CLIMATE CHANGE

Students' learning outcomes
After studying this chapter, students will be able to:

1. [B-12-U-01] Describe how climate change impacts flora and fauna.
2. [B-12-U-02] Describe how climate change can impact ocean biology in terms of its temperature and acidity as well as the resulting harmful effects.
3. [B-12-U-03] Name species that have gone extinct due to climate change.

Weather and **climate** are two closely linked terms often considered as synonyms by many people though these are quite different concepts. Weather is short term changes in environmental conditions such as temperature (hot and cold), water vapours in atmosphere (humid or dry air), precipitation (rain, snow, hails or dew), daylight (cloudy or sunny) and water availability (flooding or drought). On the other hand, climate is overall pattern of weather in an area that prevails over a period of few decades to even centuries. For example: ocean, forest, deserts and plains have all weathers, but each has distinct climate. In this chapter, you will learn about the concept of climate change, its causes and impacts on biotic and abiotic components of earth ecosystem.

13.1 CLIMATE CHANGE, ITS CAUSES AND IMPACTS ON BIODIVERSITY

Climate change refers to the long-term, gradual and apparently irreversible changes in climatic conditions of an area that may affect the whole world with passage of time. Major events of climate change include:

(i) Average rise in global air (atmospheric) temperature,
(ii) ocean acidification,
(iii) changes in the seasonal duration,
(iv) changes in the monsoon raining pattern,
(v) extreme hot and cold, and
(vi) extreme flooding and drought etc.

While climate naturally changes over thousands and millions of years due to factors like volcanic eruptions and variations in Earth's orbit, the term climate change today often refers to human-caused (**anthropogenic**) climate changes happening rapidly over the last century after industrial revolution.

13.1.1 Causes of Climate Change (Extra reading material)

The Earth's climate is driven by the balance of energy entering and leaving the atmosphere. This balance is disrupted by both natural and anthropogenic factors:

Natural Factors Causing Climate Change

Natural processes can influence Earth's climate over long periods of time, though their effects are often gradual and cyclical.

i. Volcanic Activity

Large volcanic eruptions release huge amounts of dust, ash and gases like sulfur dioxide into the atmosphere. These particles can block sunlight, causing temporary cooling of the Earth's surface. However, volcanic eruptions also release CO_2, contributing to the greenhouse effect over time.

ii. Solar Variability

The Sun's energy output is not constant and can vary over time due to solar cycles. Changes in solar radiation can influence Earth's climate. During periods of higher solar activity, more solar energy reaches the Earth, causing temporary warming.

Fig. 13.1: Volcanic eruption in 2018 near Antigua, Guatemala, Central America.

iii. Milankovitch Cycles

These are long-term changes in the Earth's orbit and axial tilt, affecting the amount of sunlight the planet receives. The shape of the Earth's orbit (eccentricity), the tilt of its axis (obliquity), and direction of its axis (precession) change slowly and periodically over time. These cycles cause variations in the amount of solar energy reaching the Earth.

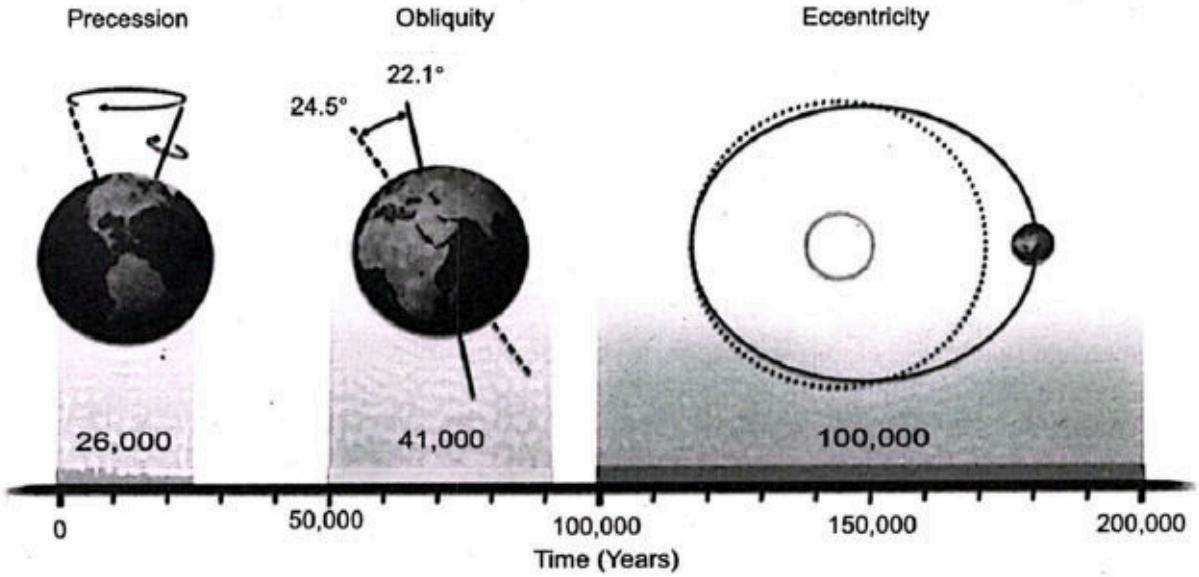


Fig. 13.2: Milankovitch Cycles

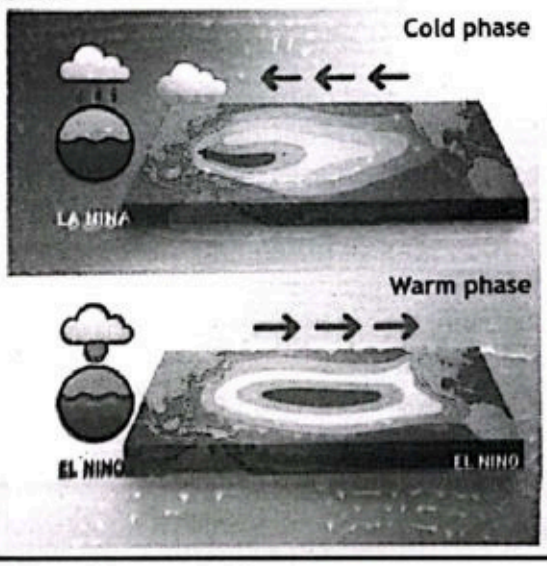
Eccentricity: This cycle affects the shape of the Earth's orbit around the Sun, alternating between more circular and more elliptical orbits. The cycle occurs over 100,000 years.

