2007	IPCC 2014	Initiated
Level	District	District	Taluk level	District	District	District	District	District	
Observed vulnerability	✓	x	✓	Not specified	✓	✓	✓	✓	
Climate component	✓ (2)	✓ (6)	x	Not specified	✓ (2)	✓ (4)	✓ (2)	✓ (5)	
Ecological and physical components	x	x	✓ (7)	Not specified	✓ (10)	✓ (24)	✓ (3)	✓ (2)	
Socio-economic component	✓ (14)	✓ (12)	✓ (2)	Not specified	✓ (9)	✓ (35)	✓ (10)	✓(13)	
Sectoral vulnerability	✓ (8)	x	x	Not specified	✓ (5)	✓ (7)	x	✓	
Future vulnerability	✓	x	x	Not specified	✓	✓	✓	x	
Climate projection									
Extreme rainfall	✓	✓	✓	✓	✓	✓	✓	✓	✓
Extreme temperature	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cyclone risk	X	X	✓ (m)	✓	X	X	✓		✓
Sea level rise	✓	✓(p)	✓	✓	✓	✓(p)	✓	✓	x
Coastal zone management	✓	✓	✓	X	✓	✓	✓	✓	✓
Coastal erosion	✓	X	✓	✓	✓	✓	✓	✓	x
Flood management	✓	✓	X	X	✓	✓	✓	✓	✓
Disaster management	✓	X	✓	✓	✓	✓	✓	✓	x
Loss and Damage Assessment to Climate Risk	x	x	x	x	x	X	✓	x	x
Mangrove restoration/management	✓	✓	✓	✓	✓	✓	✓	✓	✓
Coastal area-specific adaptation strategy	✓	X	X	✓	✓	✓	✓	✓	✓

"m" represents mention of the climate risk and "p" represents the inclusion of projected analysis of the climate risk in SAPCC. The numbers in the bracket indicate the number of parameters in each component.

Authority, 2017; Karnataka State Disaster Management Authority, 2021; Gujarat State Disaster Management Authority, 2021; Tamil Nadu State Disaster Management Authority, 2023). Sound approaches to DRR mainstreaming inherently incorporate how climate change influences the disaster risk scenarios because they function as risk multipliers, aggravating uncertainty related to practically every hydrometeorological hazard (Karnataka State Disaster Management Authority, 2021). This is only achievable when in-depth research and analysis on mainstreaming DRR and CAA (Climate Adaptation Action) is undertaken at the sub-district/district/state levels and incorporated into their respective disaster management plan.

3.4. Climate risk and coastal zone management in India

The Coastal Regulation Zone Notification, 1991 is the primary law regarding managing coastal areas in India. According to the notification, the entire coastal belt of India was divided into different zones (I, II, III and IV), each having prohibitions and provisions for various activities based on ecology and human settlements (Krishnamurthy et al., 2014). Initially, it adopted a "one-size-fits" approach for the entire Indian coast, inviting much criticism and hurdles in implementation. The subsequent notifications (CRZ, 2011; CRZ, 2019) addressed these lacunae by accommodating the diverse nature of the Indian coasts. However, the same cannot be said about incorporating climate risk in coastal management.

