Impact of the tropical cyclone "REMAL" along the coast of Bangladesh: Perspective Analysis

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Abstract: Cyclone Remal was the first severe cyclonic storm of the 2024 North Indian Ocean cyclone season. It formed as a deep depression and intensified, making landfall on May 26, 2024, with wind speeds ranging from 90 to 120 km/h, killing 19 people and leaving several injured. cyclone Remal that hit the coast of Bangladesh. Using information obtained from different sources, this study identified some reasons for the economic cost and suffering for coastal people resulting from storm surges. A tropical cyclone has a great impact on agriculture and rural infrastructure such as shelter, sanitation, drinking water, electricity supplies, and transportation services. It causes huge damage not only to livelihoods but also to engineering structures like rural roads, dams, embankments, farm buildings, dairy houses, etc. This paper depicts the results of recent studies on the impact of tropical cyclones on rural and agricultural engineering infrastructures in Bangladesh. This study investigates the impacts of cyclone Remal on the coastal communities of Bangladesh, focusing on the extent of damage, the affected population, and the response measures. Using data from government reports and press releases, the findings aim to provide insights into disaster preparedness and management strategies.

Key Words: Remal; Bay of Bengal; Cyclone; Infrastructure; Storm Surge.

1. INTRODUCTION :

On may 26, 2024 Tropical Cyclone Remal made landfall along the coast of Bangladesh, bringing with it powerful winds, heavy rainfall, and a devastating storm surge. The cyclone's impact was felt across the country, particularly in the vulnerable coastal regions, where communities and infrastructure were severely affected. This perspective analysis aims to provide an in-depth examination of the impact of Cyclone Remal on Bangladesh's coastal areas, including the social, economic, and environmental consequences. By analyzing the effects of the cyclone on various sectors and populations, this analysis seeks to identify key lessons and areas for improvement in disaster preparedness, response, and resilience-building in Bangladesh. The insights gained from this analysis will contribute to the development of more effective strategies for mitigating the impact of future cyclones in the region. "Tropical disturbances are classified under different nomenclature as adopted by the Regional Specialized Meteorological Centre (RSMC) Tropical Cyclones, New Delhi. The classification of disturbances is shown in the following table.

Sl no	Type	Wind speed Km/hr	Wind speed Knot (mps)
1	Low pressure area (L)	Less than 31	Less than 17
2	Depression (D)	31-49	17-27
3	Deep Depression (DD)	50-61	28-33
4	Cyclonic Strom (CS)	62-88	34-47
5	Severe Cyclonic Strom (SCS)	89-118	48-63
6	Very Extremely Cyclonic Strom (VECS)	119-165	64-89
7	Extremely Severe Cyclonic Strom (VSCS)	166-220	90-119
8	Super Cyclonic Strom (SCS)	221 above	120 above

Source: Indian Meteorological Department (IMD)

The cyclone Remal hit the southwestern parts of Bangladesh, like Satkhira, Khulna, Bagerhat, Pirojpur, Bhola, Patuakhali, Barishal, Noakhali, and Lakshmipur, on May 26, 2024, and caused about 19 deaths. Residents, homesteads, roads, and embankments were destroyed due to the flooding associated with the cyclone. In total, over 1.9 million people were affected, and nearly 489226 katcha and jhupri houses were destroyed. It is pertinent to point out here that fishing, agriculture, shrimp farming, salt farming, and tourism are the main economic activities of this coastal area. But cyclone REMAL washed away all the houses, crops, and agricultural land. The Ministry of Fisheries and Livestock reported that 50,000 fish enclosures, 34,000 ponds, and 4,000 crab farms were flooded during the cyclone. The damage to the infrastructure was huge; it also destroyed the livelihoods of the people. We have pointed out some reasonable steps to minimize the resulting damage from storm surges. But the mitigation measures are highly dependent on a proper warning system, which in turn depends on an efficient storm surge prediction model. In contrast, Cyclone Remal, which made landfall on May 26, 2024, impacted both West Bengal and Bangladesh. As the first severe cyclonic storm of the 2024 North Indian Ocean cyclone season, Remal brought winds ranging from 90 to 120 km/h. The tidal surge breached embankments, resulting in extensive flooding and damage to homes, agricultural fields, and fishing farms in low-lying areas.
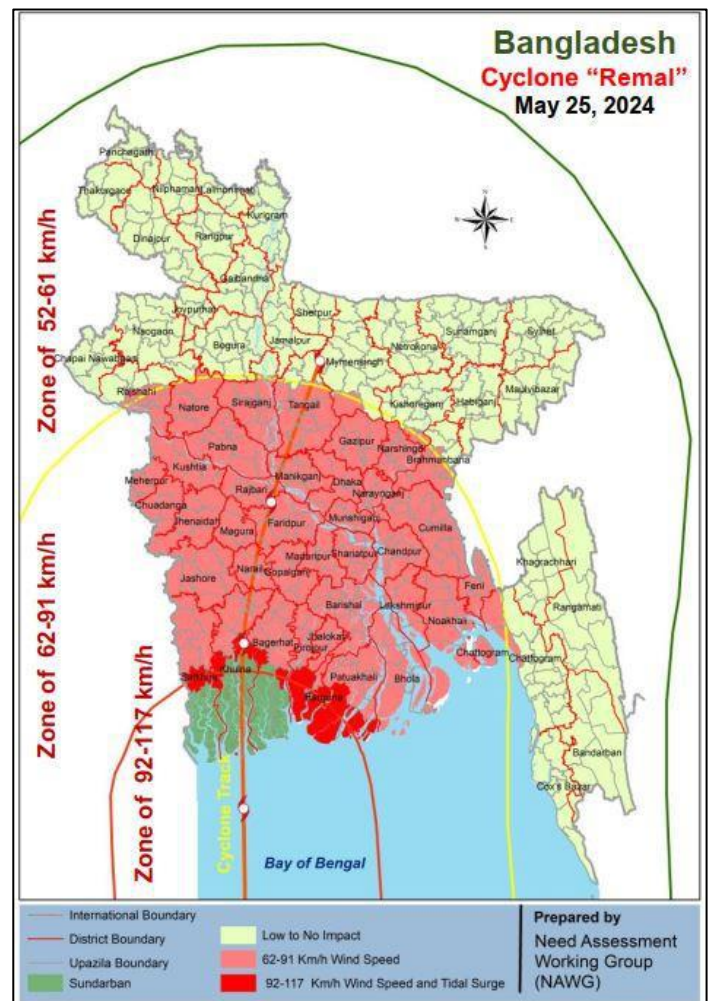

