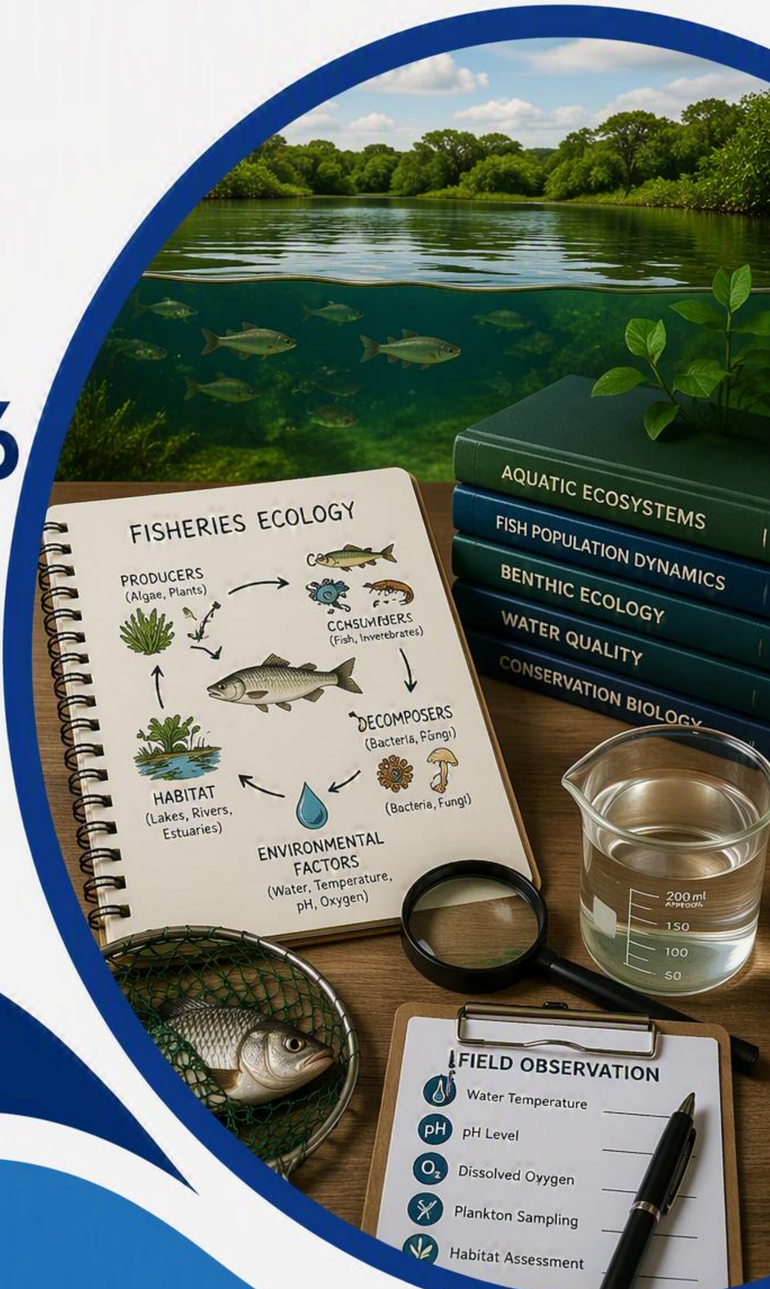
FAA 306

FISHERIES ECOLOGY



Course code: FAA 306

Course title: Fisheries Ecology

Course credit load: 2 Units

Series 1: Principles of Ecology and Ecological Processes

Part 1.1: Foundations of Ecology

Sub Part 1.1.1: Definition and scope of ecology

Sub Part 1.1.2: Principles of ecological organisation

Sub Part 1.1.3: Importance of ecology in fisheries

Part 1.2: Ecological Processes and Regulatory Factors

Sub Part 1.2.1: Energy flow and nutrient cycling

Sub Part 1.2.2: Primary production and regulatory factors

Sub Part 1.2.3: Role of abiotic and biotic factors

Part 1.3: Diversity and Abundance in Aquatic Systems

Sub Part 1.3.1: Fish diversity and ecological niches

Sub Part 1.3.2: Population dynamics and abundance

Sub Part 1.3.3: Habitat selection and adaptation

Part 1.4: Food Chains, Webs, and Trophic Relationships

Sub Part 1.4.1: Structure of food chains and webs

Sub Part 1.4.2: Trophic levels and energy transfer

Sub Part 1.4.3: Implications for fisheries ecology

Introduction

Ecology provides the foundation for understanding how living organisms interact with one another and with their environment. In fisheries, these ecological principles are particularly important because they explain the processes that regulate fish diversity, abundance, and survival. By studying ecological processes, learners gain insight into how energy flows through aquatic systems, how nutrients are cycled, and how both biotic and abiotic factors shape the distribution of species. This Series sets the stage for the rest of the course by equipping you with the ecological knowledge needed to interpret fisheries systems in Nigeria and beyond.

The aim of this Series is to introduce you to the fundamental principles of ecology and to explain the ecological processes that regulate fish populations and aquatic environments. It seeks to provide you with the skills to analyse ecological organisation, interpret diversity and abundance, and understand the role of food chains and webs in fisheries ecology.

We shall commence this Series by examining the foundations of ecology, including its definition, scope, and importance in fisheries. Next, we will explore ecological processes and regulatory factors, focusing on energy flow, nutrient cycling, and the role of biotic and abiotic influences. Following that, we will study diversity and abundance in aquatic systems, considering fish populations, niches, and habitat selection. Finally, we will conclude by analysing food chains, webs, and trophic relationships, highlighting their implications for fisheries ecology.

Series Learning Outcomes

Upon completing this Series, you should be able to:

SLO 1.1 define ecology and explain its scope in relation to fisheries (Linked to Part 1.1),

SLO 1.2 describe the principles of ecological organisation and their relevance to aquatic systems (Linked to Part 1.1),

SLO 1.3 explain the importance of ecology in fisheries management and resource sustainability (Linked to Part 1.1),

SLO 1.4 analyse ecological processes such as energy flow and nutrient cycling in aquatic environments (Linked to Part 1.2),

SLO 1.5 explain how primary production is regulated by abiotic and biotic factors (Linked to Part 1.2),

SLO 1.6 describe the role of biotic and abiotic factors in shaping fish diversity and abundance (Linked to Part 1.2),

SLO 1.7 identify patterns of fish diversity and ecological niches in aquatic systems (Linked to Part 1.3),

SLO 1.8 analyse population dynamics and factors influencing fish abundance (Linked to Part 1.3),

SLO 1.9 explain habitat selection and adaptation strategies of fish species (Linked to Part 1.3),

SLO 1.10 describe the structure of food chains and webs in aquatic ecosystems (Linked to Part 1.4),

SLO 1.11 explain trophic levels and energy transfer in fisheries ecology (Linked to Part 1.4), and

SLO 1.12 evaluate the implications of food chains and webs for fisheries management (Linked to Part 1.4).

1.1 Foundations Of Ecology

1.1.1 Definition and scope of ecology

Ecology is the scientific study of how organisms interact with one another and with their physical environment. It examines relationships at different levels, from individuals and populations to communities and ecosystems. The scope of ecology in fisheries is broad, as it helps us understand how fish species survive, reproduce, and thrive in aquatic systems. By studying ecology, we can interpret patterns of distribution, abundance, and the factors that regulate aquatic life.

Fill in the blank: Ecology is the scientific study of how organisms interact with one another and with their ______ environment.

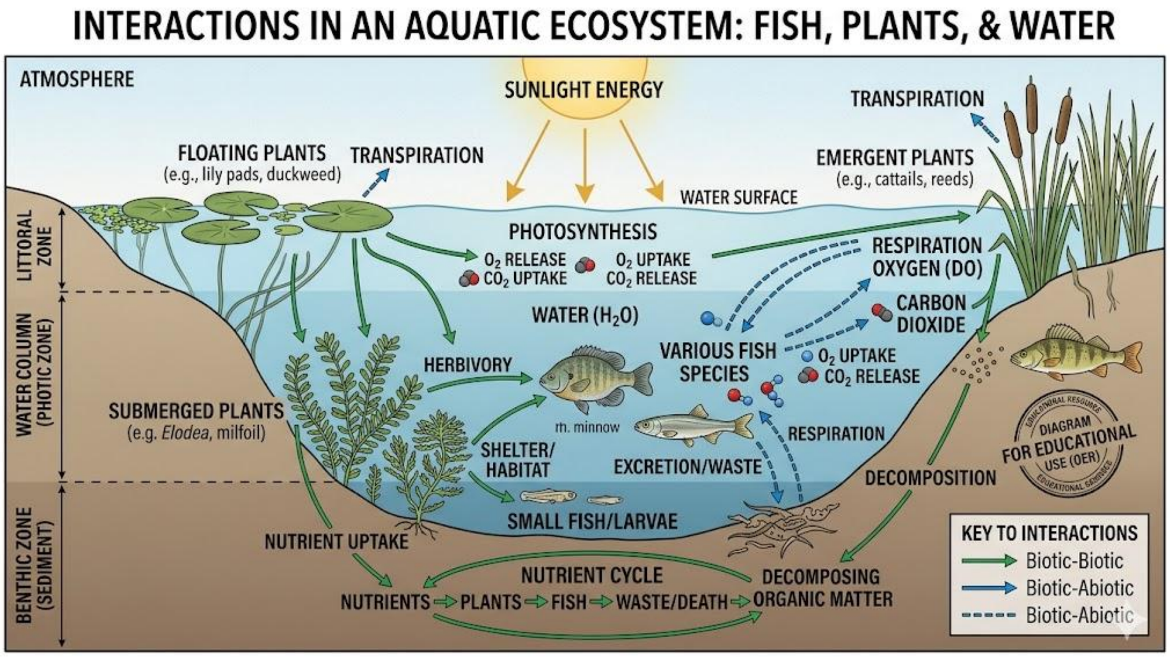


Figure 1.1 Organism–environment interactions in ecology

1.1.2 Principles of ecological organisation

Ecological organisation refers to the hierarchical structure of life within ecosystems. The main levels include **individuals** (single organisms), **populations** (groups of the same species), **communities** (different species living together), and **ecosystems** (communities interacting with their physical environment). Each level provides insights into how energy flows, how species interact, and how systems remain balanced. In fisheries, ecological organisation helps us analyse fish populations, their habitats, and the wider aquatic systems they depend on.

Fill in the blank: The four main levels of ecological organisation are individuals, populations, communities, and ______.

Level	Description
Individual	A single organism of a species (e.g., one fish, one tree).
Population	A group of individuals of the same species living in a defined area.
Community	Different populations of species interacting within the same environment.
Ecosystem	Communities interacting with their physical environment (biotic + abiotic factors).

Table 1.1 Levels of ecological organisation

1.1.3 Importance of ecology in fisheries

Ecology is important in fisheries because it provides the framework for managing aquatic resources sustainably. By applying ecological principles, managers can predict how fish populations respond to environmental changes, regulate fishing practices, and maintain biodiversity. For example, understanding food webs helps identify the impact of removing certain species, while knowledge of population dynamics guides decisions on fishing quotas. In Nigeria, ecological studies are essential for balancing artisanal and industrial fisheries, ensuring long-term productivity.

Fill in the blank: Ecology helps fisheries managers regulate fishing practices and maintain ______.

Key Point	**Explanation**
Sustainability	Ecological knowledge ensures fishing practices maintain long-term stock health and resource availability.
Biodiversity	Protects diverse species and habitats, reducing risks of ecosystem imbalance.
Regulation	Provides the scientific basis for rules such as gear restrictions, closed seasons, and quotas.
Productivity	Healthy ecosystems support higher yields and stable fisheries, benefiting communities and economies.
Resilience	Understanding ecological interactions helps fisheries adapt to environmental changes and climate impacts.

Box 1.1 Importance of ecology in fisheries

Pilot questions 1.1

Define ecology and explain its scope in fisheries.

List the four main levels of ecological organisation.

State one reason why ecology is important in fisheries management.

Give one example of how ecological knowledge can guide fishing practices.

Explain how ecological organisation helps in analysing fish populations.

1.2 Ecological Processes And Regulatory Factors

1.2.1 Energy flow and nutrient cycling

Energy flow refers to the movement of energy through an ecosystem, beginning with producers such as algae and aquatic plants, which capture solar energy through photosynthesis. This energy is then transferred to consumers like herbivorous and carnivorous fish, and finally to decomposers that recycle nutrients back into the system. **Nutrient cycling** is the continuous movement of essential elements such as carbon, nitrogen, and phosphorus within ecosystems. Together, energy flow and nutrient cycling maintain balance and productivity in aquatic environments.

Fill in the blank: Energy flow begins with producers such as ______ and aquatic plants.

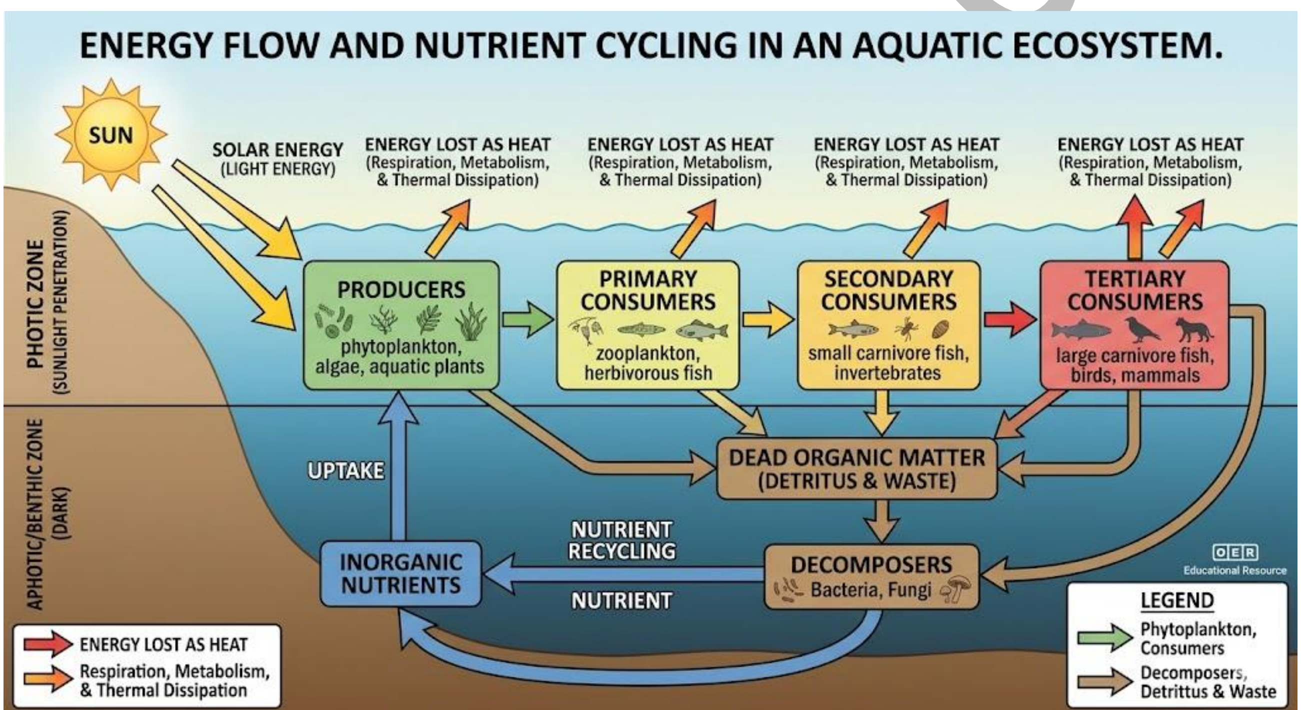


Figure 1.2 Energy flow and nutrient cycling in aquatic ecosystems

1.2.2 Primary production and regulatory factors

Primary production is the rate at which producers, mainly algae and aquatic plants, convert solar energy into organic matter. This process forms the basis of aquatic food webs. Regulatory factors include **abiotic factors** such as light, temperature, and nutrient availability, and **biotic factors** such as grazing pressure from herbivores. When conditions are optimal, primary production increases, supporting higher fish abundance. Conversely, poor conditions can limit productivity and reduce fish populations.

Fill in the blank: Primary production is the rate at which producers convert ______ energy into organic matter.

