DP IB Environmental Systems & Societies (ESS): SL

Your notes

4.3 Aquatic Food Production Systems

Contents

Aquatic Food Webs

Your notes

Aquatic Food Webs

- Aquatic food webs show how energy and nutrients move through freshwater and marine ecosystems

Phytoplankton

- Phytoplankton are microscopic organisms found in marine and fresh water bodies that can perform **photosynthesis**
  - Phytoplankton are **not plants**
  - They include a variety of autotrophic microorganisms, such as:
    - Algae (e.g. diatoms)
    - Cyanobacteria (prokaryotic organisms that are also known as blue-green algae)
- Role in food webs:
  - They form the **base** of most aquatic food webs
  - They capture solar energy and convert it into biomass through photosynthesis
  - They are consumed by primary consumers (zooplankton and small fish)
  - They contribute to oxygen production and nutrient cycling

Macrophytes

- Macrophytes are **aquatic plants** that are visible to the naked eye
- They can be:
  - **Emergent**: plants that grow above the water surface (e.g. cattails or bulrushes)
  - **Submerged**: plants that grow completely underwater (e.g. seagrass)
  - **Floating**: plants that float on the water surface (e.g. water lilies or duckweed)
- Role in food webs:
  - They provide **habitat** and **food** for various aquatic organisms
  - They capture solar energy and convert it into biomass through photosynthesis
  - They contribute to oxygen production and nutrient cycling

Energy flow in aquatic food webs

- **Producers**: phytoplankton and macrophytes capture energy from sunlight through photosynthesis
- **Primary consumers**: zooplankton, small fish and some invertebrates and birds feed on primary producers
- **Secondary consumers**: larger fish and birds consume primary consumers
- **Tertiary consumers**: top predators like sharks and birds of prey eat secondary consumers
- **Decomposers**: aquatic bacteria and fungi break down dead organisms, recycling nutrients back into the ecosystem

Examiner Tips and Tricks

Be clear on the differences between phytoplankton and macrophytes—although they play similar roles in aquatic food webs, they are very different groups of organisms.

Your notes

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Human Consumption & Increasing Demand

- Humans consume a variety of organisms (flora and fauna) from both freshwater and marine environments
- These organisms provide essential nutrients and form a significant part of many cultures' diets
- Consumption patterns vary locally and globally
  - This reflects availability, tradition and sustainability concerns

Examples of aquatic food resources

Local and Global Examples of Aquatic Flora and Fauna Consumed by Humans

Organism	Type of organism	Type of aquatic environment	How widely consumed	Description
Watercress	Flora	Freshwater	Local	Leafy green plant Popular in the UK Grown in shallow, flowing water beds fed by natural springs or streams Used in salads and soups
Spirulina	Flora	Freshwater	Global	Blue-green algae (cyanobacteria) Consumed worldwide Grown in freshwater ponds and lakes Harvested by filtering the water and then drying the algae Used as a dietary supplement
Dulse	Flora	Marine	Local	Type of red seaweed Traditionally eaten in Ireland Hand-harvested from rocks during low tide along the coastline

				Dried in the sun or indoors Consumed dried or cooked
Nori	Flora	Marine	Global	Type of red seaweed Popular globally, especially in Japan Farmed in coastal waters on nets suspended from bamboo poles or floating rafts Harvested, then dried and processed into sheets Used in sushi and snacks
Trout	Fauna	Freshwater	Local	Freshwater fish Commonly consumed in the UK Raised in freshwater ponds or tanks with controlled water quality Harvested by netting when they reach market size
Tilapia	Fauna	Freshwater	Global	Freshwater fish Consumed worldwide Raised in freshwater ponds or recirculating aquaculture systems Harvested by draining the ponds or using nets
Orkney Scallops	Fauna	Marine	Local	Type of shellfish A delicacy in Scotland, UK Collected by divers from the seabed around the Orkney Islands (ensures minimal environmental impact)
Shrimp	Fauna	Marine	Global	Small crustacean

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				Found in oceans worldwide and consumed globally Raised in coastal ponds or tanks Harvested by draining the ponds and collecting the shrimp with nets

