Research Article

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A Comprehensive Study of Biparjoy Cyclone Disaster Management in Gujarat: A Case Study

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Abstract

Gujarat, a coastal state in India, has a long history of cyclone occurrences and has developed comprehensive disaster management strategies over the years. The study aims to analyze the effectiveness of these strategies by examining the response to the Biparjoy Cyclone, which occurred in June, 2023. The paper explores various aspects of cyclone disaster management in Gujarat, including early warning systems, evacuation planning, coordination mechanisms, relief and recovery efforts, infrastructure resilience, and community participation. By comparing the response to the Biparjoy Cyclone with previous cyclone events in Gujarat, valuable insights and lessons are derived to enhance future disaster management strategies.

Preliminary findings indicate both successes and challenges in Gujarat's cyclone disaster management. The state's early warning systems effectively alerted communities and facilitated timely evacuations, resulting in reduced casualties. However, certain areas, such as coordination among different agencies and post-disaster recovery, require further improvement. The research paper concludes by synthesizing the lessons learned from the Biparjoy Cyclone and making recommendations for enhancing cyclone disaster management in Gujarat. The findings add to the current volume of expertise on disaster management and equip policymakers, practitioners, and researchers working in the sector with practical insights. Finally, the study hopes to contribute to the creation of more robust and effective cyclone disaster management systems in Gujarat and other cyclone-prone regions of India.

Keywords: Biparjoy Cyclone, Meteorological Observations, Disaster Management, Miscellaneous Observations, Best Practice in Disaster Management, Synchronization of Agencies

Abbreviations

DWR	: Doppler Weather Radar
JTWC	: Joint Typhoon Warning Centre
IMD	: India Meteorological Department
NASA	: National Aeronautics and Space Administration
NDRF	: National Disaster Response Force
MGVLC	: Madhya Gujarat Vij Company Limited
PGVCL	: Paschim Gujarat Vij Company Limited
SDRF	: State Disaster Response Force
SSHWS	: Saffir-Simpson hurricane wind scale
WMO	: World Meteorological Organization

1. Introduction to Cyclone Biparjoy

The Cyclone was named "Biparjoy" by Bangladesh, indicating calamity or disaster. According to reports, the name was adopted by countries belonging to the World Meteorological Organization (WMO) in 2020. Biparjoy, was the first cyclonic storm over the Arabian sea on 6th June and had landfall over Saurastra and Kutch on June 15 before weakening into a depression on 8th June, 2023. Regional regulations for naming tropical cyclones encompass those occurring in the North Indian Ocean, which includes the Bay of Bengal and the Arabian Sea.

1.1 History of Cyclone in Arabian Sea

The Arabian Sea, situated in the northwestern part of the Indian Ocean, has a history of cyclonic activity influenced by various

meteorological factors. Cyclones in this region occur less frequently compared to the Bay of Bengal. The Arabian Sea experiences tropical cyclones primarily during two seasons: the pre-monsoon season (April to June) and the post-monsoon season (September to December). Factors such as sea surface temperatures, wind patterns, and monsoon dynamics play a crucial role in the formation of cyclones.

Notable cyclones in the Arabian Sea include Cyclone Gonu (2007), which reached Category 5 intensity, making landfall on the coast of Oman and causing significant damage. Cyclone Phet (2010) and Cyclone Nilofar (2014) also impacted the Arabian Sea region, bringing heavy rainfall and causing floods in Oman and Pakistan. The tabulated information in Table 1 provides a comprehensive overview of the cyclone history. A general pattern emerges, indicating that the majority of cyclones affecting Gujarat state occurred during the months of May and June.

Year	Month/ Date	Cyclone name	Severity	Landfall	Wind speed (kmph)	Deaths
1975	19-24 Oct	N/A	Severe Cyclonic Storm	Porbandar	180	85
1976	31 May- 5 June	N/A	Severe Cyclonic Storm	Saurastra Cost	167	0
1978	5-13 Nov	N/A	Extreme Cyclonic Storm		278	N/A
1982	4-9 Nov	N/A		Veraval		507
1996	17-20 June	ARB 01		Near Somnath	111	33
1998	4-9 June	ARB 02		Porbandar	195	> 10000
2001	21-29 May		Extreme Cyclonic Storm			
2001	7-13 October		Cyclonic Storm			
2004	30th Sept	Onil	Severe Cyclonic Storm	Porbandar	100	900
2006	21-24 Sept	Mukda	Severe Cyclonic Storm	Near Somnath	102	53
2010	30-May	Phet	Very Severe Cyclonic Storm			44
2011	2-Nov	Keila		Oman	65	19
2014	10-14 June	phet	Cyclonic Storm	Oman	155	5
2015	25-Oct	Chapala		Non	215	5
	3-Nov	Megh		Non	175	18
2017	29-Nov	Ochaki	Severe Cyclonic Storm	South Gujarat	155	0
2018	4-Oct	Luban	Very Severe Cyclonic Storm	Non	140	14
2019	10-17 June	Vayu	Very Severe Cyclonic Storm	Gir-Somnath	150	8
2020	1-4 June	Nisarg		Alibaugh	110	4
2021 17-May	17-May	Taukte	Extreme Cyclonic Storm	Jafrabad, Diu	185	24
2023	6-16 June	Biparjoy	Extreme Cyclonic Storm	Jakhau, Kutch	165	2
Wind Speed = 3-minute sustained (IMD)						

Table 1: History of Cyclones in Gujarat

Cyclones in the Arabian Sea pose challenges to surrounding countries like Oman, Yemen, Pakistan, and India. The arid regions around the Arabian Sea may not be well-prepared for the associated heavy rainfall and strong winds, resulting in flooding and infrastructure damage. The frequency and intensity of cyclones in the Arabian Sea vary from year to year, with some years experiencing multiple cyclones and others none. (figure-1) Climate change and rising sea surface temperatures may influence cyclone behavior in the Arabian Sea, but the scientific understanding of this process is still evolving.