Plate 1.1 Algal growth as primary production

1.2.3 Role of abiotic and biotic factors

Abiotic factors are non-living components of the environment, such as water temperature, salinity, pH, and dissolved oxygen, which directly influence fish survival and distribution. **Biotic factors** are living components, including predators, competitors, and prey species, which shape ecological interactions. Both sets of factors work together to regulate fish diversity and abundance. For example, low oxygen levels may limit fish populations, while high predation pressure can reduce abundance even in favourable physical conditions.

Fill in the blank: Temperature, salinity, and dissolved oxygen are examples of ______ factors.

Factor Type	Examples	Explanation
Abiotic	Temperature, salinity, oxygen	Physical and chemical conditions that influence fish survival, growth, and distribution.
Abiotic	Light, nutrients, pH	Affect primary productivity and habitat suitability for aquatic organisms.

Factor Type	Examples	Explanation
Biotic	Predators, competitors, prey	Biological interactions that shape population dynamics and community structure.
Biotic	Parasites, symbionts	Influence fish health, reproduction, and resilience in ecosystems.

Box 1.2 Abiotic and biotic factors in aquatic ecosystems

Pilot questions 1.2

Define energy flow and nutrient cycling in aquatic ecosystems.

Explain the importance of primary production in fisheries ecology.

Identify two abiotic factors that influence fish survival.

Give one example of a biotic factor affecting fish abundance.

Discuss how abiotic and biotic factors interact to regulate fish populations.

1.3 Diversity And Abundance In Aquatic Systems

1.3.1 Fish diversity and ecological niches

Fish diversity refers to the variety of fish species found within aquatic ecosystems. This diversity is shaped by environmental conditions, food availability, and ecological interactions. Each species occupies a specific **ecological niche**, which is its role in the ecosystem, including its feeding habits, habitat preference, and interactions with other species. High diversity often indicates a healthy ecosystem, while reduced diversity may signal environmental stress or overfishing.

Fill in the blank: The role of a species in its ecosystem, including feeding and habitat preference, is called its ecological ______.

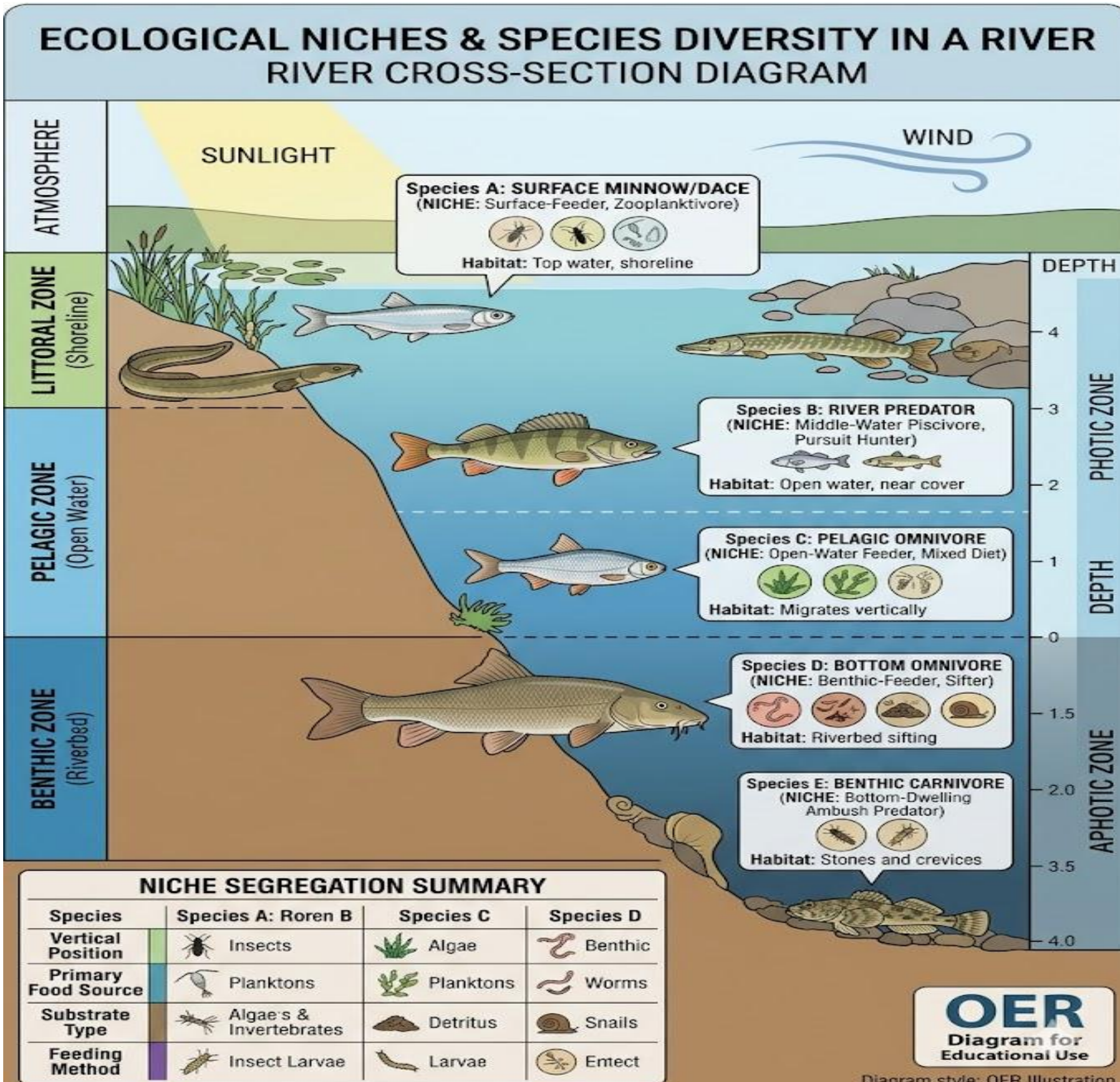


Figure 1.3 Fish diversity and ecological niches

1.3.2 Population dynamics and abundance

Population dynamics describe how fish populations change over time due to births, deaths, immigration, and emigration. **Abundance** refers to the number of individuals of a species present in a given area. These factors are influenced by environmental conditions, food supply, predation, and human activities such as fishing. Understanding population dynamics helps fisheries managers predict stock levels and set sustainable harvest limits.

Fill in the blank: The number of individuals of a species present in a given area is referred to as its ______.

Factor	Description
Births	Addition of new individuals through reproduction, increasing population size.
Deaths	Loss of individuals due to natural causes, predation, or fishing, reducing population size.
Immigration	Movement of individuals into a population from other areas, boosting local numbers.
Emigration	Movement of individuals out of a population to other areas, lowering local numbers.
Human activities	Fishing pressure, habitat alteration, pollution, and management practices that directly or indirectly affect population dynamics.

Table 1.2 Factors influencing fish population dynamics

1.3.3 Habitat selection and adaptation

Habitat selection is the process by which fish choose environments that best support their survival and reproduction. Factors such as water temperature, oxygen levels, and food availability influence this choice. **Adaptation** refers to the physiological and behavioural changes that enable fish to thrive in specific habitats. For example, some species adapt to low-oxygen environments by developing specialised breathing structures, while others migrate seasonally to exploit different habitats.

Fill in the blank: Physiological and behavioural changes that enable fish to thrive in specific habitats are called ______.

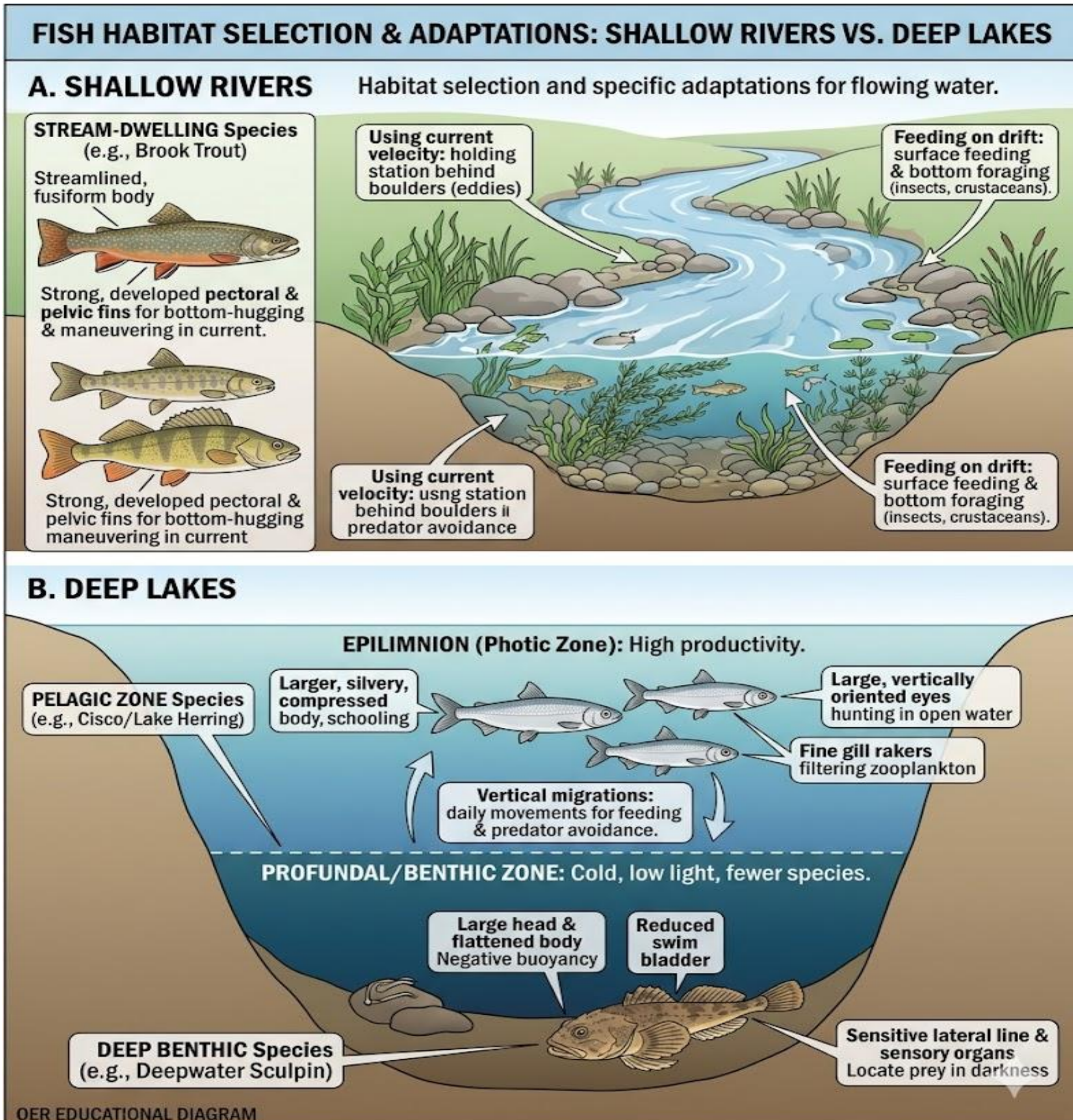


Plate 1.2 Fish habitat selection and adaptation

Pilot questions 1.3

Define fish diversity and explain its importance in aquatic ecosystems.

What is meant by an ecological niche?

Identify two factors that influence fish population dynamics.

Explain the difference between abundance and population dynamics.

Give one example of how fish adapt to their habitat.

1.4 Food Chains, Webs, And Trophic Relationships

1.4.1 Structure of food chains and webs

A **food chain** is a linear sequence showing how energy and nutrients pass from one organism to another, beginning with producers and ending with top predators. In aquatic ecosystems, algae and plankton often form the base of the chain, followed by small fish, larger fish, and eventually humans as apex consumers. A **food web** is more complex, illustrating the interconnected feeding relationships among multiple species. Food webs provide a more realistic picture of energy flow in ecosystems, as most organisms feed on more than one type of prey.

Fill in the blank: A food chain is a linear sequence of energy transfer, while a food ______ shows interconnected feeding relationships.

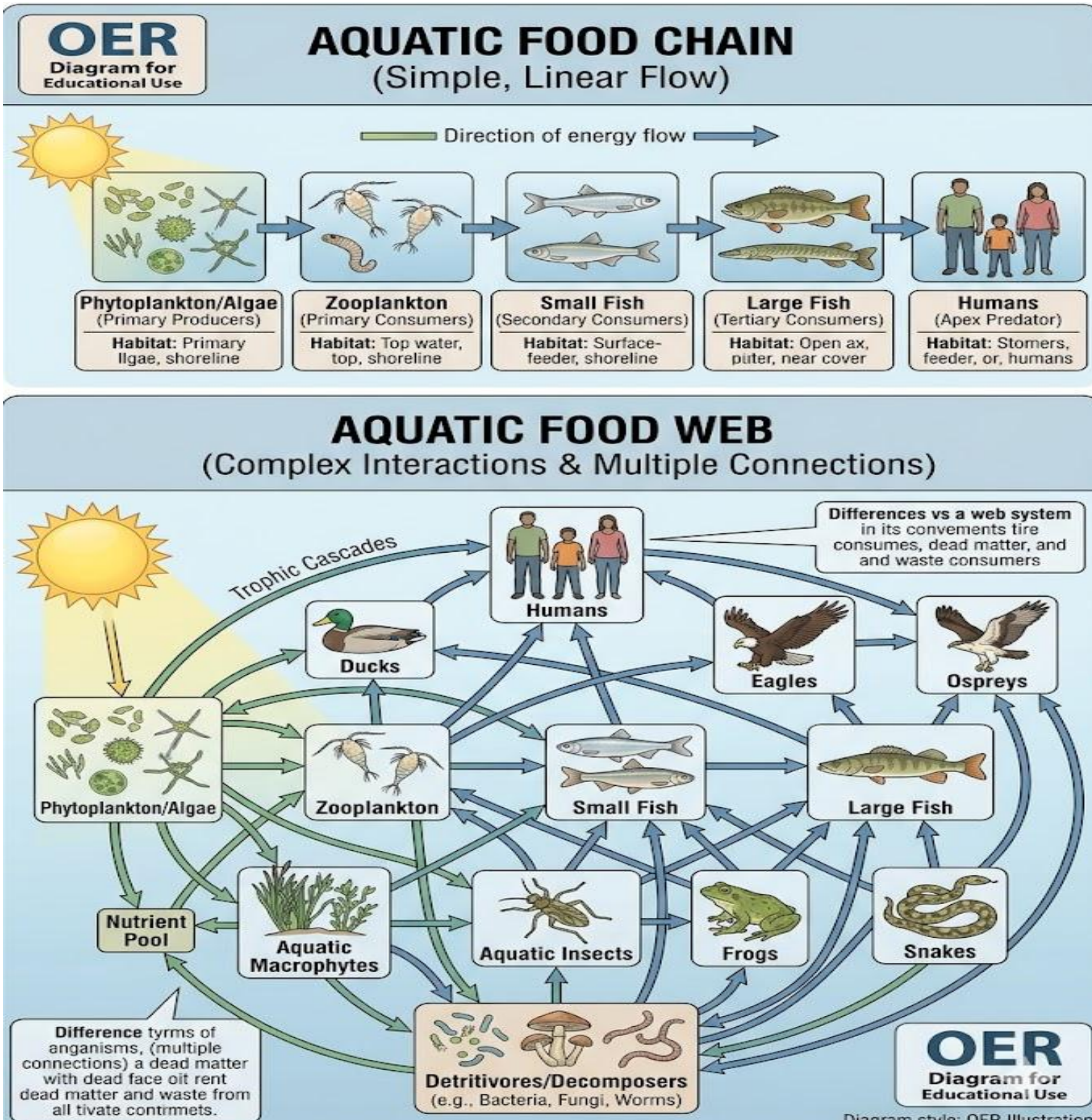


Figure 1.4 Food chains and food webs in aquatic ecosystems

1.4.2 Trophic levels and energy transfer

Trophic levels are the positions organisms occupy in a food chain or web. Producers form the first trophic level, herbivores the second, carnivores the third, and so on. Energy transfer between trophic levels is inefficient, with only about 10 percent of energy passed on to the next level. This inefficiency explains why food chains are usually short and why top predators are fewer in number. In fisheries, understanding trophic levels helps predict how harvesting one species may affect others in the ecosystem.

Fill in the blank: Only about ______ percent of energy is transferred from one trophic level to the next.