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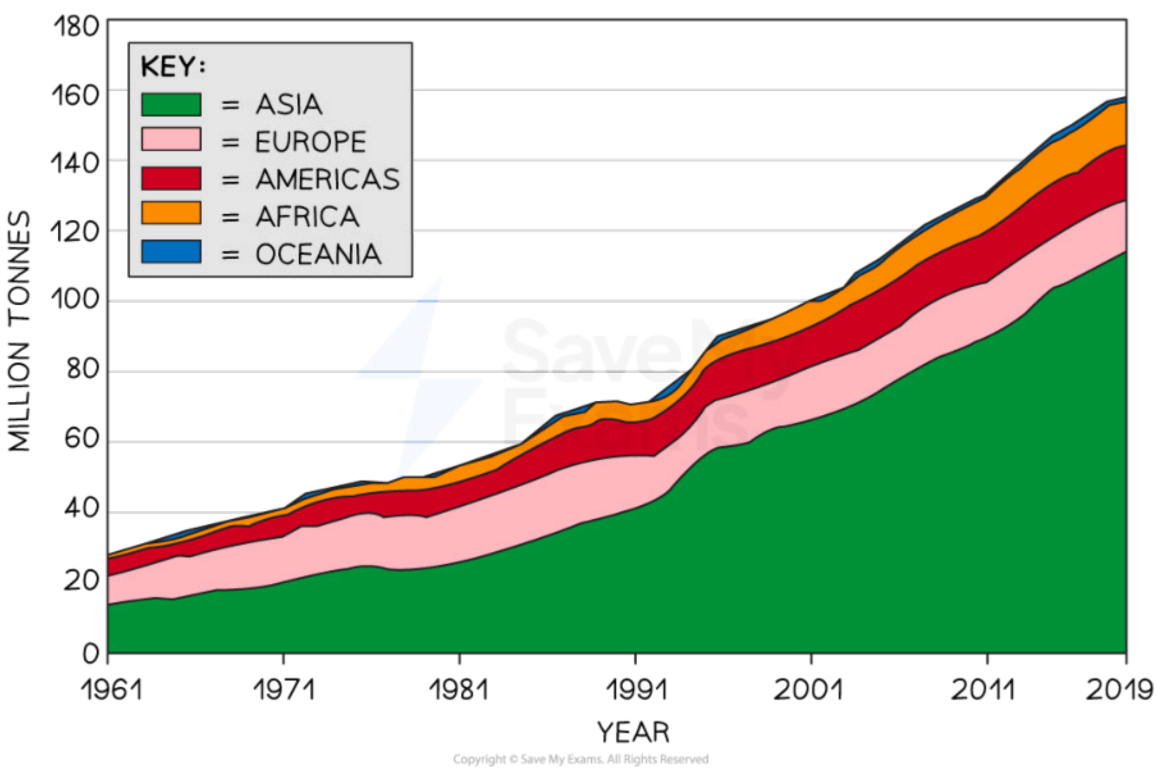
Demand for aquatic food resources



Global aquatic food consumption

- The demand for aquatic food resources has significantly **increased** in over the last 50–100 years
  - This is due to the combined effects of a **growing human population** and **dietary changes**
- As populations expand and economies develop, there is a higher demand for seafood products to meet nutritional needs and culinary preferences
- The main factors behind the increase in demand for aquatic food resources are:

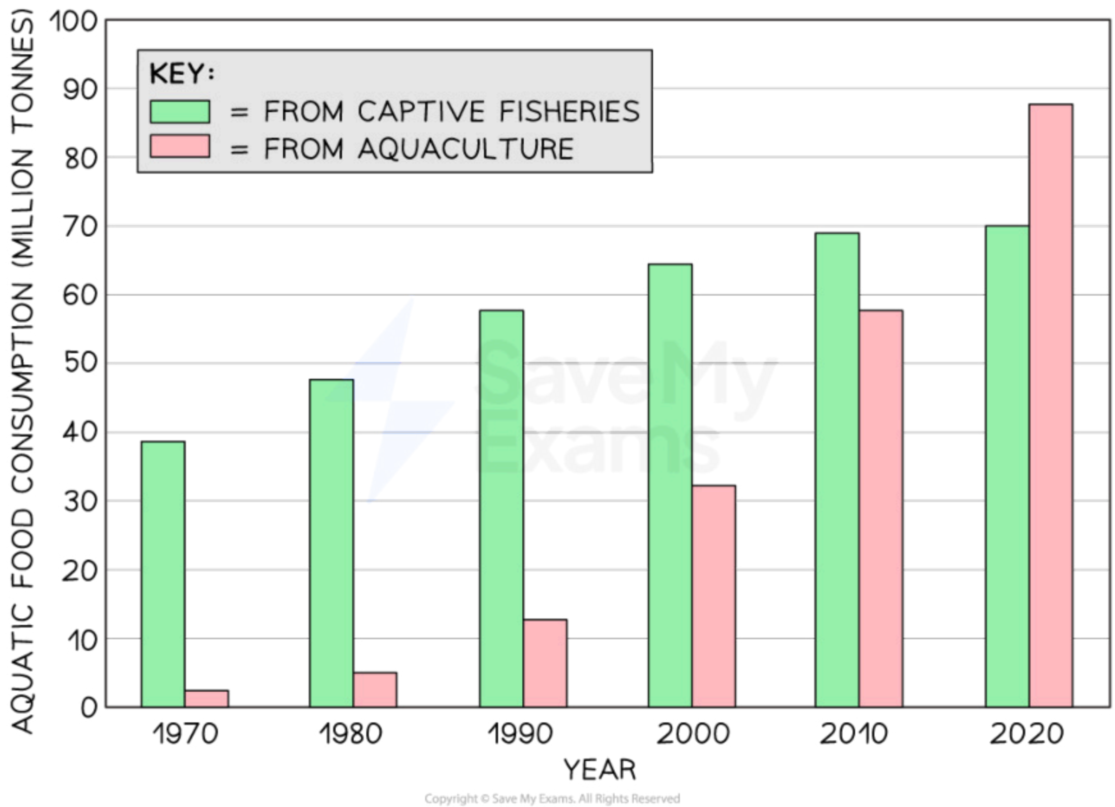
1. **Growing human population**

- The global population has rapidly increased, resulting in a larger consumer base for aquatic food resources