Fig 1: Location Map of the study area

1.1 LITERATURE REVIEW :

Tropical cyclones are the most frequent natural disasters in India. The consequences of tropical cyclones are storm surge, flood, high winds, inundation, erosion, etc., along with loss of life, casualties, and damages to properties causing socio-economic loss (Nair et al., 2018). Any cyclone, in principle, carries the potential to be severe, but those associated with high storm surge and resulting coastal inundation are indeed deadly. In the north Indian Ocean basin, the phenomenon of cyclones is recurring; however, not all of them produce significant storm surges and coastal inundations. The role of storm surge in the increasing death toll is widely documented (Dube et al., 2009; Shaji et al., 2014). Even though AILA was a cyclonic storm by definition, its impact was greater than that of the super cyclone SIDR that hit the coast of Bangladesh (Khatun, M. R., et al., 2017). Penetration can sometimes be deep inland; for example, it was up to 50 km in the case of cyclone Nargis in Myanmar (Fritz et al. 2009) and up to 20 km during the Orissa super cyclone of 1999 (Dash 2002).

1.2 OBJECTIVES :
1. To assess the extent of damage caused by Cyclones Remal in terms of human casualties, property destruction, and economic losses.
2. To assess the severity of damage caused by Cyclone Remal on coastal communities and infrastructure.
3. To evaluate the effectiveness of disaster preparedness and response measures taken by authorities.
4. To analyze the social, economic, and environmental impacts of the cyclone on affected populations.

2. DATA BASE AND METHODOLOGY:

Bangladesh is a low-lying country that is situated in the northern part of the Bay of Bengal. The coastal region of Bangladesh is very complex and is full of many small and big islands. The geographical location makes the country vulnerable to tropical cyclones and other hazards. This study employs a descriptive research design, using both qualitative and quantitative data to analyze the impact of Cyclones Remal. The data sources include government reports, press releases, field surveys, and interviews with affected communities and disaster management officials. The work is based on secondary sources of data. Then the secondary data items are usually collected from different sources, like the India Metrological Department (IMD) and Bangladesh Metrological Department (BMD) (Regional Specialized Meteorological Centre (RSMC), published papers, authorized thesis documents, and also some of the related net. The approach can be used in coastal areas of Bangladesh.

2.1 LIFE HISTORY OF REMAL

Table 1: Best track positions and other parameters of the Severe Cyclonic Storm REMAL over Bay of Bengal during 24th – 28th May, 2024
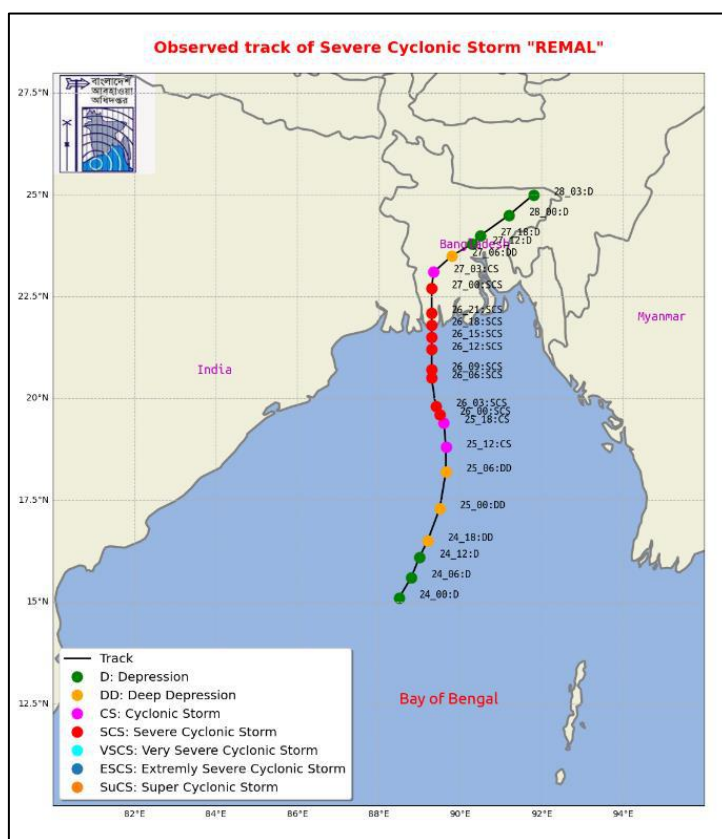
Date	Time (UTC)	Lat.	Long.	C.I. NO.	Estimated Central Pressure (hPa)	Estimated Maximum Sustained Surface Wind (kt)	Estimated Pressure drop at the Centre (hPa)	Grade
24.05.24	0000	15.0	88.4	1.5	996	25	3	D
	0300	15.5	88.7	1.5	996	25	3	D
	0600	15.8	88.9	1.5	996	25	3	D
	1200	16.2	89.1	1.5	995	25	3	D
	1800	16.8	89.4	1.5	995	25	3	D
25.05.24	0000	17.6	89.7	2.0	993	30	4	DD
	0300	18.0	89.7	2.0	992	30	5	DD
	0600	18.2	89.7	2.0	991	30	5	DD
	1200	18.8	89.5	2.5	990	35	6	CS
	1500	19.1	89.5	2.5	989	35	7	CS
	1800	19.3	89.4	2.5	988	40	8	CS
	2100	19.4	89.4	2.5	986	45	10	CS
26.05.24	0000	19.5	89.4	3.0	984	50	12	SCS
	0300	19.8	89.3	3.0	984	50	12	SCS
	0600	20.2	89.2	3.5	983	50	13	SCS
	0900	20.6	89.2	3.5	981	55	15	SCS
	1200	21.1	89.2	3.5	978	60	18	SCS
	1500	21.4	89.2	3.5	978	60	18	SCS
	Crossed the Bangladesh & adjoining West Bengal coasts between Sagar islands and Khepupara close to southwest of Mongla near latitude 21.75°N and longitude 89.20°E between 2230 hours IST/1700 UTC of 26th and 0030 hours IST/1900 UTC of 27th May 2024.							
	1800	21.7	89.2	3.5	978	60	18	SCS
	2100	22.0	89.2	-	980	55	16	SCS
27.05.24	0000	22.5	89.2	-	982	45	14	CS
	0300	22.8	89.2	-	984	40	12	CS
	0600	23.0	89.2	-	985	35	11	CS
	0900	23.3	89.3	-	986	35	10	CS
	1200	23.6	89.7	-	987	35	9	CS
	1500	23.8	90.2	-	988	30	8	DD
	1800	24.0	90.5	-	990	30	6	DD