Trophic Level	Examples	Description
Producers	Algae, phytoplankton, aquatic plants	Base of the food web; convert sunlight and nutrients into energy through photosynthesis.
Herbivores	Zooplankton, small crustaceans	Feed directly on producers, transferring energy to higher levels.
Carnivores	Small and medium-sized fish	Consume herbivores, forming intermediate levels in the food chain.
Apex predators	Large fish, birds, humans	Top of the food web; regulate populations of lower trophic levels.

Table 1.3 Trophic levels in aquatic ecosystems

1.4.3 Implications for fisheries ecology

Food chains and webs have significant implications for fisheries ecology. Overharvesting of one species can disrupt energy flow and destabilise the ecosystem. For example, removing too many herbivorous fish may lead to algal overgrowth, while reducing predator populations can cause prey species to multiply excessively. By studying trophic relationships, fisheries managers can design strategies that maintain ecological balance and ensure sustainable yields.

Fill in the blank: Overharvesting of one species can disrupt ______ flow and destabilise the ecosystem.

Implication	Explanation
Overharvesting	Removing too many individuals at one trophic level can disrupt food chains and reduce stock resilience.
Ecological balance	Maintaining predator-prey relationships ensures stable fish populations and healthy ecosystems.
Sustainability	Understanding food webs helps design fishing practices that preserve long-term productivity.
Bycatch considerations	Non-target species play roles in food webs; their removal can alter ecosystem dynamics.
Management decisions	Knowledge of trophic interactions informs quotas, gear restrictions, and conservation measures.

Box 1.3 Implications of food chains and webs for fisheries

Pilot questions 1.4

Distinguish between a food chain and a food web.

Define trophic levels and give one example from aquatic ecosystems.

Explain why energy transfer between trophic levels is inefficient.

State one implication of food chains and webs for fisheries ecology.

Give an example of how overharvesting affects ecosystem balance.

Series Summary

This Series has introduced you to the foundations of ecology and its relevance to fisheries. We began by defining ecology and exploring its scope, before moving on to the principles of ecological organisation, which highlighted the hierarchical levels of individuals, populations, communities, and ecosystems. We then examined ecological processes such as energy flow and nutrient cycling, followed by primary production and the regulatory role of abiotic and biotic factors. The Series continued with an exploration of fish diversity, population dynamics, and habitat adaptation, and concluded with food chains, webs, and trophic relationships, emphasising their implications for fisheries ecology.

By completing this Series, you should now be able to define ecology and explain its scope, describe ecological organisation, analyse energy flow and nutrient cycling, explain primary production and regulatory factors, identify fish diversity and niches, analyse population dynamics, explain habitat selection and adaptation, and evaluate the role of food chains and webs in fisheries management. These abilities directly align with the Series Learning Outcomes (SLOs) and provide you with a strong ecological foundation for understanding fisheries systems and their sustainable management.

Glossary of Terms

Abiotic factors: Non-living components of the environment, such as temperature, salinity, pH, and dissolved oxygen, which influence fish survival and distribution.

Adaptation: Physiological or behavioural changes that enable organisms to survive and reproduce in specific habitats.

Biotic factors: Living components of the environment, including predators, competitors, and prey species, which shape ecological interactions.

Ecological niche: The role of a species within its ecosystem, including its feeding habits, habitat preference, and interactions with other organisms.

Ecological organisation: The hierarchical structure of life within ecosystems, consisting of individuals, populations, communities, and ecosystems.

Ecology: The scientific study of how organisms interact with one another and with their physical environment.

Energy flow: The movement of energy through an ecosystem, beginning with producers and passing through consumers to decomposers.

Fish diversity: The variety of fish species found within aquatic ecosystems, often used as an indicator of ecosystem health.

Food chain: A linear sequence showing how energy and nutrients pass from one organism to another.

Food web: A complex network of interconnected feeding relationships among multiple species in an ecosystem.

Habitat selection: The process by which organisms choose environments that best support their survival and reproduction.

Population dynamics: The study of how populations change over time due to births, deaths, immigration, and emigration.

Primary production: The rate at which producers, such as algae and aquatic plants, convert solar energy into organic matter.

Trophic levels: The positions organisms occupy in a food chain or web, such as producers, herbivores, carnivores, and apex predators.

Nutrient cycling: The continuous movement of essential elements like carbon, nitrogen, and phosphorus within ecosystems.

Concept Check Questions [Series 1]

Objective Questions

Define ecology. (Linked to SLO 1.1)

Which of the following is not a level of ecological organisation?
a) Individual
b) Population
c) Atmosphere
d) Community (Linked to SLO 1.2)

Primary production in aquatic ecosystems is mainly carried out by:
a) Carnivorous fish
b) Algae and aquatic plants

c) Zooplankton
d) Humans (Linked to SLO 1.5)

Only about ______ percent of energy is transferred from one trophic level to the next. (Linked to SLO 1.11)

Abiotic factors such as temperature and dissolved oxygen directly influence fish ______. (Linked to SLO 1.6)

Short-Answer Questions

Explain the importance of ecology in fisheries management. (Linked to SLO 1.3)

Describe how nutrient cycling supports aquatic ecosystems. (Linked to SLO 1.4)

Identify two factors that influence fish population dynamics. (Linked to SLO 1.8)

What is meant by an ecological niche? (Linked to SLO 1.7)

Give one example of how habitat adaptation enables fish survival. (Linked to SLO 1.9)

Long-Answer Questions

Analyse the role of abiotic and biotic factors in regulating fish diversity and abundance. (Linked to SLO 1.6, SLO 1.8)

Evaluate the implications of food chains and webs for fisheries ecology, using examples to illustrate your points. (Linked to SLO 1.10, SLO 1.12)

Discuss how energy flow and trophic levels influence the sustainability of fisheries. (Linked to SLO 1.4, SLO 1.11)

Answers to Concept Check Questions [Series 1]

Objective Questions

Ecology is the scientific study of how organisms interact with one another and with their physical environment.

Correct answer: c) Atmosphere.

Correct answer: b) Algae and aquatic plants.

10 percent.

Survival.

Short-Answer Questions

Ecology helps fisheries managers regulate fishing practices, maintain biodiversity, and ensure sustainability.

Nutrient cycling recycles essential elements like carbon and nitrogen, supporting continuous productivity in aquatic ecosystems.

Births, deaths, immigration, emigration, and human activities such as fishing.

An ecological niche is the role of a species in its ecosystem, including feeding habits and habitat preference.

For example, some fish adapt to low-oxygen environments by developing specialised breathing structures.

Long-Answer Questions

Basic response: Abiotic factors such as temperature and oxygen levels influence fish survival, while biotic factors like predation and competition affect abundance.
Value-added response: In addition, abiotic and biotic factors interact. For instance, favourable abiotic conditions may still result in low abundance if predation pressure is high. Conversely, poor abiotic conditions can limit populations even when biotic interactions are minimal.

Basic response: Food chains and webs show how energy flows through ecosystems. Overharvesting one species can disrupt this balance.
Value-added response: For example, removing herbivorous fish may cause algal blooms, while reducing predator populations can lead to prey overpopulation. These disruptions highlight the need for fisheries management strategies that maintain ecological balance.

Basic response: Energy flow through trophic levels is inefficient, with only 10 percent transferred to the next level, limiting the length of food chains.
Value-added response: This inefficiency explains why apex predators are fewer and why fisheries must manage energy flow carefully. Sustainable practices ensure that lower trophic levels remain productive, supporting the entire ecosystem.

Answers to Pilot Questions [Series 1]

Part 1.1: Foundations of Ecology

Ecology is the scientific study of how organisms interact with one another and with their physical environment.

The four main levels of ecological organisation are individuals, populations, communities, and ecosystems.

Ecology is important in fisheries management because it helps regulate fishing practices and maintain biodiversity.

Ecological knowledge can guide fishing practices by predicting how fish populations respond to environmental changes.

Ecological organisation helps in analysing fish populations by showing their place within communities and ecosystems.

Part 1.2: Ecological Processes and Regulatory Factors

Energy flow is the movement of energy through an ecosystem, while nutrient cycling is the recycling of essential elements like carbon and nitrogen.

Primary production is important because it forms the basis of aquatic food webs and supports fish abundance.

Two abiotic factors that influence fish survival are temperature and dissolved oxygen.

One biotic factor affecting fish abundance is predation.

Abiotic and biotic factors interact to regulate fish populations, for example favourable abiotic conditions may still result in low abundance if predation pressure is high.

Part 1.3: Diversity and Abundance in Aquatic Systems

Fish diversity refers to the variety of fish species in aquatic ecosystems and is important as an indicator of ecosystem health.

An ecological niche is the role of a species in its ecosystem, including feeding habits and habitat preference.

Two factors that influence fish population dynamics are food supply and fishing activities.

Abundance is the number of individuals of a species present in a given area, while population dynamics describes how populations change over time.

One example of adaptation is fish developing specialised breathing structures to survive in low-oxygen environments.

Part 1.4: Food Chains, Webs, and Trophic Relationships

A food chain is a linear sequence of energy transfer, while a food web shows interconnected feeding relationships.

Trophic levels are the positions organisms occupy in a food chain or web, for example producers such as algae.

Energy transfer between trophic levels is inefficient because only about 10 percent of energy is passed on to the next level.

One implication of food chains and webs for fisheries ecology is that overharvesting can disrupt ecological balance.

Overharvesting herbivorous fish can lead to algal blooms, while reducing predator populations can cause prey overpopulation.

References and Attributions [Series 1]

Textual References (Books and External Sources)

Odum, E. P., & Barrett, G. W. (2005). *Fundamentals of Ecology* (5th ed.). Brooks Cole.

Begon, M., Townsend, C. R., & Harper, J. L. (2006). *Ecology: From individuals to ecosystems* (4th ed.). Blackwell Publishing.

Allan, J. D., & Castillo, M. M. (2007). *Stream ecology: Structure and function of running waters* (2nd ed.). Springer.

FAO (Food and Agriculture Organization of the United Nations). (2018). *Fishing gear types*. FAO Fisheries and Aquaculture Department.

Welcomme, R. L. (2001). *Inland fisheries: Ecology and management*. Oxford: Blackwell Science.

Figures, Plates, Tables, and Boxes

Figure 1.1: Organism–environment interactions in ecology
Attribution: AI generated using prompt "Generate a diagram showing fish, plants, and water interacting in an aquatic ecosystem."
Suggested OER search string: "ecology organism environment interaction diagram OER".

Table 1.1: Levels of ecological organisation
Attribution: AI generated using prompt "Generate a table listing levels of ecological organisation: individual, population, community, ecosystem, with short notes."
Suggested OER search string: "levels of ecological organisation table OER".

Box 1.1: Importance of ecology in fisheries
Attribution: AI generated using prompt "Generate a text box listing importance of ecology in fisheries: sustainability, biodiversity, regulation, productivity."
Suggested OER search string: "importance of ecology fisheries management OER".

Figure 1.2: Energy flow and nutrient cycling in aquatic ecosystems
Attribution: AI generated using prompt "Generate a diagram showing energy flow in an aquatic ecosystem, with producers, consumers, and decomposers linked by arrows."
Suggested OER search string: "energy flow nutrient cycling aquatic ecosystem diagram OER".

Plate 1.1: Algal growth as primary production
Attribution: AI generated using prompt "Generate an image of algae growth in a pond representing primary production."
Suggested OER search string: "algae growth pond primary production OER image".

Box 1.2: Abiotic and biotic factors in aquatic ecosystems
Attribution: AI generated using prompt "Generate a text box listing abiotic factors (temperature, salinity, oxygen) and biotic factors (predators, competitors, prey)."
Suggested OER search string: "abiotic biotic factors aquatic ecosystems OER".

Figure 1.3: Fish diversity and ecological niches
Attribution: AI generated using prompt "Generate a diagram showing multiple fish species in a river, each occupying different ecological niches."
Suggested OER search string: "fish diversity ecological niches diagram OER".

Table 1.2: Factors influencing fish population dynamics
Attribution: AI generated using prompt "Generate a table listing factors influencing fish population dynamics: births, deaths, immigration, emigration, human activities."
Suggested OER search string: "fish population dynamics factors table OER".

Plate 1.2: Fish habitat selection and adaptation
Attribution: AI generated using prompt "Generate an image showing fish species adapted to shallow rivers and deep lakes, highlighting habitat selection."
Suggested OER search string: "fish habitat selection adaptation OER image".

Figure 1.4: Food chains and food webs in aquatic ecosystems
Attribution: AI generated using prompt "Generate a diagram showing an aquatic food chain with algae, small fish, large fish, and humans, alongside a food web with multiple connections."
Suggested OER search string: "aquatic food chain food web diagram OER".

Table 1.3: Trophic levels in aquatic ecosystems
Attribution: AI generated using prompt "Generate a table listing trophic levels in aquatic ecosystems with examples: producers (algae), herbivores (zooplankton), carnivores (fish), apex predators (humans)."
Suggested OER search string: "trophic levels aquatic ecosystems table OER".

Box 1.3: Implications of food chains and webs for fisheries
Attribution: AI generated using prompt "Generate a text box listing implications of food chains and webs for fisheries ecology, including overharvesting, ecological balance, and sustainability."
Suggested OER search string: "food chains webs fisheries ecology implications OER".

Course code: FAA 306

Course title: Fisheries Ecology

Course credit load: 2 Units

Series 2: Fish Diversity, Abundance, and Population Ecology

Series outline

Part 2.1: Fish Diversity in Aquatic Ecosystems

Sub Part 2.1.1: Patterns of fish diversity

Sub Part 2.1.2: Factors influencing fish diversity

Sub Part 2.1.3: Fish diversity in Nigeria

Part 2.2: Fish Abundance and Distribution

Sub Part 2.2.1: Concept of fish abundance

Sub Part 2.2.2: Biotic and abiotic determinants of abundance

Sub Part 2.2.3: Species distribution and range limits

Part 2.3: Population Ecology of Fish

Sub Part 2.3.1: Structure and dynamics of fish populations

Sub Part 2.3.2: Growth, mortality, and recruitment

Sub Part 2.3.3: Population regulation and carrying capacity

Part 2.4: Ecological Niche and Habitat in Fisheries

Sub Part 2.4.1: The niche concept in fish ecology

Sub Part 2.4.2: Habitat selection and microhabitat use

Sub Part 2.4.3: Niche overlap, competition, and coexistence

Introduction

In the previous Series, we established the fundamental principles of ecology and the ecological processes that regulate aquatic systems. This Series builds directly on those foundations by focusing on the fish themselves: the diversity of species found in aquatic environments, the factors that determine how many individuals are present, and the ecological mechanisms that govern fish populations over time.

The aim of this Series is to examine fish diversity, abundance, and population ecology in depth, equipping you with the knowledge to understand how and why fish species are distributed as they are, what regulates their numbers, and how the ecological niche concept explains coexistence and competition in aquatic systems.

We shall commence this Series by exploring patterns of fish diversity and the factors that shape them, with specific reference to Nigeria. Next, we will examine the concept of fish abundance and the biotic and abiotic factors that determine where and how many fish occur. Following that, we will study the structure and dynamics of fish populations, including growth, mortality, recruitment, and carrying capacity. Finally, we will wrap up with the ecological niche concept, habitat selection, and the role of niche overlap in competition and coexistence.

Series Learning Outcomes

Upon completing this Series, you should be able to:

SLO 2.1 describe the patterns of fish diversity in aquatic ecosystems and the factors that shape them (Linked to Part 2.1),

SLO 2.2 explain the distribution of fish diversity in Nigerian aquatic systems (Linked to Part 2.1),

SLO 2.3 define fish abundance and explain the biotic and abiotic factors that determine it (Linked to Part 2.2),

SLO 2.4 describe the limits on species distribution and range (Linked to Part 2.2),

SLO 2.5 explain the structure and dynamics of fish populations including growth, mortality, and recruitment (Linked to Part 2.3),

SLO 2.6 analyse the concept of population regulation and carrying capacity in fisheries ecology (Linked to Part 2.3),

SLO 2.7 define the ecological niche and explain its relevance to fish ecology (Linked to Part 2.4),

SLO 2.8 describe how fish select habitats and use microhabitats (Linked to Part 2.4), and

SLO 2.9 explain how niche overlap, competition, and coexistence shape fish community structure (Linked to Part 2.4).