2. **Changing dietary patterns**
    - As countries undergo economic growth, there is often a shift in dietary patterns towards increased consumption of protein-rich foods, including seafood
3. **Nutritional benefits of seafood**
    - Seafood is recognised as a valuable source of essential **nutrients**, such as omega-3 fatty acids, vitamins and minerals
    - These all contribute to **human health** and well-being
4. **Urbanisation and the rising middle class**
    - Urbanisation and the emergence of a middle class in many regions have led to changes in dietary preferences
    - This has increased demand for diverse and higher-value food options, including seafood
5. **Global trade and supply chains**
    - Advances in transportation and the expansion of global trade networks have made it easier to **import** and **export** seafood products
    - This has increased their availability to communities
6. **Aquaculture production**
    - Aquaculture, the farming of aquatic organisms, has experienced significant growth to meet the rising demand for seafood

Your notes

Your notes



The relative contribution of aquaculture and capture fisheries

Unsustainable Harvesting Practices & Overexploitation

Your notes

Unsustainable Harvesting Practices

- The rising global demand for seafood has led to the use of unsustainable harvesting practices
  - These methods often **damage marine ecosystems** and lead to **overexploitation** of fish stocks

1. **Bottom trawling:**
   - This method involves dragging heavy nets along the seabed
   - Impacts:
     - Destroys habitats such as coral reefs
     - Results in significant bycatch (catching non-target species)
     - Disturbs sediment, causing sediment pollution and releasing other trapped pollutants
2. **Ghost fishing:**
   - This occurs when abandoned or lost fishing gear continues to catch marine life
     - E.g. ghost nets
   - Impacts:
     - Continues to catch fish and other marine animals, leading to unnecessary deaths
     - Causes entanglement of marine organisms, including endangered species
     - Contributes to marine debris and pollution
3. **Use of poisons:**
   - Some fishermen use poisons and toxic substances, such as cyanide, to stun or kill fish, making them easier to catch
   - Impacts:
     - Poisons kill or damage a wide range of marine life
     - Cyanide kills coral polyps and other organisms that form the coral reef structure, leading to reef degradation and overall loss of biodiversity
     - This method is highly unsustainable and illegal in many places
4. **Use of explosives:**

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- Some fishermen use explosives, such as dynamite, to stun or kill fish, making them easier to catch
- Impacts:
  - Explosives destroy marine habitats and kill indiscriminately (kill non-target species)
  - Causes extensive damage to coral reefs and other important marine habitats
  - This method is also highly unsustainable and illegal in many places

Overexploitation

- Developments in fishing equipment and increased use of unsustainable fishing methods have led to declining fish stocks and damage to habitats
  - **Fish stocks** in the oceans are rapidly decreasing in size
  - This is mainly due to **overfishing**
- Overexploitation happens when fish are harvested at a rate faster than they can **reproduce**
  - This can eventually lead to the **collapse** of fisheries, where the fish population drops so low that it **cannot recover**

Case Study

Cod Fishery on the Grand Banks of Newfoundland

Background

- **Location:**
  - Grand Banks, southeast of Newfoundland, Canada
- **Historical context:**
  - These were rich fishing grounds for centuries, with cod fishing dating back to the 15th century

Timeline of the collapse

- **1960s:**
  - Advances in fishing technologies led to increased cod catches
- **1970s–1980s:**
  - Peak catches despite declining cod population
- **Early 1980s:**
  - Warnings from scientists about overfishing were ignored

- **Late 1980s:**
  - Significant depletion of cod stocks
- **1992:**
  - Canadian government imposed a moratorium on cod fishing to allow recovery

Causes of the collapse

- **Overfishing:**
  - Excessive harvesting due to high demand and advanced technology
- **Inadequate management:**
  - Quotas were set too high and were not based on scientific advice
  - Poor enforcement of regulations allowed overfishing to continue unchecked

Impacts of the collapse

- **Economic consequences:**
  - Loss of about 40 000 jobs in the fishing industry
  - Severe economic decline in communities dependent on fishing in Newfoundland and Labrador
- **Ecological consequences:**
  - Rapid decrease in cod population, with slow recovery

Current status

- **Partial recovery:**
  - Some improvement in cod populations, but even after decades, they are still below historical levels
- **Ongoing challenges:**
  - The ecosystem has changed significantly, and full recovery of cod stocks may take many more years or may never return to pre-collapse levels
- **Adaptive management:**
  - Ongoing adaptive management practices aim to balance ecological sustainability with the economic needs of fishing communities.