Axial Tilt (Obliquity): This cycle refers to changes in the angle of the Earth's tilt on its axis. The tilt varies between 22.1° and 24.5° over a period of about 41,000 years.

Precession: This is the wobble or change in the direction of the Earth's axis of rotation, like a spinning top. This cycle has a duration of about 26,000 years.

CONCEPT BUILDER

El Niño and La Niña are opposite phases of a climate pattern known as the **El Niño-Southern Oscillation (ENSO)**, which significantly influences global weather and climate conditions. **El Niño** brings warmer sea surface temperatures in the central/eastern Pacific, leading to wetter and warmer conditions in some regions and drought in others. **La Niña** brings cooler sea surface temperatures, leading to more rainfall in some areas (like Southeast Asia) and drier, cooler conditions in others (like South America). Both phenomena can last for several months and have widespread effects on weather, agriculture, ecosystems, and economies globally.



iv. Ocean Currents

The oceans store and transport heat around the world through currents. Changes in ocean circulation patterns, such as El Niño and La Niña events, can cause short-term climate changes, affecting weather patterns like rainfall and temperature distribution.

v. Natural Greenhouse Gas Emissions

Naturally occurring processes like the decay of organic matter, respiration of plants and animals, and wetlands release greenhouse gases like carbon dioxide (CO_2) and methane (CH_4) into the atmosphere. These gases trap heat, contributing to the natural greenhouse effect.

Anthropogenic (Human-Caused) Factors Causing Climate Change

Human activities since the Industrial Revolution have been the primary drivers of rapid climate change. These activities significantly increase the concentration of greenhouse gases in the atmosphere, accelerating global warming. Major anthropogenic factors include:

i. Deforestation and urbanization

Trees absorb CO_2 through photosynthesis, helping to regulate the Earth's climate, therefore called **environmental buffers.** Deforestation is the cutting of trees by man for various purposes. When forests are cut down for agriculture, logging, or urban development i.e., expansion of cities (urbanization), this carbon sink is lost (Fig. 13.3). Additionally, burning trees during deforestation releases stored CO_2 into the atmosphere.

Fig. 13.3: (a) Deforestation and (b) Urbanization contributing in climate change

ii. Burning of Fossil Fuels

The combustion of coal, oil, and natural gas for energy production, transportation, and industry is the largest source of CO_2 emissions. This leads to an enhanced greenhouse effect, where more heat i s trapped in the atmosphere, causing the planet to warm.

iii. Industrial Processes and Agriculture

Industrial activities like cement production and certain chemical processes release CO_2 and other gases. Agriculture is a significant source of methane (CH_4), especially from livestock (cows and sheep) and rice paddies, as well as nitrous oxide (N_2O) from fertilizers.

iv. Land Use Changes

Beyond deforestation, other land use changes such as urbanization and soil degradation also contribute to climate change by reducing natural vegetation that absorbs carbon and increasing heat absorption by cities (urban heat islands).

Fig. 13.4: Industrial processes releasing greenhouse gases contribute in climate change

v. Waste Management

Landfills produce methane (CH_4) as organic waste breaks down. Improperly managed waste, including food waste and discarded products, increases the release of greenhouse gases.

vi. Transportation

The global reliance on vehicles powered by gasoline and diesel engines emits significant amounts of CO_2. Air travel and shipping also contribute to greenhouse gas emissions.

vii. Aerosols and Chemicals

Human-made aerosols, such as those from industrial pollution, can have both cooling and warming effects on the climate. Some aerosols reflect sunlight (cooling effect), but others, such as black carbon (soot), absorb heat and contribute to warming. Additionally, chlorofluorocarbons (CFCs) and other chemicals not only damage the ozone layer but are also potent greenhouse gases.

13.1.2 Impact of Climate Change on Biodiversity (Flora and Fauna)

The flora (overall plants) and fauna (overall animals) in an area together referred to as biodiversity. Although, climate change has its impact on all environmental compartments, but biodiversity shows significant impact of climate change.

Impact of Climate Change on Flora (Plants)

Plants depend on specific conditions like temperature, rainfall, and soil quality to grow. Climate change alters these conditions, making it difficult for many plants to survive.

i. Changes in Growing Seasons

The growing season is the time of year when plants can grow due to favorable temperatures conditions. With climate change, growing seasons are becoming longer in some regions and shorter in others. This inconsistency affects when plants flower, produce fruit, or go dormant.

ii. Increased Stress from Extreme Weather

As climate change causes more frequent and intense storms, floods, or droughts, plants may struggle to survive. Droughts can dry out the soil, preventing plants from getting enough water, while floods can waterlog their roots.

iii. Migration of Plants

Plants can not move like animals, but seeds can spread to new areas through wind, water or animals. As climates change, plants that once thrived in a particular area may begin growing in new regions better suited to the altered climate, while others might disappear from their original habitats.

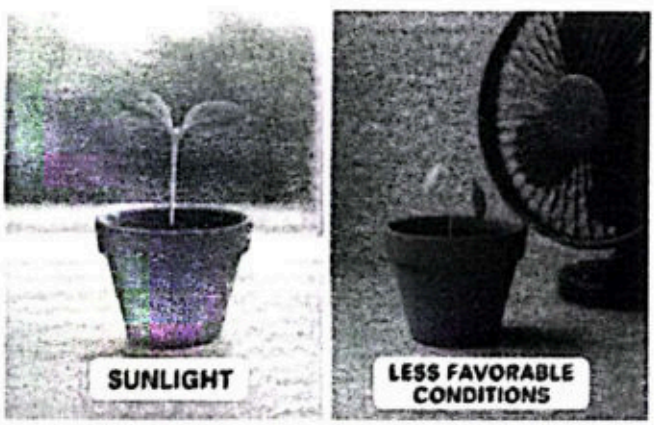


Fig. 13.5: Activity to demonstrate the impact of changes in growing seasons.