From the climate change adaptation and mitigation perspective, the 1991 notification assigned power to determine and include areas under CRZ I if they are inundated by SLR. Apart from this precautionary step, no proactive actions were provided under the act. Even the concept of Integrated Coastal Zone Management (ICZM), part of agenda 21 of the Rio Conference of 1992, was included later in the CRZ notification of 2011 (Rio Declaration on Environment and Development, 1992; Purohit and Markus, 2013). Additionally, it gave a more comprehensive plan for managing fragile coastal ecosystems with the livelihood of fisherfolk, preserving coastal ecology, and promoting economic activity. Disaster management and bottom-up governance strategies also found their way into the notification after the 2006 tsunami. Furthermore, it proposed demarcating the hazard line through the coast based on SLR, wave height and tidal surge data. This has been further developed in the Coastal Regulation Zone notification 2019, which stipulated that developmental activities in the area between the hazard line and high tide line (HTL) should be carried out based on climate change/risk and shoreline changes (CRZ, 2019). While a general trend is observed towards an in-principle inclusion of climate change in coastal management policies, various provisions like the increase in floor space index for construction of buildings in CRZ III and the reduction of no development zone (NDZ) limit from 200 to 50 m from the coast have been diluted over the years under the pretence of improving the livelihood of coastal communities. However, these interventions catered to business interests like tourism, mining, etc., often disturbing the delicate balance between coastal protection and development (Puthucherril, 2011). A prior Environmental Impact Assessment (EIA) clearance was introduced as a criterion in the 2011 notification. However, the latest changes in the Environmental Impact Assessment Notification (2006) introduce a provision of a "post-facto" clearance mechanism for projects violating EIA notification (Ministry of Environment Forest and Climate Change, 2020; Yadav and Aggarwal, 2023). In addition, introducing a rating system for State Environmental Impact Assessment Agencies based on their speedy clearance of projects also favours development while undermining the conservation of coastal areas.

The issue gets further complicated due to the diversity of laws and institutions managing and governing the coastal zones. The Marine Protected Areas (MPAs), which form a part of CRZ I-A, are governed according to the Wildlife (Protection) Act 1972 (WPA, 1972). While the previous CRZ notifications did not allow for any activities within the CRZ I, the 2019 notification allows for activities like ecotourism, sea links, salt harvesting roads on stilts, desalination plants, etc., which prima facie conflicts with the protection of such fragile ecosystems (Appendix A, Table S3). Basu and Mandal (2023) rightly pointed out the peculiar relationship between these two policies, which either strengthens or weakens each other's effectiveness depending upon the context. Similarly, fishing activities permitted and regulated within CRZ IV-A (low tide level up to 12 nautical miles) are also subject to regulations under the Marine Fisheries Regulation Act by states.

The most recent policy document on climate adaptation in the Indian coast is the Reference Manual on Climate Change Adaptation Guidelines for Coastal Protection and Management in India (Black et al., 2018). It provided regulatory and intervention guidelines to improve the county's ICZM strategies. The document recognises that the CRZ regulations don't account for SLR and introduces the Minimum Beach Level (MBL) and a Minimum Floor Level (MFL) for buildings. It proposed Shoreline Management Plan (SMP) principles to identify social and economic aspects while providing the best methods to reduce coastal risk and sustainably manage coastal resources. At the same time, the intervention guidelines are heavily coastal engineering-oriented.

The existence of multiple stand-alone regulations limits the achievement of coastal management and protection goals. It also hinders the lives and livelihoods of people whose livelihood-generating activities are regulated from multiple fronts, especially traditional fishermen. Fig. 4 summarises the emergence of climate risks vis-à-vis the evolution of various coastal governance instruments at the national level.

4. Discussion

Coastal ecosystems are so diverse that they become a governance challenge (Glaser and Glaeser, 2014). The multiplicity of stakeholders, sectors and the interconnections between terrestrial and oceanic governance itself complicate coastal governance. Climate change adaptation fundamentally is a complicated mix of multiple sectors, stakeholders and priorities, which further aggravate the challenges of coastal governance. Thus, coastal management in the context of climate change requires understanding the types of climate-induced risks and further designing contextual adaptation strategies to cope with them.

There are different methods to understand how climate change affects coastal governance; while some studies deal with coastal governance in totality, others deal with the climate adaptation aspect. Ireland's ICZM policy frameworks and Climate policy were analysed by applying the principles of Earth System Governance to understand barriers in integrating coastal management and climate adaptation (Falaleeva et al., 2011). The policies and programs of major deltaic regions of India, Ghana and Bangladesh were analysed through the lenses of human rights, natural resource management and disaster response (Hossen et al., 2019), which found that though the policies addressed climate adaptation, it falls short in the analysed angles. Capital Assets Framework was used for the temporal assessment of climate change adaptation and ICZM in the context of coastal governance in Kenya (Celliers et al., 2020), which revealed the importance of science-based policy formulation. Additionally, incorporating climate risk and projections in planning will help in predicting and thus reducing transboundary conflicts like shifting maritime boundaries due to shoreline change, fisheries disputes owing to changes in migration and distribution patterns of fish and displacement of coastal communities due to SLR, extreme events and coastal inundation. In the present work, we utilized the lens of climate risk to understand the country's policy narrative and evolution of coastal management rather than looking at coastal governance as a whole.

