CHAPTER 2
World Beneath the Waves: Ocean Ecosystems, Habitats and Interdependence
(How marine ecosystems work)

Section	Topic	What Students Will Learn
1	Marine Ecosystems and Habitat Types	Introduction to the major marine habitats of the world
2	Coral Reefs	Biodiversity hotspots, ecosystem services and reef conservation
3	Mangroves and Coastal Forests	Coastal protection, fisheries and carbon storage
4	Seagrass Meadows and Blue Carbon	Nursery habitats, dugongs and climate benefits
5	Coastal Ecosystems	Beaches, estuaries, mudflats, salt marshes and human connections
6	Open Ocean, Polar Seas and the Deep Sea	Life in some of Earth's largest and most extreme habitats
7	Food Webs and Ecological Interactions	Predation, competition, symbiosis and ecosystem balance
8	Ecosystem Services	How oceans support people through food, oxygen, climate regulation and livelihoods

Students will understand the diversity of marine habitats and the important role they play in supporting life and protecting coastlines.

SECTION 1

World Beneath the Waves:

Ocean Ecosystems, Habitats & Interdependence

How do marine ecosystems function, and how are species connected?

Introduction:

What Makes Marine Ecosystems Work?

Imagine watching a coral reef from above. Fish move through branching corals, plankton drift with currents, sea turtles graze on seagrass nearby, and predators patrol deeper waters.

At first glance, these organisms may appear independent.

In reality, marine life is connected through an intricate network of relationships involving:

- Food
- Energy
- Nutrients
- Habitats
- Competition
- Cooperation

Marine ecosystems function because organisms interact not only with one another, but also with physical conditions such as temperature, sunlight, currents and nutrients.

A change affecting one part of an ecosystem may influence many others.

For example:

- Declining phytoplankton may affect fish populations
- Coral reef degradation may reduce shelter for reef organisms
- Loss of mangroves may affect coastal fisheries

Understanding marine ecosystems means understanding these relationships and connections.

Ecosystems:

Communities Connected to Their Environment

An **ecosystem** includes:

✓ Living organisms (biotic factors)

✓ Non-living environmental conditions (abiotic factors)

together with the interactions between them.

Marine ecosystems exist at many scales.

Examples include:

- Coral reefs
- Mangroves
- Seagrass meadows
- Open oceans
- Polar seas
- Deep-sea vents

Each ecosystem contains unique environmental conditions and communities of organisms.

Did You Know?

A single coral reef ecosystem may support thousands of interacting species. The Coral Triangle supports more than 600 species of fish, ~75% of the world's coral building species.

What Makes Marine Ecosystems Different?

Marine ecosystems differ from many terrestrial ecosystems because oceans are highly connected.

Currents transport:

- Heat
- Nutrients
- Larvae
- Oxygen

across enormous distances.

This means changes in one region may sometimes influence ecosystems far away.

Ocean circulation plays a major role in regulating marine productivity and climate systems. Research in oceanography has shown that currents strongly influence biodiversity patterns and ecosystem functioning. Oceanography

Energy:

The Foundation of Ecosystems

Almost all ecosystems depend ultimately on energy from the Sun.

In marine ecosystems, microscopic phytoplankton capture solar energy through photosynthesis.

This energy then moves through food webs.

For example:

Phytoplankton
↓
Zooplankton
↓
Small fish
↓
Larger predators

This movement of energy connects organisms across ecosystems.

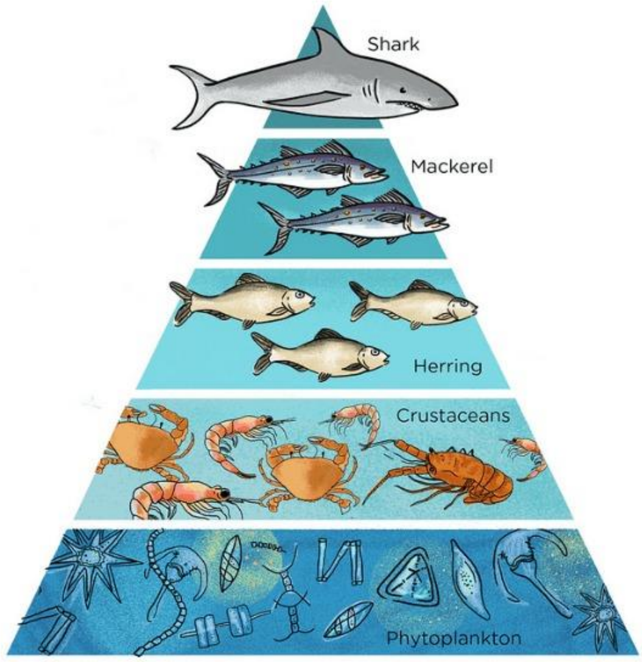

Figure 1: Simple marine food pyramid.

Interdependence:

No Species Exists Alone

Marine organisms depend on one another in many ways.

Examples include:

- Corals depending on symbiotic algae
- Cleaner fish removing parasites from larger fish
- Mangroves providing nursery habitats for juvenile fish
- Seabirds depending on fish populations

These interactions create complex ecological networks.

Ecologists study these relationships to understand ecosystem stability and resilience.

[Concept Clarifier

Habitat vs Ecosystem

A **habitat** is the place where an organism lives.

An **ecosystem** includes:

- organisms,
- physical conditions,
- and interactions between them.

Example:

A mangrove root may be a habitat. The mangrove forest, surrounding water, organisms and environmental processes together form an ecosystem.]

Why Ecosystems Matter to Humans

Marine ecosystems support humans in many ways.

They contribute to:

- Fisheries
- Oxygen production
- Climate regulation
- Coastal protection
- Tourism
- Livelihoods

Healthy ecosystems also help reduce the impacts of storms and erosion in coastal regions.

We will explore ecosystem services in greater detail later in this chapter.

Threat Alert

Marine ecosystems are increasingly affected by:

- Climate change
- Pollution
- Habitat destruction
- Overfishing

Because ecosystems are interconnected, disturbances may create cascading effects across food webs and habitats.

Looking Ahead

Marine ecosystems vary enormously across the planet.

Some occur in warm, shallow tropical waters, while others survive in darkness thousands of metres below the surface.

The next section explores some of the most important marine ecosystems on Earth — beginning with one of the most biodiverse habitats known

~~~~~~

Key Terms

Ecosystem: Organisms interacting with one another and their environment

Biotic factors: Living components of ecosystems

Abiotic factors: Non-living environmental conditions

Interdependence: Mutual dependence among organisms

Habitat: Place where an organism lives

Food web: Network of feeding relationships

~~~~~~

Things to Remember

1. Ecosystems include both living and non-living components.
2. Marine ecosystems are highly interconnected.
3. Energy enters most marine ecosystems through photosynthesis.
4. Species interactions influence ecosystem stability.
5. Changes affecting one part of an ecosystem may influence many others.

Quick Quiz

1. What is the difference between a habitat and an ecosystem?
2. What are biotic and abiotic factors?
3. Why are marine ecosystems highly interconnected?
4. How does energy enter most marine ecosystems?
5. Give one example of interdependence in marine ecosystems.

SECTION 2

Coral Reefs:

Rainforests of the Sea

Warm, shallow tropical waters contain some of the most biodiverse ecosystems on Earth: coral reefs.

Although coral reefs occupy less than 1% of the seafloor, they support enormous numbers of marine organisms, including Fish, Crustaceans, Molluscs, Sponges, Sea turtles and Sharks

Coral reefs are often called: “Rainforests of the sea” because of their extraordinary biodiversity.

Reef ecosystems also support millions of people worldwide through fisheries, tourism and coastal protection. Coral reef ecology research has shown that reefs function as highly productive ecosystems despite often occurring in nutrient-poor waters.

What Are Corals?

Corals are animals belonging to the phylum Cnidaria, the same broad group that includes jellyfish and sea anemones.

Individual coral organisms are called **polyps**.

Many reef-building corals secrete calcium carbonate skeletons that gradually accumulate to form reef structures over long periods. Some reefs visible today began forming thousands of years ago.

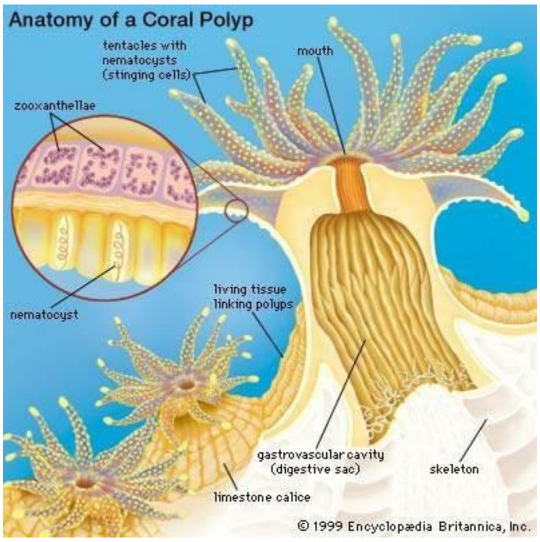

Figure 2: Structure of a coral polyp

Symbiosis:

Corals and Zooxanthellae

Most reef-building corals live in partnership with microscopic algae called **zooxanthellae**.