Plant two seeds in two small pots. Place one in normal sunlight and water it regularly. Place the other in a colder or less favorable environment (such as in a shaded area or near a fan to simulate a colder climate). Observe how differently the two plants grow. This demonstrates how environmental conditions affect plant growth.

Impact of Climate Change on Fauna (Animals)

Animals rely on stable ecosystems to find food, shelter, and mates. Climate change disrupts these ecosystems, causing a wide range of problems for wildlife.

i. Loss of Habitat

As temperatures rise, many animals lose their habitats. For example, polar bears rely on sea ice to hunt for seals. When the ice melts due to warming, they struggle to find food. This simulates the impact of climate change on animals' habitats.

Fig. 13.6: Impact of climate change on Polar Bear' habitat.

ii. Shifting Habitats

Just like plants, animals often need to move to new regions to find suitable climates. For example, birds that once migrated to warmer regions during winter may have to adjust their migration patterns as temperatures shift.

iii. Food Chain Disruption

Animals depend on specific plants and other animals for food. When climate change affects one species (e.g., a plant or prey animal), it also impacts the animals that rely on it. For example, if a type of plant that an insect feeds on goes extinct due to changing climate, the insect population will decline, which then affects animals that eat those insects.

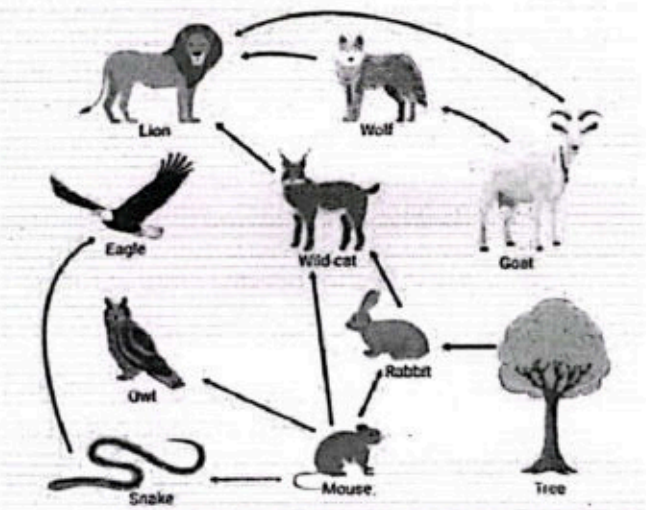


Fig. 13.7: Network of food chains (food web).

iv. Breeding and Hibernation Cycles

Many animals rely on specific temperature and weather conditions for breeding, hibernation, and migration. Climate change can throw off these cycles. For example, some animals hibernate in winter and wake up in spring when food is available. If spring comes too early or late, they may wake up at the wrong time, with no food around.

v. Ecosystem Balance and Extinction

Flora and fauna are part of an interconnected web. When one species struggles or disappears, it affects the whole system. If plants or animals can't adapt to the rapid changes in climate, they may go extinct, disrupting the balance of the ecosystem.

vi. Invasive Species

As some species move to new areas to escape changing climates, they may invade habitats where they don't naturally belong. These invasive species can outcompete native plants or animals for resources, which can harm the ecosystem.

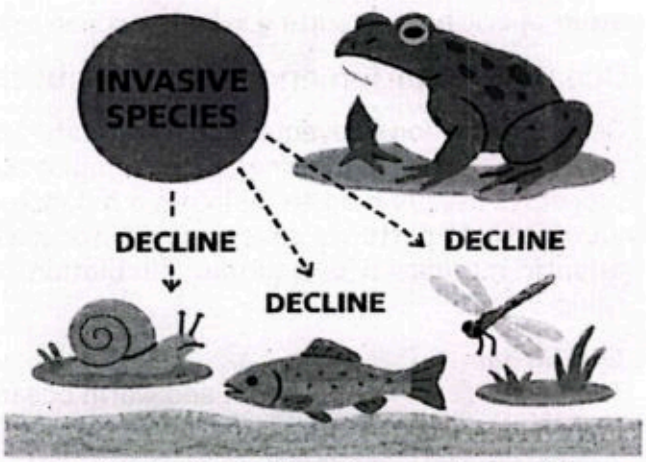


Fig. 13.8: Effect of invasive species on other species.

vii. Species Adaptation

Some species are better at adapting to new climates, but many can't keep up with the speed of climate change. Species that evolve quickly might survive, while others face extinction.

13.2 CLIMATE CHANGE IMPACTS ON OCEAN ECOSYSTEM

Climate change impacts on ocean ecosystem in three ways i.e., by causing:

i. Rise in ocean temperature
ii. Decrease in ocean pH (increased acidity)
iii. Effects on the growth of ocean biodiversity

13.2.1 Climate Change impacts Ocean Temperature

Climate change impacts ocean temperatures through several human and natural factors:

Global Warming and the Greenhouse Gasses

The process of **global warming**, primarily driven by the buildup of greenhouse gases (such as carbon dioxide, methane, and nitrous oxide) in the atmosphere. Human activities, particularly the burning of fossil fuels (coal, oil, gas), deforestation, and industrial processes, have increased the concentration of greenhouse gases in the atmosphere. These gases trap heat, preventing it from escaping back into space, which leads to global warming. The oceans absorb much of this excess heat, resulting in higher ocean temperatures.

SCIENTIFIC ENQUIRY

Warmer water expands, a process known as **thermal expansion**, which contributes to rising sea levels. This process occurs as water molecules move further apart when they are heated, leading to the expansion of the ocean's volume.

How can you prove thermal expansion in the laboratory.

High heat capacity of ocean

The oceans have a high heat capacity, which means they can absorb and store vast amounts of heat without experiencing a dramatic increase in temperature. This property also causes rise in ocean temperature.

Large surface area of oceans

Since the oceans cover more than 70% of the Earth's surface, they absorb about 90% of the atmospheric heat, resulting in higher ocean temperatures.