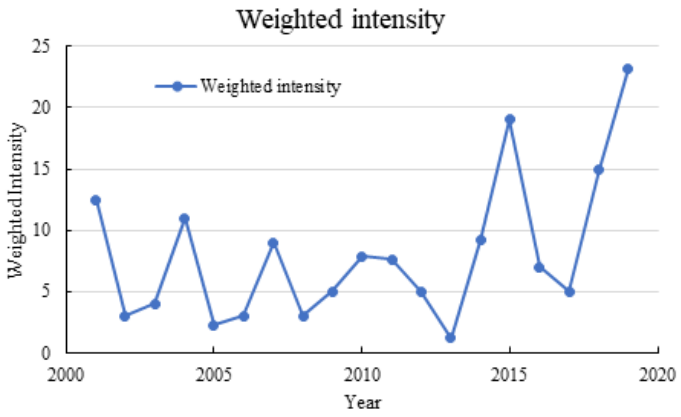

Figure 1: Year-wise Weighted Intensity of Cyclonic Activity in Arabian Sea (2001 – 2019) (ref:

Meteorological agencies, such as the Indian Meteorological Department and the Pakistan Meteorological Department, closely monitor cyclone development and movement in the Arabian Sea. Early warning systems and preparedness measures are crucial for minimizing the impact of cyclones on coastal communities. The history of cyclones in the Arabian Sea reflects the complex interplay of meteorological factors, highlighting the need for continued monitoring and preparedness in a region where cyclonic events, although less frequent, can still have significant consequences.

2. Cyclone Disaster Management

Cyclone disaster management encompasses a comprehensive approach to mitigating the devastating impact of cyclonic storms. Key components include early warning systems, accurate meteorological forecasts, timely evacuation plans for vulnerable populations, coordination among government agencies and relief organizations, establishment of cyclone shelters, securing critical infrastructure, suspending port operations, and providing essential supplies and medical support. Post-disaster efforts involve damage assessment, rescue, rehabilitation, and reconstruction. Effective communication, public awareness campaigns, and community engagement play pivotal roles in minimizing casualties and damage. Continuous monitoring, updated response protocols, and disaster preparedness are crucial for a proactive and resilient response to cyclone disasters, safeguarding lives and fostering rapid recovery in affected regions.

Cyclone disasters unfold across three distinct phases, (figure-2) each demanding specific measure for effective response:

i. Pre-Cyclone Phase: Preparedness and Warning In the lead-up to a cyclone, meteorological indicators are closely monitored to detect potential formation. Early warning systems are activated, alerting both communities and authorities to prepare for the impending disaster. Implementation of evacuation plans and preparation of emergency shelters are critical steps in ensuring the safety of residents in high-risk areas. Communication strategies, incorporating social media, traditional channels, and community engagement, play a pivotal role in disseminating information and raising awareness among vulnerable populations.

ii. Impact Phase: Cyclone Landfall and Immediate Aftermath As the cyclone makes landfall, it brings with it strong winds, heavy rainfall, storm surges, and the risk of flooding. Emergency response teams, including agencies such as the National Disaster Response Force (NDRF) and State Disaster Response Force (SDRF), are swiftly mobilized to conduct rescue operations and provide immediate relief. Deployment of medical teams and supplies becomes crucial to address health emergencies, and efforts are concentrated on restoring critical infrastructure and communication networks. Coordination among various response agencies is vital to ensure a rapid and effective response to the immediate challenges posed by the cyclone.

iii. Post-Cyclone Phase: Recovery and Rehabilitation Following the cyclone's passage, efforts shift towards recovery and rebuilding. Assessments are conducted to determine the extent of damage to infrastructure, homes, agriculture, and other essential services. Rehabilitation measures are initiated, providing shelter, food, and medical assistance to those affected. Comprehensive reconstruction and long-term recovery plans are developed to restore normalcy and enhance resilience against future cyclones. The post-cyclone phase underscores the importance of community involvement, with affected populations actively participating in rebuilding their lives and communities. Throughout these phases, effective coordination among meteorological agencies, disaster management authorities, humanitarian organizations, and the affected communities remains crucial for minimizing the impact of cyclones and facilitating a swift recovery process.

Figure 2: Chart Showing Sequence of Phases of Disaster Management

3. Disaster Prepardness

Cyclone disaster preparedness must be a continuous process that requires continuous monitoring, evaluation, and adaptation to changing environmental conditions. The goal is to reduce the vulnerability of communities and enhance their capacity to cope with and recover from the impact of cyclones. By investing in preparedness measures, societies can minimize the loss of life and property, ultimately building resilience in the face of these formidable natural disasters. Preparedness measures involve a comprehensive approach that includes early warning systems, evacuation plans, community education, and infrastructure resilience. Meteorological agencies play a crucial role in monitoring and predicting cyclones, providing timely information to authorities and the public. Early warning systems help in alerting communities well in advance, giving them sufficient time to evacuate to safer locations.

Government agencies, non-governmental organizations, and local communities collaborate to develop and implement preparedness strategies. Regular drills and exercises are conducted to ensure that emergency response mechanisms are well-practiced and can be activated swiftly when needed.

3.1 Early Warning- SOP

It involves the developing and implementing robust early warning systems to publicize timely and accurate information about cyclones to the public. On 7th June, 2023, The India Meteorological Department (IMD) had issued a warning for Saurashtra and Kutch coasts in Gujarat. The warning was published as " The deep depression over southeast and adjoining east-central Arabian Sea moved nearly northwards with a speed of 4 kmph during last 6 hours, intensified into a cyclonic storm 'Biparjoy' and lay centered at 1730 hours IST (5.30 p.m.) of today, the June 6, 2023 over east central and adjoining southeast Arabian Sea near latitude 12.1 degrees North and longitude 66.degrees East, about 920 km west-southwest of Goa, 1,050 km southwest of Mumbai, 1,130 km south-southwest of Porbandar and 1430 km south of Karachi". (Source: IMD Bulletin).

Early warning and preparedness efforts aim to provide sufficient lead time for communities to take necessary actions, such as evacuating to safe areas, securing their properties, and gathering essential supplies. By implementing these measures, the potential impact of cyclones can be minimized, and lives and property can be safeguarded. In case of Biparjoy cyclone Gujarat government had 9 days available for disaster preparedness because the landfall was occurred on 15th June evening after 5:00 PM.

3.2 Risk Assesment – Mapping, Prediction, Etc.

Meteorological Monitoring:

Mariological monitoring includes identification of atmospheric conditions that may lead to cyclone formation. These meteorological data help to develop meteorological models. Utilizing meteorological models and data, meteorology department predicts the cyclone tracks, intensities, and potential impacts.

Date (2023)	Spread (avg. diameter in Kilometers)
8th June	790
9th June	844
10th June	858
11th June	751
12th June	624
13th June	887
14th June	790
15th June	484
16th June	432
*Data generated by author from the IMD website data and from satellite image measurements.	