The algae photosynthesise, produce energy-rich compounds and corals provide shelter and nutrients. This symbiotic relationship helps explain why most reef-building corals occur in shallow, sunlit waters.

Coral-algal symbiosis is central to reef productivity and reef-building processes. Marine Symbiosis

Why Are Coral Reefs So Biodiverse?

Several factors contribute to reef biodiversity:

Habitat Complexity

Corals create three-dimensional structures containing crevices, sheltered spaces and different light conditions. These create many ecological niches.

Stable Warm Temperatures

Many tropical reefs experience relatively stable environmental conditions over long periods.

Species Interactions

Reef ecosystems contain complex feeding relationships and symbiotic interactions.

Species Spotlight

Cleaner Wrasse:

Tiny Fish with an Important Role

The Cleaner Wrasse removes parasites and dead tissue from larger fish. This interaction benefits both species wherein the Cleaner Wrasse obtain food and the larger fish reduce parasite loads. Such mutually beneficial relationships are examples of **mutualism**.

Coral reefs occupy less than 1% of the seafloor but support a remarkable proportion of marine biodiversity.

Reefs support:

- Reef fish
- Molluscs
- Crustaceans
- Sponges
- Sea turtles
- Sharks
- Microorganisms

Their high biodiversity is partly due to their structural complexity.

Reef-building corals form calcium carbonate skeletons that create three-dimensional habitats where countless organisms can shelter, feed and reproduce.

Species Spotlight

Coral Polyps:

Coral are a colony of tiny animals in a symbiosis building giant ecosystems. Each individual coral organisms are called polyps.

Most reef-building corals maintain a symbiotic relationship with microscopic algae called zooxanthellae.

The algae photosynthesise, provide energy to corals and in return, corals provide shelter and nutrients. This relationship helps explain why reefs flourish in warm, sunlit waters.

Symbiosis between corals and algae is fundamental to reef ecosystems and has been extensively studied in coral reef ecology.

Important regions with coral reefs.

Great Barrier Reef

Located off the coast of Australia, the Great Barrier Reef is the world’s largest coral reef system.

It supports:

- Thousands of reef species
- Dugongs
- Sea turtles
- Reef sharks
- Seabirds

The reef system stretches over 2,300 kilometres.

Mesoamerican Reef

The Mesoamerican Reef extends through parts of:

- Mexico
- Belize
- Guatemala
- Honduras

It is the second-largest barrier reef system in the world.

Gulf of Mannar

Located between India and Sri Lanka, the Gulf of Mannar contains:

- Coral reefs
- Seagrass meadows
- Mangroves

It supports species including:

- Dugongs
- Sea cucumbers
- Reef fish

The Gulf of Mannar is recognised for both biodiversity and cultural importance. Gulf of Mannar

Andaman & Nicobar Islands

These islands support coral reefs, mangroves and rich marine biodiversity influenced by Indo-Pacific systems.

India Spotlight

India is home to several important coral reef ecosystems. Coral reefs can be found in the Gulf of Mannar, Lakshadweep, the Andaman and Nicobar Islands and the Gulf of Kachchh. These reefs support thousands of marine species and provide food, livelihoods and coastal protection for nearby communities.

Like coral reefs around the world, Indian reefs face challenges from climate change, coral bleaching and pollution. Scientists and conservation organisations continue monitoring reef health and supporting reef conservation efforts.

Threat Alert

Coral Bleaching

Corals are highly sensitive to environmental change. When ocean temperatures rise beyond normal ranges, corals may expel their zooxanthellae. This causes corals to appear pale or white i.e. Coral bleaching. If stressful conditions continue for long periods, corals may die. Coral bleaching in turn affects the biodiversity that depends on them at multiple life stages.

Mass bleaching events linked to marine heatwaves have affected reef systems worldwide in recent decades.

Did You Know?

Some reef fish change colour, sex or behaviour during their lifetimes. All clown fish are born male and the largest sized individual becomes the dominant female and the second largest is the breeding male.

~~~~~~

Things to Remember

1. Coral reefs are among Earth's most biodiverse ecosystems.
2. Corals are animals, not plants.
3. Reef-building corals depend on symbiotic algae.
4. Habitat complexity helps support reef biodiversity.
5. Coral bleaching is linked to environmental stress, especially warming oceans.

Key Terms

Coral polyp: Individual coral organism

Zooxanthellae: Symbiotic algae living within corals

Symbiosis: Close interaction between different species

Mutualism: Interaction benefiting both organisms
~~~~~~

Coral bleaching: Loss of symbiotic algae from corals

Quick Quiz

1. Why are coral reefs called “rainforests of the sea”?
2. What are coral polyps?
3. Why do reef-building corals usually occur in shallow waters?
4. What is mutualism?
5. What causes coral bleaching?

SECTION 3

Mangroves

Forests Where Land and Sea Meet

Along many tropical and subtropical coastlines, strange-looking trees grow where most plants would struggle to survive. Their roots rise above muddy water, tides flood their surroundings daily, and salty seawater constantly challenges survival.

These remarkable coastal ecosystems are called **mangroves**.

Mangroves occur in sheltered coastal regions including:

- Estuaries
- Lagoons
- River mouths
- Tropical shorelines

They form one of the most important connections between land and sea.

What Makes Mangroves Unique?

Mangrove ecosystems experience constantly changing conditions.

Organisms living here must cope with:

- Salty water
- Shifting tides
- Low oxygen in muddy soils
- Changing water levels

Mangrove plants possess specialised adaptations allowing them to survive in these environments.

Mangrove Adaptations:

Surviving in Saltwater

Different mangrove species have evolved different strategies for dealing with salt.

Som exclude salt at their roots others remove salt through leaves.

Some mangrove leaves even develop visible salt crystals on their surfaces.

Mangrove roots also help stabilise trees in soft sediments and reduce erosion along coastlines. Mangrove ecology research has highlighted the importance of these adaptations for survival in intertidal environments.

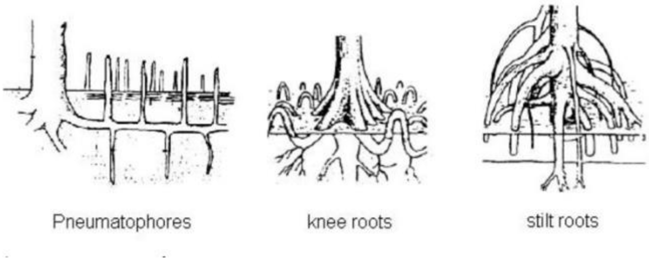

Figure 3: Root system in Mangroves

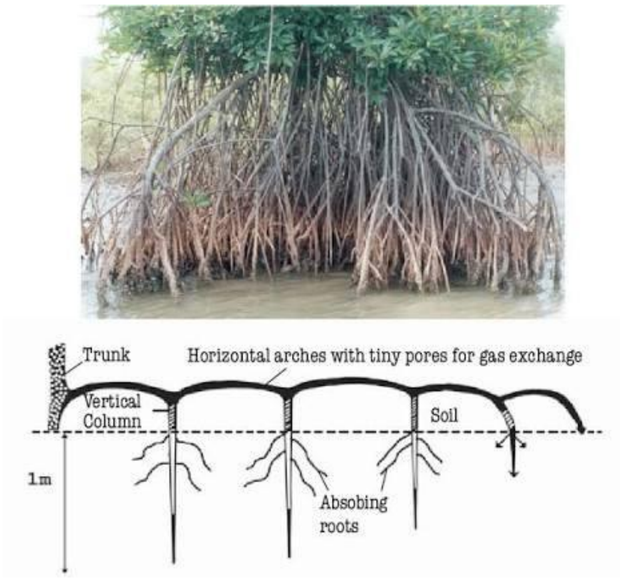

Figure 4: Pneumatophores and its structure

Pneumatophores:

Breathing Roots

Many mangrove environments contain waterlogged soils with little oxygen. Some mangrove species produce specialised aerial roots called **pneumatophores** that extend above the mud. These roots help plants obtain oxygen.

Did You Know?

Mangrove forests may appear quiet from above, but beneath the water juvenile fish, crabs and molluscs often shelter among the roots. The Sundarbans mangrove forest is the largest in the world spanning more than 10,000 km across India and Bangladesh. mangroves store large amounts of carbon and support biodiversity, they are *increasingly recognised as important ecosystems for climate resilience.*

Why Are Mangroves Important?

Mangroves provide important ecological functions and ecosystem services.

1. Nursery Habitats:

Safe Spaces for Young Marine Life

Many juvenile organisms use mangrove ecosystems for shelter during early life stages.

Examples include:

- Fish
- Crabs
- Shrimp

Complex root systems provide protection from predators.

Many commercially important fish species depend on mangrove habitats during part of their life cycles. Studies in fisheries ecology have shown strong links between mangrove habitats and coastal fish populations.