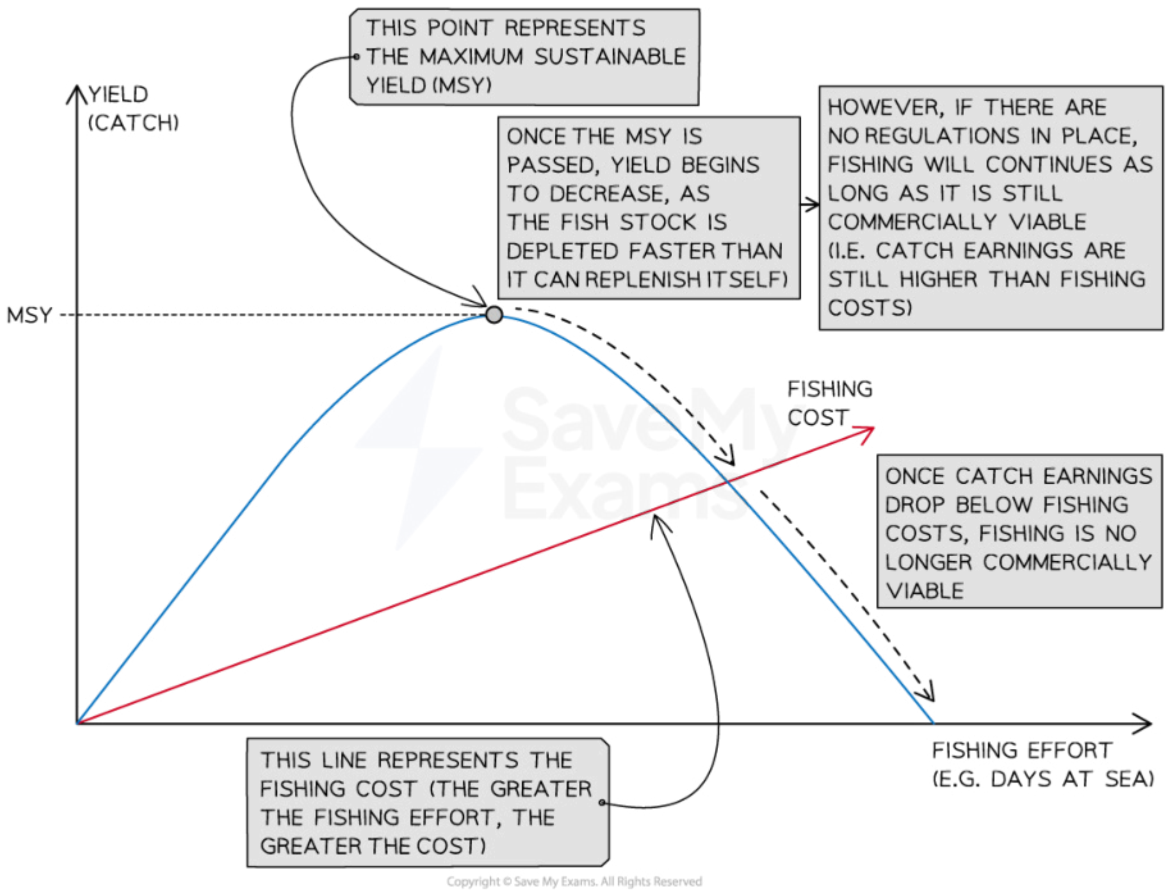
Your notes

Maximum Sustainable Yield

- The **annual yield** for a natural resource (such as a forest) is the annual **gain** in **biomass** or **energy,** through growth
- The **maximum sustainable yield** (MSY) is the maximum amount of a renewable natural resource that can be harvested annually without compromising the long-term productivity of the resource
- It is the level of **harvest** that can be maintained **indefinitely**

Your notes

- The concept of maximum sustainable yield applies to various resources, such as crops, fish, timber, and game animals
  - For example, in fisheries, the concept of maximum sustainable yield is used to determine the maximum amount of fish that can be harvested sustainably from a given population
  - This is calculated based on the population size, growth rate and reproduction rate
  - If the fishing rate exceeds the maximum sustainable yield, the population may decline, and the long-term productivity of the fishery may be affected
- In summary, the maximum sustainable yield is the **highest possible annual catch that can be sustained over time without depleting the fish stock**
- Calculating the maximum sustainable yield is important as it helps in setting appropriate limits on fishing quotas to ensure sustainable fishing practices



Yield fishing effort graph

Many fisheries still operate above the maximum sustainable yield, leading to continued overexploitation—this is because the fishing is still profitable in the short-term, even if in the long-term the stock will be depleted to the point where fishing is no longer commercially viable