Table 2: Size of Coverage of Cyclone Biparjoy

The India Meteorological Department (IMD) started keeping an eye on the possibility of the creation of a cyclonic circulation in the Arabian Sea on June 1. On June 5, a cyclonic circulation developed over the Arabian Sea. Due to the cyclonic circulation, a low-pressure area developed that day. The next day, it significantly worsened into a depression. As a result, the system received a Tropical Cyclone Formation Alert from the Joint Typhoon Warning Centre (JTWC), designating it as Invest 92A.The depression was upgraded by the IMD to a deep depression and then to a cyclonic storm, giving it the name Biparjoy. After that, the JTWC issued advisories regarding the system and designated it as Tropical Cyclone 02A. Table-2 depicts the total coverage of cyclone measured by NASA and IMD Satellites. The extreme sevearity was expresses in satellite imagery is shown in figure 4. Figure 3 shows IR satellite imagery showing probable landfall near Jakhau, Gujarat.

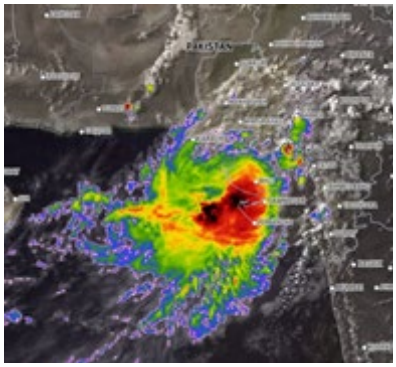

Figure-3: Revalued Enhanced Satellite Imagery of Biparjoy Making Landfall at Jakhau, North Waste Gujarat, on Evening of 15th June2023. (Source: Accuweather)

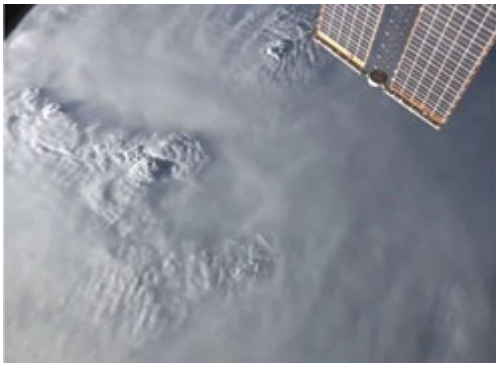

Figure-4: Satellite Image of the Cyclone Biparjoy taken from International Space Station (iss) at an Altitude of 400 kms from Earth. (courtesy: uae astronaut sultan al neyadi)

The cyclone was continuously monitored by India Meteorological Department (IMD) (Table-3) through available satellite observations from INSAT-3D and 3DR, SCAT SAT, ASCAT, microwave imageries, available ships and buoy observations in the region, and Doppler Weather Radar (DWR) at Bhuj and Jaipur.

Date/Time (IST)	Position (Lat. 0N/ long. 0E)	Maximum sustained surface wind speed (Kmph)	Category of cyclonic disturbance
13.06.23/0530	20.6/67.0	150-160 Gusting To 180	Very Severe Cyclonic Storm
13.06.23/1130	21.0/66.8	145-155 Gusting To 170	Very Severe Cyclonic Storm
13.06.23/1730	21.4/66.8	140-150 Gusting To 165	Very Severe Cyclonic Storm
13.06.23/2330	21.7/67.0	135-145 Gusting To 160	Very Severe Cyclonic Storm
14.06.23/0530	22.1/67.3	135-145 Gusting To 160	Very Severe Cyclonic Storm
14.06.23/1730	22.5/67.6	130-140 Gusting To 155	Very Severe Cyclonic Storm
15.06.23/0530	22.9/68.0	125-135 Gusting To 150	Very Severe Cyclonic Storm
15.06.23/1730	23.4/68.5	120-130 Gusting To 145	Very Severe Cyclonic Storm
16.06.23/0530	23.9/69.1	80-90 Gusting To 100	Cyclonic Storm
16.06.23/1730	24.4/70.0	50-60 Gusting To 70	Deep Depression

Table 3: Date Wise Position Maximum Sustained Surface Wind Speed and Status of Severity for Cyclone Biparjoy.

The IMD upgraded the system to a severe cyclonic storm with 3-minute sustained winds of 100 km/h (65 mph) by 00:00 UTC on June 7. As the convective burst faded and the tops of the Biparjoy clouds warmed, the storm was pushed back towards its system core by an upper-level outflow. At 06:00 UTC, Biparjoy was upgraded to a very severe cyclonic storm and, according to the Saffir-Simpson hurricane wind scale (SSHWS), this caused the system to become a Category 2-equivalent tropical cyclone. The deep convection was pushed from the low-level circulation center as a result of the cyclone being sheared by moderate easterly vertical wind shear. Deep flaring convection caused the cyclone to gradually lose strength. On June 11, Biparjoy surprisingly quickly strengthened and became a cyclone with a Category 3 equivalent.

3.3 Preparedness

Effective management of cyclone disasters relies heavily on preparedness, offering a proactive and organized response to mitigate the impact on communities and infrastructure. It is indispensable for safeguarding lives and minimizing the repercussions on communities. An anticipatory strategy, encompassing early warning systems, evacuation planning, resilient infrastructure, community engagement, resource allocation, coordination, technology integration, and post-disaster recovery planning, ensures a thorough and efficient response to cyclonic events.

Total 8 number of coastal districts were identified as most vulnerable to cyclone. Approximately 700 villages are most likely to be affected by extreme cyclone. Hence 10 km buffer zone (figure-5) from the coastal belt was made and evacuation was planned accordingly. Shelters were located beyond this buffer zone.

Figure 5: 10 km Buffer Zone from The Coast of Gujarat And Probably Highly Affected Region for Cyclones in Gujarat

Figure 6: Journey Path of Biparjoy till 10th June (In Black Dots and Line), Probable Journey and Landfall Spot Till 16th June 2023. (In Red Color Line and Dots)

Ref: IMD Bulletin as on 10th June, 2023.

(i) Co-Ardination of Different Agencies

Gujarat, renowned for its proactive approach to disaster management, demonstrated exemplary preparedness in the face of the Biparjoy cyclone. As soon as the meteorological department issued warnings, the state government swiftly activated a multi-agency coordination mechanism. The National Disaster Response Force (NDRF) and State Disaster Response Force (SDRF) were mobilized for swift deployment to vulnerable areas. The Home Ministry played a pivotal role in orchestrating these efforts, ensuring seamless coordination among various agencies. The Indian Navy and Coast Guard were on high alert, ready to assist in rescue and relief operations. District magistrates, along with their subordinates, were instrumental in implementing evacuation plans and securing vulnerable communities. The collaborative efforts of these agencies, guided by the principles of the Incident Command System, ensured a well-coordinated response. This approach, blending state-of-the-art technology with on-the-ground expertise, exemplifies Gujarat's commitment to mitigating the impact of natural disasters and safeguarding the lives and livelihoods of its residents. For quick actions and information sharing, official WhatsApp groups were created and coordinated accordingly.