	0000	24.4	91.1	-	991	20	5	D
	0300	24.7	91.5	-	992	20	4	D
28.05.24	0600	25.1	91.8	-	993	20	3	D
	1200	Weakened into a well-marked low-pressure area over Northeast Assam and neighborhood						
	Source: India Metrological Department (IMD)							

According to the Bangladesh Meteorological Department (BMD) and India Metrological Department (IMD), under the influence of a cyclonic circulation over the southwest Bay of Bengal, a low-pressure area formed over the southwest and adjoining west central Bay of Bengal at 0530 hours IST and persisted over the same region at 0830 hours IST as of today, May 22, 2024. It is very likely to move northeastwards and lay as a well-marked low-pressure area over west central and adjoining south Bay of Bengal at 0830 hrs IST on May 23, 2024. A well-marked low-pressure area over west central and adjoining south Bay of Bengal moved northeastwards during the past 12 hours and lay over the same area at 1730 hrs IST of today, May 23, 2024. The well-marked low-pressure area over west central and adjoining south Bay of Bengal moved northeastwards during the past 12 hours, concentrated into a depression, and lay centered at 0530 hrs IST of today, May 24, 2024, over central Bay of Bengal near latitude 15.0-degree N and longitude 88.4 degree E, about 800 km south-southwest of Khepupara (Bangladesh) and 810 km south of Canning (West Bengal). The depression over Eastcentral Bay of Bengal moved north-northeastwards with a speed of 15 kmph during the past 6 hours, intensified into a deep depression, and lay centered at 0530 hrs IST on May 25, 2024, over Eastcentral Bay of Bengal near latitude 17.6°N and longitude 89.7°E, about 490 km south of Khepupara (Bangladesh), about 380 km southeast of the Sagar Islands (West Bengal), and 530 km southeast of Canning (West Bengal). The Deep Depression over Eastcentral Bay of Bengal moved nearly northward with a speed of 12 kmph during the past 6 hours, intensified into a **Cyclonic Storm "Remal" (pronounced as "Re-Mal"),** and lay centered at 1730 hrs IST of that day, the 25th May, 2024, over the North and adjoining Eastcentral Bay of Bengal near latitude

Observed track of Severe Cyclonic Storm "REMAL"

18.8°N and longitude 89.5°E, about 360 km south-southeast of Khepupara (Bangladesh), 350 km south-southeast of Sagar Islands (West Bengal), and 390 km south-southeast of Canning (West Bengal). The **Severe Cyclonic Storm "Remal" (pronounced as "Re-Mal")** over North Bay of Bengal moved nearly northwards, with a speed of 07 kmph during the past 06 hours, and lay centered at 0830 hrs IST of today, the 26th May, 2024, over North Bay of Bengal near latitude 19.8°N and longitude 89.3°E, about 260 km south-southwest of Khepupara (Bangladesh), 310 km south of Mongla (Bangladesh), 240 km south-southeast of Sagar Islands (West Bengal), and 280 km south-southeast of Canning (West Bengal). Currently, a maximum sustained wind speed of 90–100 kmph, gusting to 110 kmph, prevails around the cyclone center. I crossed the Bangladesh and adjoining West Bengal coasts between the Sagar Islands and Khepupara, close to the southwest of Mongla, near latitude 21.75°N and longitude 89.20°E, between 2230 hours IST/1700 UTC on May 26th and 0030 hours IST/1900 UTC on May 27th, 2024. The Cyclonic Storm "Remal" (pronounced as "Re-Mal") over Coastal Bangladesh and adjoining Coastal West Besengal moved nearly northwards, with a speed of 15 kmph during the past 6 hours, and lay centered at 0830 hrs IST of today, May 27, 2024, over the same region, near latitude 22.8°N and longitude 89.3°E, about 40 km northwest of Mongla (Bangladesh), 90 km east of Kolkata (West Bengal), 90 km northeast of Canning (West Bengal), 130 km northwest of Khepupara (Bangladesh), and 140 km southwest of Dhaka (Bangladesh). The Depression (remnant of Cyclonic Storm "Remal") over east Bangladesh moved east-northeastwards

