Rising Cyclone Threats and Mangrove Vulnerability

For Prelims: Cyclones, Mangroves, Carbon Storage, Biodiversity, Hadley Cell, Coral Reefs, Wetlands, Sundarban, Aquaculture, Algal Blooms, Great Barrier Reef, Bengal Tigers.

For Mains: Impact of climate change on cyclones and mangroves and their implications. Suggestions to deal with increased cyclones and degraded mangroves.

Source: TH

Why in News?

A new study revealed that climate change is making cyclones **more intense and expanding** their reach into previously unaffected regions.

- It also revealed that half of the **world's** mangroves could face **severe risks by 2100**, threatening **coastal protection,** carbon storage**,** and biodiversity.

Note: Climate change is complex, so experts use **Shared Socioeconomic Pathways (SSPs)** to understand its effects. Each SSP shows a different future.

- **SSP3** describes a **divided world** with little focus on the environment.
- **SSP5** shows a world with **rapid fossil fuel use** and heavy **resource depletion**.
- **SSP5-8.5** is the **SSP5 pathway plus a radiative forcing**, the amount of extra energy being added to the planet's surface.

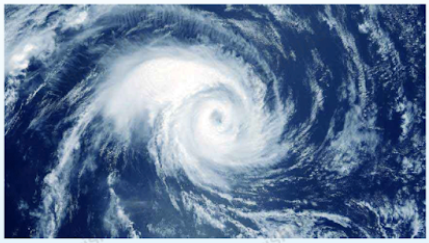
What are Key Findings of the Study on Cyclones and Mangroves?

- **Increased Cyclone Intensity and Range:** Under the **SSP5-8.5** scenario (high emissions and fossil fuel use), **tropical cyclone** belts may shift **away from the equator**, increasing risks to **higher-latitude ecosystems**.
    - **East Asia**, **Central America**, the **Caribbean**, **Madagascar**, and **Oceania** face rising **cyclone exposure.**
- **Shorter Recovery Time for Ecosystems:** In **resilient ecoregions** (historically adapted to cyclones), the **recovery time between high-intensity storms** could drop from **19 years (1980-2017) to 12 years (2015-2050)**.
    - Some ecosystems may **shift into irreversible states** due to frequent disturbances.
- **Mangroves Under Threat:** By **2100**, up to **56%** of global **mangroves** could face **high to severe risk** under **SSP5-8.5**.
    - **Southeast Asia** is especially vulnerable with **52–78%** mangroves at risk.

CYCLONE

Drishti IAS

Cyclones are rapid **inward** air circulation around a **low-pressure** area.

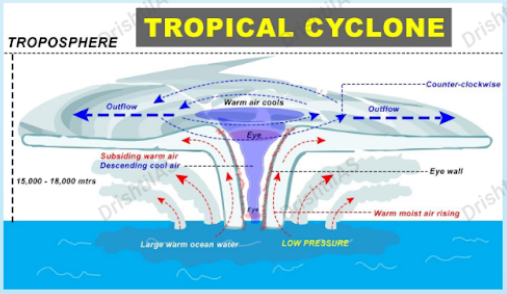


Cyclone v/s Anticyclone

Pressure System	Pressure Condition at the Center	Pattern of Wind Direction	
		Northern Hemisphere	Southern Hemisphere
Cyclone	Low	Anticlockwise	Clockwise
Anticyclone	High	Clockwise	Anticlockwise

Classification

- **Tropical Cyclones;** originate between the **Tropics of Capricorn and Cancer**
- **Extra Tropical/ Temperate Cyclones;** originate in the **Polar Regions**



Conditions for Formation

- Large sea surface with temperature >27° C.
- Presence of the **Coriolis force**
- Small **variations in the vertical wind speed**
- **A pre-existing weak low- pressure area**
- **Upper divergence** above the sea level system

Nomenclature

- Nodal Authority - **World Meteorological Organization (WMO)**
- Indian Ocean Region - **Bangladesh, India, Maldives, Myanmar, Oman, Pakistan, Sri Lanka** and **Thailand** contribute to naming cyclones that occur in this region.

Different Names for Tropical Cyclones

- **Typhoons** - Southeast Asia and China
- **Hurricanes** - North Atlantic and eastern Pacific
- **Tornados** - West Africa and southern USA
- **Willy-willies** - Northwest Australia
- **Tropical Cyclones** - Southwest Pacific and Indian Ocean

Cyclones in India

- **Bi-annual Cyclone Season** - March to May and October to December
- Recent Cyclones - **Tauktae, Vayu, Nisarga and Mekanu** (in Arabian Sea) and **Asani, Amphan, Fani, Nivar, Bulbul, Titli, Yaas and Sitrang (in Bay of Bengal)**

Why is Cyclone Intensity and Range Increasing?