4.1. Understanding climate risks in coastal India

Apart from extreme events, the most direct threat to coastal areas is SLR, which is projected to affect two-thirds of the world's coastal areas in the coming years (IPCC, 2021). Research suggests that the sea level has risen at a rate of 2.5 mm per year along the Indian coastline since the

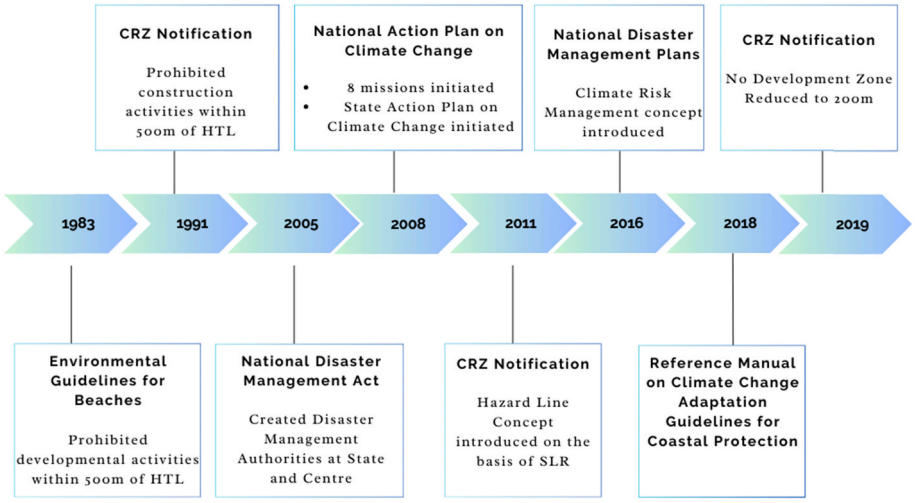

Fig. 4. Major milestones in the evolution of climate risk and coastal zone management in India.

1950s and further projected a mean SLR of between 15 and 38 cm by the middle of the 21st century (Maiti et al., 2015). The Khambhat and Kutch coasts in Gujarat, Mumbai, parts of the Konkan Coast and South Kerala are the most vulnerable stretches to SLR in India (Revi, 2008; Dhiman et al., 2019; Rehman et al., 2021). Such relative rise in sea level increases the frequency of severe coastal flooding in low-lying areas (Guhathakurta et al., 2011; IPCC, 2021). IPCC recognise climate change as a threat multiplier to other drivers of poverty (IPCC, 2018). It is estimated that India suffered an annual loss of 0.46% in GDP on account of flooding between 1980 and 2011 (Parida, 2020). The fisheries sector, encountered a significant share of this loss., The impact of climate change on critically vulnerable coastal ecosystems like corals, mangroves and wetlands spirals down to the coastal economy, pushing the dependent coastal communities to more poverty (Malakar and Mishra, 2020; Bera et al., 2021; Dasgupta et al., 2022). According to Harrod et al. (2018), small-scale fishers and aquaculture farmers are particularly vulnerable to climate change. Das et al. (2020) modelled the potential fish production and socio-economic conditions of the North Eastern Coast of India, revealing that productivity will dwindle by the end of the 21st century because of increased sea surface temperature. Weather shocks, acidification, and decreasing oxygen levels have negatively impacted the fish stock production, life cycle, behaviour, abundance, migration and distribution patterns of fishes (Khadar, 2021; Halder et al., 2022). Studies have shown that these impacts disproportionately affect low-income and traditional fishermen (Kumar and Tholkappian, 2006; Bahinipati and Patnaik, 2020; Vohra, 2020). The habitat loss of marine phytoplankton, corals and seagrasses also imperil the blue economy agenda of the country, which is at a nascent stage. The blue economy policy identifies climate change as a major challenge and focuses on developing capabilities in Coastal and Marine Spatial Planning and the National Blue Economy Council(Government of India, 2020). India has forged collaborations with countries like Norway and France on Integrated Ocean Management and acknowledged the ocean's importance in combating climate change, preserving biodiversity, and economic development. So, in the development of a well-thought-out blue economy policy, the impacts of climate risk need to be included. Thus, it becomes imperative that the existing and emerging risks be mapped and researched so as to incorporate them to have a science-based blue economy policy formulation.