with a speed of 15 kmph during the past 06 hours and lay centered at 0830 hours IST on May 28, 2024, over the same region, near latitude 24.7 °N and longitude 91.5 °E, about 50 km west-northwest of Srimangal (Bangladesh), 70 km south-southwest of Cherrapunji, 90 km north-northeast of Agartala, 100 km south-southwest of Shillong, 130 km west of Silchar (Assam), and 160 km west-southwest of Haflong.

The system is likely to move east-northeastward and weaken into a well-marked low-pressure area over Eastern Assam and its neighborhoods by the evening of May 28, 2024. (National Bulletin, IMD 2024)

3. RESULTS AND DISCUSSION :

3.1 Wind Speed and Storm Surge

In order to understand the severity of the storms of the Remal tropical cyclones in Bangladesh, a study of the wind speed and storm surge of the Remal cyclones in the Bay of Bengal was conducted from May 22 to May 28, 2024. Squally weather with wind speeds reaching 35–45 kmph and gusting to 55 kmph is likely over the south Bay of Bengal on May 22. It would gradually increase, becoming squally windy, reaching 40–50 kmph and gusting to 60 kmph over central and adjoining South Bay of Bengal on the 23rd morning. Squally wind speeds reaching 40–50 kmph and gusting to 60 kmph are likely to prevail over the central and adjoining South Bay of Bengal on May 24. It would reach 50–60 kmph, gusting to 70 kmph over central Bay of Bengal on May 24th. It would extend to adjoining areas of the North Bay of Bengal, with gale wind speeds reaching 60–70 kmph and gusting to 80 kmph on May 25th. Squally wind speeds reaching 50–60 kmph and gusting to 70 kmph are prevailing along and off Bangladesh, West Bengal, and the adjoining North Odisha coasts. It is likely to increase, with gale wind speeds reaching 70–80 kmph and gusting to 90 kmph from the afternoon of May 26 and 100–120 kmph and gusting to 135 kmph along and off Bangladesh and adjoining West Bengal coasts from the evening of May 26 to the early morning of May 27. It is likely to decrease thereafter to 60–70 kmph, gusting to 80 kmph by afternoon, and squally wind 50–60 kmph, gusting to 70 kmph by night on May 27th.

A storm surge of about 1 meter above the astronomical tide is likely to inundate low-lying areas of coastal West Bengal and 3–4 m above the astronomical tide is likely to inundate low-lying areas of coastal Bangladesh around the time of landfall. (National Bulletin, IMD 2024)
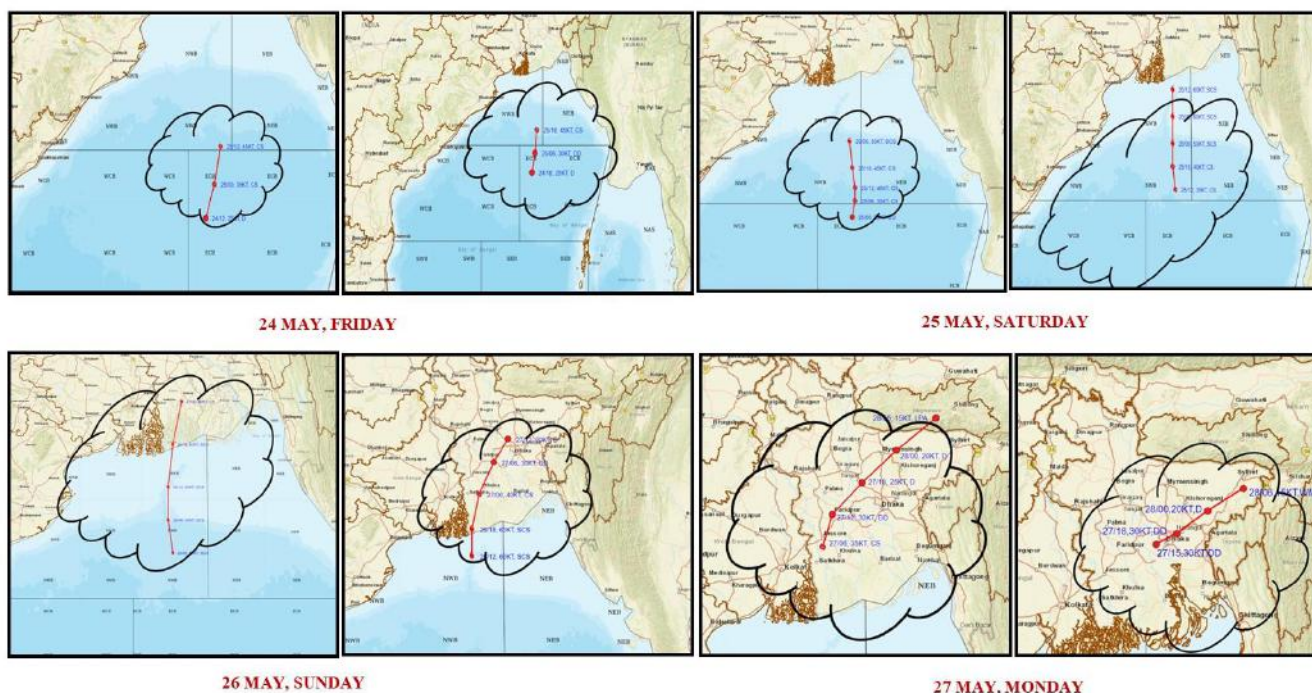