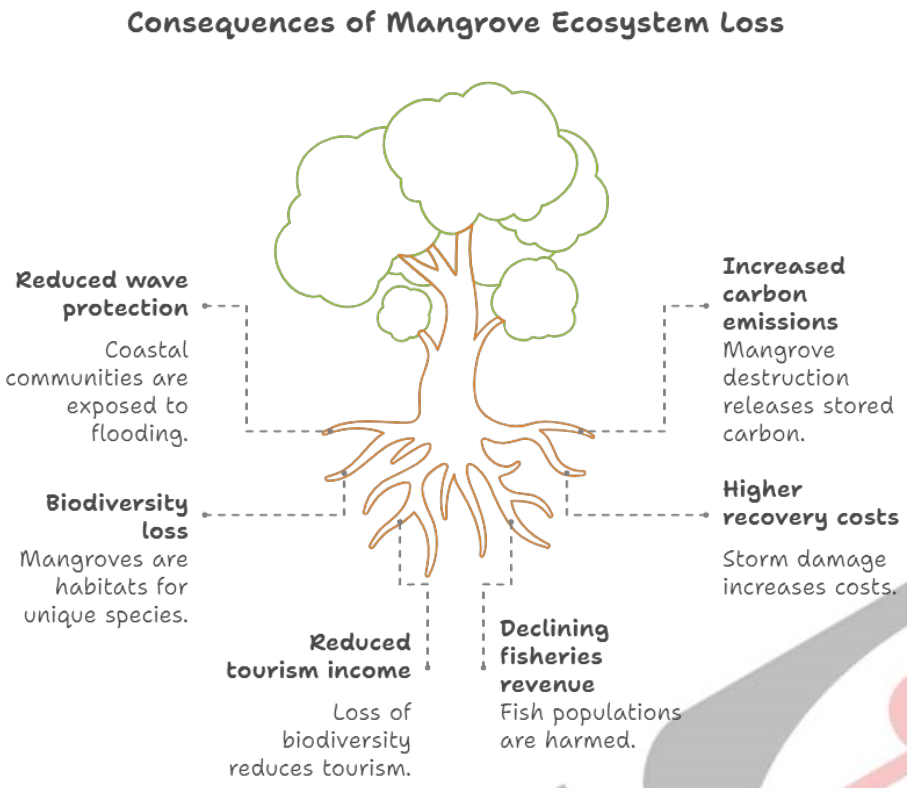
- **Warmer Ocean Temperatures:** Cyclones draw energy from **warm ocean waters** (≥26.5°C), and **climate change** raises **sea surface temperatures**, supplying more **heat** and **moisture**.
    - It leads to **higher wind speeds** (increased intensity), **more rapid intensification** (storms strengthening quickly), and **heavier rainfall** (warmer air holds more moisture).

- **Changing Wind Patterns:** As global temperatures rise, the **Hadley Cell** (atmospheric circulation near the equator) expands, pushing **storm tracks** toward higher latitudes, while changes in **wind patterns** (e.g., jet streams) shift **cyclone paths**, exposing regions like **Madagascar**, **East Asia**, and parts of the **Mediterranean** to new risks.
- **Rising Sea Levels: Higher sea levels** from **melting ice** and **warming oceans** worsen **coastal flooding** during storms, even without an increase in **cyclone frequency.**
- **Changes in Atmospheric Stability: Lower wind shear** in some regions (e.g., tropics) helps **cyclones grow stronger**, while higher shear in areas like the **Atlantic** can **weaken storms**, causing **cyclones to shift to new regions.**
    - **Wind shear** is the change in **wind speed or direction** over a short distance in the atmosphere—either **horizontally** or **vertically.**
- **Polar Warming:** Warming in the **polar regions**, which is **faster than in the tropics**, reduces the **equator-to-pole temperature gradient**, **shifting cyclone activity** away from the equator.
- **Degraded Ecosystems:** Human activity and climate stress have weakened natural buffers like **mangroves**, **coral reefs**, and **wetlands**, which protect against **storm surge**, absorb **wave energy**, and aid recovery.
    - Losing them exposes inland areas more and makes vulnerability worse over time.

Why is the Mangroves Ecosystem Under Severe Risk?

- **Climate Change:**
    - **More Powerful Cyclones:** Warmer **oceans** fuel **stronger cyclones** and **storms** that **uproot mangroves**, **erode soils**, and increase **saltwater intrusion**, harming **freshwater species.**
        - E.g., **Amphan** (1st **super cyclone** in the Bay of Bengal since 1999), damaged around **28%** of **Sundarban** **mangroves** and harmed **floral diversity** by increasing **soil salinity.**
    - **Rising Sea Levels: Mangroves face a dual threat** as they are **unable to shift inland** due to **farmlands**, **urban expansion**, and **flood-control structures**, while rising **sea levels** flood them from the coast, causing a **coastal squeeze**.
        - When **sea levels rise faster than 7 mm per year**, mangroves struggle to adapt and risk **dying from prolonged submersion.**
    - **Extreme Weather: Coral reef die-offs** (from warming) remove **natural wave barriers**, exposing mangroves to stronger waves.
- **Human Induced Destruction:**
    - **Deforestation for Aquaculture:** Since 1980, **35%** of the world's **mangroves** have vanished due to **aquaculture**, unchecked **development**, and **climate stress**.
        - In **Southeast Asia**, home to a third of global mangroves, cover declined by **3.4%** between 2000 and 2016, with **palm oil** and **rice farms** also replacing mangroves.
    - **Coastal Development: Tourism resorts**, **ports**, and **road development** lead to **habitat fragmentation**.
        - **E.g., Mumbai lost 40% of its mangroves** to **urban expansion** over the past **20 years**.
    - **Pollution & Overharvesting: Oil spills** (e.g., 2020 Mauritius) suffocate **mangrove roots**, **plastic waste** blocks **waterways**, **sewage** triggers **algal blooms**, and **illegal logging** persists in **Africa** and **Asia.**

Consequences of Losing Mangroves Ecosystem



What are the Implications of Increasing Cyclone Intensity and Geographic Spread?