2. Coastal Protection

Mangroves help reduce:

- Coastal erosion
- Storm surge impacts
- Wave energy

Their roots trap sediments and stabilize shorelines.

Research following major storms and tsunamis has shown that healthy mangrove ecosystems may reduce coastal damage in some regions.

3. Carbon Storage:

Blue Carbon Ecosystems

Mangroves store large amounts of carbon in:

- Biomass
- Sediments
- Roots

Marine ecosystems such as mangroves, seagrasses and salt marshes are sometimes called **blue carbon ecosystems** because of their role in carbon storage.

Research suggests mangroves may store carbon very efficiently compared with many terrestrial forests. Climate Science

4. Biodiversity Support

Mangroves support many organisms including:

- Fish
- Mudskippers
- Crocodiles
- Birds
- Invertebrates

They also connect ecosystems.

For example:

Nutrients and organisms may move between:

Mangroves ↔ Seagrasses ↔ Coral reefs

This ecological connectivity is important for many marine species.

Species Spotlight

Mudskippers are amphibious fish found in mangrove habitats. They spend time out of water in moist wet clay in mangroves. Mudskippers can:

- Move across mud using fins (almost looks like walking).
- Breathe partly through skin and mouth linings.
- Burrows using their mouth as a shovel.
- Attract a mate by fin flares, tail stands, push ups and high jumps (up to 2 ft sometimes).
- Survive in fluctuating tidal environments.

Mangroves in India

India contains important mangrove ecosystems including:

- Sundarbans
- Bhitarkanika
- Pichavaram
- Andaman & Nicobar Islands

The Sundarbans, shared by India and Bangladesh, form the world's largest mangrove forest system.

Mangrove ecosystems in India support biodiversity, fisheries and coastal livelihoods while also providing protection from storms and erosion. Sundarbans

Threat Alert

Mangroves Under Pressure

Mangroves face threats from:

- Coastal development
- Aquaculture expansion
- Pollution
- Climate change
- Deforestation

Historically, mangrove ecosystems declined significantly in many regions because they were often viewed as unproductive wastelands.

Scientists now recognise mangroves as among the most valuable coastal ecosystems on Earth.

[**Concept Link**

How might mangrove loss affect:

- fish populations,
- coastal communities,
- and nearby coral reefs?

(Encourages systems thinking without requiring formal activities.)]

~~~~~~

Things to Remember

1. Mangroves are coastal ecosystems adapted to salty, tidal environments.
2. Mangrove roots help stabilise shorelines and reduce erosion.
3. Mangroves function as nursery habitats for many marine organisms.
4. Mangroves are important blue carbon ecosystems.
5. Mangroves connect land and sea ecosystems.

Key Terms

Mangrove: Salt-tolerant coastal tree or shrub

Pneumatophore: Specialised aerial root helping oxygen uptake

Nursery habitat: Area where juvenile organisms develop

Blue carbon: Carbon stored in marine and coastal ecosystems

Intertidal zone: Area between high and low tide levels

Quick Quiz

1. Why are mangroves able to survive in salty environments?
2. What are pneumatophores?
3. Why are mangroves important for fisheries?
4. What is meant by "blue carbon"?
5. Name one major mangrove ecosystem in India.
~~~~~~

SECTION 4

Seagrass Meadows:

Underwater Grasslands of the Ocean

At first glance, seagrass ecosystems may not appear as colourful or dramatic as coral reefs. Yet beneath shallow coastal waters, vast underwater meadows support rich biodiversity, stabilise sediments and store enormous amounts of carbon.

Seagrasses are among the most important — and often overlooked — marine ecosystems on Earth.

They occur in shallow coastal waters where sunlight can reach the seafloor.

What Are Seagrasses?

Despite their name, seagrasses are not seaweeds.

They are true flowering plants that evolved from land plants and later adapted to marine environments.

Seagrasses possess:

- Roots
- Leaves
- Vascular tissues
- Flowers
- Seeds

This distinguishes them from algae. Seagrasses form dense underwater meadows in coastal regions worldwide.

[**Concept Clarifier**

Seagrass ≠ Seaweed

Seagrasses are flowering plants and have roots and vascular tissues

Seaweeds are types of algae and simpler body structures.]

Adaptations for Underwater Life

Living underwater presents challenges for plants.

Seagrasses have evolved several adaptations including:

- Flexible leaves that tolerate water movement
- Root systems anchoring plants in sediments
- Pollination mechanisms functioning underwater

Some seagrass species release pollen directly into surrounding water currents.

Research in marine botany has shown that seagrasses evolved independently from terrestrial grasses and represent important examples of secondary adaptation to marine life. Marine Botany

Why Are Seagrass Meadows Important?

Seagrass ecosystems provide important ecological functions and support many marine organisms.

1. Habitat and Shelter

Seagrass meadows provide habitat for:

- Fish
- Crustaceans
- Molluscs
- Seahorses
- Sea turtles

Juvenile organisms often shelter among seagrass blades, reducing predation risk.

Like mangroves, seagrasses function as nursery habitats for many species.

2. Food Sources

Several organisms feed directly on seagrasses.

Examples include:

- Dugongs
- Green sea turtles
- Some fish and invertebrates

Species Spotlight

Dugongs

Gentle Grazers of Seagrass Meadows

Dugongs are marine mammals closely related to manatees. They feed primarily on seagrasses and are sometimes called Sea cows because of their grazing behaviour. Healthy seagrass ecosystems are essential for dugong survival.

Dugong populations have declined in several regions because of habitat degradation, fishing pressures and coastal development. Conservation research consistently identifies seagrass protection as critical for dugong conservation.

3. Sediment Stabilisation

Seagrass roots help stabilise sediments on the seafloor.

This reduces:

- Erosion
- Sediment movement
- Water turbidity

Clearer water conditions may also benefit nearby ecosystems such as coral reefs.

4. Carbon Storage:

Powerful Blue Carbon Ecosystems

Like mangroves, seagrasses store significant amounts of carbon.

Carbon accumulates in:

- Plant tissues
- Underlying sediments

Because seagrass sediments may store carbon for long periods, these ecosystems play important roles in climate regulation.

Research on blue carbon ecosystems has shown that seagrass meadows are globally important carbon sinks despite covering relatively small areas. Climate Science

5. Ecosystem Connectivity:

Linking Marine Habitats

Marine ecosystems are often interconnected.

Seagrasses may connect:

- Mangroves
- Coral reefs
- Open coastal waters

Some fish species move between these habitats during different stages of their lives.

This connectivity helps maintain coastal biodiversity and ecosystem functioning.

Studies in coastal ecology have shown that habitat connectivity strongly influences fish populations and ecosystem resilience.

Did You Know?

Some seagrass meadows may be thousands of years old because plants can spread clonally through underground rhizomes. The largest single plant individual on Earth is a seagrass meadow of ribbon weed (Posidonia australis) found in Shark Bay, Australia and this clone spreads across 200 sq.kms and is ~4500 years old.

Seagrasses in India

India contains important seagrass ecosystems in regions including:

- Gulf of Mannar
- Palk Bay
- Lakshadweep
- Andaman & Nicobar Islands

These ecosystems support biodiversity and fisheries while also contributing to carbon storage.

Several dugong populations in India depend heavily on seagrass habitats.

Threat Alert

Seagrass Ecosystems Under Threat

Seagrass meadows face growing pressures from:

- Coastal development
- Pollution
- Sedimentation
- Boat damage
- Climate change

Because seagrasses occur in shallow coastal waters, human activities can strongly affect them.

Globally, many seagrass ecosystems have declined significantly over recent decades. Research in marine conservation has documented widespread seagrass loss linked to coastal disturbance and declining water quality. Marine Conservation

Connecting Ecosystems Together

Coral reefs, mangroves and seagrasses are often linked ecologically.

For example:

- Mangroves may shelter juvenile fish
- Fish later move into seagrass meadows
- Adults may eventually occupy coral reefs

Damage to one ecosystem may therefore affect others.

This interdependence is a key feature of marine ecosystems.

~~~~~~

Things to Remember

1. Seagrasses are flowering plants, not seaweeds.
2. Seagrass meadows support biodiversity and nursery habitats.
3. Dugongs depend heavily on healthy seagrass ecosystems.
4. Seagrasses stabilise sediments and improve water clarity.
5. Seagrasses are important blue carbon ecosystems.

Key Terms

Seagrass: Marine flowering plant adapted to underwater environments

Rhizome: Underground stem helping plant growth and spread

Blue carbon: Carbon stored in marine ecosystems

Habitat connectivity: Ecological links between ecosystems

Sediment stabilisation: Reduction of sediment movement

Quick Quiz

1. Why are seagrasses considered true plants?
2. Name two ecological functions of seagrass meadows.
3. Why are dugongs closely linked to seagrass ecosystems?
4. What is habitat connectivity?
5. Why are seagrass ecosystems vulnerable to human activities?
~~~~~~

SECTION 5:

Open Oceans:

Life in the Largest Habitat on Earth

When many people imagine marine life, they think of colourful coral reefs close to coastlines. Yet reefs represent only a tiny fraction of the ocean.