Fig 2: Track Position of Remal over Bay of Bengal during May 24 to 28, 2024

3.2 Sea condition:

Rough to very rough sea conditions are likely over central and adjoining south Bay of Bengal on May 24. It would become high over central Bay of Bengal on May 25 and May 26 and high to very high over North Bay of Bengal from May 25 evening until May 27 morning. Rough to very rough sea conditions are likely along and off Bangladesh, West Bengal, and adjoining North Odisha coasts from May 25th evening and high to very high along and off Bangladesh and West Bengal coasts from May 26th morning onwards until May 27th morning.

3.3 Heavy Rainfall

Light to moderate rainfall at most places, with heavy to very heavy rainfall at a few places, is likely over the coastal districts of West Bengal and the eastern districts of Gangetic West Bengal adjacent to Bangladesh on May 26th and 27th, with isolated extremely heavy rainfall (≥ 20 cm) over these districts on May 26th. The peak rainfall activity is likely from noon on May 26th to noon on May 27th. Light to moderate rainfall is expected at most places, with heavy to very heavy rainfall at isolated places, likely over the eastern districts of Sub-Himalayan West Bengal on May 27 and 28. Light to moderate rainfall is expected at most places, with isolated heavy rainfall likely over North Coastal Odisha on May 25 and 26. Light to moderate rainfall at most places, with heavy to very heavy rainfall at isolated places, is likely over Mizoram, Tripura, and South Manipur on May 26th, and over Assam, Meghalaya, Arunachal Pradesh, Nagaland, Mizoram, Manipur, and Tripura on May 27th and 28th. Isolated extremely heavy rainfall (≥ 20 cm) is also likely over Assam, Meghalaya on May 27 and 28, Arunachal Pradesh on May 28, and Mizoram and Tripura on May 27. Light to moderate rainfall at most places, with heavy rainfall at isolated places over the north Andaman Islands on May 25th
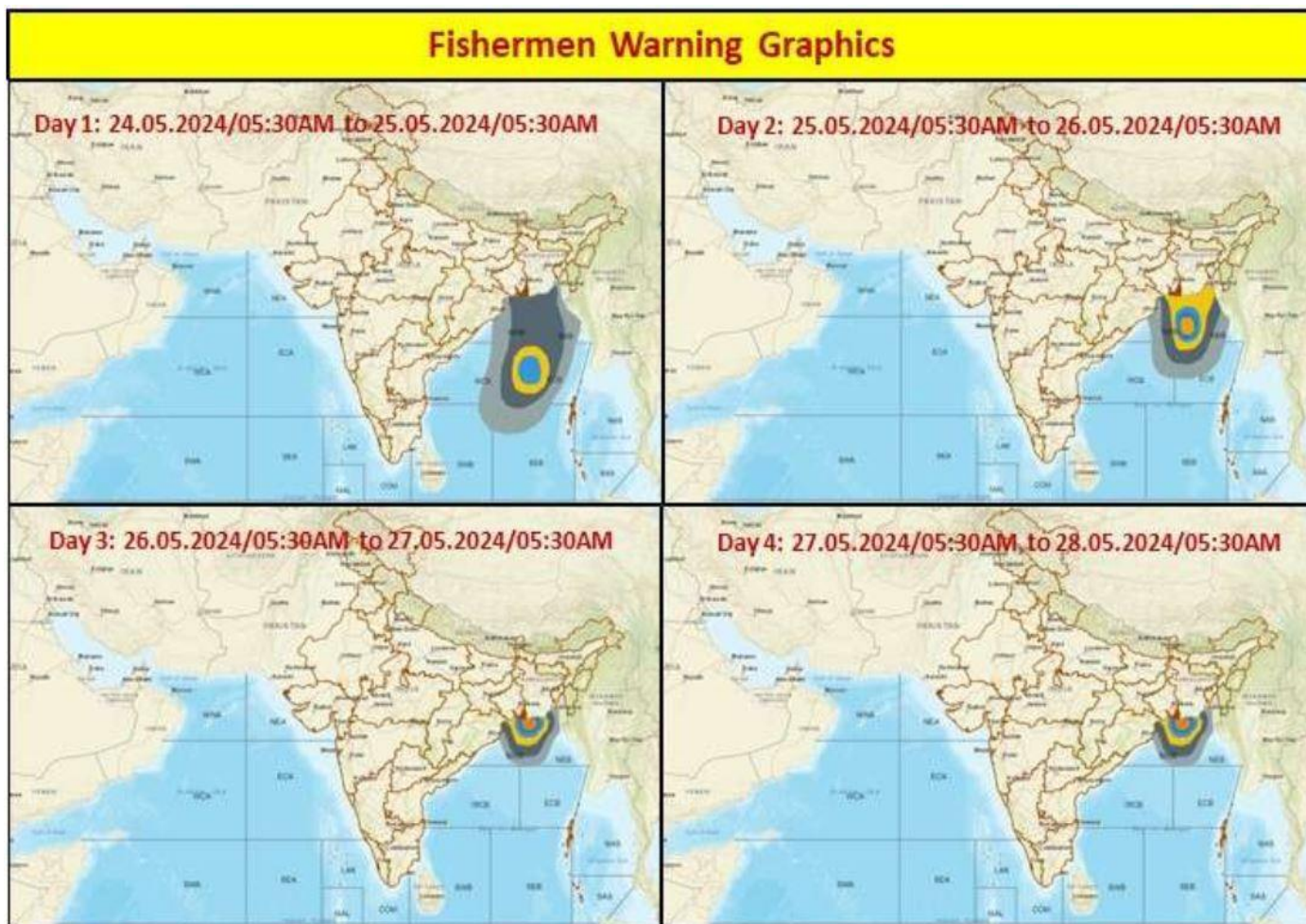