Additionally, the systematic literature review revealed that most studies are skewed towards urban coastal cities. The studies focus on inundation and flood risk in urban agglomerations (Dhiman et al., 2019), indicator-based assessment framework for vulnerability (Sherly et al., 2015) and using GIS in scenario-based risk assessment of coastal cities (Rao et al., 2015). This bias may arise due to the economic importance of the cities as ports, trade and data availability. Besides, the majority of the studies have focused on measuring the impacts of climate change on livelihoods. However, there is a need for research that focuses on tackling the different coastal climate risks for different livelihood options existing in the coastal area.

4.2. Climate policy analysis

4.2.1. National and state action plans on climate change

The proposed National Coastal Mission has the potential to become the marine conservation and climate adaptation program, which can aid in the development of a climate-resilient coastal economy while safeguarding India's coast against climate change. India's blue economy policy also recognises the integration of NCM. However, it is currently riddled with funding and institutional challenges that need to be addressed on priority. The creation of NCM in NAPCC is critical in developing a long-term action plan for building the socio-ecological resilience of the coastal communities. For example, through the National Mission for Sustainable Agriculture (NMSA), the Government of India promoted many Climate Smart Agriculture (CSA) pilot projects across states to build the resilience of agricultural communities (NABARD (n.d.)). Meanwhile, the SAPCCs of coastal states show that climate risk and coastal vulnerability are gaining importance in policy formulation.

A comparative analysis of the SAPCCs reveals that the inclusion of coastal climate risks varies across states. This can be attributed to the diversity in the geomorphology of the coasts as well as to the historical incidences of climate risks (Government of India, 2023). Extensive research shows that countries exhibiting exceptional performance in coastal areas of adaptation and resilience have made good use of the expertise and resources of specialised research institutions. Gujarat, Maharashtra and Tamil Nadu have engaged premier institutes in the country in the preparation of the latest SAPCC. This highlights the importance of increasing regional-level research that contributes to the development of evidence-based policies for climate change adaptation and mitigation. Prime Minister's ten point agenda on DRR (n.d.) encourages universities located in coastal areas to specialise in managing risks from coastal hazards. Local-level community-based adaptation is instrumental in developing an effective coastal adaptation strategy. This requires undertaking vulnerability studies at the taluk or gram panchayat level. The same has been reflected in the SAPCC of Goa state, which is a positive step in the future direction. Furthermore, in the state of Kerala, Local Self- Governments are required to integrate climate and risk information into their annual plans as a part of the Rebuild Kerala Initiative after the Kerala floods of 2018. Whereas, the coastal

adaptation strategies of Maharashtra and Goa are subsumed under different sectors like agriculture and livelihoods. Dasgupta et al. (2018) too reiterated the need for a climate-literate policy to ensure a futuristic climate strategy. Thus, research-based adaptation and mitigation plan specific to the coastal states to deal with the emerging climate risks in a human-centric way is the need of the hour.