Most marine life exists in the **open ocean**, also called the **pelagic zone**.

The open ocean forms the largest habitat on Earth, extending across enormous distances and depths. Conditions here can seem harsh compared with coastal ecosystems:

- Few places to hide
- Constant movement of water
- Vast distances between organisms
- Limited food in many regions

Despite these challenges, the open ocean supports extraordinary biodiversity and some of the planet's largest migrations.

What Is the Pelagic Zone?

The pelagic zone refers to the water column away from coastlines and the seafloor.

Scientists often divide the pelagic zone into regions based on depth and light availability.

Major Open Ocean Zones

Epipelagic Zone

(Sunlit Zone)

- Extends from the surface to around 200 metres
- Receives enough sunlight for photosynthesis
- Contains most phytoplankton production

Many fish, marine mammals and seabirds depend on this zone.

Mesopelagic Zone

(Twilight Zone)

- Receives very little light
- Photosynthesis is not possible
- Many organisms possess large eyes or bioluminescence

Bathypelagic Zone

(Midnight Zone)

- Completely dark
- Cold temperatures
- High pressure

Abyssopelagic Zone

- Extremely deep waters
- Sparse food availability
- Highly specialised organisms

Oceanographers classify pelagic environments partly based on depth because environmental conditions change dramatically with increasing depth. Oceanography

Life in a Vast Environment

Open oceans may appear empty, but they support enormous numbers of organisms.

Many pelagic species are highly adapted for:

- Efficient swimming
- Long-distance migration
- Energy conservation

Plankton:

The Foundation of Open Ocean Ecosystems

Although often invisible to the naked eye, plankton support much of open ocean life.

Phytoplankton perform photosynthesis near the ocean surface, forming the base of many marine food webs.

Zooplankton feed on phytoplankton and are then consumed by larger organisms.

Open ocean productivity depends strongly on plankton dynamics and nutrient availability. Biological oceanography research has shown that plankton influence global carbon cycles and marine ecosystem functioning. Biological Oceanography

Nekton:

Powerful Swimmers of the Open Ocean

Organisms capable of swimming actively against currents are called **nekton**.

Examples include:

- Tuna
- Sharks
- Dolphins
- Squid
- Whales

Many nekton species travel enormous distances searching for food, breeding areas or favourable environmental conditions.

Species Spotlight

Tuna, built for speed (torpedo-like body shape). Tuna are among the fastest open ocean fish. They come in various sizes and can grow up to 13 ft. Adaptations supporting efficient swimming include a streamlined body shape, powerful muscles and a crescent-shaped tails

Some tuna like bluefin tuna are warm blooded allowing them to regulate their temperature with a specialised blood vessel called counter-current exchanger. The ability to regulate their temperature allows them to adapt to varied temperatures. It also helps with speed and deep diving.

Migration:

Travelling Across Oceans

Many open ocean species undertake extraordinary migrations.

Examples include:

- Whales moving between feeding and breeding grounds
- Sea turtles crossing ocean basins
- Tuna tracking productive waters
- Seabirds travelling between hemispheres

Migration may help organisms:

- Access food
- Reproduce
- Avoid unfavourable conditions

Satellite tracking studies have revealed migration routes spanning thousands of kilometres in many pelagic species.

Did You Know?

Arctic terns, which depend heavily on marine ecosystems, perform one of the longest known animal migrations, travelling between Arctic and Antarctic regions.

The Albacore tuna never stops swimming and May 2nd is world tuna day.

Adaptations for Open Ocean Survival

Because open oceans lack reefs, rocks or vegetation for shelter, many pelagic organisms possess specialised adaptations.

Examples include:

Streamlined Bodies

Reduce drag during swimming.

Countershading

Dark upper surfaces and lighter undersides help camouflage organisms from predators above and below.

Schooling Behaviour

Fish schools may:

- Reduce predation risk
- Improve feeding efficiency

Bioluminescence

Some mesopelagic organisms produce light using chemical reactions.

Bioluminescence may help with:

- Communication
- Camouflage
- Predation
- Defence

Bioluminescence is widespread in deep and open ocean ecosystems and represents one of the most important adaptations to low-light environments.

Marine Snow:

Food Falling from Above

In deep open ocean environments, food is often scarce.

One important food source is:

Marine snow

Marine snow consists of sinking organic material including:

- Dead plankton
- Waste particles
- Mucus
- Tiny fragments of organisms

This material transports nutrients and energy from surface waters into deeper ecosystems.

Deep-sea food webs depend heavily on organic matter transported downward from surface ecosystems.

Open Oceans and Climate

Open oceans influence Earth's climate systems by:

- Absorbing heat
- Storing carbon dioxide
- Circulating nutrients and energy globally

Phytoplankton also contribute to global biogeochemical cycles through photosynthesis.

Because oceans are closely linked to climate systems, changes affecting pelagic ecosystems may have global consequences.

Threat Alert

Challenges Facing Open Ocean Ecosystems

Open ocean ecosystems face growing pressures including:

- Overfishing
- Plastic pollution
- Climate change
- Shipping impacts
- Noise pollution

Highly migratory species may cross many national and international waters, making conservation more challenging.

[**Concept Link**

How might declining plankton populations affect:

- fish,
- whales,
- seabirds,
- and even global climate systems?]

The Deep Sea:

Life in Extreme Environments

Far below the ocean surface lies one of the most mysterious environments on Earth. Sunlight disappears, temperatures drop close to freezing and pressure becomes so intense that it would crush most organisms living at the surface. Yet despite these harsh conditions, the deep sea is filled with extraordinary forms of life.

The deep ocean begins roughly 200 metres below the surface, where sunlight becomes too weak for photosynthesis. Beyond this depth, oceans enter zones of permanent darkness. For a long time, scientists believed very little life could survive there. However, deep-sea exploration revealed ecosystems filled with organisms specially adapted to extreme conditions.

The deep sea is not a single uniform environment. It includes:

- vast abyssal plains,
- underwater mountains,
- deep trenches,
- hydrothermal vents,
- and cold seep ecosystems.

Each environment supports different communities of organisms adapted to darkness, cold temperatures and immense pressure.

What Is the Deep Sea?

The deep sea generally refers to ocean regions below the reach of sunlight. As depth increases,

pressure rises, temperatures decrease and light disappears. Yet organisms continue to survive across these environments. The deep ocean represents the largest habitat on Earth by volume.

Pressure:

The Weight of the Ocean

Water is heavy. As depth increases, pressure increases rapidly. At depths of several thousand metres, organisms experience pressures hundreds of times greater than those at the surface.

Deep-sea organisms possess specialised adaptations allowing survival under these extreme conditions.

Deep-sea biology research has shown that cellular structures, membranes and enzymes may function differently under high-pressure environments. Deep-Sea Biology

Darkness:
A World Without Sunlight

Sunlight penetrates only limited ocean depths. Below the photic zone, darkness dominates. Without sunlight photosynthesis cannot occur, food becomes limited and organisms rely on alternative energy sources. Many deep-sea organisms possess enlarged eyes, heightened sensory systems or bioluminescence.

Deep Sea adaptations

One of the most remarkable deep-sea adaptations is **Bioluminescence**

Bioluminescence is the production of light by living organisms through chemical reactions inside their bodies.

In the deep sea, many organisms produce blue or green light to:

- attract prey,
- communicate,
- camouflage themselves,
- or confuse predators.

Some fish use glowing lures to attract prey in complete darkness. Others produce flashing patterns along their bodies.

Bioluminescence is extremely common in deep-sea ecosystems because sunlight does not reach these depths.

Research in deep-sea biology suggests that a large proportion of deep-sea organisms may possess some form of bioluminescence. Deep-Sea Biology

Species Spotlight

Anglerfish are deep sea hunters with living "Fishing Rods"

Some anglerfish possess glowing structures extending from their heads. These glowing lures attract prey in dark environments. Anglerfish are among the best-known examples of deep-sea adaptation.

It is extremely difficult to find a mate in the deep ocean due to which species such as the angler fish have evolved and adapted brilliantly. The male, significantly smaller than the female, upon maturity, finds and physically fuses to a female for life. The male loses its eyes and internal organs except its testes. One female may have 5-6 males attached.

Figure 5: Image credit: Online Britannica encyclopedia

Another extraordinary deep-sea ecosystem exists around

Hydrothermal Vents

Hydrothermal vents form where seawater enters cracks in the seafloor near volcanic regions, becomes superheated and rises back into the ocean carrying dissolved minerals.

Temperatures near some vents may exceed 350°C, yet specialised organisms thrive there.

Unlike most ecosystems on Earth, hydrothermal vent communities do not depend on sunlight. Instead, bacteria use chemicals such as hydrogen sulfide to produce energy through a process called:

Chemosynthesis

These bacteria form the foundation of vent food webs.

Giant tube worms, vent crabs and specialised shrimp survive in these environments through close relationships with chemosynthetic bacteria.