Your notes

Mitigation Strategies

Your notes

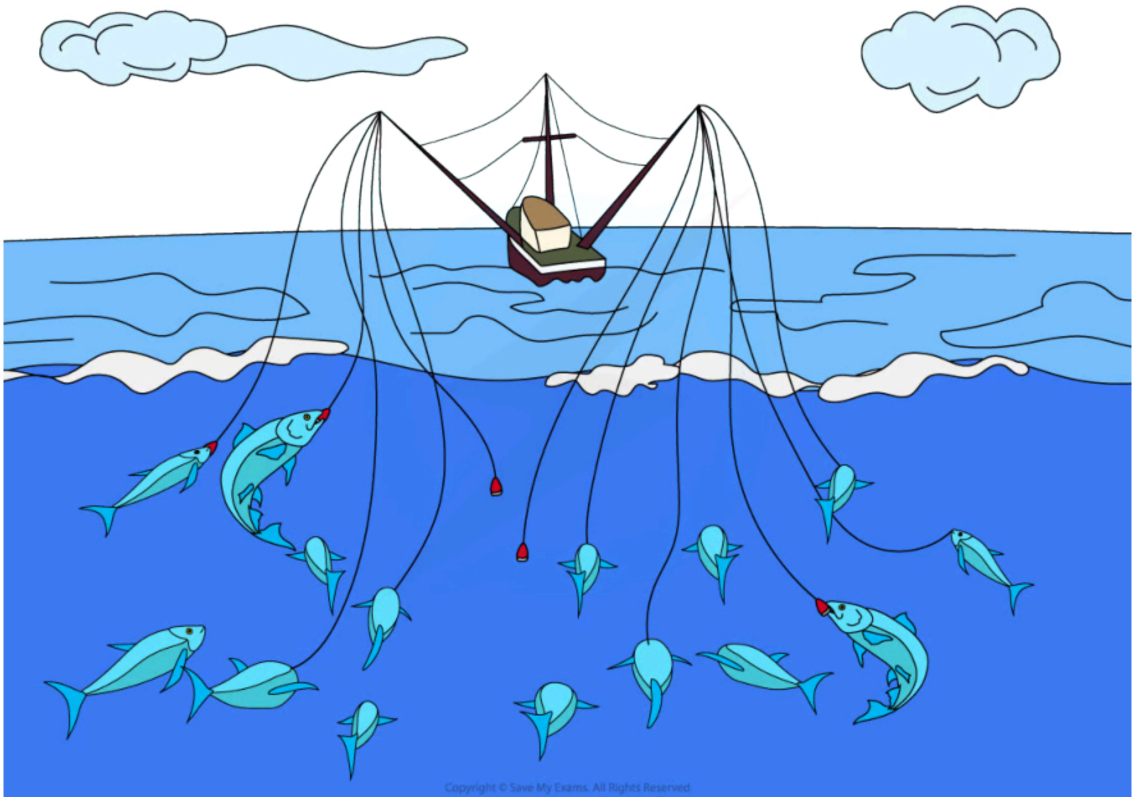
Mitigation Strategies

- Unsustainable exploitation of aquatic systems can be mitigated at a variety of levels (international, national, local and individual)
  - This can be achieved through policy, legislation and changes in consumer behaviour
    - For example, **control of net size** and the introduction of fishing quotas play important roles in the conservation of fish stocks
    - Strategies like these can keep fish stocks at a sustainable level

International and National Level Actions

- **Increasing** the **size of gaps** in fishing nets can help in two main ways:
  - **Fewer unwanted species** (that are often discarded) will be caught and killed
    - This is because they can **escape through larger net gaps** (as long as they are smaller than the species being caught)
    - The accidental capture and killing of larger, unwanted species is still a problem
  - **Juvenile fish** of the fish species being caught can escape through larger net gaps
    - This means they can **reach breeding age** and have **offspring** before they are caught and killed
    - This ensures the population of the fish species being caught can be **replenished**
- **Fishing quotas** limit the number and size of particular fish species that can be caught in a given area
  - Many nations have introduced quotas to prevent overfishing of certain species
- There are several ways to enforce governmental regulations:
  - Establishing **fishing quotas**
  - Agreeing zones or areas of the ocean where fishing is **banned** (e.g. spawning grounds) and **permitted** (e.g. within a country's territorial waters)
  - Agreeing specific times of the year when fishing is not allowed to let fish populations recover (e.g. spawning season)
  - Regulating **mesh size** of nets (to allow undersized/juvenile fish to escape)
  - Limiting the **size of the fishing fleet** by issuing licences and permits

- **Inspecting the catch** as a fishing boat returns to port
- **Banning** certain practices, e.g. **gillnets** (static nets that catch anything that swims past),
- Promoting sustainable practices such as **trolling** (different to **trawling**) that reduce **bycatch**



Trolling uses hook-and-line and reduces bycatch and damage to the seabed

Local and Individual Level Actions

- **Sustainable seafood choices:**
  - Encouraging consumers to buy seafood that is **certified** as **sustainable**
    - For example, the Marine Stewardship Council (MSC) label indicates sustainably sourced seafood
- **Food labelling:**
  - Providing clear information on the **origin** and **sustainability** of seafood products to help consumers make **informed choices**
    - For example, the UK's "Blue Fish" label signifies fish caught using sustainable practices
- **Community initiatives:**

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- Educating the public about the importance of sustainable fishing and responsible seafood consumption
- Supporting local fishing communities that practice sustainable fishing
- Participating in local conservation efforts
- Involving local communities in **managing** and **protecting** their own fisheries
  - For example, in the Philippines, community-based coastal resource management has successfully increased fish stocks and biodiversity

Marine Protected Areas

- Marine Protected Areas (MPAs) are designated regions of seas and oceans where human activities are **restricted** or **managed**
  - This is to protect marine ecosystems and biodiversity
- MPAs play a crucial role in **supporting aquatic food chains** and maintaining **sustainable yields**
  - They do this by providing safe areas for marine life