4.2.2. Disaster policy analysis

Risk assessment planning is an important component of disaster management, which involves identification of potential risks and vulnerabilities on the basis of which comprehensive plans are developed. International policy, such as the Hyogo Framework for Action (HFA) identified disaster risk management planning as the key to tackle climate change threats (United Nations International Strategy for Disaster Reduction, 2005). Ratter and Leyshon (2021) opined that the ability of a system to adapt to the changing climate is dependent on its flexibility and capacity to transition from existing old norms and practices to new technology and information-based options. The last 30 years witnessed a shift in the disaster management policy from disaster response-based action to disaster preparedness. In the same period, an increase in the type and distribution of different climate-related disasters was recorded. The impact and vulnerability of coastal infrastructure to disasters, especially cyclones, are widely researched world over (Bianchi and Malki-Epshtein, 2021), and in India. Center (2015) has largely acknowledged the significance of local knowledge in reducing and managing sustainable disaster risk. However, how well the understanding of climate risk is translated into an actionable policy is a debatable question (Bwambale et al., 2020). The present study reveals that the synergy between Climate Change Adaptation and Disaster Risk Reduction is fragmented in India. The same issue has been observed in South Africa by Busayo and Kalumba (2020), who emphasized that the harmonization of policy, programme and practice is an effective enabler to achieve this convergence. Similarly, the State Disaster Management Plans recognise the need to ensure synergy between climate adaptation action and disaster risk reduction. It reiterates that decentralisation is critical in developing local area-specific, effective adaptation and mitigation strategies, especially in a diverse country like India.

4.2.3. Coastal zone management and climate risks in India

Studies have shown that climate change adaptation strategies are either absent or poorly represented internationally in oceans and fisheries management policies (UNEP, 2016; de Lima et al., 2022). The evolution of policies in response to coastal stressors shows that although climate change is recognised in the policy documents, enforcement of zoning and other regulations for coastal conservation is seldom followed (Sanò et al., 2010; Birchall, 2020). The same has been observed in India's case. While conservation was the cornerstone in the initial years of coastal zone management, the dilution of CRZ notification over the years has put it on the back foot. A similar trend was observed in the case of the Environmental Impact Assessment Notification (2006), the dilution of which may intensify the widespread conversion of coastal zones to other uses, reducing coastal protection and thus making the coastal states vulnerable to natural hazards (Bijlsma, 1997; Untawale, 2006). While new guidelines and concepts like Minimum Beach Level (MBL), Minimum Floor Level (MFL), and Shoreline Management Plan (SMP) are coming to the forefront, unless and until the extent of climate risk is categorically included in the existing legislations, an effective and inclusive integrated coastal zone management is not achievable. From the review of the evolution of coastal management in India, it is learned that there has been a dilution in the conservation of coastal ecosystems and reduction of no development zone in the pretext of enhancing livelihoods. In addition to this, there are multiple stand-alone regulations that conflict with each other. This necessitates synergising different acts and regulations to strengthen the ecological integrity of coastal ecosystems and the livelihood security of coastal communities.

Studies show that there is a dearth of research in the analysis of climate risk in ICZM and the solution addressing them is not only a concern to India but across the globe (Bavinck et al., 2013; Krishnamurthy et al., 2014). In this context, emerging climate risks should form an intrinsic part of the management of coastal areas, and an in-depth understanding of coastal vulnerability to these risks becomes essential to develop an effective adaptation strategy. Furthermore, climate change adaptation in the fisheries and aquaculture sector is a governance challenge, where different levels and sectors of government, civil societies, community organisations, and academia need to interact to formulate and implement different pathways and policies (Kooiman et al., 2005; Bavinck et al., 2013; Kalikoski et al., 2019). Studies on climate change and coastal areas of the country show the need for formulating pro-poor policies based on the framework of sustainable development (Salim et al., 2018; Kantamaneni et al., 2019; Shaji, 2021). The key to achieving this is to undertake interdisciplinary research through leading institutes to aid in developing decentralised and climate risk-inclusive adaptation and disaster management plans.

5. Conclusion

Exploring climate adaptation through a legal and governance lens has been carried out in different countries (Falaleeva et al., 2011; McDonald and McCormack, 2021). They opine that learnings from ICZM and climate policy can be a strong backbone for coastal climate adaptation. However, in order to formulate/modify the policies related to managing the coast in the context of climate change, it is necessary to understand the emerging climate risks and their impacts on the coast and coastal communities. As a result, the paper attempts to map the climate risks across the Indian coast through a systematic literature review between 1991 and 2022 and further examines the policies' responsiveness towards climate risks.