The discovery of hydrothermal vent ecosystems transformed scientific understanding of how life may survive in extreme environments.
Chemosynthesis

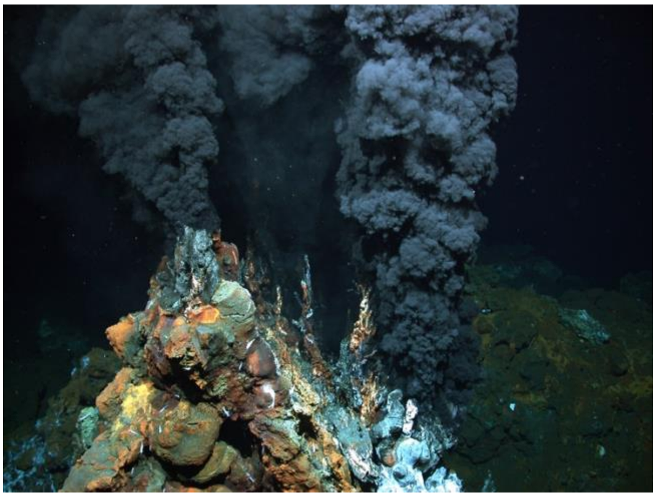

Figure 6: Hydrothermal vents in the deep sea.

Deep-sea organisms often display unusual physical adaptations. Some species have:

- enormous eyes,
- transparent bodies,
- expandable stomachs,
- or extremely slow metabolisms.

Because food is limited in deep oceans, many organisms must survive long periods between meals.

Certain deep-sea animals also grow surprisingly large. This phenomenon is sometimes called:

Deep-Sea Gigantism

Giant squid, giant isopods and massive sea spiders are examples of organisms larger than many of their shallow-water relatives.

Scientists continue studying why some deep-sea organisms evolve such enormous sizes.

Although deep oceans may seem remote, they are increasingly affected by human activities. Deep-sea mining, pollution, climate change and fishing are now reaching ecosystems once thought isolated from human influence.

Scientists are still discovering new species in deep oceans every year, which means many deep-sea ecosystems remain poorly understood. Some researchers believe the deep sea may contain millions of undiscovered organisms.

Studying these environments helps scientists understand:

- biodiversity,
- evolution,
- Earth's geology,
- and even the possible origins of life.

Some scientists also study deep-sea ecosystems to explore whether similar forms of life could exist on other planets or moons with oceans beneath ice layers.

The deep ocean therefore remains one of the last great frontiers of scientific discovery on Earth.

Food in the Deep Sea:

Living on Limited Resources

Because photosynthesis occurs near the surface, food availability decreases with depth.

Many deep-sea ecosystems depend on:

- Marine snow
- Sinking carcasses

- Organic debris

Food arriving from surface waters may support organisms far below.

Large whale carcasses sinking to the seafloor, known as **whale falls**, can support deep-sea communities for years or even decades. Whale-fall ecology research has shown these carcasses create temporary biodiversity hotspots in deep environments.

Did You Know?

A single whale fall may support hundreds of species over time, especially in nutrient deficient deep waters. Species such as hagfish, sleeper sharks, deep sea crabs scavenge on its blubber and flesh down to its bone. Zombie worms, a species of genus Osedax was first discovered on a 3 kms whale fall.

Species Spotlight

Giant Tube Worms (*Riftia pachyptila*) are deep sea polychaete annelids.

These are animals without mouths. They live near hydrothermal vents and may grow over two metres long. Remarkably, adult tube worms lack mouths, stomachs, or any semblance ofa digestive systems. Instead, they rely on a symbiotic relationship with chemosynthetic bacteria living within their bodies in a spongy tube-like organ called trophosome. The bacteria produce nutrients supporting the worms.

They are some of the fastest growing invertebrates, growing 33 inches a year

Deep-Sea Biodiversity

Deep oceans contain many groups including:

- Sea cucumbers
- Crustaceans
- Jellyfish
- Cephalopods
- Deep-sea fish
- Microorganisms

Scientists continue discovering previously unknown species during deep-sea expeditions.

Because deep oceans remain difficult to explore, much biodiversity likely remains undocumented.

Ocean Trenches:

The Deepest Places on Earth

Ocean trenches form where tectonic plates interact.

The deepest known point in the ocean is:

Challenger Deep

located within the Mariana Trench.

Depth:
~11 kilometres below sea level

Despite these extreme conditions, life still exists there.

Research in hadal ecology continues revealing organisms adapted to trench environments.

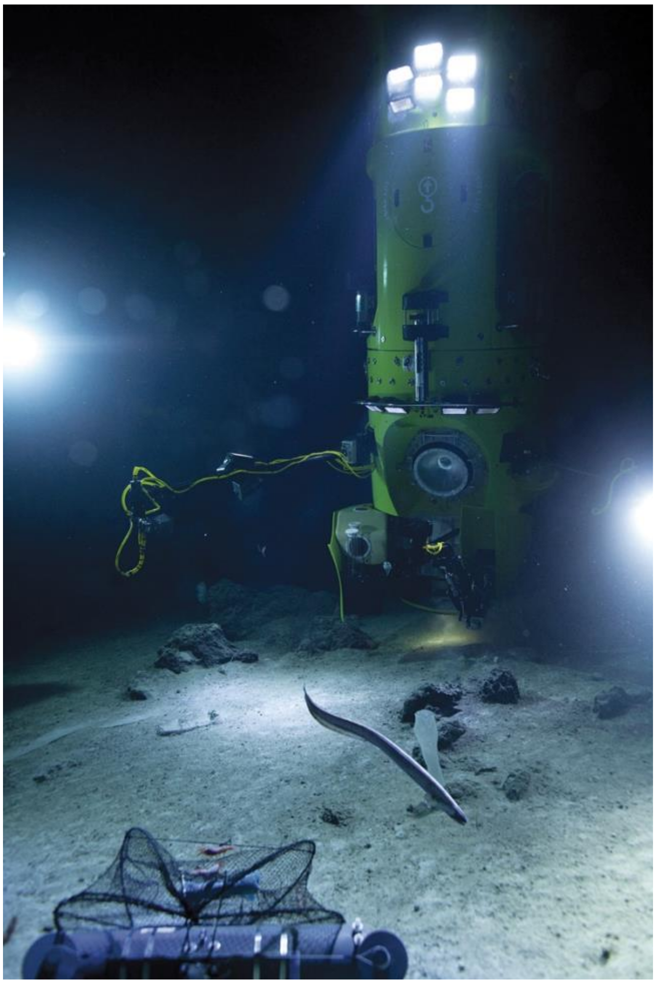

Figure 7: A dive to the Challenger deep. Image credit: Science.org

Threat Alert

Human Impacts Reaching the Deep Sea

For a long time, deep oceans were viewed as isolated from human influence.

Scientists now know deep-sea ecosystems are affected by:

- Plastic pollution
- Climate change
- Deep-sea mining
- Fishing impacts

Because many deep-sea organisms grow slowly and reproduce infrequently, recovery from disturbance may take extremely long periods.

Deep-sea conservation has become an increasingly important area of marine policy and ecological research. Marine Conservation

Why Does the Deep Sea Matter?

Deep-sea ecosystems are important because they:

- Influence global nutrient cycles
- Store carbon
- Support biodiversity
- Help scientists understand evolution and adaptation
- Provide clues about possible extraterrestrial life

Studying deep oceans also reminds us how much remains unknown about Earth itself.

~~~~~~

Things to Remember

1. The open ocean is Earth's largest habitat.
2. Pelagic zones differ based on depth and light availability.
3. Plankton form the foundation of most open ocean food webs.
4. Many pelagic species undertake long migrations.
5. Open oceans play important roles in regulating climate.

6. The deep sea is cold, dark and under immense pressure.
7. Many deep-sea organisms produce light through bioluminescence.
8. Hydrothermal vent ecosystems rely on chemosynthesis instead of sunlight.
9. Deep-sea organisms show extraordinary adaptations for survival.
10. Much of the deep ocean remains unexplored.

Key Terms

Pelagic zone: Open ocean water away from coastlines and seafloor

Nekton: Actively swimming marine organisms

Bioluminescence: Production of light by living organisms

Countershading: Colour pattern aiding camouflage

Marine snow: Sinking organic material supporting deep-sea food webs

Migration: Regular large-scale movement of organisms

Bioluminescence: Production of light by living organisms

Hydrothermal vent: Hot mineral-rich opening on the seafloor

Chemosynthesis: Production of energy using chemicals rather than sunlight

Abyssal zone: Deep ocean region below the midnight zone

Deep-sea gigantism: Tendency for some deep-sea organisms to grow unusually large

Pressure adaptation: Biological feature helping organisms survive high pressure

Hadal zone: Deep trench environments of the ocean

Whale fall: Whale carcass supporting deep-sea ecosystems

Quick Quiz

1. Why is the deep sea permanently dark?
~~~~~~

2. What is bioluminescence?
3. How do hydrothermal vent ecosystems obtain energy?
4. What is chemosynthesis?
5. What is the pelagic zone?
6. Why is the epipelagic zone important for productivity?
7. What are nekton?
8. Why do many pelagic species migrate?
9. What is marine snow, and why is it important?
10. Why are deep-sea ecosystems important to study?