2.1 Fish Diversity in Aquatic Ecosystems

2.1.1 Patterns of fish diversity

Fish diversity refers to the variety of fish species present in an aquatic ecosystem and is one of the most widely used indicators of ecosystem health and complexity. Globally, fish represent the most species-rich group of vertebrates, with more than 35,000 recognised species inhabiting freshwater, marine, and brackish environments. Diversity patterns are not uniform; they vary with latitude, altitude, habitat type, and the historical processes that shaped each water body.

Species richness, the number of species in a defined area, tends to be highest in tropical regions and declines towards the poles. In freshwater systems, large, well-connected river basins such as the Amazon and the Congo support extraordinary species richness. In marine systems, coral reef ecosystems are the most diverse, hosting thousands of fish species within relatively small geographic areas. These spatial patterns of diversity reflect the combined influence of climate, habitat productivity, and evolutionary history.

Fill in the blank: Species richness, the number of species in a defined area, tends to be highest in ________ regions and declines towards the poles.

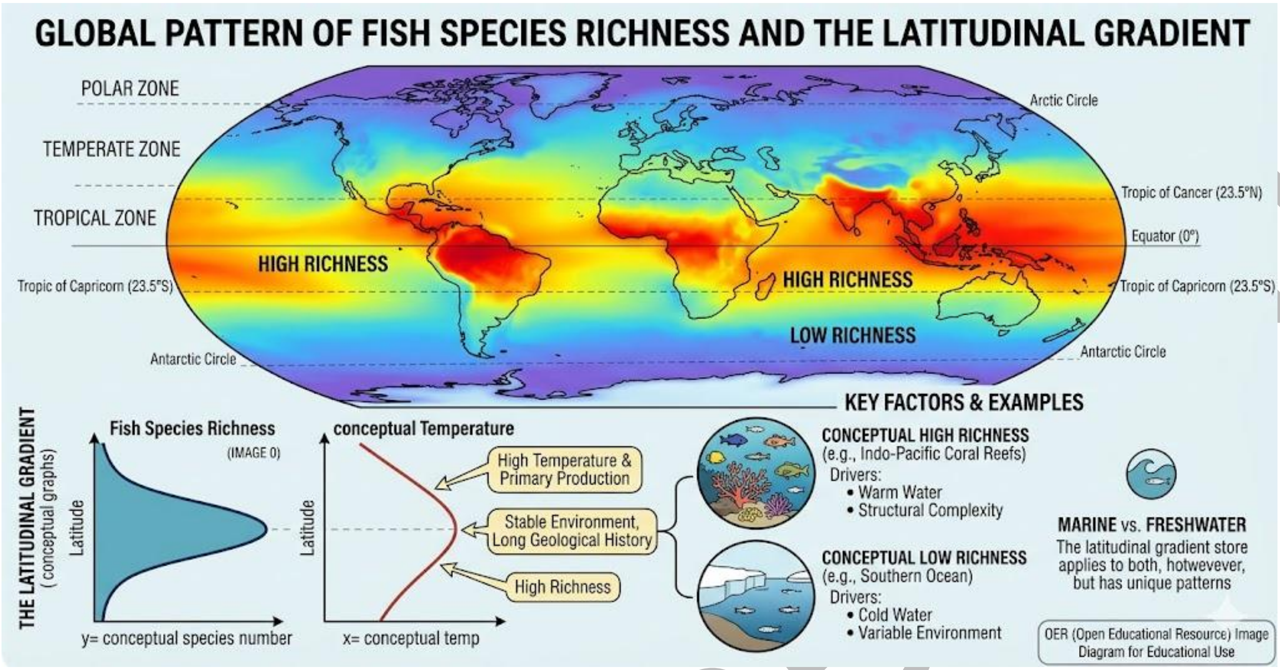


Figure 2.1: Global patterns of fish species richness showing latitudinal gradient from tropics to poles

2.1.2 Factors influencing fish diversity

Environmental factors are the primary drivers of fish diversity. Water temperature influences metabolic rates and sets physiological limits on species ranges, with warm tropical waters supporting greater metabolic diversity than cold polar ones. Habitat complexity, including the diversity of substrates, vegetation types, and structural features such as rocks and woody debris, provides more ecological niches and therefore supports more species.

Water chemistry, particularly pH, salinity, dissolved oxygen, and nutrient levels, further filters which species can survive in a given environment. Historical factors also play a role; water bodies that have been isolated for long periods tend to develop endemic species through speciation, while those that are geologically young or frequently disturbed typically support fewer species. Human activities including pollution, dam construction, habitat destruction, and the introduction of invasive species are among the most important contemporary drivers of fish diversity loss.

Fill in the blank: Habitat _________, including diversity of substrates and vegetation types, provides more ecological niches and supports greater fish diversity.

Factor Type	Examples	Explanation
Environmental	Temperature, habitat complexity, water chemistry, oxygen levels	Physical and chemical conditions shape species distribution, survival, and reproduction.

Factor Type	Examples	Explanation
Historical	Geological events, isolation, evolutionary history	Past isolation and evolutionary processes determine species richness and endemism.
Human activities	Fishing pressure, pollution, habitat alteration, introduction of exotic species	Directly impact fish diversity by altering ecosystems and reducing native populations.

Box 2.1: Key factors influencing fish diversity in aquatic ecosystems

2.1.3 Fish diversity in Nigeria

Nigeria is one of the most fish-diverse countries in Africa, reflecting its vast and varied aquatic resources. The country's major freshwater systems include the Niger and Benue rivers and their tributaries, Lake Chad, the Cross River basin, and numerous inland lakes and floodplains. These systems collectively support hundreds of fish species, including commercially important groups such as cichlids, characins, mormyrids, and catfishes.

Nigeria's coastal and marine waters, spanning the Gulf of Guinea, support additional diversity including both pelagic species such as sardinellas and bonga, and demersal species such as croakers and snappers. The freshwater-marine transition zones in the Niger Delta and estuaries of the Cross River and other coastal rivers create unique ecological conditions that support estuarine-adapted species. Nigeria's fish diversity makes its aquatic systems a critical resource for food security, livelihoods, and biodiversity conservation.

Fill in the blank: Nigeria's major freshwater systems include the Niger and Benue rivers, Lake Chad, and the ________ River basin.

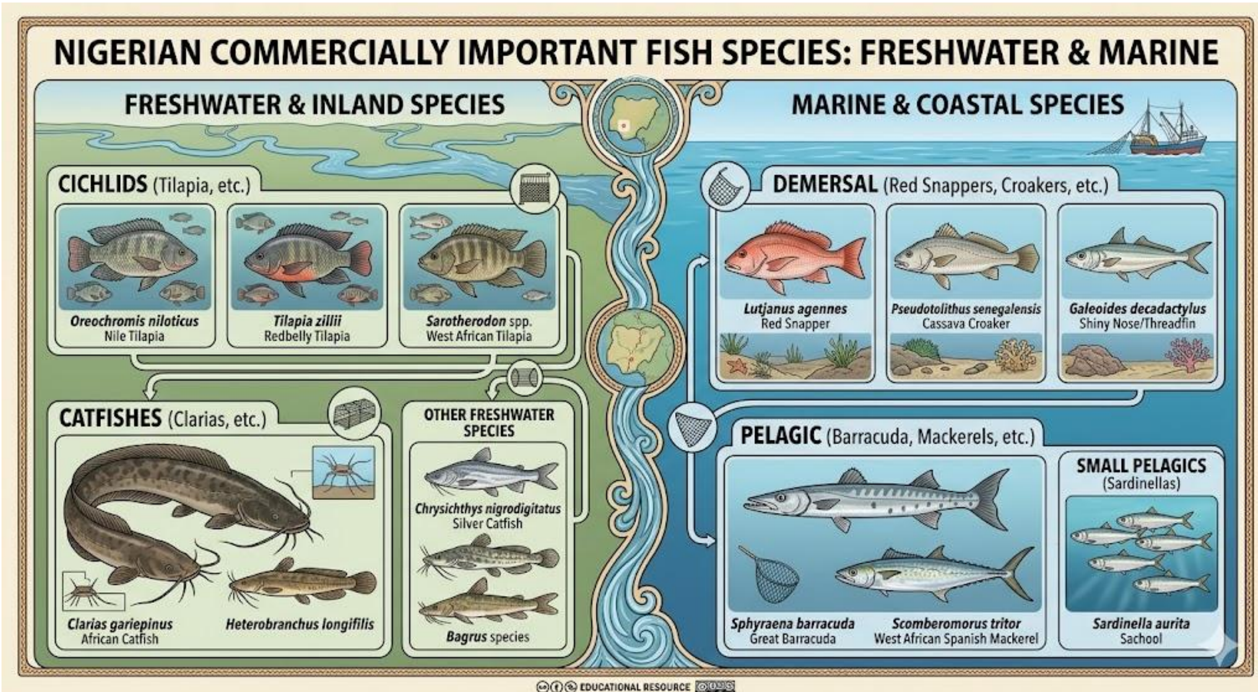


Plate 2.1: Selected commercially important fish species found in Nigerian freshwater and coastal systems

Pilot questions 2.1

Define fish diversity and explain why it is used as an indicator of ecosystem health.

Describe the general global pattern of fish species richness.

State two environmental factors that influence fish diversity.

Explain how habitat complexity affects fish diversity.

Name two major freshwater systems in Nigeria that support high fish diversity.

2.2 Fish Abundance and Distribution

2.2.1 Concept of fish abundance

Fish abundance refers to the number of individuals of a species present in a defined area at a given time. It is a dynamic quantity that changes with seasons, life stages, environmental conditions, and the balance between population gains (births and immigration) and losses (deaths and emigration). Abundance is distinct from distribution, which describes the spatial range within which a species occurs.

Abundance is measured using a variety of methods in fisheries science, including direct counts in visual surveys, acoustic echo-integration, mark-recapture studies, and analysis of catch per unit effort (CPUE) data from commercial or research fishing. Changes in abundance over time are used to assess population trends, detect overfishing, and guide management decisions. High abundance of a target species does not always indicate a healthy population if the age or size structure is skewed towards juveniles due to excessive harvesting of adults.

Fill in the blank: Changes in fish abundance over time are used to assess population trends and detect ________.

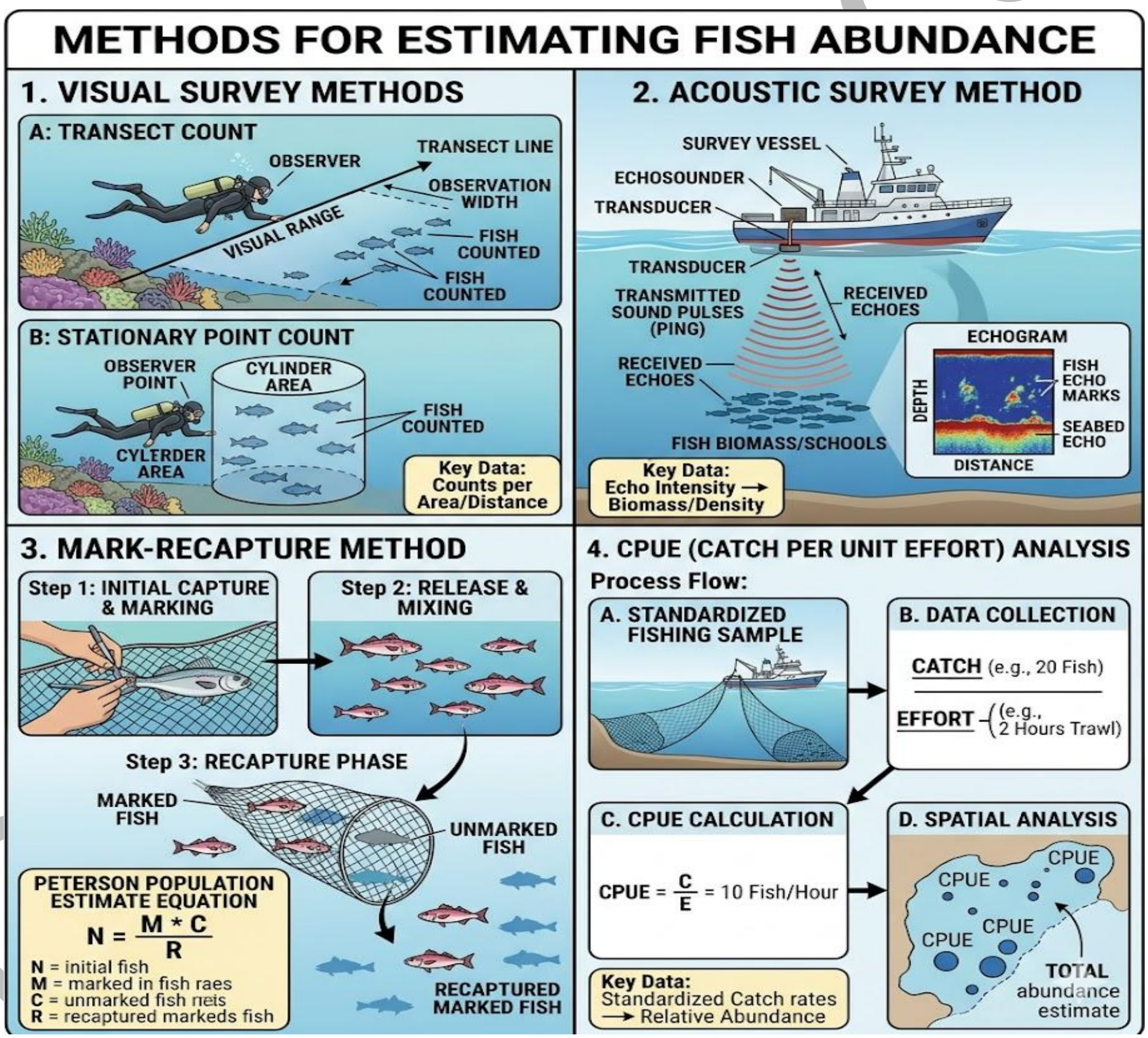


Figure 2.2: Methods used to estimate fish abundance, including visual survey, acoustic survey, and mark-recapture

2.2.2 Biotic and abiotic determinants of abundance

Abiotic factors set the physical boundaries within which fish populations can persist. Temperature determines metabolic rate and reproduction timing; dissolved oxygen is the immediate survival limit below which most fish cannot sustain aerobic respiration; salinity constrains distribution between freshwater, brackish, and marine environments; and water flow influences the distribution of food resources and spawning habitat availability.

Biotic factors operate within the physical boundaries set by abiotic conditions. Prey availability determines how much energy is available for growth and reproduction. Predation pressure reduces the abundance of prey species and can structure entire communities. Competition for food, space, and breeding sites limits the number of individuals that can be supported in an area. Disease and parasitism can suppress population sizes even when physical conditions are favourable, contributing to the complex regulation of fish abundance in natural systems.

Fill in the blank: Dissolved oxygen is the immediate survival limit below which most fish cannot sustain ________ respiration.

Factor Type	Examples	Explanation
Abiotic	Temperature, dissolved oxygen, salinity, water chemistry	Physical and chemical conditions directly affect fish survival, growth, and distribution.
Abiotic	Light availability, nutrient levels, habitat structure	Influence primary productivity and habitat suitability for fish populations.
Biotic	Prey availability, predation pressure, competition	Biological interactions determine feeding success, mortality rates, and population balance.
Biotic	Disease, parasites, symbiotic relationships	Affect fish health, reproduction, and resilience within ecosystems.

Box 2.2: Biotic and abiotic determinants of fish abundance

2.2.3 Species distribution and range limits

Species distribution describes the geographic area within which a species can be found. The range of a species is determined by the combined effects of abiotic tolerance limits, dispersal ability, and biotic interactions. Each species has a fundamental niche defined by the full range of abiotic conditions it can physiologically tolerate, and a realised niche that is typically smaller due to the additional constraints imposed by competition, predation, and other biotic interactions.

Range limits in fish are often set by specific environmental thresholds. For example, cold-water stenothermal species such as trout are absent from warm lowland rivers where summer temperatures exceed their thermal maximum. Diadromous species that migrate between freshwater and marine environments have distribution patterns constrained by the location of suitable spawning grounds, migration pathways, and seasonal water quality. Human modifications such as dam construction can fragment distributions by blocking migration routes, effectively reducing the accessible range of many riverine species.

Fill in the blank: The ________ niche is the full range of abiotic conditions a species can physiologically tolerate, while the realised niche is typically smaller due to biotic constraints.