Fig 3: Fishermen Warning during 24may to 28 may over Bay of Bengal

3.4 Death and Damages

The number of deaths due to cyclones in Bangladesh is given as follows: at least 16 people have died after a cyclone crashed into coastal parts of India and southern Bangladesh. The region was hit by strong gales of 110 km/h, torrential rain, and tidal surges that have left low-lying areas flooded. Nearly a million people were evacuated as Cyclone Remal made landfall on Sunday evening. According to local authorities, approximately 8.4 million people lived in the cyclone's path, including 3.6 million children. The storm passed through the Bangladeshi port of Mongla and the Sagar Islands of West Bengal, India, on Sunday, weakening the following day. Seven people have died in Bangladesh's Barishal, Satkhira, Patuakhali, Bhola and Chattogram, according to a news release by the Bangladeshi developmental organisation BRAC.
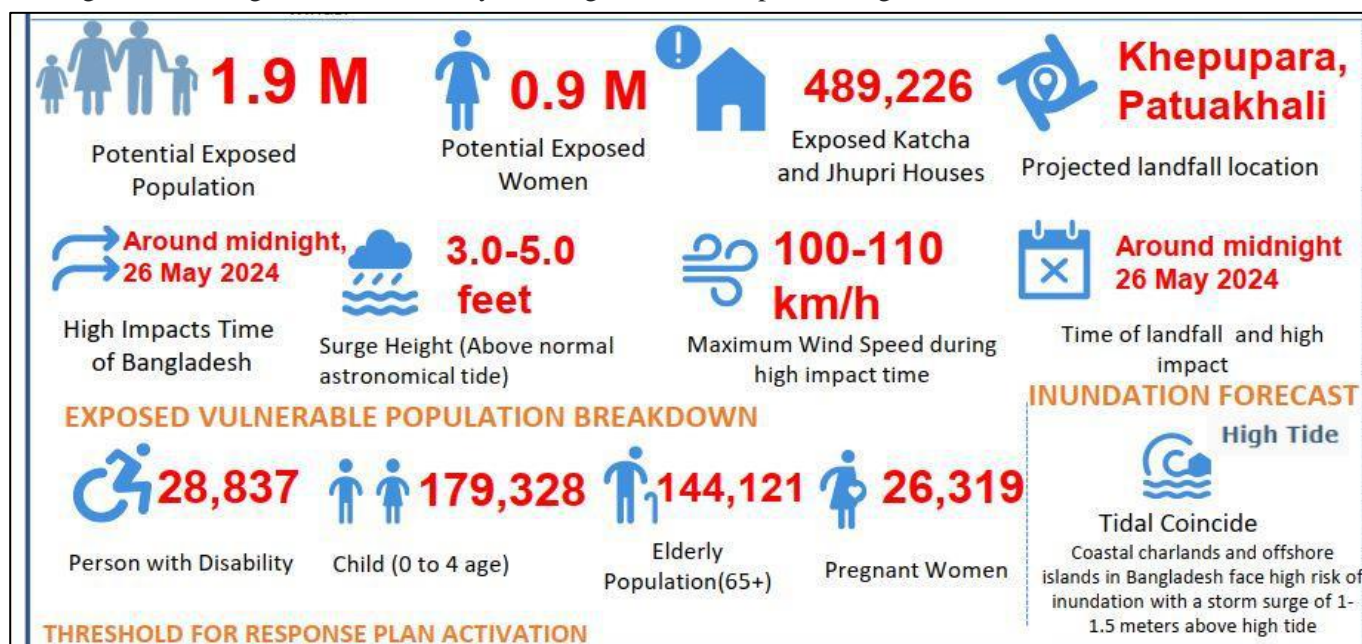

Fig 4: outline of a remal cyclone effect

Remal cyclones notice that the number of deaths is decreasing, despite the damage to properties in recent years. This clearly indicates the awareness and preparedness of the people in the coastal region, the improvement of the weather broadcasting system, and countermeasures taken by the government of the country. However, these measures could not be considered enough yet, and more action needs to be taken to minimize the deaths and damages to the people, their homes, cattle, agriculture, forestry, and fisheries, as well as their environment, biodiversity, the Sundarbans (the world's largest mangrove), and wildlife.

