

Climate change and coastal fisherfolk: Impact of storms on marine fisheries

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A storm is a major atmospheric disturbance followed by sudden and often violent changes in weather conditions. It typically involves the rapid movement of air masses, leading to strong winds, heavy rain, lightning, thunderstorm, dust storm etc. Storms are caused by sudden changes in atmospheric pressure and can vary in intensity from mild to extreme. These disturbances arise from interactions between warm and cold air masses. Storm develops due to instability in atmospheric conditions. Depending on the geographic location and severity, storms can manifest in various types like tropical storms, cyclones, hurricanes or typhoons.

The effects of storms can range from localized weather changes to large-scale natural disasters, impacting both terrestrial and marine environments. In marine areas, storms disturb ocean surface conditions, influence wave patterns and significantly alter ecological dynamics. Storms generate strong surface winds, which transfer energy to the water, creating large waves and rough sea conditions. Storm winds mix the upper ocean layers, disrupting the stable stratification and causing upwelling and downwelling. Due to vertical mixing, heat from the surface spreads deeper, cooling the surface and consequently changes Sea Surface Temperature (SST). Low atmospheric pressure and strong winds create storm surges that raise sea level along coastlines. This can cause severe coastal flooding and erosion. When turbulence is high, it re-suspends sediments from the seabed, which reduces water clarity and negatively impacts coral reefs, seagrass beds, and various marine habitats. Storms play a significant role in altering local ecosystems. Storms significantly reshape local marine ecosystems by

overturning the water column. This process brings oxygen-rich water from the surface downwards and draws nutrient-rich water from the depths upwards.

Key drivers of storm development

1. Ocean warming

The primary factor driving the development and intensification of storms, particularly tropical cyclones (hurricanes/typhoons), is the high amount of energy they derive from warm ocean waters. Storms originate when sea surface temperature exceed 26.5°C, as warmer oceans supply more latent heat from evaporation and more moisture in the atmosphere and resulting in stronger and more intense storms. Warmer ocean temperatures are leading to a rise in Category 4 and 5 storms. These warmer waters sustain storms longer and can lead to rapid intensification. Ocean temperature directly influences storm strength. Intergovernmental Panel on Climate Change (IPCC) reports indicate that for every 1°C rise in sea surface temperature, storm intensity can increase by 3-5%. This correlation is supported by historical data, which shows that the strongest storms today are stronger than decades ago.

2. Moisture availability in the atmosphere

The term Moisture is used to describe the presence of water vapor in the air. Moisture in the air is crucial for formation of cloud and precipitation, and plays a significant role in the transfer of energy within the atmosphere. Water vapor is a key component

of the hydrological cycle. The level of moisture is commonly expressed as humidity. Higher moisture levels often make the air feel warmer and can significantly influence storm development along with other weather phenomena. The presence of moist air in the mid-troposphere (around 5 km altitude) is crucial for the development and strengthening of storm.

3. Low vertical wind shear

Wind Shear is the difference in wind speed and direction with height in the atmosphere. Low vertical wind shear allows the storm structure (tropical cyclones) to remain vertically organized; high shear disrupts storm formation by tilting or breaking apart storm clouds. When the difference in wind speed and direction between the ground surface and upper levels of the atmosphere is small, the developing storm can maintain its vertical alignment. This means the warm, moist air can rise directly upward, and the system can efficiently organize and strengthen.

4. Coriolis Effect

The Coriolis effect, resulting from Earth's rotation, it provides the necessary spin for the storm. The effect of Coriolis force is strongest near the poles and weakest at the equator. This is why tropical cyclones do not form near the equator (Coriolis is near zero there). Coriolis force causes the rotation of storms (anticlockwise in the Northern Hemisphere, clockwise in the Southern Hemisphere) and also influences the direction of major currents.

Effects of Storms on Marine Fisheries

1. Fish breeding cycles

This refers to the reproductive strategies and seasonal breeding patterns of fish species throughout the year. These cycles are influenced by environmental, biological, and ecological factors like temperature, photoperiod (Day Length), salinity and water flow, food availability and environmental stability that regulate when, where, and how fish reproduce. Storms significantly disrupt fish breeding cycles because these cycles depend on stable environmental conditions Table 1.

Table 1. Effects and Impacts of storms on fish breeding cycles

Effects	Impacts
Disruption of spawning grounds	Storms disturb seabed habitats (coral reefs, estuaries, and mangroves), destroying eggs and nesting sites.
Changes in water temperature	Sudden fluctuations delay or inhibit spawning as many species require specific temperature ranges.
Altered salinity levels	Freshwater runoff lowers salinity, causing stress or mortality in eggs, larvae, and broodstock.
Reduced oxygen levels	Increased turbidity lowers photosynthesis, reducing dissolved oxygen and impacting reproduction.
Migration pattern disruptions	Altered currents and cues delay or prevent migration to spawning grounds.
Increased mortality of eggs and larvae	High-energy waves and sediments destroy eggs and increase larval mortality.