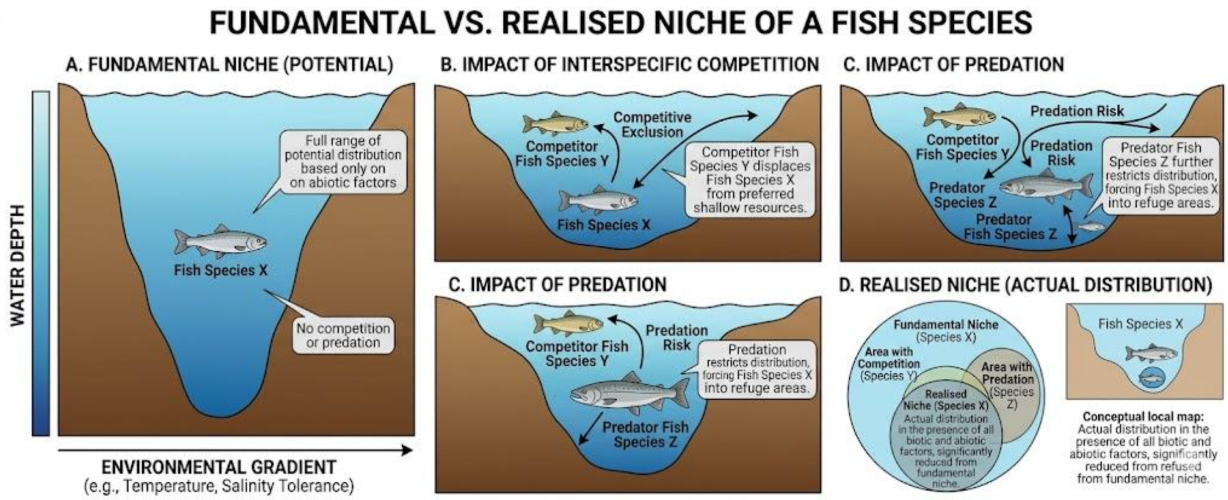


Figure 2.3: Diagram illustrating fundamental niche versus realised niche and the role of biotic factors

Pilot questions 2.2

Define fish abundance and distinguish it from fish distribution.

State two methods used to estimate fish abundance in aquatic systems.

Explain how temperature and dissolved oxygen influence fish abundance.

Describe two biotic factors that limit fish abundance.

Explain the difference between a fundamental niche and a realised niche.

2.3 Population Ecology of Fish

2.3.1 Structure and dynamics of fish populations

A fish population is a group of individuals of the same species occupying a defined area and capable of interbreeding. Population structure refers to the composition of the population in terms of age classes and size classes, which reflects the balance between past reproduction, growth, and mortality. A healthy, unexploited population typically shows a broad age structure with many juveniles, fewer sub-adults, and even fewer large adults.

Population dynamics describe how the size and structure of a population change over time. The four fundamental demographic processes are births (natality), deaths (mortality), immigration of individuals from other populations, and emigration of individuals out of the population. The net change in population size over any time period is the outcome of the balance between these four processes. Understanding population dynamics is essential for setting sustainable fishing limits and predicting the response of a stock to harvesting pressure.

Fill in the blank: The four fundamental demographic processes in fish population dynamics are natality, mortality, immigration, and ________.

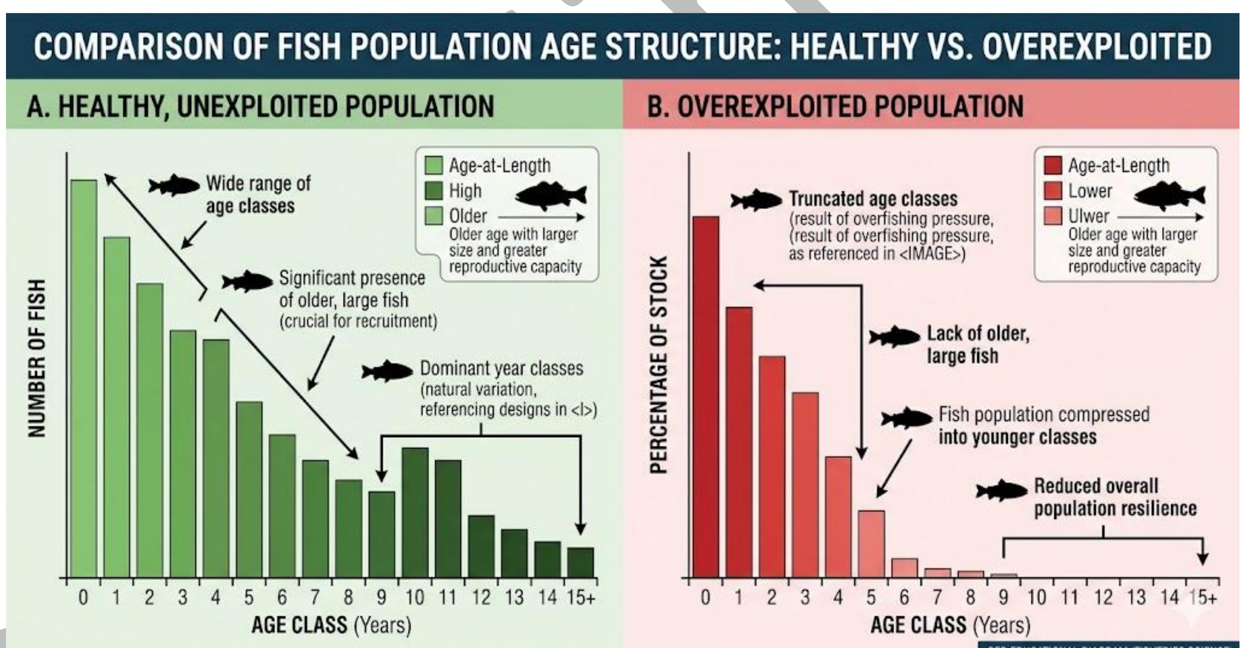


Figure 2.4: Age structure diagram of a healthy unexploited fish population and an overexploited population

2.3.2 Growth, mortality, and recruitment

Fish growth is the increase in body size over time and is described in fisheries science by the von Bertalanffy growth equation, which expresses the asymptotic maximum body length and the rate at which a fish approaches that maximum. Growth rates vary with water temperature, food availability, and population density; fish in warm, food-rich environments with low competition typically grow faster than those in cold, food-poor, or crowded conditions.

Mortality comprises natural mortality (M), caused by predation, disease, starvation, and senescence, and fishing mortality (F), caused by harvesting. Total mortality ($Z = M + F$) determines how rapidly a cohort is removed from the population over time. **Recruitment** is the addition of new individuals to the fishable portion of the population, typically defined as the number of juveniles that survive to a defined minimum catchable size. Recruitment variability is one of the largest sources of uncertainty in fish stock assessments.

Fill in the blank: Total mortality (Z) is the sum of natural mortality (M) and ________ mortality (F).

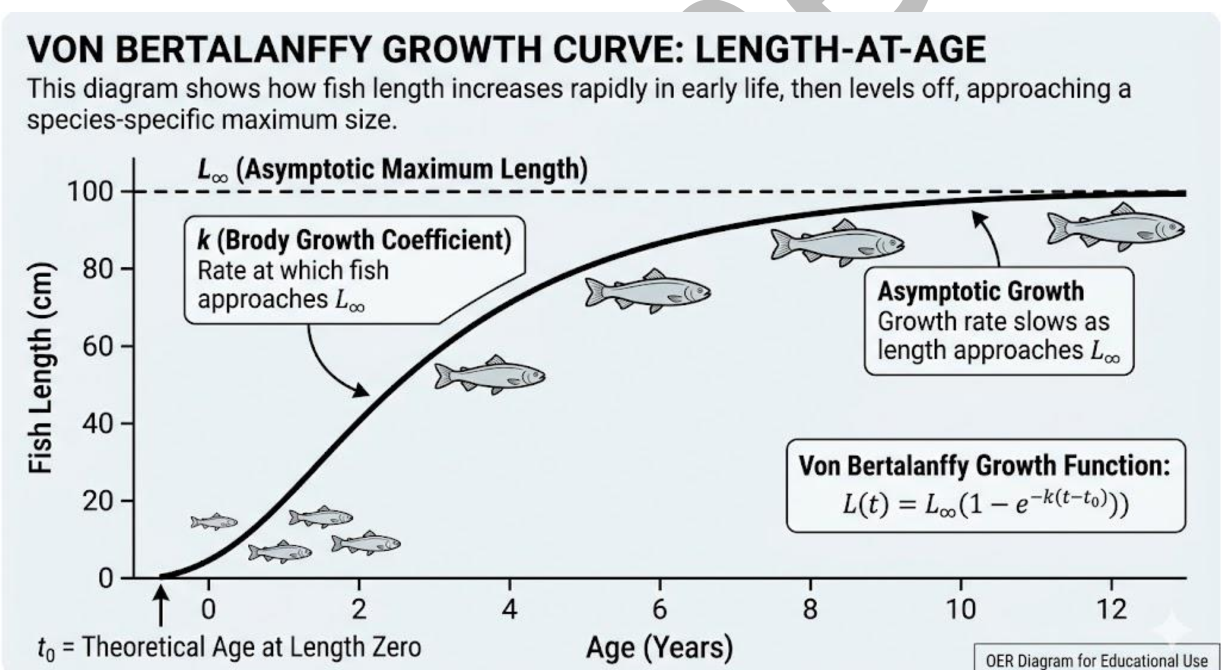


Figure 2.5: Von Bertalanffy growth curve showing fish length against age approaching asymptotic maximum length

2.3.3 Population regulation and carrying capacity

Carrying capacity (K) is the maximum population size that a given environment can sustainably support, determined by the availability of food, space, and other resources. When population size is well below K, resources are abundant, competition is low, and per capita birth rates are high relative to death rates, causing the population to grow. As population size approaches K, resources become limiting, competition increases, and growth rate declines, producing the logistic or S-shaped growth curve characteristic of populations regulated by density-dependent factors.

Density-dependent regulation occurs when birth or death rates change as a function of population density, providing negative feedback that stabilises population size around K. Examples include reduced per capita food availability at high density, increased predation or disease transmission in crowded conditions, and reduced breeding success when territorial space is limited. Density-independent factors such as floods, droughts, and extreme temperature events can reduce population size regardless of density, sometimes driving populations far below K and creating the recruitment variability that makes fish stock assessment challenging.

Fill in the blank: Carrying capacity (K) is the maximum population size that an environment can sustainably support, determined by the availability of food, space, and other ________.

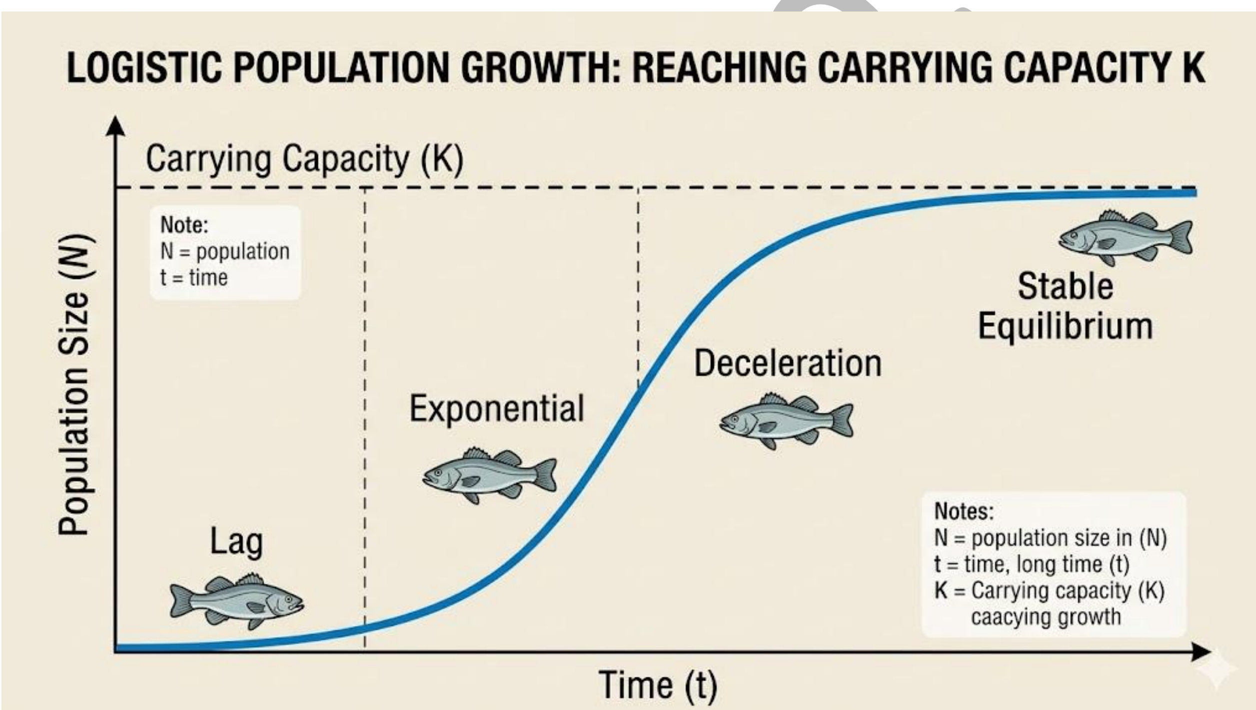


Figure 2.6: Logistic population growth curve showing S-shaped growth approaching carrying capacity K

Pilot questions 2.3

Define a fish population and describe what is meant by population structure.

Name the four demographic processes that determine fish population dynamics.

Explain what the von Bertalanffy growth equation describes in fisheries science.

Distinguish between natural mortality and fishing mortality.

Explain carrying capacity and describe how density-dependent regulation maintains populations near K.

2.4 Ecological Niche and Habitat in Fisheries

2.4.1 The niche concept in fish ecology

The ecological niche of a species is its multidimensional role in the ecosystem, encompassing all of the biotic and abiotic conditions it requires to persist, grow, and reproduce. Hutchinson's n-dimensional hypervolume model conceptualises the niche as the full range of environmental conditions (food type and size, temperature, oxygen, depth, substrate) within which a species can survive. No two species can indefinitely occupy exactly the same niche in the same place, a principle known as the competitive exclusion principle.

In fish ecology, the niche concept is applied to understand resource partitioning in diverse communities. Species that appear to coexist in the same habitat often differ subtly in their feeding behaviour, feeding depth, timing of activity, or reproductive microhabitat, allowing them to partition resources and reduce competition. Understanding the niches of commercially important species helps fisheries managers predict how changes in one species' abundance, whether through harvesting or environmental change, will affect others sharing the same ecological space.

Fill in the blank: The principle that no two species can indefinitely occupy exactly the same niche in the same place is known as the competitive ________ principle.