Benefits of marine protected areas

Biodiversity conservation

- **Habitat protection:**
  - MPAs protect critical habitats like coral reefs, seagrass beds and mangroves
    - For example, the Great Barrier Reef Marine Park protects one of the most biodiverse ecosystems on the planet
- **Species protection:**
  - MPAs protect endangered and vulnerable species by reducing human-induced pressures such as **fishing** and **pollution**
    - For example, the Galápagos Marine Reserve protects unique species found nowhere else in the world
    - It does this by imposing fishing restrictions and carefully managing tourism

Support for aquatic food chains

- **Spawning and nursery grounds:**
  - MPAs provide safe areas for fish and other marine organisms to **reproduce** and for juveniles to grow

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- **Feeding grounds:**
  - By protecting areas rich in food sources, MPAs ensure that marine species have access to enough food

Spillover effect

- **Population growth beyond MPA boundaries:**
  - Healthy and abundant populations within MPAs can **migrate** to nearby areas
  - This replenishes fish stocks and benefits fisheries outside the protected zones
- **Genetic diversity:**
  - MPAs maintain genetic diversity by protecting breeding populations
  - This contributes to the resilience of marine species
    - For example, the Chagos Marine Reserve in the Indian Ocean supports genetically diverse populations of fish and coral

Sustainable yields

- **Fisheries management:**
  - MPAs can help maintain sustainable fishery yields by **preventing overfishing** and allowing fish populations to **recover**
  - Sustainable fish populations lead to more **stable and long-term economic benefits** for fishing communities

Examiner Tips and Tricks

You should familiarise yourself with at least one specific example of an MPA and its impacts on marine life and local communities—a few examples you could focus on include:

- Great Barrier Reef Marine Park (Australia)
- Papahānaumokuākea Marine National Monument (Hawaii)
- Galápagos Marine Reserve (Ecuador)
- Chagos Marine Reserve (British Indian Ocean Territory)
- Monterey Bay National Marine Sanctuary (United States)

Aquaculture

Your notes

Aquaculture

What is aquaculture?

- Aquaculture, also known as fish farming or aquafarming, refers to the **cultivation** of aquatic organisms in **controlled environments** such as ponds, tanks, or ocean enclosures
- It involves the rearing, breeding, and harvesting of various species of fish, shellfish, algae and other aquatic organisms for commercial, recreational, or conservation purposes
- Aquatic flora and fauna, both freshwater and marine, are harvested by humans through various methods to meet different needs and purposes

Fish farming is one example of aquaculture (photo by Lucut Razvan on Unsplash)

- Aquatic organisms that are farmed include:
    - **Fish**

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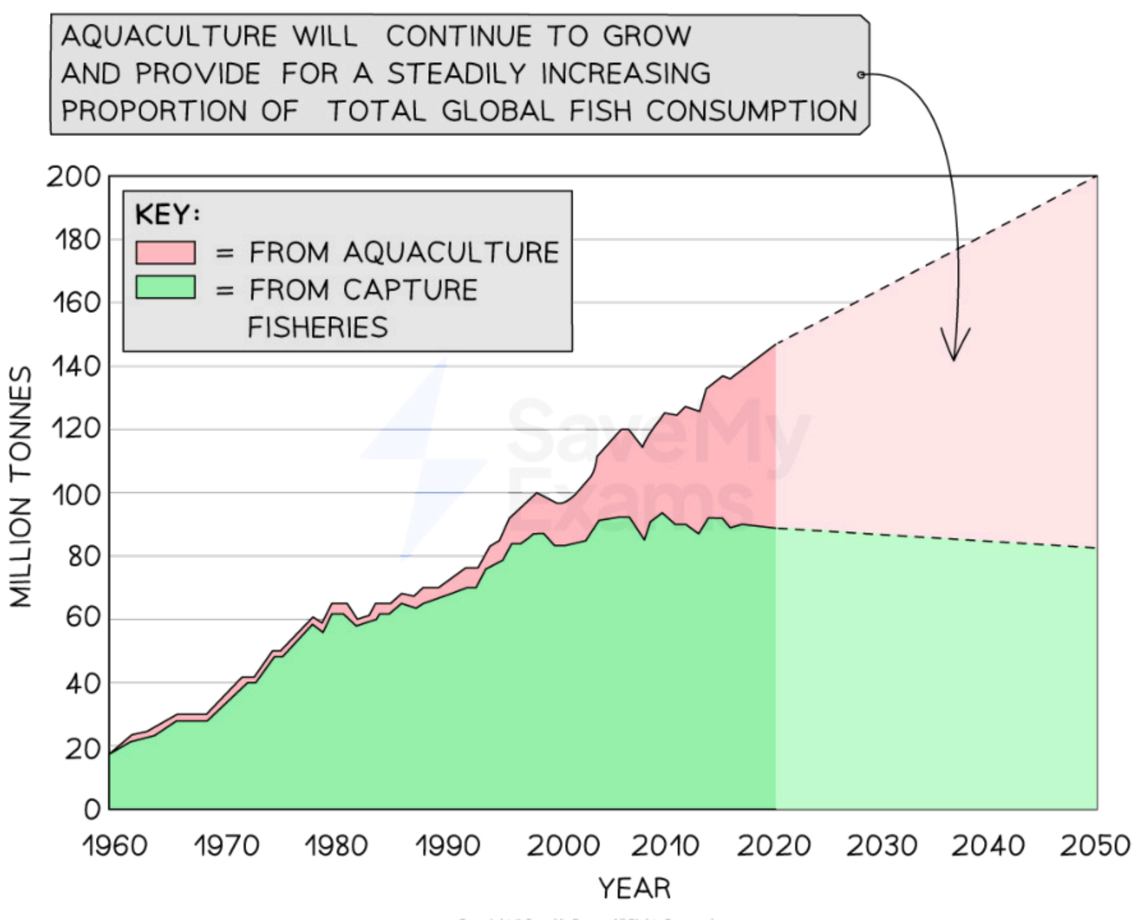
    - e.g. salmon, tilapia and catfish
- **Molluscs**
    - e.g. oysters, mussels, scallops and clams
    - e.g. snails
    - e.g. octopus and squid
- **Crustaceans**
    - e.g. shrimp, prawns, lobsters and crabs
- **Aquatic plants**
    - E.g. seaweed and algae