Ocean Circulation and Heat Distribution

Ocean circulation (movement of ocean water vertically or horizontally) and heat distribution play a critical role in regulating ocean temperatures across different regions of the world. These processes usually help to maintain a balance in ocean heat distribution, but climate change is altering these patterns, causing a rise in ocean temperatures in several ways, such as gulf stream, atlantic meridional overturning circulation, El Nino and La Nina Events, Sea Ice and ocean temperature.

Gulf Stream

The Gulf Stream is a powerful and warm ocean current that originates in the Gulf of Mexico and flows along the eastern coast of the United States before crossing the Atlantic Ocean toward Europe. It plays a key role in regulating the climate of the North Atlantic region and has a significant impact on weather patterns, especially in North America and Western Europe.

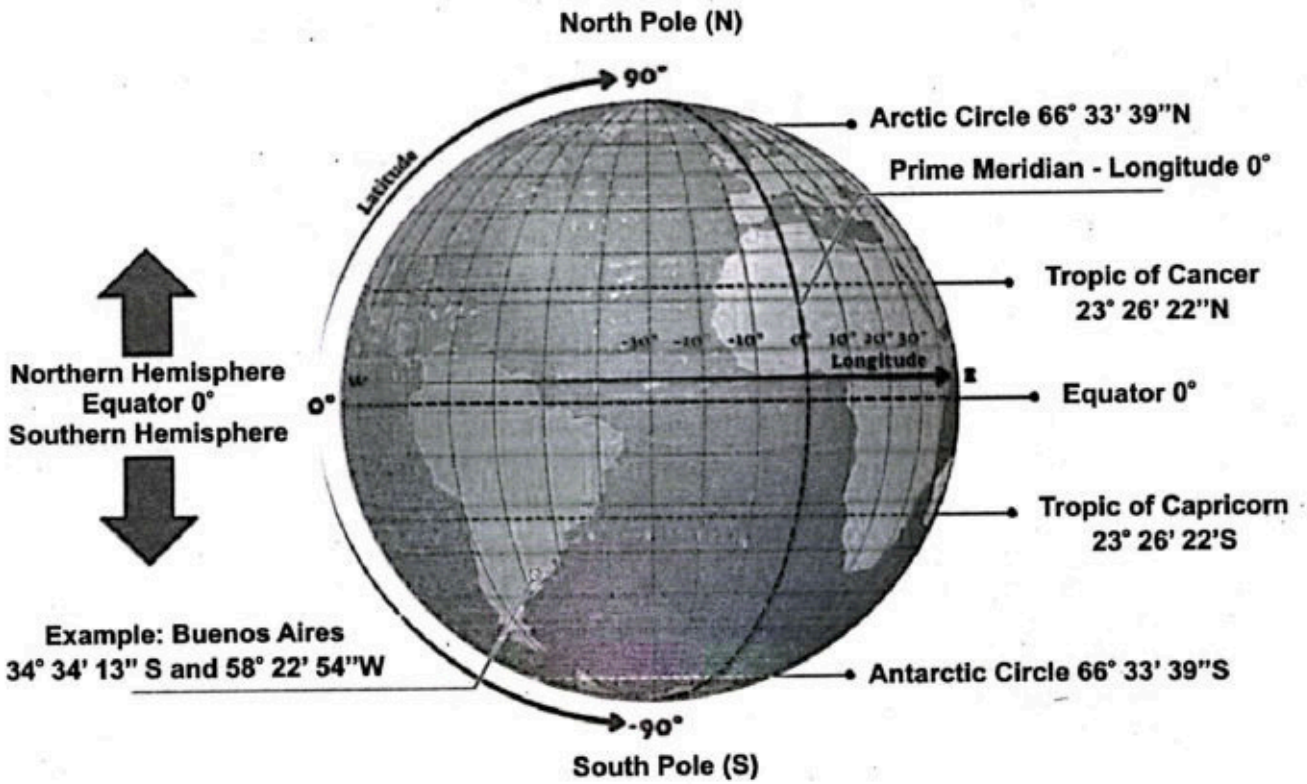


Fig. 13.9: Geographical distribution of earth. The numbers like 23° 26' 22" N, represent the geographic coordinates that specify the exact latitude. For example: 23° 26' 22" N is the precise position of the Tropic of Cancer, which is one of the major circles of latitude on Earth.

23°: This represents 23 degrees of latitude north of the equator.

26': The single apostrophe (') represents 26 minutes of latitude. There are 60 minutes in one degree.

22": The double apostrophe (") represents 22 seconds of latitude. There are 60 seconds in one minute.

N: Indicates that this latitude is in the Northern Hemisphere.

Meaning: The Tropic of Cancer is located at 23 degrees, 26 minutes, and 22 seconds north of the equator.

Normally, this heat is distributed more evenly across the globe. Climate change is causing these currents to weaken or shift, leading to an uneven distribution of heat. For example, some regions may experience a buildup of heat, causing ocean temperatures to rise more rapidly.

Atlantic Meridional Overturning Circulation (AMOC)

Atlantic Meridional Overturning Circulation (AMOC) is a type of ocean current, which carries warm surface water from the tropics to the North Atlantic, where it cools and sinks before flowing back toward the equator as cold, deep water.

As global temperatures rise due to climate change, polar ice melts, adding large amounts of freshwater into the North Atlantic. This reduces the water's salinity, making it less dense and preventing it from sinking as usual. When the AMOC slows down, less heat is transported to the poles, causing warmer ocean temperatures in tropical and subtropical regions. This warming further contributes to rising ocean temperatures and disrupts weather patterns globally.

El Niño and La Niña Events

El Niño and La Niña are climate phenomena that result from changes in ocean circulation in the Pacific Ocean, affecting global weather and ocean temperatures.

El Niño events occur when warm surface waters shift eastward toward the coast of South America, leading to warmer ocean temperatures in the central and eastern Pacific. This also affects weather patterns around the world, contributing to rising temperatures. La Niña is the opposite, where cooler waters dominate, but the later strong El Niño events often causes a significant increase in global ocean temperatures.