SECTION 6

Polar Oceans:

Life at the Frozen Edges of the Earth

At the northern and southern extremes of our planet lie some of the most challenging marine environments on Earth.

Polar oceans experience:

- Extremely cold temperatures
- Seasonal darkness
- Expanding and melting sea ice
- Strong seasonal changes in productivity

Despite these harsh conditions, polar marine ecosystems support remarkable biodiversity and some of the largest seasonal wildlife gatherings on Earth.

Polar oceans are also deeply connected to global climate systems and ocean circulation.

The Two Polar Regions

Earth has two major polar marine regions:

The Arctic Ocean

Northern Polar Region

The Arctic is an ocean surrounded largely by continents.

It contains:

- Seasonal sea ice
- Cold surface waters
- Polar marine mammals
- Productive summer ecosystems

The Southern Ocean

Antarctic Region

The Southern Ocean surrounds Antarctica.

Unlike the Arctic, it is connected continuously around the continent, allowing strong ocean circulation.

This region supports:

- Antarctic krill
- Penguins
- Seals
- Whales
- Seabirds

The Southern Ocean plays an important role in regulating global ocean circulation and climate systems. Polar oceanography research has highlighted its importance in heat and carbon exchange.

Sea Ice:

More Than Frozen Water

Sea ice is a defining feature of many polar marine ecosystems. Importantly the sea ice is not empty.

It supports microorganisms including:

- Algae
- Bacteria
- Tiny invertebrates

These organisms contribute to polar food webs.

Sea ice also provides habitat for Polar bears, Seals and Penguins depending on the region.

Changes in sea ice strongly influence polar ecosystems.

Figure 8: Polar ice

Seasonal Light Cycles

Polar regions experience dramatic seasonal shifts.

During summer:

- Long daylight periods increase productivity

During winter:

- Extended darkness reduces photosynthesis

This creates strong seasonal pulses of biological activity.

Polar Productivity:

Short Summers, Intense Life

When sunlight returns during polar summers, phytoplankton blooms may develop rapidly.

These blooms support highly productive food webs.

One of the most important organisms in Antarctic ecosystems is:

Antarctic Krill

Krill are small crustaceans that feed on phytoplankton and form dense swarms.

They are a key link between microscopic producers and larger predators.

Species Spotlight

Antarctic Krill (*Euphausia superba*) are tiny organisms supporting giant ecosystems

Many Antarctic animals depend directly or indirectly on krill, including penguins, seals, fish, squid and baleen whales. Some whale species consume enormous quantities of krill during feeding seasons.

Research in Antarctic ecology consistently identifies krill as a foundational species within Southern Ocean food webs.

More on Antarctic krill here - https://www.antarctica.gov.au/news/explore-antarctica/krill/

Adaptations to Cold Environments

Polar organisms possess specialised adaptations helping them survive freezing conditions.

Examples include:

Insulation

Marine mammals often possess thick layers of fat called **blubber** that reduce heat loss.

Antifreeze Proteins

Some polar fish produce proteins helping prevent ice crystal formation in body fluids.

Seasonal Behaviour

Many species migrate seasonally to access food or breeding areas.

Body Shape

Compact body shapes may reduce heat loss.

Penguins:

Birds Adapted for Marine Life

Penguins are highly specialised seabirds adapted for swimming rather than flight.

Adaptations include:

- Streamlined bodies
- Dense waterproof feathers
- Strong flippers

Many penguin species depend heavily on marine ecosystems for food.

Did You Know?

Antarctic krill can change from adults to juveniles making it difficult to age them. Like other crustaceans moult and grow bigger till adulthood. But these krill need to survive extreme temperatures and food shortages and so moult for life and downsize.

Marine Mammals of Polar Oceans

Polar ecosystems support several marine mammals including:

- Seals
- Walruses
- Whales
- Polar bears (Arctic only)

Many species depend strongly on sea ice conditions.

For example:

Some seals use sea ice for:

- Resting
- Breeding
- Raising young

Why Polar Oceans Matter Globally

Polar oceans influence Earth's climate systems in several ways.

Heat Regulation

Cold polar waters help drive global ocean circulation.

Carbon Storage

Polar oceans absorb significant amounts of carbon dioxide.

Climate Feedbacks

Changes in sea ice affect how much sunlight Earth reflects back into space.

Ocean Circulation

Dense cold waters sinking in polar regions influence global circulation systems.

Scientists often describe oceans as part of a global "conveyor belt" transporting heat and nutrients worldwide. Thermohaline Circulation

Threat Alert

Polar Ecosystems Under Rapid Change

Polar regions are warming faster than many other parts of Earth.

Scientists have documented major changes including:

- Declining sea ice
- Glacier melt
- Shifts in species distributions
- Changing food webs

Climate change is now one of the greatest challenges facing polar marine ecosystems. Research from climate science and polar ecology has documented rapid environmental change across both Arctic and Antarctic systems. Climate Science

Conservation Challenges in Polar Oceans

Protecting polar ecosystems can be difficult because:

- Species migrate across enormous distances
- International cooperation is required
- Climate change affects entire regions

Several international agreements and scientific collaborations help support polar conservation and research.

We will revisit ocean governance and conservation later in the guide.

Connecting Polar Oceans to the Rest of the Planet

Although polar oceans may seem remote, they influence ecosystems and climate worldwide.

Changes in polar systems may affect:

- Ocean circulation
- Sea levels
- Global climate
- Marine food webs

Understanding polar ecosystems therefore helps scientists understand Earth as an interconnected system.

~~~~~~

Things to Remember

1. Polar oceans are cold, seasonal and highly productive ecosystems.
2. Sea ice supports important habitats and food webs.
3. Antarctic krill are foundational organisms in Southern Ocean ecosystems.
4. Polar organisms possess specialised cold-environment adaptations.
5. Polar oceans play important roles in global climate regulation.

Key Terms

Sea ice: Frozen ocean water

Krill: Small crustaceans important in polar food webs

Blubber: Thick fat layer reducing heat loss

Thermohaline circulation: Global ocean circulation driven by temperature and salinity differences

Polar ecosystem: Marine ecosystem occurring in Arctic or Antarctic regions

Quick Quiz

1. Why are polar oceans highly seasonal ecosystems?
2. Why is Antarctic krill considered ecologically important?
3. What adaptations help polar organisms survive cold temperatures?
4. How do polar oceans influence global climate?
5. Why are polar ecosystems vulnerable to climate change?
~~~~~~

SECTION 7

Food Webs & Trophic Levels:

How Does Energy Move Through Marine Ecosystems?

Every marine organism needs energy to survive.

Fish must swim, corals must grow, whales must migrate and microscopic plankton must reproduce.

But where does this energy come from?

In most marine ecosystems, energy ultimately originates from the Sun and moves through ecosystems as organisms feed on one another.

Understanding these feeding relationships helps scientists understand how ecosystems function and how disturbances may affect entire food webs.

Food Chains:

Simple Pathways of Energy

A **food chain** shows how energy moves from one organism to another.

For example:

Phytoplankton
↓
Zooplankton
↓
Small fish
↓
Tuna
↓
Shark

Each step represents energy transfer through feeding relationships.

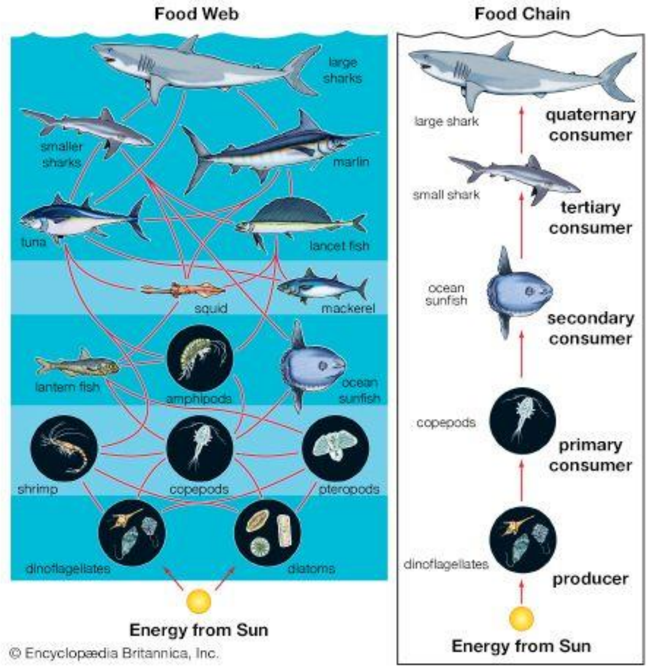

Figure 9: Ocean food chain and food web (diagram credit - Britanica encyclopedia)

Producers:

The Foundation of Marine Food Webs

Most marine food webs begin with **primary producers**.

These organisms produce energy-rich organic material using photosynthesis.

The most important marine producers are:

- Phytoplankton
- Algae
- Seagrasses

Phytoplankton are especially important because they support vast marine ecosystems and contribute significantly to global oxygen production. Marine primary productivity research has shown that microscopic producers underpin most ocean food webs. Biological Oceanography

Consumers:

Organisms That Obtain Energy by Feeding

Consumers obtain energy by eating other organisms.