- **Ecological Devastation:**
  - **Stronger cyclones** uproot **mangroves** while **saltwater intrusion** kills **freshwater-dependent plants.** E.g., **62%** of mangroves in **southwest Florida** suffered **canopy damage** from **Hurricane Irma.**
  - **Coral Reef Destruction: Cyclones** damage **coral reefs** that protect shorelines, while **warmer seas** and storms trigger **mass bleaching** (e.g., **Great Barrier Reef**).
  - **Biodiversity Loss: Coastal ecosystems (seagrass, estuaries)** face habitat fragmentation. **Endangered species** (e.g., **Bengal tigers** in Sundarbans) lose refuge.
- **Human & Economic Crises:**
  - **Deadlier Storms & Flooding: Storms** with **higher wind speeds** destroy **homes** and **infrastructure**, while **heavier rainfall** causes **inland flooding**. E..g, **Cyclone Idai** (2019) killed over **1,300 people** in **Mozambique.**
  - **Mass Displacement & Migration: Small island nations** (e.g., **Fiji**, **Bahamas**) face **existential threats**, with a **2021 World Bank report** warning that **+200 million people** could be **displaced by 2050** due to the **climate crisis.**
  - **Economic Losses: Climate-related damage** rose from **USD 450 billion** (2000–2004) to over **USD 1 trillion** (2020–2024). E.g., **Hurricane Helene** (2024) alone caused **USD 100+ billion** in damage, making it one of the **costliest US hurricanes.**
- **Food Security Risks: Rice paddies & crops** in cyclone-prone Asia (India, Bangladesh) face **salinization**.
  - E.g., **Cyclone Amphan** washed away about **1.7 million hectares of productive cropland** and **aquaculture farms** and **killed 2.1 million animals** in India (West Bengal and Odisha).
- **New Regions at Risk: Mediterranean**, **South Atlantic**, and **higher**

latitudes (e.g., **Japan**, **New Zealand**) may face first-ever **cyclones.**
    - **Mega-cities** like **Miami**, **Shanghai**, and **Lagos**, built for past climates, face **catastrophic damage.**

Way Forward

- **Building Resilience Against Cyclones:** Expand **cyclone tracking** with satellites and AI; conduct **evacuation drills** and build **storm-resistant infrastructure**. Restore **coral reefs**, **wetlands**, and protect **mangroves** as natural barriers.
    - According to the **UN Environment Programme**, every **USD 1 invested** in **climate change adaptation** generates a **USD 4 return** by reducing **economic losses** and cutting **disaster recovery costs.**
- **Restoring Mangrove Ecosystems:** Strictly enforce bans on **illegal logging** and **aquaculture** in mangrove areas while scaling up **restoration** efforts using **"Building with Nature"** approaches. Implement.
    - Implement **zoning laws** to limit **sprawl**, engage **communities** with **incentives**, and promote **ecotourism** and **sustainable fishing** to reduce harmful practices.
- **Climate Mitigation Efforts:** Accelerate the shift to **renewable energy** to keep warming under 2°C, enforce **carbon pricing** and stricter **emission regulations**, strengthen **NDCs**, and boost **climate financing** for vulnerable nations.
- **International Cooperation:** The **Loss and Damage Fund** should prioritize **cyclone-prone** and **mangrove-rich nations**. Use **debt-for-nature swaps** (e.g., Indonesia, Bangladesh) and develop **stress-tolerant mangroves**.

Drishti Mains Question:

Q. Discuss the impact of climate change on the intensity and geographic spread of tropical cyclones. How can this affect vulnerable ecosystems and human settlements?

UPSC Civil Services Examination Previous Year Question (PYQ)

Prelims

Q. Consider the following statements: (2020)

1. Jet streams occur in the Northern Hemisphere only.
2. Only some cyclones develop an eye.
3. The temperature inside the eye of a cyclone is nearly 10ºC lesser than that of the surroundings.

Which of the statements given above is/are correct?

(a) 1 only

(b) 2 and 3 only

(c) 2 only

(d) 1 and 3 only

Ans: (c)

Q. In the South Atlantic and South-Eastern Pacific regions in tropical latitudes, cyclone does not originate. What is the reason? (2015)

(a) Sea surface temperatures are low

(b) Inter-Tropical Convergence Zone seldom occurs

(c) Coriolis force is too weak

(d) Absence of land in those regions

Ans: (b)

Mains

Q. Tropical cyclones are largely confined to the South China Sea, Bay of Bengal and Gulf of Mexico. Why? (2014)