Sea Ice and Ocean Temperature

As ocean temperatures rise, sea ice and glaciers at the poles (particularly in the Arctic and Antarctic) are melting at an accelerated rate. Sea ice acts as a reflective shield, bouncing sunlight back into space. When it melts, darker ocean water is exposed, which absorbs more heat, further accelerating ocean warming.

CRITICAL THINKING

Climate change creates feedback loops that amplify ocean warming. For example, as ice melts and more heat is absorbed by the ocean, the ocean's ability to store carbon dioxide diminishes. This, in turn, increases atmospheric CO_2 levels, trapping more heat and further warming both the atmosphere and the oceans.

Is this feedback positive or negative?

CRITICAL THINKING

Even if greenhouse gas emissions were to stop today, the heat already absorbed by the oceans would continue to warm the planet for centuries. This is known as committed warming.

Why does this happen?

13.2.2 Climate Change impacts Ocean Acidification (Low pH)

Climate change is significantly contributing to ocean acidification, a process where the ocean becomes more acidic (lower pH) due to the absorption of increasing amounts of carbon dioxide (CO_2) from the atmosphere.

Ocean as a Carbon Sink

The ocean acts as a carbon sink, meaning it absorbs large quantities of CO_2 from the atmosphere. Since the Industrial Revolution, the concentration of CO_2 in the atmosphere has increased dramatically due to human activities like burning fossil fuels (coal, oil, and gas), deforestation, and industrial processes. To balance the increased atmospheric CO_2, the ocean has absorbed about 30% of this excess CO_2.

CO_2 Dissolving in Ocean Water

When CO_2 dissolves in seawater, it undergoes a chemical reaction to form carbonic acid (H_2CO_3):

$$CO_2 + H_2O \rightarrow H_2CO_3$$

Carbonic acid is unstable and dissociates into bicarbonate ions (HCO_3^-) and hydrogen ions (H^+):

$$H_2CO_3 \rightarrow HCO_3^- + H^+$$

The increase in hydrogen ions (H^+) is what causes the pH of the ocean to decrease, making the ocean more acidic. Ocean acidification refers to this long-term lowering of pH levels due to the absorption of CO_2. Ocean acidification and climate change are interlinked. As climate change causes ocean temperatures to rise, it reduces the ability of the ocean to absorb CO_2. Warmer water holds less gas, meaning that in the future, more CO_2 will remain in the atmosphere,

accelerating global warming.

As the ocean becomes more acidic, it affects the delicate balance of ocean chemistry, which has serious consequences for marine life and ecosystems.

Regional Variations in Ocean acidification

Ocean acidification doesn't happen evenly across the globe. Some regions, like the polar oceans, are more vulnerable. Cold water absorbs more CO_2 than warm water, which means that areas like the Arctic and Southern Oceans are acidifying faster. This puts polar marine life, such as cold-water corals species that thrive in these environments, at greater risk.

13.2.3 Harmful Effects of High Ocean Temperature and Ocean Acidification on Marine Biology

High ocean temperatures and ocean acidification, both consequences of climate change, have profound and harmful effects on marine biology. These environmental changes threaten the survival of numerous marine species and ecosystems, disrupting food webs, biodiversity, and the services oceans provide to humanity.

Harmful Effects of High Ocean Temperature on Marine Biology

High Ocean Temperature affects marine life in several ways:

Coral bleaching

Coral reefs are among the most diverse ecosystems in the ocean, but they are extremely sensitive to temperature changes. When ocean temperatures rise, corals experience stress, which causes them to expel the symbiotic algae (called **zooxanthellae**) that live within their tissues and provide them with nutrients. This phenomenon where corals expel the symbiotic algae living in their tissues, causing the coral to turn completely white or pale is called **Coral bleaching**. The loss of the algae exposes coral's white calcium carbonate skeleton, giving the coral a "bleached" appearance. While bleached corals are not dead, they are more vulnerable to diseases and are unable to grow or reproduce efficiently.

Fig. 13.10: Bleaching was recorded in coral reefs of National Marine Sanctuary of American Samoa (a US territory located in the Polynesia region of the South Pacific Ocean) between 2014 and 2015.

Prolonged exposure to high temperatures leads to coral death, and the loss of coral reefs results in the destruction of habitats for many marine species, threatening the biodiversity and ecosystem services which reefs provide, such as coastal protection and fisheries.

Disruption of Marine Ecosystems

Temperature-sensitive species, such as certain types of fish and plankton, are particularly affected by rising temperatures. Many species must migrate to cooler waters, shifting the balance of ecosystems and affecting food chains.

Species that can't migrate quickly enough or that depend on specific habitats may face local or global extinction. For example, fish populations that live in cooler waters may decline, disrupting

the marine food web, from small plankton to large predators.

Impact on Fish Reproduction and Growth

Many fish species are cold-blooded, meaning their body temperatures are influenced by the surrounding water temperature. Warmer oceans can alter the metabolism, growth, and reproduction of these species.

Warmer waters can cause fish to grow smaller, affecting their reproductive success and survival rates. For example, certain fish species may produce fewer offspring or experience developmental problems in warmer environments.

Marine Heatwaves

Just like heatwaves on land, the ocean experiences periods of extreme heat called marine heatwaves. These events have intensified with climate change, causing mass die-offs of marine species, including fish, shellfish, and marine mammals.

Melting Polar Ice and Habitat Loss

In polar regions, rising ocean temperatures are causing sea ice to melt. Many species, such as polar bears, seals, and walruses, depend on sea ice for hunting and breeding. As the ice disappears, these species face habitat loss and are forced to migrate or adapt to unfamiliar environments, leading to population declines. The loss of sea ice also impacts the food chains in these regions, particularly affecting krill, an important food source for whales, seals, and penguins.

Fig. 13.11: Antarctic Krill (Genus: *Euphausia*) a Crustacean Arthropod.