The Gujarat Disaster Management Authority (GDMA) is pivotal, receiving and processing early warnings. Upon activation, the State Emergency Operation Center (SEOC) takes center stage as the central coordination hub, orchestrating the response efforts. State agencies, including the State Disaster Response Force (SDRF) and National Disaster Response Force (NDRF), are swiftly mobilized, alongside the activation of medical response teams by the health department. (Table-4) District administrations play a crucial role, receiving alerts from SEOC and activating District Emergency Operation Centers (DEOC).

The planning phase involves SEOC collaborating with district authorities to strategize evacuation routes and shelters, with extensive communication channels utilized to reach vulnerable communities. Community engagement becomes paramount, with local authorities, NGOs, and volunteers leveraging social media and local leaders to raise awareness. The outlined flowchart (figure-7) highlights the dynamic and comprehensive nature of the cyclone management plan, demonstrating adaptability and resilience in the face of natural disasters.

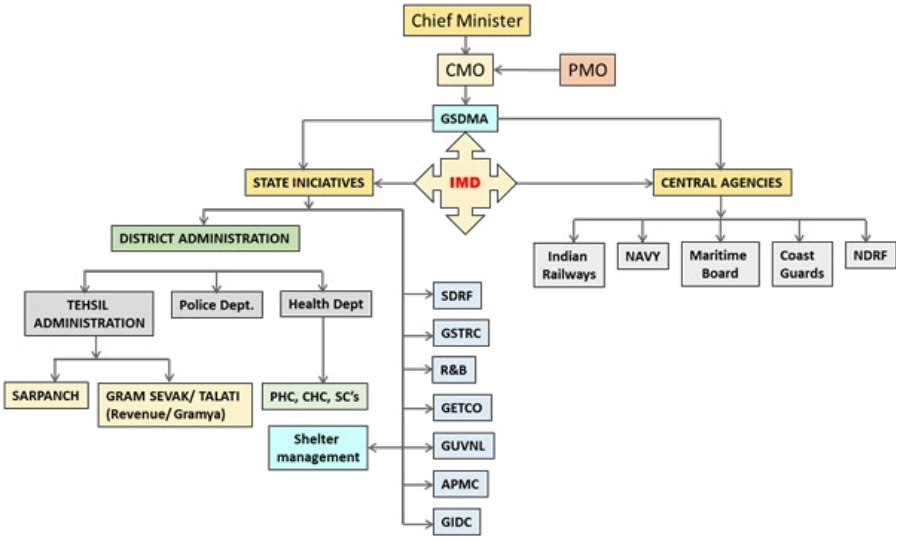

Figure 7: Flow Chart of Co-Ordination of Different Agencies to Cater Biparjoy Cyclone

Central agencies and defense forces, such as the Indian Navy (Table-5) and Coast Guard, standby for immediate response, with coordination maintained through the Home Ministry, providing regular updates to the Prime Minister's Office (PMO).

Emergency services, including road clearance and energy sector inspections, are initiated promptly. Communication infrastructure is fortified with satellite phones and HAM radios. Evacuation plans are executed under the supervision of district authorities, with monitoring and support from SDRF, NDRF, and defense forces.

Post-landfall response focuses on assessing the immediate impact, restoring critical infrastructure, and delivering medical aid and relief. The subsequent phases involve extensive assessments for damage extent, initiation of rehabilitation efforts, and the development of long-term recovery plans.

Community involvement is integral, with affected communities actively participating in rebuilding efforts, supported by the collaborative efforts of NGOs and local bodies. Continuous monitoring and learning form a vital feedback loop, facilitating improvements in disaster management strategies for future challenges.

(ii) Deployment of Various Agencies

Coordination and communication play a crucial role in effective cyclone disaster management. They involve establishing clear lines of communication, coordinating efforts among various stakeholders, and ensuring the timely dissemination of information. Here are the key aspects of coordination and communication in cyclone disaster management:

(iii) Multi-Agency Coordination:

Establishing a command structure that includes representatives from relevant government agencies, disaster management organizations, meteorological departments, emergency services, and other key stakeholders. Designating a central coordination center to facilitate communication, decision-making, and resource allocation during the cyclone event. Conducting regular meetings, briefings, and training sessions to enhance coordination and collaboration among different agencies and organizations involved in disaster management.

NDRF TEAMS DEPLOYED AT VARIOUS DISTRICTS OF GUJARAT			**SDRF TEAMS DEPLOYED AT VARIOUS DISTRICTS OF GUJARAT**		
Sr. No.	District	Total number of team deployed	Sr. No.	District	Total number of team deployed
1	Kutch	6	1	Kutch	2
2	Devbhoomi Dwarka	3	2	Dev bhoomi Dwarka	2
3	Rajkot	2	3	Jamnagar	2
4	Jamnagar	2	4	Junagadh	1
5	Junagadh	1	5	Porbandar	1
6	Porbandar	1	6	Gir Somnath	1
7	Gir Somnath	1	7	Morbi	1
8	Morbi	1	8	Patan	1
9	Valsad	1	9	Banas kantha	1
	Total	18		Total	12

Table 4: NDRF / SDRF Teams Deployment at Key Positions at the District Level

Indian navy deployment at different locations to handle cyclone disaster. It includes the manpower along with helicopters.

Sr.No.	**Number of teams**	**Location of deployment**
1	5- Relief teams	Porbandar
2	5- Relief teams	Okha
3	15- Relief teams	INS Valsura at Jamnagar
4	5 Helicopters	INS Hansa at Goa
5	6 Helicopters	INS Shikhara at Mumbai

Table 5: Indian Navy Teams Deployed at Various Locations

(iii) Awareness, education and Information sharing

Public awareness, education and co-ordination and communication plays crucial role in disaster management. (figure-8) Proper organization and hierarchical set-up were observed during the cyclone Biparjoy which is the best example of information sharing and implementation for Gujarat Disaster management authority. Total 32.67 crore SMS es were sent using the "Sachet" protocol of the national disaster management authority. 5.63 crore SMS es were sent to fishermen through INCOIS (Indian national Center for Ocean Information Services) and 2.7 lakh SMSs were sent to registered users mainly in the field of general public in coastal states and central and state-level disaster managers.