The growth of aquaculture



The growth of global aquaculture

Your notes

- Aquaculture has experienced significant growth to meet the increasing global demand for seafood
  - This is driven by population growth, changing dietary preferences and rising incomes
- Aquaculture has the potential to provide a reliable and sustainable source of seafood
  - This can help to meet the protein needs of a **growing population**
  - At the same time, minimise the impact on **wild fish stocks**
- By cultivating aquatic organisms through aquaculture, the pressure on wild fish populations can be reduced
  - This allows them to **recover** and the **ecological balance** of these marine ecosystems to be **restored**

1. Providing additional food resources:

- Aquaculture contributes to global food security by providing an additional source of nutritious food resources
- Cultivating fish and shellfish through aquaculture offers a **consistent supply** of **protein-rich** seafood
  - This can help address **nutritional deficiencies** and improve human health in many parts of the world
- The controlled environments of aquaculture systems allow for efficient production and reduced waste

2. Supporting economic development:

- Aquaculture has emerged as a significant sector in the global economy
  - It generates employment opportunities, income and economic growth
- It provides livelihoods for millions of people, particularly in coastal and rural communities, where fishing and aquaculture activities are integral to the **local economy**
- Aquaculture encourages trade and investments, contributing to the overall **development** and **prosperity** of regions and whole countries

Food for future generations

Your notes

A shrimp hatchery attempts to provide a sustainable source of seafood (Image from NOAA: public domain, via Wikimedia Commons)

- The growth of aquaculture is expected to continue in the coming years due to several factors:
  - **Rising global demand for seafood**: the growing population, urbanisation and changing dietary preferences drive the need for increased seafood production
  - **Technological advancements**: ongoing research and technological developments in aquaculture practices, breeding techniques, feed formulations and disease management are enhancing production efficiency and sustainability
  - **Environmental considerations**: aquaculture is evolving towards more environmentally friendly and sustainable practices, addressing concerns such as waste management and habitat impacts
  - **Innovation and diversification**: the development of new species for aquaculture, such as high-value fish and seaweed, opens up opportunities for market expansion
  - **Policy support**: governments and international organisations are promoting and investing in aquaculture development to address food security, reduce pressure on wild fish stocks and

Your notes

support economic growth

Aquaculture Issues

- Issues caused by aquaculture include:
  - Habitat loss
  - Pollution (with feed, antifouling agents, antibiotics and other medicines added to fish pens)
  - Spread of diseases
  - Escaped species (sometimes involving genetically modified organisms)
  - Ethical Issues and biorights

Issues in Aquaculture

Issue	Description
Habitat loss	Aquaculture facilities often require the **conversion of natural habitats** such as wetlands, mangroves, or coastal areas into fish farms These habitats are **cleared** or **modified** to create suitable spaces for aquaculture operations This habitat loss can have negative impacts on biodiversity, ecosystem functions and the livelihood of local communities
Pollution	**Excess nutrients** from uneaten feed and fish waste can leach into the surrounding water bodies, leading to **eutrophication**, algal blooms and **oxygen depletion** Some feed formulations may contain **additives,** such as growth enhancers or colourants, that can potentially negatively impact water quality Powerful chemicals known as **antifouling agents** are used to prevent the growth of marine organisms (e.g. mussels and barnacles) on aquaculture infrastructure These biocides can leach into the surrounding water, potentially causing harm to marine life To prevent and treat diseases, aquaculture operations may use **antibiotics** and **other medicines**, which can enter the surrounding waters, posing risks to aquatic organisms and contributing to antibiotic resistance
Spread of diseases	The **high density** of fish in aquaculture facilities facilitates the spread of diseases among farmed fish