Ocean Deoxygenation

Warmer ocean waters hold less oxygen, leading to areas of low oxygen concentration (**hypoxic zones**) or even dead zones (**anoxic zones**), where oxygen is so depleted that marine life cannot survive. Fish, crabs, and other marine species either die or move to other regions, further stressing marine ecosystems. Deoxygenation disrupts marine biodiversity and can lead to declines in fisheries.

Harmful Effects of Ocean Acidification on Marine Biology

Ocean acidification affects marine life in several ways:

Impact on Calcifying Organisms

Many marine organisms, such as corals, shellfish (oysters, clams), sea urchins and plankton rely on calcium carbonate ($CaCO_3$) to build their skeletons and shells. These are called calcifying organisms. As ocean acidification lowers the pH of seawater, it reduces the availability of carbonate ions (CO^{2-}_3), which these organisms need to form

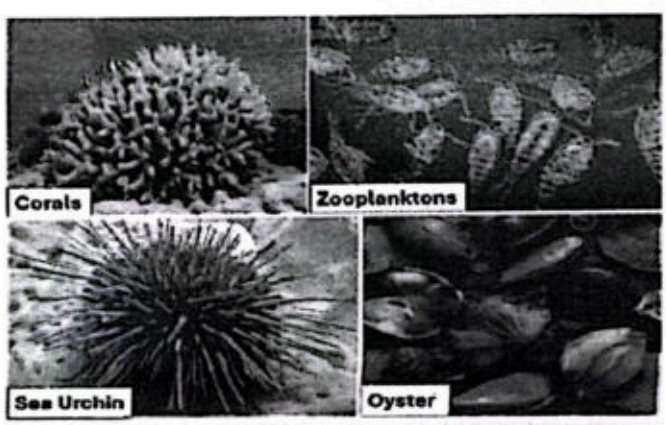


Fig. 13.12: Calcifying Organisms

calcium carbonate. This makes it harder for them to build and maintain their skeletons and shells. For example:

i. Oyster larvae struggle to form shells in acidic water,

ii. leading to high mortality rates in oyster populations.

iii. Coral reefs, which provide critical habitats for many marine species, are at risk of erosion and collapse as ocean acidification weakens their structures. The loss of coral reefs would have cascading effects throughout marine ecosystems.

Disruption of Food Chains

Plankton, particularly species like pteropods (tiny marine snails), are at the base of many marine food webs and are especially vulnerable to ocean acidification. Pteropods and other planktonic organisms struggle to form their shells in acidic water. As plankton populations decline, the species that depend on them for food, such as fish, whales, and seabirds, face reduced food availability, disrupting entire food webs.

Behavioural Changes in Marine Life

Ocean acidification can also affect the behaviour of marine animals. Studies show that elevated CO_2 levels can impair the ability of fish to smell, navigate, and avoid predators. Fish exposed to more acidic water may have trouble finding food, recognizing danger, or navigating their environments, making them more vulnerable to predators and less successful in finding mates or reproducing.

Do you know?

The Intergovernmental Panel on Climate Change (IPCC) is an international body established in 1988 by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO). Its primary role is to assess scientific research related to climate change, including its causes, impacts, and potential strategies for adaptation and mitigation. The IPCC serves as a bridge between the scientific community and policymakers, ensuring that climate actions are based on the best available evidence.

13.3 SPECIES EXTINCTION DUE TO CLIMATE CHANGE

Climate change contributes to species extinction by drastically altering the habitats and ecosystems that species depend on for survival. The rapid changes in temperature, precipitation, and the frequency of extreme weather events caused by climate change can push species beyond their ability to adapt.

13.3.1 Species that have gone extinct due to climate change

There are many species that have gone extinct due to climate change. Some of them are:

Bramble Cay Melomys (*Melomys rubicola*)

This small rodent, native to the tiny island of Bramble Cay off the coast of Australia, is considered the first mammal to go extinct due to climate change. Rising sea levels and storm surges wiped out its habitat, leading to its extinction.