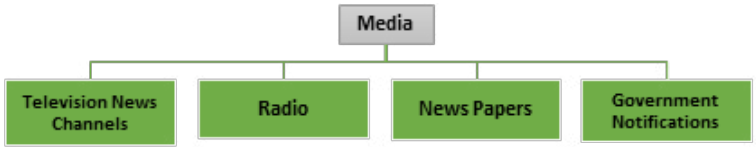

Figure 8: Chart Showing Types of Media Involved in Awareness About the Disaster

(iv) Role of Social media and television

Effective coordination and communication among all stakeholders involved in cyclone disaster management ensure a unified and timely response, improve resource allocation, and enhance public safety. Regular drills, training exercises, and continuous evaluation of communication systems contribute to better coordination and preparedness for future cyclone events.

Figure 9: List of Social Media, Played Crucial Role in Disaster Management for Communication and Public Awareness

During Cyclone Biparjoy, social media platforms listed in figure-9 emerged as indispensable tools for communication and information dissemination. WhatsApp facilitated real-time communication through groups and broadcasts, enabling authorities to send updates and evacuation plans directly to residents. Facebook served as a crucial platform for official pages of government agencies, disaster management authorities, and local administrations to share timely updates and emergency information. Twitter, with its real-time nature, played a vital role in disseminating urgent information, including updates from government agencies, meteorological departments, and relief organizations. Snapchat's map feature allowed users to share real-time updates on their conditions and locations, offering valuable insights for authorities. YouTube became a hub for informative videos on cyclone preparedness and safety measures. Additionally, traditional SMS played a critical role in reaching individuals without internet access, as authorities could send mass SMS alerts with essential information and evacuation instructions. The collaborative use of these social media platforms facilitated swift information dissemination, aided in organizing rescue efforts, and kept citizens informed and connected throughout Cyclone Biparjoy.

3.4 Evacuation Planning and Management

First step for evacuation planning is to identifying vulnerable areas, coastal regions, and communities at high risk of cyclone impact. With satellite data, census data, local administrative data collection and past disaster impact plans high risk coastal zone and po ssible point of landfall identified as North-waste of Gujarat in between Dwarika and Jakhau. Based on this probabilistic information evacuation planning was carried out. Coordination was setup with local authorities, law enforcement agencies, and transportation providers to ensure smooth and efficient evacuation operations.

Mobilizing resources and personnel to assist vulnerable populations, including the elderly, disabled individuals, pregnant women, and those with special needs, during the evacuation process. Providing transportation support, such as buses, boats, or helicopters, to facilitate the movement of evacuees. Coordinating with local communities and volunteers to assist in the evacuation and ensure the safety and well-being of evacuees.

3.4.1 Port suspension: Implementing a crucial safety protocol, port operations are suspended during cyclone disasters to protect lives,

vessels, and cargo from severe weather conditions. The process begins with diligent monitoring of weather forecasts and cyclone alerts by meteorological agencies and port authorities. (Table-6) Early warning systems and effective communication channels play a central role in informing stakeholders about the cyclone's anticipated path and impact. Ship evacuation takes precedence, with ship owners and operators advised to relocate vessels to safer areas, such as designated anchorages or ports away from the cyclone's trajectory. Simultaneously, the port area is secured by closing main gates, allowing only essential personnel to remain. Cargo handling is halted, and measures are taken to secure port infrastructure, minimizing potential damage. Emergency response plans are activated, mariners are kept informed, and navigation restrictions are enforced. Decisions on resuming port operations are guided by continuous monitoring and assessments to ensure safety. Post-cyclone inspections and cleanup efforts are promptly initiated to restore normalcy. This coordinated approach guarantees the protection of lives, assets, and the environment in the face of cyclone events.

Sr.No.	Port Name	Classification	District
1	Kandla Port (Deendayal)	Major Port	Kutch
2	Mundra Port		Kutch
3	Pipavav Port		Amreli
4	Dahej Port		Bharuch
5	Hazira Port		Surat
6	Vadinar Port		Devbhoomi Dwarka
7	Okha Port	Minor Port	Devbhoomi Dwarka
8	Porbandar Port		Porbandar
9	Navlakhi Port		Jamnagar
10	Bedi Port		Jamnagar
11	Sikka Port		Jamnagar
12	Veraval Port		Gir Somnath
13	Mangrol Port		Junagadh
14	Jafarabad Port		Amreli
15	Salaya Port		Devbhoomi Dwarka
16	Sutrapada Port		Gir Somnath
17	Gopnath Port		Bhavnagar
18	Mithapur Port	Private Port	Devbhoomi Dwarka
19	Positra Port		Devbhoomi Dwarka
20	Jafrabad (SEZ) Port		Amreli
21	Mundra SEZ Port		Kutch
22	Mahuva Port (Tata & Adani)		Bhavnagar

Table 6: Ports of Gujarat Suspended Port Operation During Cyclone Biparjoy.

On June 11, 2023, the deployment of Signal 10, indicating "Great danger," was introduced for Okha, Jakhau, Mandavi, Mundra, Kandla, Navlakhi, Sikka, and Bedi ports. In response to the impending threat, the Maritime Board took precautionary measures, temporarily suspending the Okha-Bet Dwarka ferry boat service. Access for fishermen to engage in fishing activities was strictly prohibited, and their boats were securely anchored at safe docking yards. Fishermen already at sea were promptly called back to the nearest port and directed to seek refuge in designated safe areas, such as cyclone shelters.

Cargo unloading from 35 vessels was expedited, and 30 vessels were rerouted to secure ports until further notice. To bolster port management capabilities, expert engineers were dispatched from Bhavnagar and Magadalla (Surat) ports. Each port established primary and secondary control rooms operating 24/7 to ensure continuous monitoring and response during the critical period.

3.4.2 Commerce and Industry:

Fishermen were warned to enter the sea waters and their boats were moored to the safe place on respective dockyards with extra care. Trains were cancelled in Sauratra region to avoid possible carrying of tourists inside the risk zone. GSTRC (Gujarat state road Transport Corporation) buses of Sauratra region were allowed to do return journey without passengers and with those who are natives of the region. Rest of the depos of north, central and south Gujarat, cancelled their bus routes to Saurastra from 13th June till further notice. 3243 *Agariyas* (People involved in salt making business) were shifted to safe place. APMC (Agricultural Produce Market Committee) markets of Jamnagar, Morbi, and Junagadh were

suspended for a week. In Rajkot district only 84,150 electricity polls were kept stand by PGVCL to restore power if there may be possible collapse of number of electricity polls. All the wind mills were closed its operation in *Dev Bhomi Dwarika* and *Mandavi*, Bhuj District.