3.5 Shelter : The cyclone Remal hit the southwestern parts of Bangladesh, like Satkhira, Khulna, Bagerhat, Pirojpur, Bhola, Patuakhali, Barishal, Noakhali, and Lakshmipur, on May 26, 2024, and Residents, homesteads, roads, and embankments were destroyed due to the flooding associated with the cyclone. In total, over 1.9 million people were affected, and nearly 489226 katcha and jhupri houses were destroyed. Moreover, 150,457 houses were damaged during the storm. Among these, 35,483 houses were fully damaged in 107 unions and 914 municipalities in Bangladesh, according to the state minister. He spoke about the damage caused by cyclonic storm Remal during the press briefing held at the Secretariat on Monday. A total of 9424 shelters have been opened in the coastal districts of Bangladesh, and more than 800,000 people have taken shelter there. In addition, 52,146 domestic animals were also
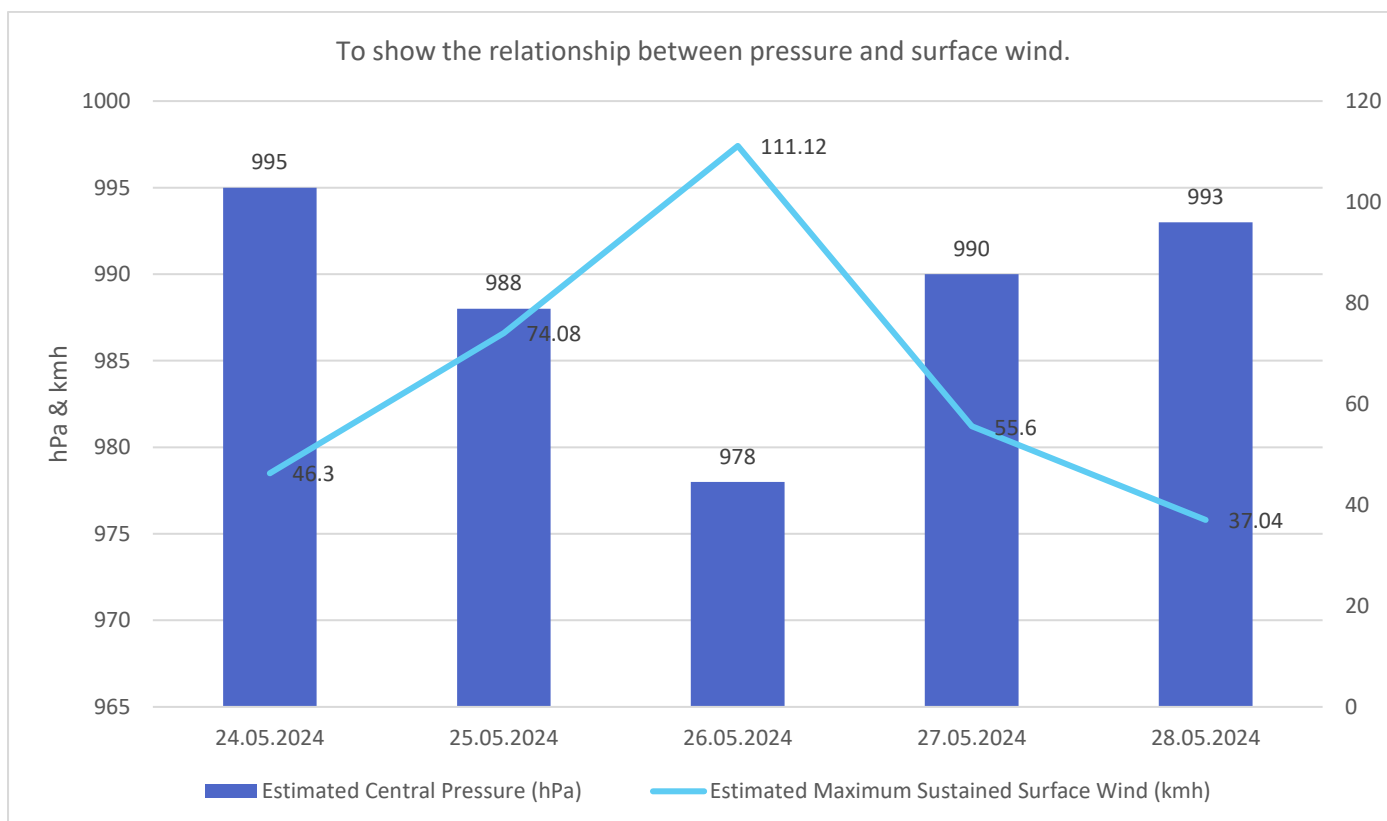
housed there. He further said that no major damage occurred due to measures taken by the ministry as per the directives issued by Bangladesh Prime Minister Sheikh Hasina (The Economic Times, 2024).

3.6 Water and Sanitation

The availability and accessibility of safe water have been consistently difficult to achieve in Bangladesh after the Remal Cyclone Effect. Nearly half of the population consumes water that does not comply with the Bangladesh standard for both arsenic and *Escherichia coli* (UNICEF 2018). Safe water scarcity is a growing problem in the coastal regions of Bangladesh, particularly due to saline water intrusion occurring in Remal Cyclone. Damage to sanitation facilities and infrastructure was significant. For some of the worst-affected areas, one estimate puts the percentage of slab latrines damaged or destroyed at as high as 70%. The affected population was vulnerable to outbreaks of diarrhea and other hygiene-related diseases. Drinking water sources in many communities had been contaminated by saline and debris. Power outages had affected water supplies in areas with piped water. Respondents were facing a number of issues because of insufficient and inadequate sanitation facilities. All of the respondents reported having been experiencing difficulties accessing toilets during high tide as they became submerged underwater during this time. They had to wait it out until there was a low tide. This also meant that the people were unable to visit toilets on time, which was a problem that all of the participants faced. In addition, the toilets have become unsuitable and uncomfortable for use, especially for women and the elderly.
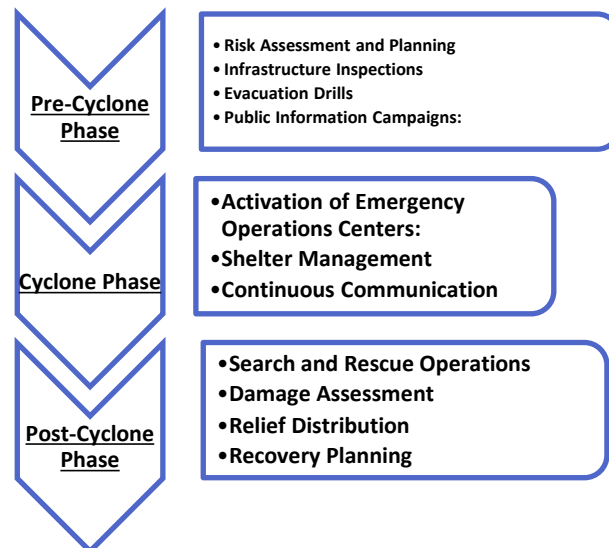
3.7 Transport