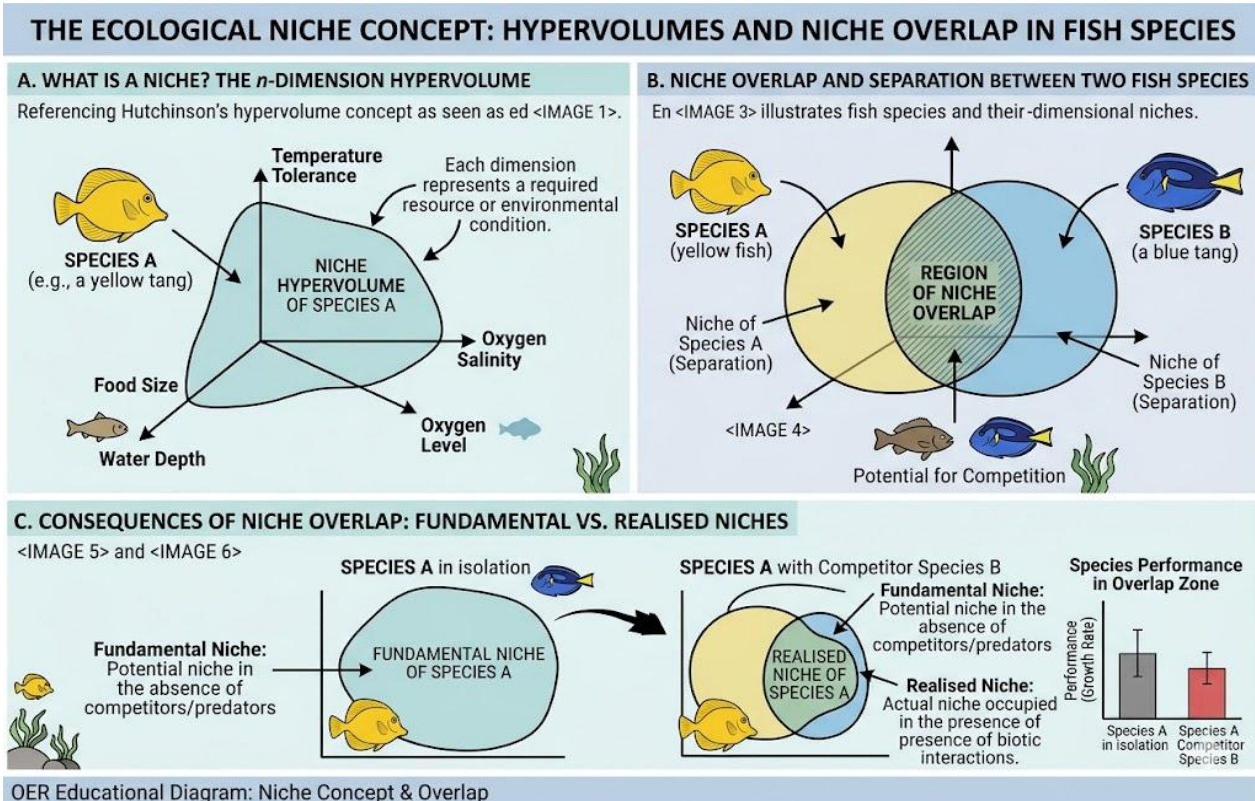


Figure 2.7: Hutchinson's n-dimensional hypervolume niche concept illustrated for two fish species showing niche overlap and separation

2.4.2 Habitat selection and microhabitat use

Habitat selection is the behavioural process by which individual fish choose to occupy specific areas within their available environment. Selection is driven by the need to optimise fitness-related outcomes: maximising food intake, minimising predation risk, finding suitable thermal conditions, and securing reproductive sites. Fish do not occupy all areas of a water body uniformly; they show predictable preferences for particular combinations of physical and biological conditions.

Microhabitat use refers to the fine-scale selection of specific features within a broader habitat, such as a particular substrate type, water depth, current velocity, or proximity to vegetation or woody debris. For example, juvenile salmon preferentially occupy shallow riffle areas with cobble substrate for their cover value and the invertebrate food resources associated with the substrate, while adults prefer deeper pools. Microhabitat preferences often vary with age, size, season, and time of day, reflecting the shifting balance of energetic and risk-based trade-offs throughout a fish's life history.

Fill in the blank: Microhabitat use refers to fine-scale selection of specific features such as substrate type, water depth, and ________ velocity within a broader habitat.

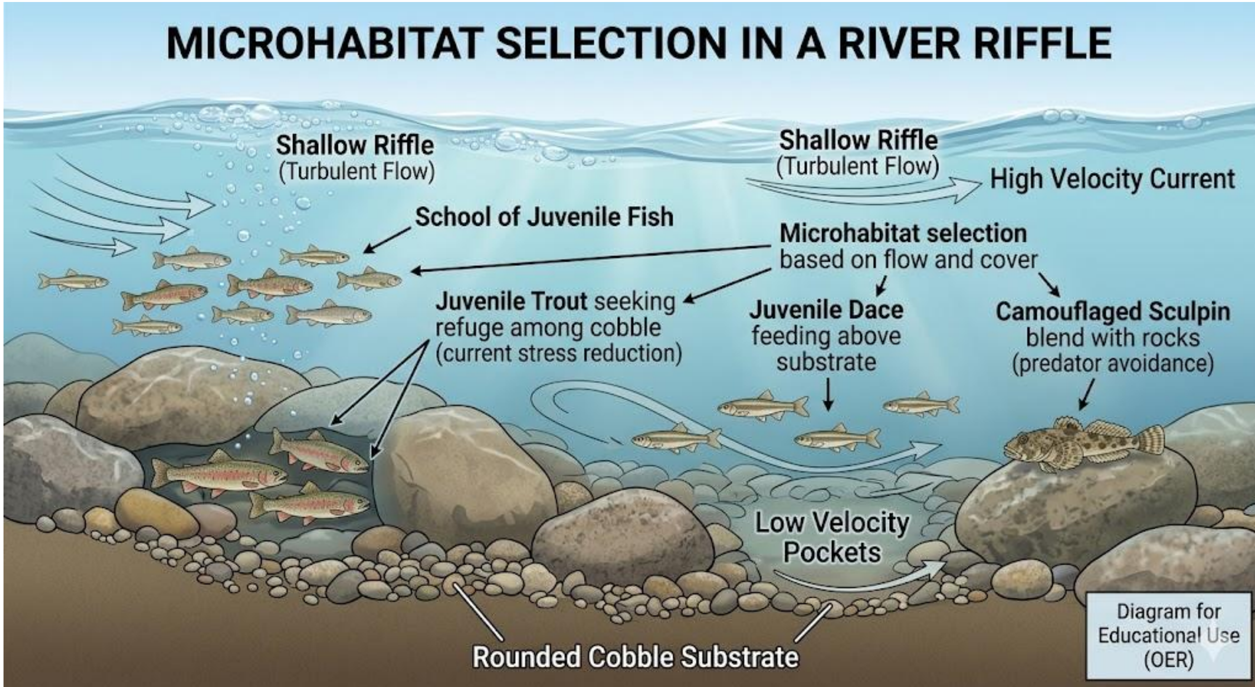


Plate 2.2: Juvenile fish occupying a shallow riffle microhabitat with cobble substrate in a river

2.4.3 Niche overlap, competition, and coexistence

Niche overlap occurs when two or more species share a portion of their resource requirements, creating the conditions for interspecific competition. The intensity of competition is proportional to the degree of niche overlap: species with high overlap compete strongly, potentially leading to competitive exclusion of the weaker competitor from the shared resource space. Species with low niche overlap can coexist stably because each is limited more by its own intraspecific competition than by competition from the other.

In diverse fish communities, coexistence is maintained through a variety of mechanisms including resource partitioning (dividing food types, feeding depths, or microhabitats), character displacement (evolutionary divergence in morphology that reduces niche overlap), and the stabilising effects of environmental variability, which periodically resets competitive interactions before exclusion can occur. In Nigerian fisheries, understanding niche overlap and competition between native and invasive species, or between artisanal target species and those exploited by industrial trawlers, is important for sustainable management of shared fish communities.

Fill in the blank: Species with high niche overlap compete strongly, potentially leading to competitive ________ of the weaker competitor.

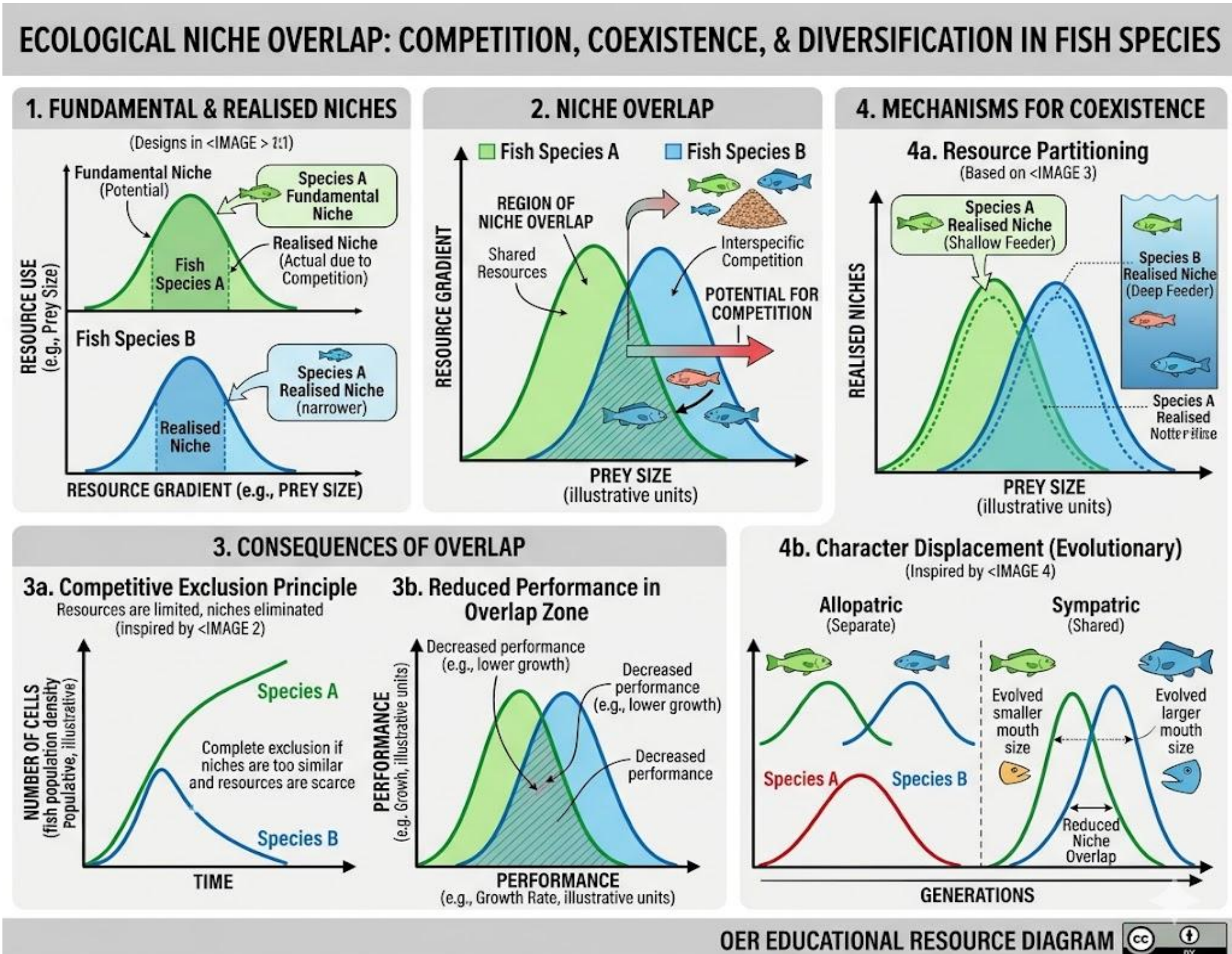


Figure 2.8: Diagram showing niche overlap between two fish species and the consequences for competition and coexistence

Pilot questions 2.4

Define the ecological niche and explain how Hutchinson's hypervolume model describes it.

What is the competitive exclusion principle?

Explain why fish in the same habitat often show different microhabitat preferences.

Define niche overlap and explain its relationship to interspecific competition.

State two mechanisms that allow competing fish species to coexist in the same community.

Series Summary

This Series has examined fish diversity, abundance, and population ecology, building on the ecological foundations established in Series 1. We began by exploring the global and regional patterns of fish diversity, the environmental and human factors that shape them, and Nigeria's exceptional fish diversity across its freshwater, estuarine, and coastal systems. We then defined fish abundance, examined the biotic and abiotic factors that determine where and how many fish occur, and explored the concepts of species distribution and range limits, including the distinction between fundamental and realised niches.

Following that, we studied the structure and dynamics of fish populations, covering growth, mortality, recruitment, and the mechanisms of population regulation around carrying capacity. Finally, we examined the ecological niche concept, habitat selection, microhabitat use, and the role of niche overlap in mediating competition and coexistence in fish communities. By completing this Series, you should now be able to achieve all nine Series Learning Outcomes (SLO 2.1 to SLO 2.9).

Glossary of Terms

Abundance: the number of individuals of a species present in a defined area at a given time; a key measure of population status used in fisheries assessment.

Carrying capacity (K): the maximum population size that a given environment can sustainably support, determined by the availability of food, space, and other limiting resources.

Character displacement: evolutionary divergence in the morphology or behaviour of competing species that reduces niche overlap and competition, enabling coexistence.

Competitive exclusion principle: the ecological principle that no two species can indefinitely occupy exactly the same niche in the same place; one will eventually exclude the other.

Density-dependent regulation: population regulation in which birth or death rates change as a function of population density, providing negative feedback that stabilises population size near carrying capacity.

Diadromous: describes fish that migrate between freshwater and marine environments as part of their life cycle; includes anadromous (sea to freshwater for spawning) and catadromous (freshwater to sea for spawning) species.

Ecological niche: the multidimensional role of a species in its ecosystem, encompassing all biotic and abiotic conditions required for the species to persist, grow, and reproduce.

Fishing mortality (F): the rate at which fish are removed from a population by harvesting; one component of total mortality ($Z = M + F$).

Fundamental niche: the full range of biotic and abiotic conditions within which a species can survive and reproduce in the absence of competitors and predators.

Microhabitat: the fine-scale physical and biological features within a broader habitat that individual fish select based on food availability, shelter, thermal conditions, and risk of predation.

Natural mortality (M): the rate at which fish die from causes other than harvesting, including predation, disease, starvation, and old age.

Population dynamics: the study of how fish population size and structure change over time as a function of natality, mortality, immigration, and emigration.

Population structure: the composition of a fish population in terms of age classes and size classes, reflecting the balance between past reproduction, growth, and mortality.

Realised niche: the subset of the fundamental niche actually occupied by a species in the presence of competitors, predators, and other biotic constraints.

Recruitment: the addition of new individuals to the fishable portion of a population; typically expressed as the number of juveniles surviving to a defined minimum catchable size.

Resource partitioning: the division of shared resources among competing species through differences in food type, feeding depth, microhabitat use, or activity timing, enabling coexistence.

Species richness: the number of distinct species present in a defined area; the most common measure of biodiversity used in ecological assessments.

Von Bertalanffy growth equation: a mathematical model describing fish growth as a function of age, expressing the asymptotic maximum body length and the rate at which the fish approaches that maximum.

Concept Check Questions [Series 2]

Objective Questions

Define fish diversity. (Linked to SLO 2.1)

Species richness tends to be highest in which climatic zone? (Linked to SLO 2.1)

Fill in the blank: Total mortality Z equals natural mortality M plus ________ mortality F. (Linked to SLO 2.5)

The maximum population size a habitat can support is called its ________. (Linked to SLO 2.6)

The principle that no two species can indefinitely occupy the same niche in the same place is the competitive ________ principle. (Linked to SLO 2.7)

Short-Answer Questions

Describe two abiotic factors that determine fish abundance. (Linked to SLO 2.3)

Explain the difference between a fundamental niche and a realised niche. (Linked to SLO 2.4)

Define recruitment in fish population ecology and explain why it is important in stock assessment. (Linked to SLO 2.5)

Explain how density-dependent regulation stabilises fish populations near carrying capacity. (Linked to SLO 2.6)

State two mechanisms that allow competing fish species to coexist in the same community. (Linked to SLO 2.9)

Long-Answer Questions

Analyse the factors that influence fish diversity in aquatic ecosystems, using examples from Nigerian waters to illustrate your answer. (Linked to SLOs 2.1, 2.2)

Discuss the structure and dynamics of fish populations, explaining how growth, mortality, and recruitment interact to determine stock size over time. (Linked to SLOs 2.5, 2.6)

Evaluate the ecological niche concept and explain how niche overlap, competition, and coexistence shape the structure of fish communities. (Linked to SLOs 2.7, 2.8, 2.9)

Answers to Concept Check Questions [Series 2]

Objective Questions

Fish diversity is the variety of fish species present in an aquatic ecosystem, used as an indicator of ecosystem health and complexity.

Tropical regions.

Fishing.

Carrying capacity (K).

Exclusion.

Short-Answer Questions

Any two: temperature (determines metabolic rate and sets physiological limits on species ranges); dissolved oxygen (the immediate survival limit below which most fish cannot sustain aerobic respiration); salinity (constrains distribution between freshwater, brackish, and marine environments); water flow (influences food resource distribution and spawning habitat availability).

The fundamental niche is the full range of biotic and abiotic conditions within which a species can survive and reproduce in the absence of competitors and predators. The realised niche is the subset actually occupied by the species in the presence of biotic constraints such as competition and predation, and is typically smaller than the fundamental niche.

Recruitment is the addition of new individuals to the fishable portion of a population, typically the number of juveniles surviving to a minimum catchable size. It is important because high variability in recruitment from year to year creates large uncertainty in stock assessments and in predictions of future yield.