2. Fish population

Storms like tropical cyclones, can have a profound and often detrimental impact on fish populations (Table 2). These effects can be both immediate and long-term, influencing fish survival, behaviour, reproduction, and overall ecosystem health.

Table 2. Impacts of storms on fish population

Impact of Storms	Effect on Fish Population
Habitat Destruction	Damages coral reefs, mangroves, and seagrass beds; reduces breeding and feeding grounds.
Increased Mortality	Eggs, larvae, and juveniles killed by turbulence; adults suffer stress or oxygen depletion.
Changes in Water Quality	Runoff reduces salinity, increases turbidity, and introduces pollutants, harming fish health.
Disruption of Feeding & Breeding	Reduced food availability and interrupted spawning cycles, lowering recruitment.
Altered Distribution & Migration	Fish move to deeper or safer waters, changing population structure and availability.
Long-term Stock Decline	Repeated storms reduce population recovery and may cause commercial species collapse.

3. Fish habitats

Tropical cyclones and hurricanes can severely disrupt fish habitats, producing short and long term impacts on fish populations. These impacts is

primarily driven by intense winds, waves, rain, and storm surges Table 3.

Table 3. Impacts of storms on fish habitats

Impact of Storms	Explanation
Destruction of Physical Habitats	Strong waves and surges damage coral reefs, mangroves, and seagrass beds essential for fish life
Increased Turbidity	Sediment runoff makes water murky, reducing light available for photosynthesis and disrupts the food chains
Altered Water Chemistry	Heavy rainfall lowers salinity; runoff adds pollutants, degrading water quality
Loss of Shelter and Breeding Grounds	Breaking of reefs and uprooting of mangroves eliminates protective and spawning areas
Habitat Fragmentation	Storm surges disconnect estuaries and lagoons, disrupting fish migration and breeding

4. Marine food chain

Storms can have significant and complex impacts on marine food chains, sometimes triggering cascading effects that transform the entire ecosystem (Table 4). These impacts vary depending on the intensity of the storm, the specific marine environment and the season.

Table 4. Impacts of storms on marine food chain

Trophic Level	Impact
Primary Producers (Phytoplankton)	Increased turbidity reduces sunlight and photosynthesis; storm mixing may cause short-term nutrient boost
Zooplankton	Decline in food availability; turbulence disperses or kills delicate organisms
Small Pelagic Fish	Reduced zooplankton lowers food supply; alters migration patterns
Predatory Fish	Less prey availability causes feeding stress; forces migration and increases competition
Marine Mammals & Birds	Food scarcity affects feeding and breeding behaviour
Overall Food Web	Disrupted energy flow leads to imbalance; opportunistic species may dominate

5. Ecosystem imbalance

Intense and frequent storms can profoundly disrupt the delicate balance of ecosystems, triggering a chain of effects that modify community composition, energy dynamics, and overall ecosystem integrity. These disturbances can manifest in various ways, often with long-term consequences (Table 5).

Table 5. Impacts of storms on Ecosystem imbalance

Impact Area	Description	Examples
Physical Habitat Damage	Strong waves and storm surges damage habitats.	Coral reef breakage, mangrove uprooting
Coastal Erosion & Sediment Transport	Erosion of shorelines and sediment resuspension smothers benthic life.	Loss of beaches, seagrass burial
Disruption of Food Webs	Alters plankton communities, impacts fish larvae and recruitment.	Fish population decline
Oxygen Imbalance	Post-storm organic decay leads to hypoxia (low oxygen zones).	Fish kills, dead zones
Species Displacement & Mortality	Displaces or kills sensitive species.	Coral bleaching, shellfish mortality
Salinity & Temperature Changes	Freshwater runoff lowers salinity; surface cooling from mixing.	Stress on marine species
Pollution & Contaminants	Storm runoff brings chemicals, plastics, and sewage into marine areas.	Water contamination, bioaccumulation
Long-term consequences	Habitat loss and altered nutrient cycles reduce biodiversity and resilience.	Dominance of invasive species

Conclusion

Storms have profound and multifaceted impacts on marine ecosystems, disrupting critical habitats such as coral reefs, seagrass beds, and mangroves, which serve as breeding and nursery grounds for numerous fish species. Repeated storm events cause cumulative habitat degradation, risking long-term biodiversity loss and collapse of fish communities. Damage to artificial reefs and conservation zones further undermines marine protection efforts, while socioeconomic repercussions for coastal fisheries demand adaptive strategies in marine resource management.