Scientists often group consumers into trophic levels.

Primary Consumers

Feed directly on producers.

Examples:

- Zooplankton
- Some molluscs
- Grazing fish

Secondary Consumers

Feed on primary consumers.

Examples:

- Small predatory fish
- Jellyfish

Tertiary Consumers

Feed on other predators.

Examples:

- Tuna
- Larger fish
- Seabirds

Apex Predators

Organisms at or near the top of food webs.

Examples:

- Sharks
- Orcas
- Some large tuna

Figure 10: Orcas in the ocean

Apex predators often influence ecosystem balance by regulating prey populations.

Research in ecology has shown that predator declines may alter food web structure and ecosystem functioning.

Trophic Levels:

Steps in Energy Transfer

Each feeding level in a food web is called a **trophic level**.

Energy decreases as it moves upward through trophic levels because organisms use much of their energy for:

- Movement
- Growth
- Respiration
- Reproduction

As a result:

Only part of the energy available at one trophic level transfers to the next.

This helps explain why:

- ecosystems contain many plankton,
- fewer large predators,
- and very few apex predators.

Food Webs:

More Complex Than Food Chains

Real ecosystems rarely follow simple linear food chains.

Most organisms feed on multiple species and may themselves be eaten by several predators.

These interconnected feeding relationships form:

Food webs

Food webs help ecosystems remain functional even if some feeding relationships change.

Example:

Coral Reef Food Webs

On coral reefs:

- Herbivorous fish graze algae
- Predatory fish feed on smaller fish
- Sharks prey on larger organisms
- Corals capture plankton

Many feeding relationships overlap.

This complexity contributes to reef biodiversity and ecosystem resilience.

Species Spotlight

Sharks are apex predators with important ecological roles

Many sharks function as apex or near-apex predators. But many small bodied species of sharks are prey for larger sharks.

By influencing prey populations and behaviour, sharks help maintain food web balance. In some ecosystems, predator declines may trigger trophic cascades. A trophic cascade occurs when changes at one trophic level affect multiple lower levels within a food web.

Studies in marine ecology have shown that removing predators may alter ecosystem structure and species interactions.

[**Concept Clarifier**

Food Chain vs Food Web

A food chain is the primary unit of a food web or a linear pathway from the primary producer to the tertiary consumer. Whereas, a Food web is a complex network of feeding interactions (food chains interconnected). Ecosystems in the natural world are usually made up of food webs consisting of various trophic levels.]

Detritivores and Decomposers:

Recycling Nutrients

Not all organisms feed on living prey.

Some feed on dead organisms, waste material and organic debris These organisms help recycle nutrients back into ecosystems.

Examples include:

- Some worms
- Sea cucumbers
- Bacteria

Decomposition plays important roles in nutrient cycling and ecosystem functioning.

Marine Snow:

Energy Falling into the Deep Sea

Deep-sea ecosystems often depend on organic material sinking from surface waters.

This material, called **marine snow**, includes:

- Dead plankton
- Tiny particles
- Organic waste

Marine snow transfers energy from productive surface waters into deep ocean ecosystems.

Did You Know?

Some deep-sea organisms may survive long periods with very little food because energy availability is so limited. Deep sea investigations have shown gonatid squid demonstrating cannibalism.

Refer to www.naturalworldfacts.com for deep sea food web knowledge.

Ecosystem Balance and Interdependence

Marine food webs demonstrate how interconnected ecosystems are.

For example:

Declining plankton populations may influence:

- fish,
- seabirds,
- whales,
- and fisheries.

Similarly:

Loss of apex predators may alter prey populations and ecosystem structure.

Ecologists study food webs because they help explain ecosystem stability, biodiversity patterns and responses to environmental change.

Threat Alert

Human Impacts on Marine Food Webs

Human activities increasingly affect marine food webs.

Examples include:

- Overfishing
- Climate change
- Pollution
- Habitat loss

Removing large predators or reducing plankton productivity may create cascading ecological effects across ecosystems.

Climate-driven changes in marine productivity and species distributions are already affecting some ocean food webs. Climate Science

Why Food Webs Matter

Understanding marine food webs helps scientists:

- Predict ecosystem changes
- Manage fisheries
- Study biodiversity
- Assess environmental impacts
- Understand ecosystem resilience

Food webs reveal that ecosystems function through connections, not isolated species.

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

Things to Remember

1. Most marine food webs begin with primary producers such as phytoplankton.
2. Energy decreases as it moves upward through trophic levels.
3. Food webs are more complex than simple food chains.
4. Apex predators help influence ecosystem balance.
5. Human activities may disrupt marine food webs.

Key Terms

Producer: Organism producing energy through photosynthesis

Consumer: Organism obtaining energy by feeding

Trophic level: Feeding position within a food web

Apex predator: Predator near the top of a food web

Food web: Network of feeding relationships

Trophic cascade: Ecosystem changes caused by shifts in trophic interactions

Detritivore: Organism feeding on dead organic material

Quick Quiz

1. What is the difference between a food chain and a food web?
2. Why are phytoplankton important in marine ecosystems?
3. What happens to energy as it moves through trophic levels?
4. What is a trophic cascade?
5. Why are apex predators ecologically important?
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

SECTION 8

Species Interactions:

Competition, Cooperation and Survival in Marine Ecosystems

No organism lives completely independently.

Marine ecosystems function through countless interactions between species. Some organisms compete for resources, some cooperate, some depend on one another for survival, while others hunt or parasitise each other.

These interactions influence:

- Population sizes
- Species distributions
- Ecosystem stability
- Evolutionary adaptations

Understanding species interactions helps explain how marine ecosystems remain dynamic and interconnected.

Competition:

When Organisms Need the Same Resources

Competition occurs when organisms use the same limited resources.

These resources may include:

- Food
- Space
- Shelter
- Light
- Mates

Competition may occur:

- within the same species,
- or between different species.

Example:

Coral Reef Competition

Corals compete intensely for:

- sunlight,
- space,
- and nutrients.

Some corals grow rapidly to outcompete neighbours, while others use specialised stinging structures to defend territory.

Competition strongly influences reef structure and species composition. Coral reef ecology studies have shown that competition for space is one of the most important processes shaping reef communities.

[**Concept Clarifier**

Resources Are Often Limited

Even highly biodiverse ecosystems contain limited:

- space,
- nutrients,
- and energy.

Competition is therefore common in nature.]

Predation:

Hunting and Being Hunted

Predation occurs when one organism captures and consumes another.

Predators influence:

- prey populations,
- prey behaviour,
- and food web structure.

Examples include:

- Sharks feeding on fish
- Octopuses hunting crabs
- Seabirds catching fish

Predation is an important ecological force influencing ecosystem balance.

Species Spotlight

Tiger Sharks

Flexible Ocean Predators

Tiger sharks are generalists i.e they consume a wide range of prey including fish, turtles, seabirds, and invertebrates. Because they feed on many species, tiger sharks help connect different parts of marine food webs.

Large marine predators often influence ecosystem structure through both direct predation and behavioural effects on prey species.

Symbiosis:

Close Relationships Between Species

Some species interact so closely that their lives become interconnected.

These close interactions are called:

Symbiosis

There are several forms of symbiosis.

Mutualism:

When Both Species Benefit

In mutualistic relationships, both organisms benefit.

Example:

Cleaner Fish and Larger Fish

Cleaner wrasse removes parasites and dead tissue from larger fish.

Benefits:

- Cleaner fish obtain food
- Larger fish reduce parasite loads

Example:

Corals and Zooxanthellae

Corals provide shelter for algae.

Algae provides energy through photosynthesis.

This partnership supports reef ecosystems.

Symbiotic interactions are fundamental components of many marine ecosystems and may strongly influence biodiversity and ecosystem functioning.

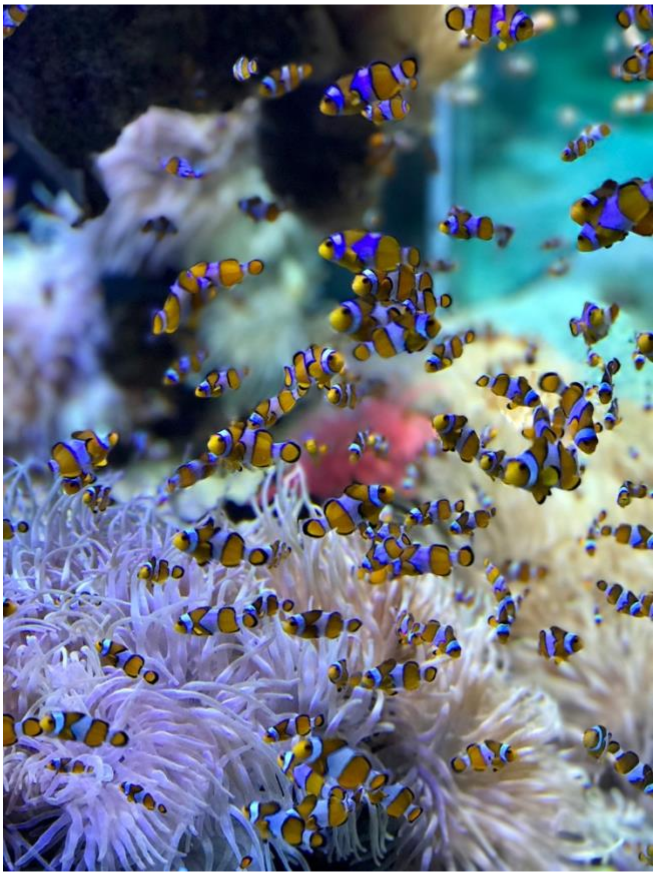

Figure 11: Clown fish showing mutualism with sea anemones

Commensalism:

One Species Benefits, the Other Is Mostly Unaffected

In commensal relationships:

- one organism benefits,
- while the other experiences little or no effect.