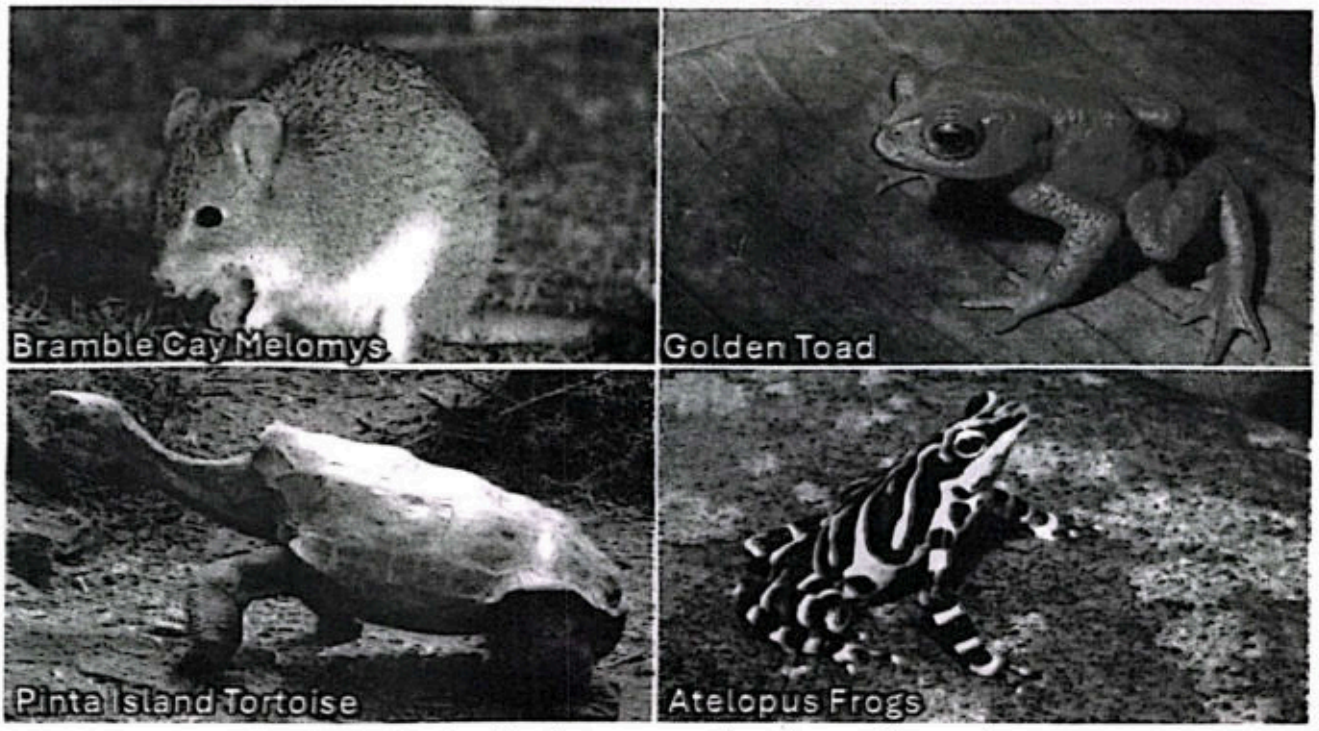


Fig. 13.13: Species that have gone extinct due to climate change

Golden Toad (*Incilius periglenes*)

The golden toad, once found in Costa Rica's Monteverde Cloud Forest, is believed to have gone extinct in the late 1980s due to climate change-induced drought and shifts in temperature. The changing climate made the forest less hospitable, and disease further decimated the population.

Pinta Island Tortoise (*Chelonoidis abingdonii*)

The last individual of this species, known as Lonesome George, died in 2012. While habitat loss and human activity contributed to its decline, climate change played a role by disrupting the ecosystem on the Galápagos Islands, particularly affecting the food and water availability for the tortoises.

Atelopus Frogs (Several species)

Many species of Atelopus, or harlequin frogs, have gone extinct in recent decades, largely due to the spread of the chytrid fungus (pathogenic fungus that affects amphibians worldwide), which is promoted by climate change. Rising temperatures and changes in humidity have helped the fungus spread in highland areas, leading to the collapse of amphibian populations.

13.3.2 Species that have gone endangered due to climate change (Extra Reading Material)

While several species have gone extinct, many species have become endangered due to the impacts of climate change. Here are some notable examples:

Polar Bears (*Ursus maritimus*)

Polar bears rely on sea ice to hunt for seals. As Arctic ice melts due to rising temperatures, their hunting grounds shrink, threatening their survival.

Adélie Penguins (*Pygoscelis adeliae*)

These penguins depend on Antarctic Sea ice for breeding and feeding. Warming temperatures and changing ice patterns are reducing their habitat.

Koalas (*Phascolarctos cinereus*)

Increased heatwaves and bushfires, exacerbated by climate change, along with habitat loss, have pushed koalas closer to endangerment.

Snow Leopards (*Panthera uncia*)

Rising temperatures are affecting the mountain ecosystems they inhabit, shrinking their prey base and increasing human-wildlife conflict.

Coral Species (e.g., Staghorn Coral)

Coral reefs are being devastated by ocean warming and acidification, leading to large-scale coral bleaching events that threaten the survival of many coral species.

Monarch Butterflies (*Danaus plexippus*)

Climate change is altering their migration patterns and reducing the availability of milkweed, their primary food source, pushing them toward endangerment.

Atlantic Cod (*Gadus morhua*)

Rising ocean temperatures are disrupting cod breeding grounds and food availability, causing declines in their population.

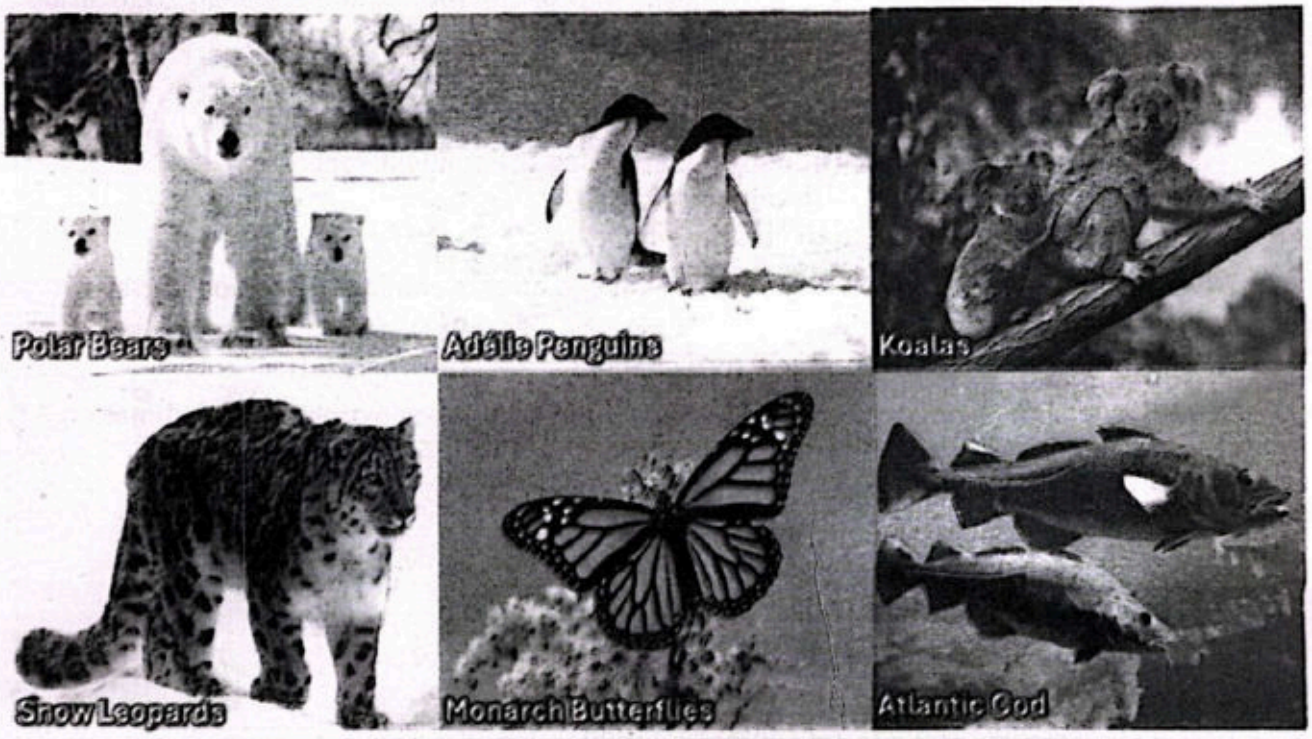


Fig. 13.14: Species that have gone endangered due to climate change

These species are just a few of the many that are struggling to adapt to the rapidly changing climate.