When population density is high, per capita food availability declines, competition intensifies, and predation or disease transmission increases. These density-dependent effects raise mortality rates and reduce birth rates, slowing or reversing population growth. As density falls below K, conditions improve and the population recovers, producing negative feedback that stabilises size near carrying capacity.

Any two: resource partitioning (dividing food types, feeding depths, or microhabitats so each species exploits a different part of the resource space); character displacement (evolutionary divergence in morphology or behaviour reducing niche overlap); stabilising effects of environmental variability periodically resetting competitive interactions before exclusion can occur.

Long-Answer Questions

Basic response: Fish diversity is shaped by environmental factors including temperature, habitat complexity, and water chemistry, and by historical factors such as isolation and speciation. Nigeria supports high diversity across the Niger and Benue river systems, Lake Chad, Cross River basin, and coastal waters.

Value-added response: Human activities including pollution, dam construction, habitat destruction, and invasive species introductions are among the most significant contemporary threats to Nigerian fish diversity. Protecting habitat complexity and water quality, managing migratory pathways, and controlling invasive species are priority actions for sustaining Nigeria's exceptional fish diversity.

Basic response: Population size changes through natality, mortality, immigration, and emigration. Growth is described by the von Bertalanffy equation; mortality comprises natural (M) and fishing (F) components; recruitment adds new individuals to the exploitable stock. The balance of these processes determines stock size.

Value-added response: Variability in recruitment is the largest source of uncertainty in stock assessment. In overexploited stocks, high fishing mortality removes large adults before they contribute multiple spawning seasons, reducing reproductive output and destabilising age structure. Maintaining a broad age structure through appropriate harvest limits protects long-term stock productivity.

Basic response: The ecological niche defines the multidimensional requirements of a species. Niche overlap creates conditions for interspecific competition; the competitive exclusion principle states that complete overlap leads to exclusion of the weaker competitor. Coexistence is maintained through resource partitioning, character displacement, and environmental variability.

Value-added response: In diverse fish communities, subtle differences in feeding behaviour, microhabitat use, or spawning timing allow species with apparently similar niches to coexist. Understanding niche overlap between target species and between native and invasive species is important for Nigerian fisheries management, where trawl fisheries and artisanal fisheries often compete for the same demersal resources.

Answers to Pilot Questions [Series 2]

Part 2.1: Fish Diversity in Aquatic Ecosystems

Fish diversity is the variety of fish species in an aquatic ecosystem; it is used as an indicator of ecosystem health because high diversity generally reflects stable, complex, and productive conditions, while reduced diversity signals environmental stress or overexploitation.

Species richness is highest in tropical regions and declines with increasing latitude towards the poles.

Any two: water temperature; habitat complexity; water chemistry (pH, dissolved oxygen, salinity, nutrients); historical isolation; human activities.

Greater habitat complexity provides more distinct ecological niches, allowing more species with different resource requirements to coexist, thereby supporting higher species richness.

Any two: Niger River, Benue River, Lake Chad, Cross River basin.

Part 2.2: Fish Abundance and Distribution

Fish abundance is the number of individuals of a species present in a defined area at a given time; distribution is the geographic range within which a species can be found. Abundance varies over time within the distribution range.

Any two: visual surveys; acoustic echo-integration; mark-recapture studies; catch per unit effort (CPUE) analysis.

Temperature affects metabolic rate and reproduction timing, determining which species can survive in a given environment. Dissolved oxygen is the immediate survival threshold; fish cannot sustain aerobic respiration below species-specific minimum levels.

Any two: predation (reduces prey species abundance); competition (limits individuals that can be supported when food or space is scarce); disease and parasitism (can suppress populations even in favourable physical conditions).

The fundamental niche is the full range of conditions a species can tolerate physiologically in the absence of competitors and predators. The realised niche is the smaller subset actually occupied due to competition, predation, and other biotic constraints.

Part 2.3: Population Ecology of Fish

A fish population is a group of individuals of the same species in a defined area capable of interbreeding. Population structure is its composition in terms of age and size classes, reflecting past reproduction, growth, and mortality.

Natality (births), mortality (deaths), immigration, and emigration.

The von Bertalanffy growth equation describes fish growth as a function of age, expressing the asymptotic maximum body length and the rate at which the fish approaches that maximum; it is the standard model for describing growth in fisheries stock assessments.

Natural mortality (M) is death from predation, disease, starvation, and old age. Fishing mortality (F) is death caused by harvesting. Together they give total mortality $Z = M + F$.

Carrying capacity K is the maximum population size a habitat can sustainably support given its resources. Density-dependent regulation occurs when birth rates decline and death rates increase as density rises toward K, providing negative feedback that prevents indefinite growth and stabilises population size near K.

Part 2.4: Ecological Niche and Habitat in Fisheries

The ecological niche is the multidimensional role of a species encompassing all biotic and abiotic conditions required for persistence. Hutchinson's hypervolume model represents the niche as an n-dimensional space defined by all relevant environmental variables, within which the species can survive and reproduce.

The competitive exclusion principle states that no two species can indefinitely occupy exactly the same niche in the same place; one will outcompete and exclude the other.

Even in the same broad habitat, fish partition resources by using different substrate types, water depths, current velocities, or food types, reducing direct competition and allowing multiple species to coexist without complete niche overlap.

Niche overlap is the degree to which two species share resource requirements; the greater the overlap, the more intense the interspecific competition, potentially leading to competitive exclusion of the weaker competitor.

Any two: resource partitioning (dividing food types, microhabitats, or activity timing); character displacement (evolutionary divergence reducing overlap); stabilising effects of periodic environmental disturbance.

References and Attributions [Series 2]

Textual References (Books and External Sources)

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FAO (Food and Agriculture Organization of the United Nations). (2025). Guidelines for sustainable fisheries. FAO.

Figures, Plates, Tables, and Boxes

Figure 2.1: Global patterns of fish species richness Attribution: AI generated using prompt "Generate a diagram showing the global pattern of fish species richness, illustrating the latitudinal gradient from tropics to poles." Suggested OER search string: "global fish species richness latitudinal gradient OER diagram".

Box 2.1: Key factors influencing fish diversity Attribution: AI generated using prompt "Generate a text box listing the key factors influencing fish diversity, including temperature, habitat complexity, water chemistry, and human activities." Suggested OER search string: "factors influencing fish diversity aquatic ecosystems OER".

Plate 2.1: Selected commercially important fish species in Nigerian systems Attribution: AI generated using prompt "Generate an image showing commercially important Nigerian fish species from freshwater and marine environments." Suggested OER search string: "Nigerian fish diversity freshwater marine species OER image".

Figure 2.2: Methods used to estimate fish abundance Attribution: AI generated using prompt "Generate a diagram showing the main methods used to estimate fish abundance, including visual survey, acoustic survey, mark-recapture, and CPUE analysis." Suggested OER search string: "methods estimating fish abundance OER diagram".

Box 2.2: Biotic and abiotic determinants of fish abundance Attribution: AI generated using prompt "Generate a text box listing the biotic and abiotic determinants of fish abundance." Suggested OER search string: "biotic abiotic determinants fish abundance OER".

Figure 2.3: Fundamental niche versus realised niche Attribution: AI generated using prompt "Generate a diagram showing the fundamental niche versus realised niche of a fish species, illustrating how competition and predation reduce the realised niche." Suggested OER search string: "fundamental realised niche fish species distribution OER diagram".

Figure 2.4: Age structure diagram of fish populations Attribution: AI generated using prompt "Generate a diagram comparing the age structure of a healthy unexploited fish population with an overexploited population." Suggested OER search string: "fish population age structure healthy overexploited OER diagram".

Figure 2.5: Von Bertalanffy growth curve Attribution: AI generated using prompt "Generate a graph showing a von Bertalanffy growth curve with fish length on the y-axis and age on the x-axis approaching an asymptotic maximum." Suggested OER search string: "von Bertalanffy fish growth curve length age OER diagram".

Figure 2.6: Logistic population growth curve approaching carrying capacity K Attribution: AI generated using prompt "Generate a graph showing logistic population growth approaching carrying capacity K, with an S-shaped curve." Suggested OER search string: "logistic population growth carrying capacity K fish OER diagram".

Figure 2.7: Niche hypervolume and overlap for two fish species Attribution: AI generated using prompt "Generate a diagram illustrating the niche concept with two overlapping hypervolumes representing the niches of two fish species." Suggested OER search string: "ecological niche hypervolume niche overlap fish species OER diagram".

Plate 2.2: Juvenile fish in riffle microhabitat Attribution: AI generated using prompt "Generate an image showing juvenile fish in a shallow riffle microhabitat with cobble substrate in a river." Suggested OER search string: "juvenile fish riffle microhabitat cobble substrate OER image".

Figure 2.8: Niche overlap and consequences for competition and coexistence Attribution: AI generated using prompt "Generate a diagram showing two overlapping bell curves representing resource use of two fish species, illustrating niche overlap and coexistence conditions." Suggested OER search string: "niche overlap competition coexistence fish species OER diagram".

Series 3: Aquatic Production, Food Chains, and Species Interactions

Series outline

Introduction

In the previous Series, we examined fish diversity, abundance, and population ecology. This Series extends those ideas by exploring how energy is produced and transferred in aquatic systems and how species interact within those systems. Understanding aquatic production and species interactions is central to interpreting how fisheries communities are structured and how human exploitation affects them.

The aim of this Series is to examine the processes that generate organic production in aquatic environments, the roles of plankton and benthos, the structure of food chains and webs, and the categories of species interactions that shape community composition and fish abundance.

We shall commence this Series by examining primary and secondary production and their regulatory factors. Next, we will explore plankton, benthic communities, and the processes of algal bloom formation and eutrophication. Following that, we will study the structure of food chains, food webs, and trophic levels, including fish feeding habits. Finally, we will wrap up with the major categories of species interactions: predation, competition, and symbiotic relationships.

Series Learning Outcomes

Upon completing this Series, you should be able to:

SLO 3.1 explain the processes of primary and secondary production in aquatic systems and the factors that regulate them (Linked to Part 3.1),

SLO 3.2 describe the ecology of phytoplankton, zooplankton, and benthic communities and their roles in aquatic production (Linked to Part 3.2),

SLO 3.3 explain the causes and ecological consequences of algal blooms and eutrophication (Linked to Part 3.2),

SLO 3.4 describe the structure of food chains and food webs in aquatic ecosystems (Linked to Part 3.3),

SLO 3.5 explain trophic levels and energy transfer efficiency and their implications for fisheries (Linked to Part 3.3),

SLO 3.6 describe the food and feeding habits of selected fish species (Linked to Part 3.3),

SLO 3.7 explain predation and its effects on prey populations and community structure (Linked to Part 3.4),

SLO 3.8 describe competition as a species interaction and explain its role in regulating fish abundance (Linked to Part 3.4), and

SLO 3.9 distinguish between mutualism, commensalism, and parasitism and explain their occurrence in aquatic systems (Linked to Part 3.4).

3.1 Aquatic Production and Its Regulatory Factors

3.1.1 Primary production in aquatic systems

Primary production is the synthesis of organic matter from inorganic compounds using sunlight or chemical energy. In aquatic systems, it is carried out mainly by phytoplankton, aquatic macrophytes, and benthic algae through photosynthesis. It forms the energy base of all aquatic food webs and ultimately determines the productivity and fish-carrying capacity of a water body.

Gross primary production (GPP) is the total organic matter synthesised, while net primary production (NPP) is what remains after the producers use some for their own respiration. NPP is the fraction available to consumers at higher trophic levels. In tropical freshwater systems such as those in Nigeria, high solar radiation and warm temperatures can sustain high primary production year-round, though this may be seasonally modulated by flooding cycles.

Fill in the blank: Net primary production is the organic matter remaining after producers use some for their own ________.

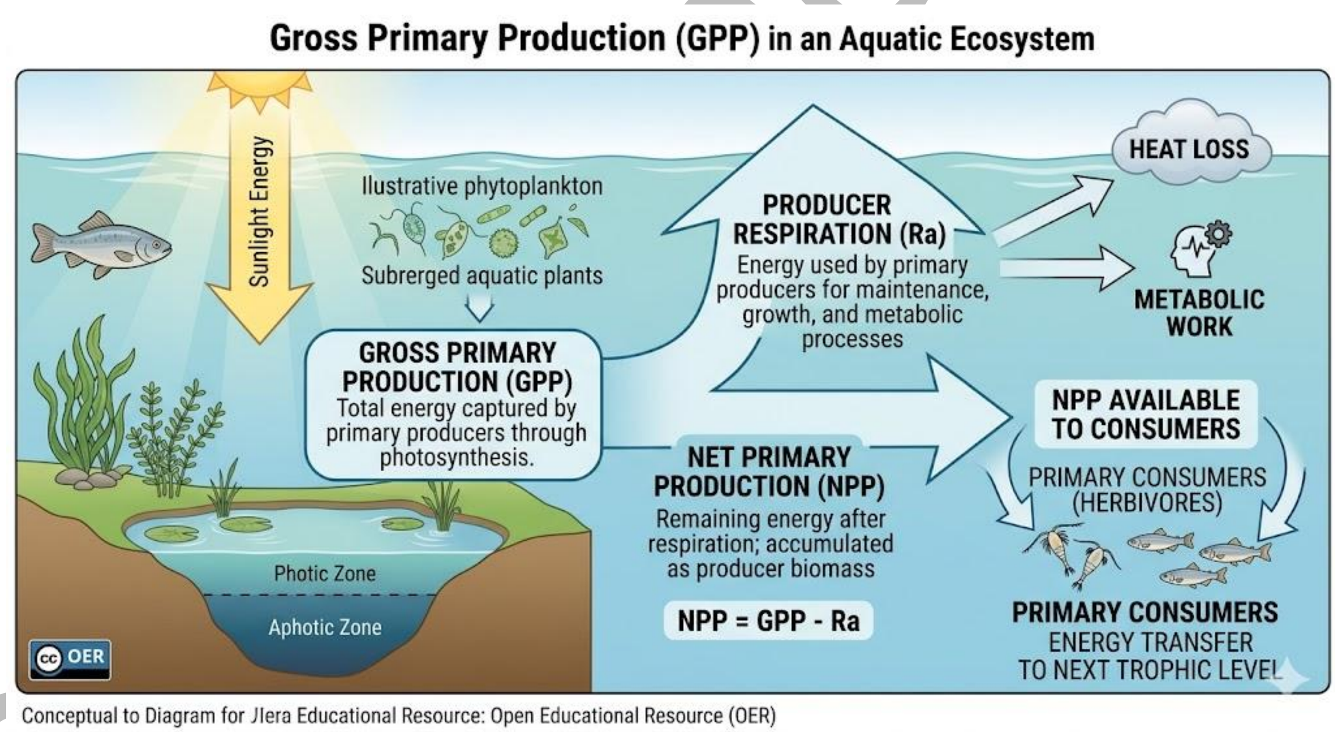


Figure 3.1: Diagram showing gross and net primary production in an aquatic ecosystem

3.1.2 Secondary production and trophic transfer

Secondary production is the formation of organic biomass by consumers, that is, organisms that obtain energy by consuming other organisms. Herbivores feeding on phytoplankton convert primary production into animal biomass, making it available to carnivores at the next trophic level. Secondary production therefore links primary producers to the fish populations of direct interest to fisheries.

Energy transfer between trophic levels is inefficient; only about ten per cent of the energy at one level is incorporated into the biomass of the next, a generalisation known as the ten per cent rule. The remainder is lost as metabolic heat, excretion, and uneaten material. This inefficiency means that aquatic systems can support substantially more herbivorous biomass than carnivorous biomass, which has direct implications for the maximum sustainable yield of higher-trophic-level fish species.

Fill in the blank: Only about ________ per cent of energy at one trophic level is transferred to the biomass of the next.

