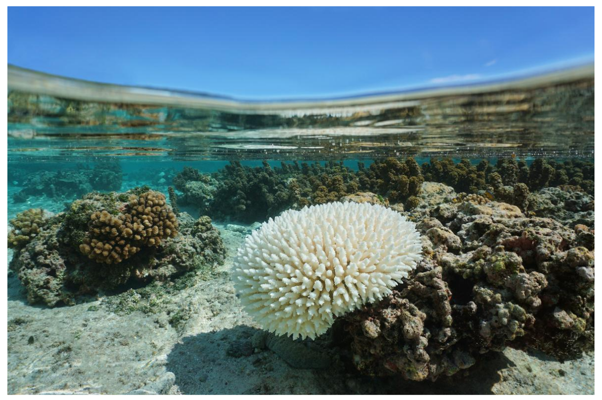
Coral Bleaching – Causes, Mechanisms, and Global Impacts

AIM:

What causes coral bleaching, how does it impact reef ecosystems, and what role does climate change play in driving its frequency and severity?



Do Now:

Corals live in shallow, tropical oceans and rely on sunlight. What do you think happens to corals when ocean conditions change too quickly or become too extreme? Briefly write what might cause stress to a coral.

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NGSS Standards

- HS-LS2-6: Evaluate the impact of environmental changes on biodiversity and ecosystem stability.
- HS-ESS3-5: Analyze geoscientific data to forecast the impacts of climate change on natural systems.
- HS-LS4-5: Evaluate evidence supporting how environmental pressures influence species survival and ecosystem structure.

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Objectives

- Define coral bleaching and explain its biological mechanism.
- Identify the key environmental stressors that cause bleaching.
- Understand the symbiotic relationship between coral polyps and zooxanthellae.
- Analyze how climate change has increased the frequency and severity of bleaching events.
- Evaluate the ecological and economic consequences of mass coral bleaching.
- Describe potential mitigation and adaptation strategies to protect coral reefs.

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Introduction/Review to Coral Biology

A. What Are Corals?

- Marine invertebrates in the phylum Cnidaria; colonial polyps build calcium carbonate skeletons.
- Live in shallow, sunlit waters of tropical oceans.
- Foundation species in reef ecosystems.

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Introduction/Review to Coral Biology

B. Coral–Zooxanthellae Symbiosis

- Corals contain symbiotic algae called zooxanthellae (dinoflagellates).
- Zooxanthellae photosynthesize, providing food (up to 90% of energy) to corals.
- In exchange, corals provide shelter, nutrients, and CO_2.

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What is Coral Bleaching?

A. Definition and Description

- Coral bleaching is the loss of symbiotic zooxanthellae or their pigments, resulting in pale or white corals.
- Bleached corals are still alive but are severely stressed and vulnerable to disease or death.
- If conditions return to normal, within two weeks, corals may recover. Prolonged bleaching leads to mortality.

What is Coral Bleaching?

B. Visual Characteristics

- Corals appear bright white (skeleton visible through transparent tissue).
- Some may fluoresce as a stress response before complete bleaching.

Causes of Coral Bleaching

A. Temperature Stress

- Most common trigger: elevated sea surface temperatures (≥1–2°C above normal).
- Even short heatwaves (lasting weeks) can trigger mass bleaching.
- Linked to El Niño events and global ocean warming.

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Causes of Coral Bleaching

B. Light Stress (Solar Irradiance)

- Excess sunlight intensifies temperature-induced stress.
- Cloudless, calm conditions can exacerbate bleaching.

C. Ocean Acidification

- Increased CO_2 lowers ocean pH → reduces carbonate ions needed for skeletal building.
- Weakens coral resilience, even if it doesn't directly cause bleaching.

Causes of Coral Bleaching

D. Pollution and Eutrophication

- Runoff from land introduces sediment, nutrients, and toxins.
- Can disrupt the coral–algae balance and make reefs more susceptible to bleaching.

E. Other Stressors

- Salinity changes (e.g., heavy rain or runoff).
- Disease outbreaks, overfishing (which disrupts reef food webs), physical damage from tourism.

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Climate Change and Global Trends

A. Global Bleaching Events

- 1998: First global bleaching event linked to strong El Niño.
- 2010, 2014–2017: Widespread bleaching during extended marine heatwaves.
- Great Barrier Reef: ~50% coral loss between 2016–2017 due to back-to-back bleaching.

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Climate Change and Global Trends

B. Warming Oceans

- IPCC reports project increased marine heatwaves under continued emissions.
- Most coral reefs may face annual bleaching by mid-century without emissions reductions.

C. Ocean Acidification

- CO_2 reacts with water → carbonic acid → lowers pH.
- Slows reef-building, stresses coral physiology, and impairs larval development.

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Ecological and Economic Impacts

A. Biodiversity Loss

- Coral reefs host ~25% of all marine species.
- Loss of structure affects fish, invertebrates, and entire food webs.

B. Coastal Protection

- Reefs buffer shorelines from waves and storm surges.
- Bleached or dead reefs offer less protection.

Ecological and Economic Impacts

C. Economic Impacts

- Coral reef tourism generates billions annually.
- Fisheries depend on reef-associated species.
- Bleaching reduces reef productivity and economic value.

Adaptation, Mitigation, and Restoration

A. Reducing Global Emissions

- Limiting global warming to <1.5°C is critical for reef survival.
- Paris Agreement and international climate policy.

B. Local Reef Management

- Marine Protected Areas (MPAs) reduce fishing and development pressure.
- Wastewater treatment and sustainable tourism reduce local stressors.

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Adaptation, Mitigation, and Restoration

C. Assisted Evolution & Restoration

- Selective breeding of heat-tolerant coral strains.
- Coral gardening: replanting fragments on damaged reefs.
- Research into artificial reefs and probiotics for coral health.

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Reflection

- Coral bleaching is primarily driven by thermal stress and threatens reef ecosystems globally.
- It results from the breakdown of coral–zooxanthellae symbiosis.
- Climate change is increasing bleaching frequency, severity, and duration.
- Mitigating emissions and reducing local stressors are both essential for reef survival.