EXERCISE

Section I: Multiple Choice Questions
Select the correct answer:

1. What is the primary difference between weather and climate?
   A. Weather is long-term environment and climate is short-term environment.
   B. Weather is short-term changes, while climate is the long-term pattern of weather.
   C. Weather affects larger areas, while climate affects smaller regions.
   D. Climate changes daily, while weather remains constant.
2. Which of the following is an example of a natural factor that causes climate change?
   A. Deforestation
   B. Burning of fossil fuels
   C. Volcanic activity
   D. Urbanization
3. How does ocean acidification relate to climate change?
   A. It is caused by an increase in solar radiation.
   B. It results from increased levels of carbon dioxide in the atmosphere.
   C. It occurs due to the natural release of methane.
   D. It is caused by fluctuations in the Earth's orbit.
4. Which of the following best describes the term "anthropogenic climate change"?
   A. Climate change caused by natural factors such as volcanic eruptions.
   B. Climate change that occurs gradually over millions of years.
   C. Climate change results from human activities like deforestation and industrialization.
   D. Climate change due to changes in the Earth's orbit.
5. How do Milankovitch cycles affect Earth's climate?
   A. By increasing volcanic activity.
   B. By changing the Earth's orbit and tilt, affecting the sunlight received.
   C. By reducing the amount of greenhouse gases.
   D. By causing ocean currents to circulate heat.
6. Which of the following impacts of climate change affects animals' migration patterns?
   A) Increased volcanic eruptions
   B) Ocean acidification
   C) Shifting habitats due to temperature changes
   D) Urbanization
7. What happens to the ecosystem balance when a species goes extinct due to climate change?
   A. The balance remains unaffected.
   B. It strengthens the remaining species.
   C. It disrupts the entire ecosystem balance.
   D. It causes new species to evolve immediately.
8. Why is deforestation a major contributor to climate change?
   A. It releases sulfur dioxide, leading to global cooling.
   B. It increases the production of solar radiation.
   C. It reduces the Earth's capacity to absorb CO_2.
   D. It has no impact on climate change.

9. Which of the following factors directly contributes to the rise in ocean temperatures due to climate change?
   A. Increased ocean salinity
   B. Melting glaciers releasing fresh water
   C. Enhanced greenhouse effect trapping heat in the atmosphere
   D. Reduced marine biodiversity
10. Why does the ocean have a high heat capacity, affecting the global climate?
   A. It reflects sunlight back into space.
   B. It can store large amounts of heat without a significant temperature increase.
   C. It has a high salt content.
   D. It has a lower density than freshwater.
11. What role does the Atlantic Meridional Overturning Circulation (AMOC) play in ocean temperature regulation?
   A. It reduces ocean acidity.
   B. It transfers warm surface water to the North Atlantic and returns cold water to the tropics.
   C. It blocks the flow of ocean currents towards Europe.
   D. It increases the salinity of tropical waters.
12. What is coral bleaching, and why does it occur?
   A. It is the whitening of coral due to loss of algae, caused by higher ocean temperatures.
   B. It is the natural growth process of coral reefs in warmer waters.
   C. It is the formation of new coral structures due to ocean acidification.
   D. It is the process of corals adapting to cooler ocean temperatures.
13. Which oceanic region is more susceptible to ocean acidification?
   A. Equatorial regions
   B. Arctic and Southern Oceans
   C. Subtropical regions
   D. Mediterranean Sea
14. Which phenomenon is characterized by a significant increase in ocean temperatures due to shifts in warm water toward the coast of South America?
   A. La Niña
   B. Gulf Stream strengthening
   C. Ocean deoxygenation
   D. El Niño
15. Which of the following species is considered the first mammal to go extinct directly due to climate change?
   A. Pinta Island Tortoise
   B. Golden Toad
   C. Bramble Cay Melomys
   D. Adélie Penguin

Section II: Short Answer Questions

1. How does climate change impact ocean temperature?
2. What is the role of the ocean's high heat capacity in climate change?
3. Name three animal species that went extinct due to climate change.
4. What phenomenon results in extreme ocean heat events, like heatwaves on land?
5. How does ocean acidification occur?
6. What is coral bleaching?

7. Which ocean current plays a critical role in regulating the climate of the North Atlantic region?
8. Why are polar bears threatened by climate change?
9. What impact does warmer ocean water have on oxygen levels?
10. How has climate change contributed to the spread of the chytrid fungus in amphibians?
11. What is the primary factor causing ocean warming?
12. Which species went extinct in Costa Rica due to climate change-induced drought?
13. What is the relationship between sea ice and ocean temperature?
14. How does ocean acidification affect calcifying organisms?
15. Differentiate between weather and climate

Section III: Extensive Answer Questions

1. Explain how global warming and greenhouse gases contribute to rising ocean temperatures.
2. Describe the process of ocean acidification and its impact on marine life.
3. How do El Niño and La Niña events influence ocean temperatures and global climate patterns?
4. What role does the Atlantic Meridional Overturning Circulation (AMOC) play in ocean heat distribution, and how is it affected by climate change?
5. Discuss the impact of high ocean temperatures on coral reefs and marine biodiversity.
6. How does climate change contribute to species extinction, and provide an example?
7. Describe how climate change has affected polar ecosystems and the species that inhabit them.
8. Explain the concept of marine heatwaves and their impact on ocean ecosystems.
9. What are the challenges faced by species that become endangered due to climate change, such as the snow leopard?
10. How does the melting of polar ice influence global climate patterns and ocean circulation?