There was widespread damage to transport and communications networks. Rural roads, and many of the embankments protecting such roads, were extensively damaged. Most of the road damage was associated with the tidal surges in coastal areas. Large uprooted trees on roadsides also account for some of the damages, as trees were uprooted segments of tarmac or earthen roads became cracked or fragmented. Damage to transport infrastructure in coastal and inland waterways had occurred. Numerous ferries, and associated landing and loading areas were damaged.
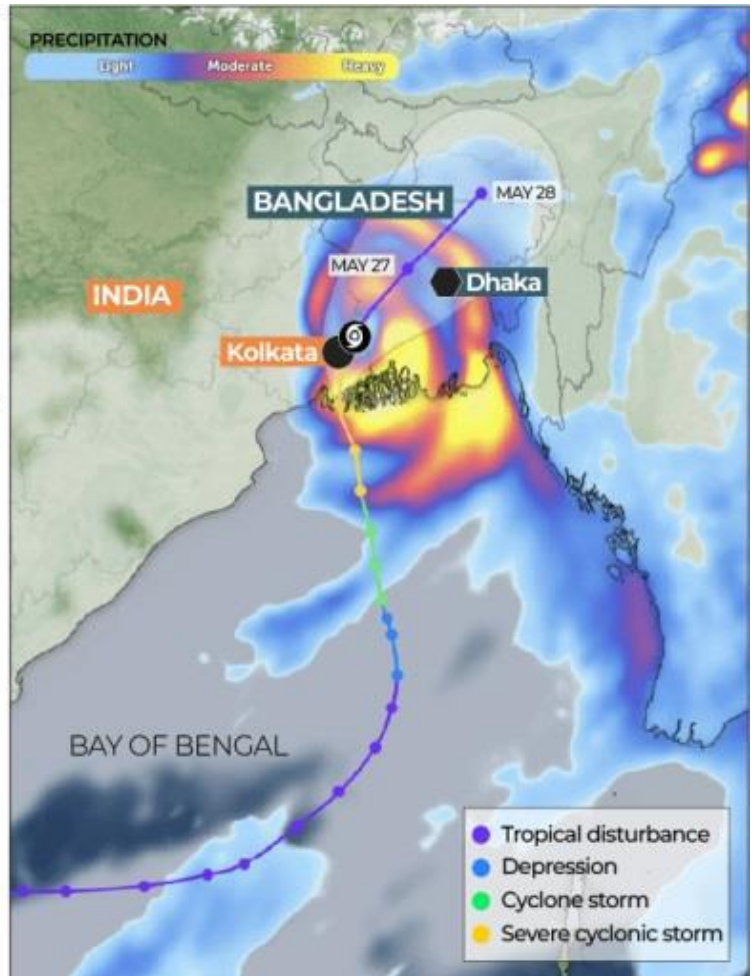
PREPAREDNESS AND RESPONSE

Pre-Cyclone Phase
- Risk Assessment and Planning
- Infrastructure Inspections
- Evacuation Drills
- Public Information Campaigns:

Cyclone Phase
- Activation of Emergency Operations Centers:
- Shelter Management
- Continuous Communication

Post-Cyclone Phase
- Search and Rescue Operations
- Damage Assessment
- Relief Distribution
- Recovery Planning

4. NECESSARY FUTURE STEPS :

1. Early warning systems and forecasting station buildings.
2. Capacity building to make preparedness for cyclones and its associated threats.
3. Preparedness for effective disaster response.
4. Estimation of the Impact on Human Settlements.
5. Emergency Helpline.
6. Relief Measures.
7. Restoration of Critical Infrastructure and Essential Services.
8. Multi-purpose Cyclone Shelter Setup, Etc.

5. CONCLUSION :

In conclusion, Tropical Cyclone Remal's impact on Bangladesh's coastal regions was severe and far-reaching, resulting in loss of life, displacement, and significant economic and environmental damage. The analysis highlighted the vulnerability of coastal communities and the need for improved disaster preparedness and response measures. The study also underscored the importance of addressing climate change, infrastructure development, and ecosystem management to reduce the risk of future cyclones. The key takeaways from this analysis are: improved early warning systems and evacuation plans are crucial; infrastructure development should prioritize climate resilience; ecosystem restoration and conservation are essential; and community-based initiatives and international cooperation are vital. The lessons learned from these cyclones can inform future disaster management strategies, contributing to the overall resilience of vulnerable coastal communities. By understanding these past events, Bangladesh can continue to improve its preparedness and resilience-building strategies to better face future cyclones. Bangladesh is one of the most disaster-prone areas in the world. In this study, we have reviewed the cyclonic storm Remal, which furiously hit the south-western region of Bangladesh. The study suggests that research and development activities focused on cyclone mitigation, including short- and long-term measures like a proper warning system based on an accurate forecasting model, afforestation, and embankment establishment, should receive priority attention from the academic community in developing societies. This article recommends improvements to the cyclone warning systems, the establishment of more public cyclone shelters, preparedness, institutional arrangements, policy formulation, and implementation of an education campaign in coastal areas to increase the utilization of public shelters for future cyclone events.

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Short Biography of Author

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