No. of Trains	Action
69	Trains -cancelled
33	Trains - Short- Terminated
27	Trains - Short- Originated
Total 129 trains affected in western Railways, Saurastra Region of Gujarat	

Table7: Indian Railways Train Management During Biparjoy

3.4.3 Pilgrimage and Tourists Management

Public notice issued by local respective district magistrates to vacate the places of tourism and Hotels were instructed to cancel the registration of guests from the possible day of increased activity of cyclone to further notice. Beaches of Shivrajpur, Diu, Mandavi, Tithal and Madhvpur were closed and IPC 144 implemented to avoid unnecessary management of human resources. Rope-way service for tourist of Girnar was suspended till June 20, 2023. Table-8 and 9 provides location of different pilgrimage places as well as tourist places.

Pilgrimage Place	District
Palitana Temples	Bhavnagar
Gopnath Mahadev Temple	Bhavnagar
Beyt Dwarka (Bet Dwarka)	Devbhoomi Dwarka
Dwarkadhish Temple	Devbhoomi Dwarka
Mahakaleshwar Temple	Devbhoomi Dwarka
Nageshwar Jyotirlinga	Devbhoomi Dwarka
Bhalka Tirth	Gir Somnath
Rukmini Temple	Gir Somnath
Somnath Jyotirlinga Temple	Gir Somnath
Harshad	Porbandar
Madhavpur Ghed	Porbandar
Mata-No-Madh	Kutch

Table 8: Major Pilgrimage Places Which Were Announced Closed.

Tourist Place	District
Shivrajpur Beach	Devbhoomi Dwarka
Diu Island and Beaches	Diu
Gir National Park and Wildlife Sanctuary	Gir Somnath
Sasangir	
Somnath Beach	
Chorwad Beach	
Jamnagar	Jamnagar
Junagadh	Junagadh
Grnar Mountain	
Mandvi Beach	Kutch
Bhuj and Rann of Kutch	
Porbandar	Porbandar

Table 9: Major Tourist Places Banned to Visit Before Landfall of Biparjoy Cyclone.

3.4.4 Native Population Evacuation

Evacuation and sheltering plans were custom-made to local conditions and the specific risks posed by cyclones in a given area. Approximately fifty thousand people were shifted to safe locations from the cyclone severity zone. The shelters identified was kept at least 10 km away from coastal buffer zone. 1.5 to 2.0 lack small and big animals moved to higher altitude places to save them from possible flood after severe rain of post landfall. 13 people were rescued on 13th June from the offshore ONGC jake-up rig "Key Singapore" near the coastline of Dwarika.

Evacuation plan includes possible clear routes to the safe location of shelters. Local administrative authorities along with social workers, political party leaders and workers, and response teams are necessary to convince local residents for evacuation and later on to conduct the operation of evacuation. To facilitate evacuation transportation arrangements, including buses, boats, or helicopters, are required. For timely evacuation the evacuation procedures started on 12th June 2023.

Sr. No.	District	No. of persons shifted
1	Junagadh	4462
2	Kutch	17739
3	Jamnagar	8542
4	Porbandar	3496
5	Devbhoomi Dwarka	4863
6	Gir Somnath	1605
7	Morbi	1936
8	Rajkot	4497
TOTAL Evacuated Population		47140

Table 10: District Wise Evacuation.

Saurastra region of Gujarat consists of major religious pilgrimage places, beaches and ports. Table-10 shows the detail of evacuation district wise. Most of them were lying across the high-risk zone of cyclone Biparjoy. Hence, it is necessary to vacate these places and restrict the entry of tourists, visitors and stockholders, till the effect of cyclone diminishes. Information of possible cyclone attack forwarded to media, social media and stockholders.

"Shala Praveshotsav" was postponed in 6 coastal districts of Gujarat and team of 9 ministers were made to observe the implementation of disaster management guidelines. The state government has coordinated the assistance of air force, Navy, coast guards and army if required during this potential disaster. Army cantonments of Bhuj, Jamnagar, Gandhidham, Drangadra, Vadodara and Gandhinagar were kept on alert mode before possible cyclone disaster. Schools and Collages like educational institutes were declared holidays for next three days on 13th June 2023.

Pruning trees was undertaken as a precautionary measure to thwart uprooting, and the dismantling of 4,317 hoardings aimed to prevent them from becoming hazardous projectiles in the high-speed winds. In a proactive move, 1,152 pregnant women with delivery periods coinciding with the cyclone's passage were relocated to hospitals, ensuring their safety. Remarkably, 707 children were born in a secure environment during the cyclonic event.

The districts with a higher likelihood of experiencing the impact of the disaster were identified. Consequently, a total of 521 Primary Health Centers (PHC) and Community Health Centers (CHC) across the eight districts were placed on high alert, operating 24/7. Additional stocks of medicines were supplied to these healthcare facilities to ensure preparedness for any severe outcomes of the disaster. Diesel generator sets were installed in each CHC and PHC to address potential electricity failures during and after the cyclone's landfall. A fleet of 157 ambulances was on standby in emergency mode. To maintain open roads and assess unsafe housing conditions during the cyclonic storm, 95 teams from the road and building department were mobilized. In the energy sector, 577 teams inspected 6950 feeders to ensure continuity of services in critical situations.

To address communication challenges, satellite phones and Ham radios were deployed in the eight districts, along with trained operators, in case of cellphone communication tower failures. Help desks were established at western railway stations, including Bhavnagar, Veraval, Porbandar, Junagadh, Okha, Dwarka, Khambhadiya, Jamnagar, Hapa, Surendranagar, Morbi, Gandhidham, and Bhuj. The Gujarat State Road Transport Corporation (GSRTC) suspended 4300 trips in all eight potentially affected districts.

In maritime preparedness, the Indian Coast Guard maintained 10 vessels on standby, equipped with 1000 life jackets. Eight interceptor boats were in operational condition. Garud commandos were prepared at Jamnagar, Naliya, and Bhuj Airbase, while Chetak commandos were stationed at Ahmedabad airport. Cargo planes with essential rescue equipment and resources were kept ready in Delhi. National Disaster Response Force (NDRF) teams from Bhatinda and Ernakulam were on standby to handle situations exceeding initial expectations. Figure-11 shows the preparedness of NDRF team in Devbhoomi Dwarika District.

3.4.5 Shelter Management

Safety and management of cyclone shelters are necessary to operate smooth rescue operations. The GSDMA has set up 1521 cyclone shelters across the Gujarat state. These shelters are located in schools, community centers, and other public buildings. They are equipped with essential facilities such as food, water, and medical supplies. 1600 shelter homes set up in Gujarat as preventive measure. Figure-10 is showing the shelter in which people evacuated from Kandla port was shifted to Cyclone shelter at Gandhdham, Bhuj District.