Example:

Remoras and Sharks

Remoras attach themselves to larger animals such as sharks.

They gain:

- transportation,
- protection,

- and food scraps.

The shark is usually not significantly affected.

Parasitism:

One Benefits, One Is Harmed

Parasites live on or within other organisms, obtaining nutrients at the host's expense.

Examples include:

- parasitic copepods,
- worms,
- and some fish parasites.

Parasitism is common in marine ecosystems and may influence growth, reproduction and behaviour.

Schooling:

Safety in Numbers

Many fish species form schools.

Schooling may help:

- reduce predation risk,
- improve feeding success,
- and increase swimming efficiency.

Large coordinated schools also confuse predators.

Research in behavioural ecology has shown that schooling behaviour may emerge from relatively simple interactions between individuals.

Figure 12: Shoal of fish.

Did You Know?

Some schools of fish contain millions of individuals moving together in highly coordinated patterns. This is usually used as a safety mechanism to confuse predators.

Cooperation:

Working Together

Not all interactions involve competition.

Some marine organisms cooperate in ways that improve survival.

Examples include:

- cooperative hunting in dolphins,
- group defence in fish schools,
- and social communication among whales.

Marine mammals in particular display complex social behaviours and communication systems. Research in marine mammal science continues revealing sophisticated social interactions in dolphins and whales. Marine Mammal Science

Keystone Species:

Small Influence, Big Impact

Some organisms have ecological impacts far greater than expected from their abundance.

These are called:

Keystone species

Removing keystone species may trigger major ecosystem changes.

Example:

Sea Otters and Kelp Forests

Sea otters feed on sea urchins.

Without otters:

- sea urchin populations may increase,
- leading to overgrazing of kelp forests.

This is an example of a trophic cascade.

Research on keystone species helped transform ecological understanding of ecosystem stability and species interactions. Keystone Species

Ecosystem Balance Is Dynamic

Marine ecosystems are constantly changing.

Species interactions shift because of:

- environmental conditions,
- migration,
- seasonal changes,
- and disturbances.

Healthy ecosystems are dynamic rather than perfectly stable.

Ecologists often focus on resilience — the ability of ecosystems to respond to disturbances while maintaining important functions.

Threat Alert

Human Activities Can Alter Species Interactions

Human impacts may change ecological relationships.

Examples include:

- overfishing predators,
- invasive species introductions,
- habitat destruction,
- and climate-driven species shifts.

When interactions change, ecosystems may also change.

~~~~~~

Things to Remember

1. Marine organisms interact through competition, predation and symbiosis.
2. Mutualism benefits both species.
3. Commensalism benefits one species without strongly affecting the other.
4. Keystone species may strongly influence ecosystems.
5. Species interactions help shape ecosystem structure and biodiversity.

Key Terms

Competition: Interaction involving shared limited resources

Predation: One organism consuming another

Symbiosis: Close interaction between species

Mutualism: Both species benefit

Commensalism: One benefits, the other is mostly unaffected

Parasitism: One benefits while the host is harmed

Keystone species: Species with disproportionately large ecological influence

Quick Quiz

1. What is competition?
2. How does mutualism differ from parasitism?
~~~~~~

3. Why are cleaner wrasse considered mutualistic organisms?
4. What is a keystone species?
5. How might human activities alter species interactions?

SECTION 9:

Ecosystem Services:

Why Healthy Oceans Matter to Humans

Marine ecosystems are important not only for biodiversity, but also for people.

Humans depend on oceans in countless ways, often without realising it.

Healthy marine ecosystems provide benefits known as:

Ecosystem services

These services support:

- food systems,
- economies,
- climate regulation,
- and human well-being.

Understanding ecosystem services helps explain why marine conservation matters beyond protecting individual species.

What Are Ecosystem Services?

Ecosystem services are the benefits humans obtain from ecosystems.

Marine ecosystem services may be grouped into several categories.

1. Provisioning Services:

Resources Provided by Oceans

Marine ecosystems provide:

- fish,
- shellfish,
- seaweed,
- medicines,
- and raw materials.

Millions of people depend directly on fisheries for food and livelihoods.

According to global fisheries assessments, marine fisheries remain important sources of protein and employment for many coastal communities worldwide. Food and Agriculture Organization

2. Regulating Services:

Oceans Help Regulate Earth Systems

Marine ecosystems influence:

- climate,
- carbon cycles,
- coastal protection,
- and water quality.

Carbon Storage

Mangroves, seagrasses and salt marshes store significant amounts of carbon.

These "blue carbon" ecosystems help regulate atmospheric carbon dioxide.

Coastal Protection

Coral reefs and mangroves may reduce:

- wave energy,
- erosion,
- and storm impacts.

Research in coastal ecology has demonstrated the important role of coastal ecosystems in reducing shoreline vulnerability.

3. Supporting Services:

Processes That Maintain Ecosystems

Marine ecosystems support processes including:

- nutrient cycling,
- oxygen production,
- habitat formation,
- and food web functioning.

Phytoplankton play particularly important roles in marine productivity and global biogeochemical cycles.

4. Cultural Services:

Human Connections to Oceans

Oceans influence:

- recreation,
- tourism,
- traditions,

- art,
- spirituality,
- and cultural identity.

Many coastal communities maintain deep cultural relationships with marine environments developed over generations.

Species Spotlight

Whales act like the ecosystem engineers of the ocean. They influence marine ecosystems in several ways, for example, whale waste (faecal matter) redistributes nutrients in the ocean as their faecal plumes contain iron, nitrogen and phosphorus that stimulate the production of microscopic marine algae or phytoplankton.

According to a study on blue whales in the Southern Ocean, they found that fecal plumes increased primary production available to support fisheries by 240,000 metric tonnes of organic carbon (which all animals in the oceans need to survive) per year.

Research on whale ecology suggests marine mammals also contribute to nutrient cycling and ecosystem productivity.

Oceans and Oxygen

Marine photosynthetic organisms contribute significantly to Earth's oxygen production.

Although exact percentages vary among studies and environmental conditions, phytoplankton are globally important oxygen producers. This demonstrates how microscopic organisms influence planetary systems.

Did You Know?

Some medicines and biomedical compounds have been developed from marine organisms including sponges and cone snails. The blue blood of the horse shoe crab contains blood cells highly sensitive to toxic bacteria. These clever blood cells were used by scientists to develop a test to check for vaccines called Limulus Amebocyte Lysate.

Ecosystem Services Are Connected

Marine ecosystem services depend on healthy biodiversity and functioning ecosystems.

For example:

- fisheries depend on food webs,
- coastal protection depends on reefs and mangroves,
- Carbon storage depends on healthy coastal ecosystems.

If ecosystems decline, ecosystem services may also weaken.

Threat Alert

Declining Ecosystems Affect People Too

Human pressures including:

- pollution,
- climate change,
- overfishing,
- and habitat loss

may reduce ecosystem services over time.

Protecting ecosystems therefore supports both biodiversity and human societies.

Why Ecosystem Services Matter

Understanding ecosystem services helps scientists and policymakers:

- manage resources,
- support conservation,
- evaluate environmental impacts,
- and balance human needs with ecosystem protection.

Marine ecosystems are not isolated from humans.

People are part of these systems too.

~~~~~~

Things to Remember

1. Ecosystem services are benefits humans obtain from ecosystems.
2. Marine ecosystems provide food, climate regulation and coastal protection.
3. Blue carbon ecosystems store significant amounts of carbon.
4. Healthy biodiversity supports ecosystem functioning.
~~~~~~

5. Human well-being is closely connected to healthy oceans.

Key Terms

Ecosystem services: Benefits humans obtain from ecosystems

Provisioning services: Resources obtained from ecosystems

Regulating services: Ecosystem processes influencing environmental conditions

Blue carbon: Carbon stored in marine ecosystems

Nutrient cycling: Movement and recycling of nutrients through ecosystems

Ecosystem engineer: Organism strongly influencing ecosystem structure or processes

Quick Quiz

1. What are ecosystem services?
2. Name two provisioning services provided by oceans.
3. Why are mangroves important for coastal protection?
4. What are blue carbon ecosystems?
5. Why are healthy ecosystems important for humans?