The overall policy analysis in India shows that the country's coastal governance is riddled with multiple challenges, as described below.

i. *Fragmented institutional structure:* Coastal management in India is staggered across multiple jurisdictions with state and central laws for different aspects and sectors. While they are seemingly apart, it often leads to coordination issues, overlapping responsibilities and a lack of synergy, which ultimately limits the development of a coherent plan at the local level.
ii. *Inadequate enforcement:* The Coastal Regulation Zone rule is one of the most frequently violated legislations in the country. In addition, there has been a constant dilution in multiple policies related to conservation.
iii. *Lack of integrated planning among different sectors in coastal governance:* Coastal governance has multiple stakeholders and multiple sectors, each of which will be affected by the increasing coastal climate risk, directly or indirectly. The National Coastal Mission is mentioned in different policy documents, like blue economy draft, INDC, NAPCC but the subsequent actions are still not streamlined.
iv. *Lack of community involvement in planning:* Studies point out a lack of community involvement in CRZ planning.
v. *Insufficient inclusion of climate change in the planning process for coastal governance:* The study revealed that though there is a consensus on climate change being an emerging issue, the efforts of incorporating climate adaptation and mitigation in the documents and, subsequently, the coastal management planning were weak.

Similar challenges have been identified by studies across the world, like the South Africa (Celliers et al., 2020), Kenya (Ojwang et al., 2017) and Spain (Máñez et al., 2014), highlighting the integration of climate risk-specific knowledge in Integrated Coastal Management and Climate Change Adaptation to achieve effective coastal governance. This would entail a thorough analysis of contextual policies related to climate

change/risks to aid in effective coastal adaptation planning. Managing climate risk is built upon the foundation of knowledge on impacts, vulnerability and adaptation. Countries like Kenya, which has only policies at the national level to combat climate change (Ojwang et al., 2017), can learn from India's efforts at climate adaptation at the national and state levels. Similarly, while ICZM has been identified as a tool for coastal management and climate adaptation, it is not popularised in all countries as it has been in Europe, the USA, South Africa and India (Celliers et al., 2020; Tang et al., 2011; Shipman and Stojanovic, 2007). Analysis of the evolution of ICZM will help understand the pitfalls and challenges for other countries.

India, which has more than 60 million people living in Low Elevation Coastal Zones (Vinke et al., 2017), has a diverse coastal area and has also been under diverse coastal climate risks. Their impacts will also vary depending on the population density and their adaptive capacity, especially linked to the chief livelihood strategy followed by the people. It is, therefore, suggested that the diversity and severity of climate risks should be mapped at the state/district/sub-district levels to develop a climate-inclusive coastal governance strategy. For that, understanding the climate risk inclusiveness of the current acts and policies related to coastal management is essential. As India advances its Blue Economy Policy to boost fisheries and related sectors in its GDP, while ensuring the protection of coastal areas, addressing climate risks and weather shocks in coastal areas is vital for its successful planning and implementation. Additionally, India can enhance blue carbon sequestration by integrating SDGs, Disaster Risk Reduction, and climate adaptation principles at the community level.

6. Limitations and future directions

The present study attempted to analyse the evolution of India's coastal zone management policies in response to the increasing climate risks over the last 30 years. The systematic literature review was limited to articles in English language and using the freely available Google Scholar database. The inclusion of more research databases like Scopus and Web of Science will increase the number of articles for the screening process, thus will increase the diversity and coverage. Since the systematic review used "climate risk" as the keyword to identify the climate risks in coastal areas, biodiversity loss due to climate change and other impact aspects were not included in the review. We acknowledge the restricted nature of the conclusions drawn in this article due to its reliance solely on a desk-based analysis. However, the study makes it evident that there is a need to look into different aspects of coastal governance and how climate risk affects different sectors, actors, and stakeholders for effective coastal governance in India, utilising a systematic literature review. This entails incorporating empirical data and field based analyses. This will provide a more comprehensive identification of gaps in coastal governance in the changing climate scenario.

CRediT authorship contribution statement

Jyotsna C: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Bhaskar Sinha:** Writing – review & editing, Writing – original draft, Validation, Supervision, Conceptualization. **Jigyasa Bisaria:** Writing – review & editing, Supervision, Software, Methodology.

Declaration of competing interest

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants, participation in speakers' bureaus, membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Data availability

No data was used for the research described in the article.

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Appendix A. Supplementary data

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