Post-Evacuation Support:

Post evacuation support is important to effectively manage facilities of migrated people. It is required to regularly assess the situation and monitoring the cyclone's progress to determine the appropriate time for evacuees to return home safely. Facilitating the return and reintegration of evacuees to their communities. Providing assistance and support for post-disaster recovery efforts, including damage assessment, relief distribution, and rebuilding efforts.

Figure 10: People Evacuated from Kandala Port, In Cyclone Shelter at Gandhidham, Kutch

Figure 11: NDRF Team and Army Jointly Planned Relief Operations with Civil Administration

4. Crisis Managemnt - Cyclone

Cyclone Biparjoy made landfall in Gujarat's coastal area on 15th June, evening at 5:30 PM near Jakhau. Maximum sustained wind speed observed was 115-125 kmph gusting to 140kmph for few hours. Total 51 tehsils of 8 districts observed very heavy rainfall. Just after landfall 235 villages observed electricity failure, 383 electricity polls fall down, and 729 feeders were failed to supply electricity. On 16th June 2023, total 1083 villages observed electricity failure. 36 sub stations of 66KV in Jamnagar district and 34 substations in Dwarika district were affected. 11 Kv's 2442 feeders were shut down.

4.1 Post Cyclone Management

Post-cyclone disaster management requires a collaborative and multi-disciplinary approach, involving local, regional, and national authorities, along with humanitarian organizations and communities. The goal is to restore normalcy, support affected populations, and build resilience against future cyclonic events.

4.2 Damage Assesment

After landfall on 15th June evening, on the next date rapid damage assessments was conducted to evaluate the extent of infrastructure damage, including buildings, roads, bridges, and utilities. Data was collected for the impact on livelihoods, agriculture, and other sectors to inform recovery planning. Collaboration was made to collect data with relevant agencies and organizations to develop comprehensive recovery plans and strategies.

Figure 12: Flooding on Road and Collapsed Tree in Mandavi

Figure 13: Broken Bridge, After Cyclone Biparjoy Made Landfall, Along the Naliya-Bhuj Highway

Figure 14: Inundated Street at the Coastal Town of Mandvi

Courtesy:https://gulfnews.com/photos/news/in-photos-cyclone-biparjoy-unleashes-its-fury-coastal-india-brace-for-impact

Storm surges up to 6 to 10 ft and even 10 to 18 ft above the astronomical tide flooded the low-lying areas in Dwarka, (figure-16) Jamnagar, and Porbandar etc. in Gujarat. Heavy to very heavy rains also caused waterlogging in the coastal areas. (figure-14, 15, 16) No death reported due to cyclone Biparjoy, this is the example of excellence towards disaster management in new era of India. Only 47 people injured and 234 cattle died in this cyclone. More than 4600 villages were reported without electricity after 16th June. Closure of three state highways occurred due to damages and the falling of trees. Reports indicate that a total of 581 trees were uprooted. The cyclone resulted in the destruction of nine pucca houses and 20 kutcha houses, while two pucca houses and 474 kutcha houses suffered partial damages.

Figure 15: Electric Transformer Damaged at Mandavi on 16th June, After Landfall of Cyclone Biparjoy. (Photo: - Sam Panthaky/ Afp Via Getty Images)

Figure 16: Storm Surge Observed On 16th June In Dwarika

Total 80,000 electric polls collapsed in Kutch district alone. Over 192 transformers damaged and 5120 electric poles toppled (figure-15). More than 1137 trees were broken, bent down and uprooted in Gujarat. More than 700 houses got damaged in coastal belt of Gujarat. Two residents from Bhavnagar died due to flash flood occurred due to post cyclone rain. More than 450 birds died during this natural calamity. About 33,000 hectares of farmland were heavily affected. 1000 team's deployed for power restoration, 20 kutcha, 9 pucca houses, 65 huts completely damaged.

Damage Assessment

Damage assessment was conducted on 17th June,2023, a day after the landfall of the cyclone Biparjoy. There were problems such as accessibility to the remote areas because of heavy rain followed by flooding and collapsed trees. Table-10 shows various attributes of damage occurred after Cyclone Biparjoy.

District	Roads damaged	Road become operational after 24 hours	Road closed	Trees collapsed
Kutch	158	143	15	2405
Jamnagar	96	95	1	1125
Porbandar	78	76	2	495
Morbi	40	40	-	305
Junagadh	58	58	-	845
Gir Somnath	50	50	-	630
Dwarka	116	113	3	955
TOTAL	596	575	21	6760

Table 10: Damage Assessment in 8 Districts

4.3 Rescue and Rehabilitation

The success of rescue and rehabilitation efforts relies on the coordination and collaboration of various stakeholders, including government agencies, humanitarian organizations, and local communities. The goal is to restore normalcy, enhance resilience, and ensure the well-being of those affected by the cyclone disaster.

15 teams of the state road and building department, and 397 of the state electricity department were deployed in different coastal districts. Power supply was suspended in 3,400 villages due to the cyclone, out of which power had been restored in 1,600 villages within 24 hours,

The Gujarat government unveiled a relief package amounting to ₹2.4 billion (US$29 million) for farmers. The government's assessment indicated that the cyclone had caused damage to crops and trees covering an extensive 1,30,000 hectares (3,20,000 acres) of land. (Ref: Indinexpress.com / outlookindia.com)

5. Unique Features of Cyclone Biparjoy

Biparjoy was the first cyclonic storm ever attacked on Gujarat in the month of June, 2023. The cyclonic storm had depression to depression life was 13 days and 3 hours, which was longest ever after 1977 storm (November 8-23, 14 days and 6 hours) over Bay of Bengal. Biparjoy had changed its direction, 9 times in its 2525 km long path in Arabian Sea, before landfall. It had intensified on June 11 to extremely severe cyclone, but weakened to a very severe cyclonic storm after land fall on June 14, 21:00 hours the severity remains same even after 4 days (i.e. 18th June 2023). Biparjoy traveled unusually slowly during its lifetime, with an average 12-hour translational speed of 7.7 km per hour, compared to the VSCS category's typical speed across the Arabian Sea during the monsoon season of roughly 15 km per hour. The typical duration for the landfall of cyclones of this magnitude is usually three to four hours. However, in the case of Biparjoy, this process extended to approximately five hours. The cyclone's relatively slow speed allowed it to sustain itself by extracting moisture from the sea for an extended period after making landfall. Prolonged landfalls significantly elevate the potential for causing widespread devastation.