Your notes

	This leads to increased disease risks and the need for **disease management strategies** If proper **biosecurity measures** are not in place, pathogens can also spread from aquaculture facilities to **wild fish populations**, impacting their health and survival
Escaped species	Escape of farmed fish from aquaculture facilities can lead to **genetic interactions** with **wild populations** This impacts wild species through competition, interbreeding, or transmission of genetic diseases Some aquaculture operations involve the use of **genetically modified fish** This raises concerns about potential ecological impacts and ethical considerations if these fish breed with wild populations
Ethical Issues and biorights	Aquaculture raises ethical questions regarding the **treatment** and **welfare** of farmed animals, particularly in **intensive** farming systems Concerns centre around the **confinement** and **stress** experienced by farmed species, the use of antibiotics and growth enhancers, and the overall quality of life for the animals

- In addition, issues in aquaculture can often arise regarding **international conservation legislation**
  - Aquaculture must comply with international conservation legislation and regulations to ensure the sustainable use of resources and to protect biodiversity
  - Compliance with these regulations helps **prevent** the **exploitation** of threatened species, maintain ecological balance and ensure the long-term viability of aquaculture practices
- Balancing environmental sustainability, animal welfare and legal obligations is crucial to maintaining an equitable and socially responsible aquaculture sector

Your notes

Climate Change & Ocean Acidification

What is climate change?

- Climate change refers to significant changes in **global temperatures** and **weather patterns** over time
  - Mostly driven by human activities such as burning fossil fuels, deforestation and industrial processes
  - Leads to global warming, which is an increase in Earth's average surface temperature

What is ocean acidification?

- Ocean acidification is the ongoing **decrease** in the **pH** of Earth's oceans
  - Caused by **absorption of excess carbon dioxide** (CO_2) from the atmosphere
  - When CO_2 dissolves in seawater, it forms carbonic acid, which lowers the pH

Impacts on ecosystems

Climate change effects

- **Temperature rise**:
  - Warmer waters can **alter habitat ranges** for marine species
    - For example, many fish populations are migrating to cooler waters, impacting local fishing industries
- **Melting ice caps**:
  - Polar ice is important for the **survival** of many species
    - For example, the loss of important ice habitats will affect polar bears and seals that need them for **hunting**, **avoiding predators** and **raising offspring**
    - Walruses are increasingly forced to rest on land, leading to **overcrowding** and **increased mortality**
  - Leads to sea level rise, threatening coastal ecosystems
    - For example, rising sea levels are threatening the coastal mangrove forests in Bangladesh, which serve as crucial habitats for many species and protect the coastline from erosion
- **Hurricane damage**:

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- Increased intensity and frequency of hurricanes is damaging coral reefs (e.g. in the Caribbean)
  - For example, hurricane Irma in 2017 caused widespread coral destruction, particularly affecting the coral reefs around the Florida Keys and the Virgin Islands

Ocean acidification effects

- **Coral bleaching**:
  - Warmer temperatures and acidification cause coral to expel the algae that live in their tissues
  - This causes the coral to turn white (known as bleaching)
  - This often leads to **coral death** if the stressful conditions persist
    - For example, the Great Barrier Reef is currently experiencing massive coral bleaching events
- **Shellfish vulnerability**:
  - Acidic waters **weaken** calcium carbonate shells of marine organisms like oysters, clams, and sea urchins
  - This makes them **more vulnerable** to predation, disease and environmental stress,
  - This can lead to **population declines** and **disruption of marine food webs**
    - For example, oyster populations in the Pacific Northwest (USA) are in decline partly due to ocean acidification
    - Oyster farms here are struggling with reduced harvests due to shell degradation

Case Study

The Great Barrier Reef

Location and importance

- Located off the coast of Queensland, Australia
- World's largest coral reef system is home to diverse marine life
- Supports tourism and fishing industries, crucial to the local economy

Stress factors

- **Coral bleaching events**:
  - Repeated bleaching events have caused significant damage
  - In 2016 and 2017, back-to-back bleaching events affected two-thirds of the reef
- **Rising sea temperatures**:

- Even very small increases in temperature can trigger bleaching events
- **Ocean acidification**:
  - This is weakening coral structures, making them more susceptible to erosion and breakage

Wider impacts on the ecosystem

- **Biodiversity loss**:
  - Coral reefs support many marine species
  - Coral bleaching leads to the loss of habitat and food sources for these organisms, resulting in decreased biodiversity
- **Fishing industry**:
  - The Great Barrier Reef supports commercial and recreational fishing industries
  - Coral bleaching reduces fish populations, affecting the livelihoods of local fishermen and the economy
- **Tourism**:
  - The reef is a major tourist attraction, bringing in millions of visitors annually
  - Bleached and dying corals reduce the aesthetic and ecological value of the reef
  - This leads to a drop in tourism revenue
    - For example, snorkelling and diving tours experience decreased interest as the vibrant coral ecosystems become bleached and lifeless
- **Coastal protection**:
  - Coral reefs act as natural barriers, protecting coastlines from storm surges and erosion
  - Damaged and weakened reefs are less effective at buffering waves, leading to increased vulnerability of coastal populations
    - For example, communities along the Queensland coast are facing higher risks of flooding and property damage due to weakened reef structures
- **Marine food web disruption**:
  - Coral reefs are integral to marine food webs
  - Bleaching disrupts these webs by removing key species and altering predator-prey relationships

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