6. Discussion

According to a report published by NASA's Earth Observatory, Roxy Mathew Koll, a climate scientist at the Indian Institute of Tropical Meteorology, pointed out that the sea surface temperature in the Arabian Sea was between 31 and 32 degrees Celsius in the past week, which is two to four degrees Celsius higher than the average. A general guideline in climatological science states that ocean temperatures should be above 27 degrees Celsius for a tropical cyclone to persist. This temperature increase played a role in maintaining a low-pressure area in the sea, leading to the further intensification of Cyclone Biparjoy.

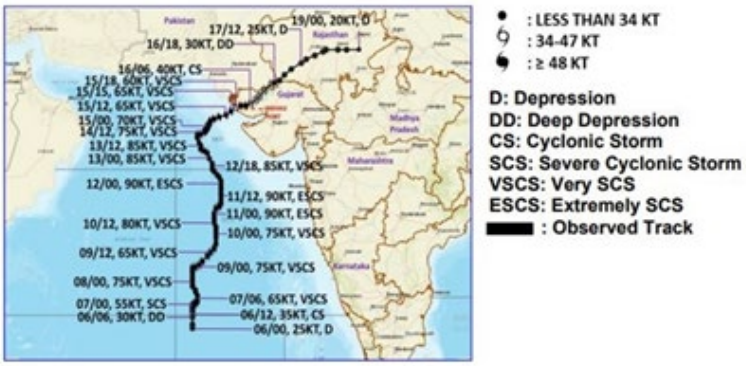

Figure 17: The Observed Trajectory of The Extremely Strong Cyclonic Storm "Biparjoy" Across the Arabian Sea From 6th June to 19th June, 2023.

As quoted in the report, Raghu Murtugudde, a visiting professor at IIT-Bombay, stated that Biparjoy serves as an illustration of how climate change, particularly the warming of the upper ocean, is playing a role in the slower movement and prolonged duration of cyclones.

The exemplary response to a significant disaster, marked by a well-organized and synchronized effort that successfully achieved zero casualties, has established a benchmark of inspiration. Crucial elements contributing to this success include heightened community awareness, as acknowledged by the Prime Minister, meticulous planning for all foreseeable circumstances, and proactive measures. To replicate such achievements, other states must ensure the year-round availability of a dedicated, well-equipped, and adequately trained State Disaster Response Force (SDRF) in sufficient numbers.

The disaster preparedness and mitigation efforts implemented by the government of Gujarat during Cyclone Biparjoy have showcased a commendable commitment to ensuring the safety and well-being of its citizens. The zero casualties recorded during the cyclone can be attributed to the meticulous planning, coordination, and execution of various strategies. First and foremost, the efficient early warning systems enabled timely evacuation, allowing residents to move to safer locations well in advance. The seamless collaboration between different agencies, including the National Disaster Response Force (NDRF), State Disaster Response Force (SDRF), Home Ministry, Indian Navy, Coast Guard, and district authorities, played a pivotal role in executing evacuation plans and providing timely assistance.

Furthermore, the utilization of modern technologies, such as social media platforms, WhatsApp, Facebook, Twitter, and SMS, enhanced communication and information dissemination. The government's proactive engagement with citizens through these channels ensured a widespread understanding of evacuation procedures, emergency contacts, and real-time updates. The effective utilization of traditional methods, such as community engagement, awareness campaigns, and coordination at the grassroots level, contributed significantly to the success of the disaster management efforts.

While celebrating the achievement of zero casualties, it is crucial to recognize the ongoing commitment needed to refine and improve disaster preparedness strategies continually. Lessons learned from Cyclone Biparjoy can serve as a foundation for future initiatives, emphasizing the importance of community involvement, technological innovation, and inter-agency coordination. In essence, the government's success in averting loss of life during this cyclone stands as a testament to the efficacy of well-prepared disaster management plans and serves as an inspiration for future resilience-building endeavors.

7. Concussion

• Gujarat's response to Cyclone Biparjoy achieved zero casualties, setting an inspiring benchmark.
• Key contributors to success include heightened community awareness, meticulous planning, and proactive measures.
• The year-round availability of a well-equipped and trained State Disaster Response Force (SDRF) is crucial for other states to replicate success.
• Efficient early warning systems facilitated timely evacuation, a pivotal factor in preventing casualties.
• Collaboration between various agencies, including NDRF, SDRF, Home Ministry, Indian Navy, Coast Guard, and district authorities, played a crucial role.
• Utilization of modern technologies, such as social media platforms and messaging apps, enhanced communication and information dissemination.
• Proactive engagement with citizens through social media ensured widespread understanding of evacuation procedures and real-time updates.
• Traditional methods like community engagement and awareness campaigns at the grassroots level contributed significantly.
• Ongoing commitment is essential for refining and improving disaster preparedness strategies continuously.
• Lessons learned from Cyclone Biparjoy emphasize the importance of community involvement, technological innovation, and inter-agency coordination.
• The success in averting loss of life stands as a testament to the efficacy of well-prepared disaster management plans.
• The research paper provides a comprehensive examination of cyclone preparedness and response, focusing on the Biparjoy Cyclone in Gujarat.
• The study highlights strengths and areas for improvement in the existing cyclone management framework.
• Insights underscore the critical importance of proactive measures, community awareness, and robust infrastructure in mitigating cyclone impact.
• Lessons learned from the Biparjoy Cyclone experience can inform policy decisions and contribute to building more resilient communities in the face of climatic challenges [1-13].

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Appendix

Stages	Warning	Meaning
Stage 1	Cyclone Watch	Issued 72 hours in advance, it discusses the likelihood of development of a cyclonic disturbance in the north Indian Ocean and the coastal region likely to experience adverse weather.
Stage 2	Cyclone Alert	Issued 48 hours in advance of the commencement of adverse weather over the coastal areas.
Stage 3	Cyclone Warning	Issued 24 hours in advance of the commencement of adverse weather over the coastal areas. The location of landfall is discussed at this stage.
Stage 4	Landfall Outlook	Issued 12 hours in advance of the commencement of adverse weather over the coastal areas. The track of the cyclone after the landfall and the possible impact inland is discussed at this stage.

Table-A1: The Imd Issues Warnings in Four Stages for The Indian Coast

Sr.No.	Cyclonic Activity	Sustained Winds	Weight
1	Depression (D)	31–50 km/h	1
2	Deep Depression (DD)	51–62 km/h	2
3	Cyclonic Storm (CS)	63–88 km/h	3
4	Severe Cyclonic Storm (SCS)	89–117 km/h	4
5	Very Severe Cyclonic Storm (VSCS)	118–165 km/h	5
6	Extremely Severe Cyclonic Storm (ESCS)	166–220 km/h	6
7	Super Cyclonic Storm (SuCS)	≥221 km/h	7

Table-A2 : India Meteorological Department Tropical Cyclone Classification