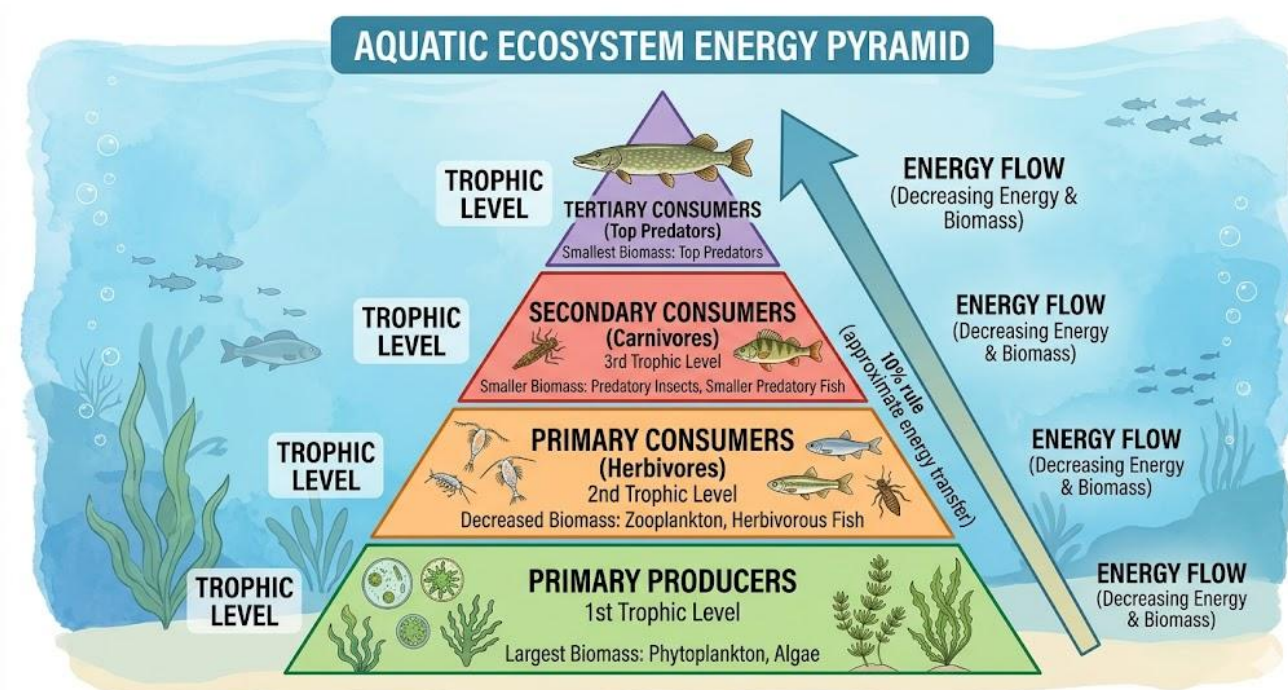


Figure 3.2: Energy pyramid showing decreasing biomass at successive trophic levels in an aquatic food web

3.1.3 Regulatory factors of aquatic production

Abiotic factors are the primary regulators of aquatic production. Light availability determines the depth of the photic zone in which photosynthesis can occur. Nutrients, particularly nitrogen, phosphorus, and silica, are often the limiting factors for phytoplankton growth; when they are scarce, production is low regardless of other conditions. Temperature affects the metabolic rates of both producers and consumers, with warmer waters generally supporting faster growth.

Biotic regulatory factors include grazing pressure from zooplankton and herbivorous fish, which can substantially reduce phytoplankton standing stock, and nutrient recycling by decomposers that return minerals to the water. Water residence time, stratification, and mixing regimes also control nutrient availability at the surface. In Nigerian rivers and lakes, seasonal flooding, upstream land use, and the input of agricultural nutrients significantly modify the natural regulation of aquatic production.

Fill in the blank: Nitrogen and phosphorus are often the ________ factors for phytoplankton growth in aquatic systems.

Factor Type	Examples	Explanation
Abiotic	Temperature, dissolved oxygen, salinity, water chemistry	Physical and chemical conditions directly affect fish survival, growth, and distribution.
Abiotic	Light availability, nutrient levels, habitat structure	Influence primary productivity and habitat suitability for fish populations.
Biotic	Prey availability, predation pressure, competition	Biological interactions determine feeding success, mortality rates, and population balance.
Biotic	Disease, parasites, symbiotic relationships	Affect fish health, reproduction, and resilience within ecosystems.

Box 3.1: Key abiotic and biotic factors regulating aquatic primary production

Pilot questions 3.1

Define primary production and distinguish between gross and net primary production.

Explain the role of primary production in supporting fish populations.

Define secondary production and explain how it links producers to fish.

State two abiotic factors that regulate primary production in aquatic systems.

Explain why energy transfer between trophic levels is inefficient.

3.2 Plankton, Benthos, and Organic Production

3.2.1 Ecology of phytoplankton and zooplankton

Phytoplankton are microscopic photosynthetic organisms that drift in the water column, including diatoms, dinoflagellates, and cyanobacteria. They are the dominant primary producers in most open-water aquatic systems and form the base of the planktonic food web. Their abundance fluctuates seasonally with light, temperature, and nutrient availability, often showing characteristic seasonal blooms in temperate and upwelling zones.

Zooplankton are small animals that feed on phytoplankton and each other, including copepods, cladocerans, and larval stages of many invertebrates and fish. They form the critical link between primary producers and larger consumers. Many commercially important fish species feed on zooplankton as larvae and juveniles, making zooplankton abundance and timing a key determinant of fish recruitment success.

Fill in the blank: Zooplankton form the critical link between ________ and larger consumers in the aquatic food web.

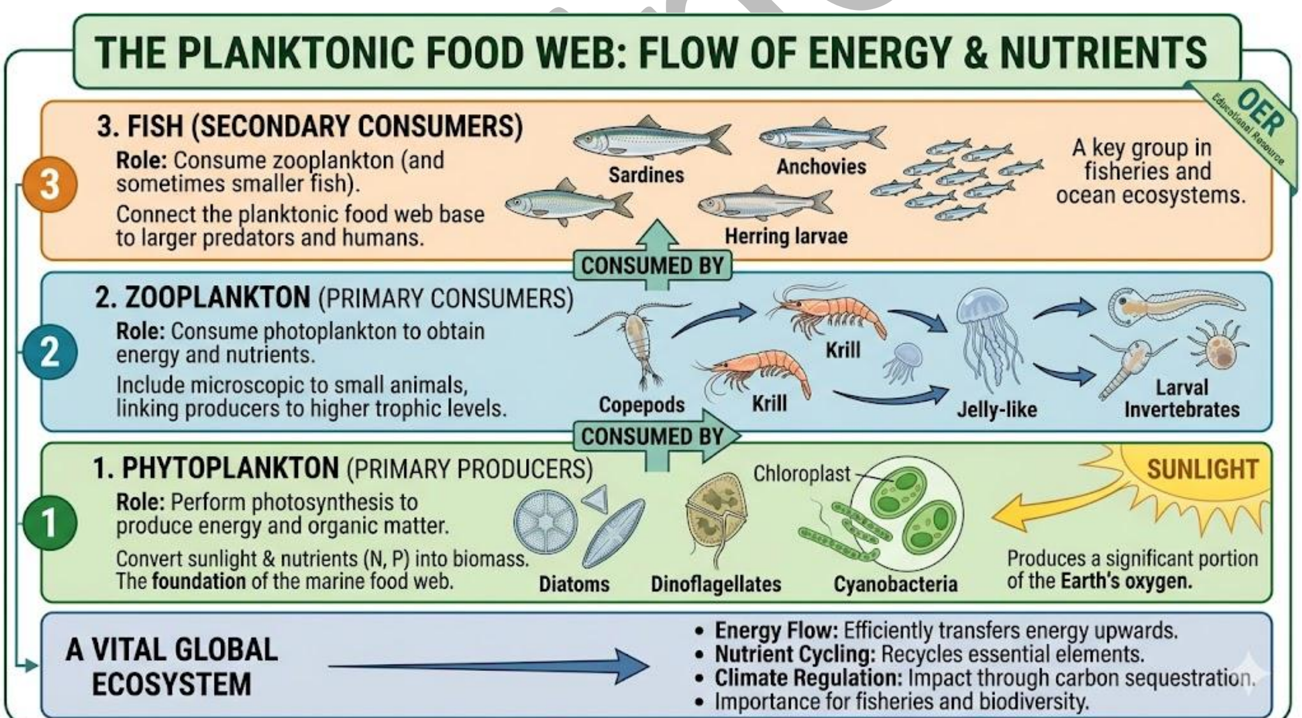


Figure 3.3: Diagram showing phytoplankton and zooplankton in the planktonic food web of an aquatic ecosystem

3.2.2 Benthic communities and their role

Benthic communities are assemblages of organisms living on or in the sediment at the bottom of water bodies. They include macroalgae, aquatic insects, worms, molluscs, crustaceans, and bottom-dwelling fish. Benthic organisms perform critical ecological functions: they process organic matter deposited from the water column, recycle nutrients back into the water, provide food for demersal fish, and are important indicators of water quality and ecosystem health.

The biomass and diversity of benthic communities depend on substrate type, organic matter input, dissolved oxygen in bottom waters, and water depth. In Nigerian river systems and coastal estuaries, benthic invertebrates such as chironomid larvae, oligochaete worms, and molluscs support important artisanal fisheries directly and indirectly by providing the food base for demersal fish stocks.

Fill in the blank: Benthic organisms recycle ________ back into the water column by processing organic matter deposited from above.

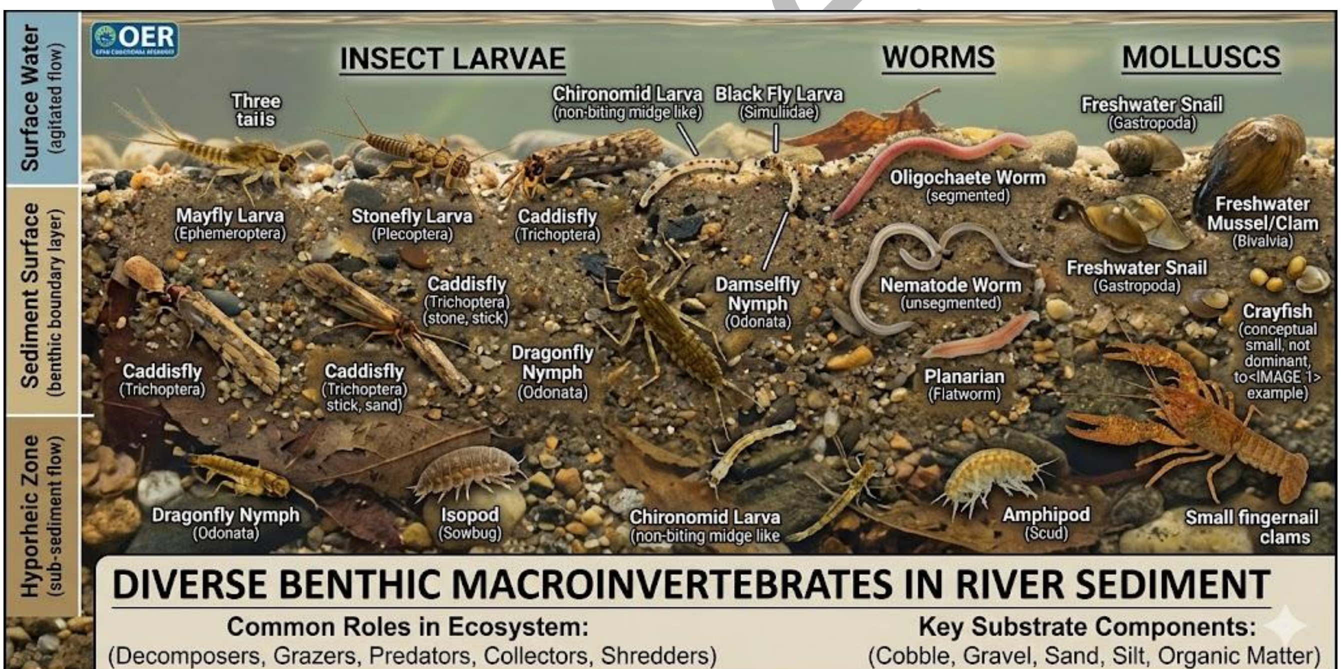


Plate 3.1: Benthic macroinvertebrates in river sediment, illustrating the diversity of benthic communities

3.2.3 Algal blooms, eutrophication, and nutrient cycling

Eutrophication is the process by which a water body becomes enriched with nutrients, particularly nitrogen and phosphorus, leading to excessive algal growth. When nutrient inputs from agricultural runoff, sewage, or industrial discharge exceed the natural buffering capacity of the system, phytoplankton populations explode into **algal blooms**. These blooms reduce light penetration, deplete dissolved oxygen as they decompose, and can produce toxins harmful to fish and humans.

Nutrient cycling involves the continuous movement of elements such as carbon, nitrogen, and phosphorus between the water, sediment, and living organisms. Decomposers break down dead organic matter and release inorganic nutrients that are taken up again by primary producers, maintaining the productivity of the system. Disruption of nutrient cycling through excessive loading or physical alteration of water bodies can destabilise production and trigger the eutrophication that characterises many degraded Nigerian water bodies.

Fill in the blank: Eutrophication is driven by excess inputs of ________ and phosphorus, leading to excessive algal growth.

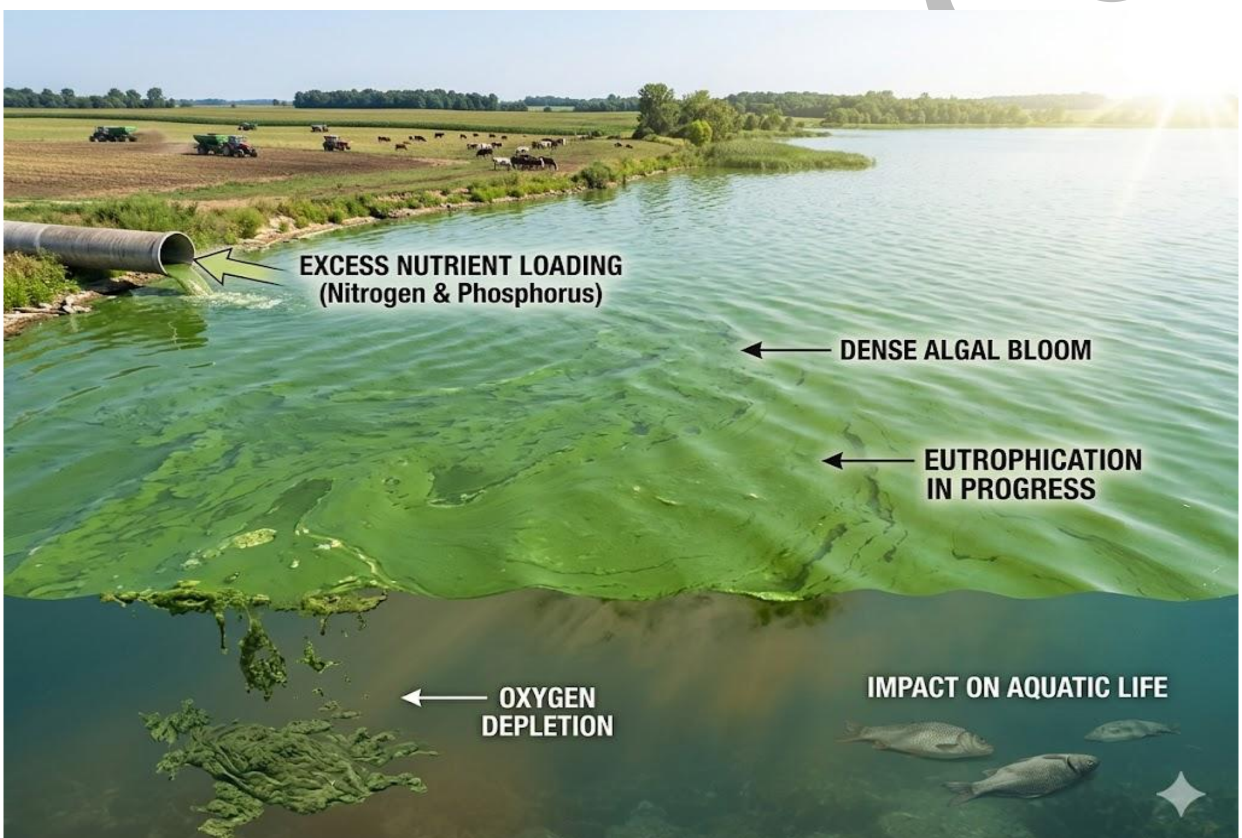


Plate 3.2: Algal bloom covering the surface of a eutrophic water body

Pilot questions 3.2

Name two types of phytoplankton found in aquatic systems.

Explain the role of zooplankton in the aquatic food web.

State two ecological functions of benthic communities.

Define eutrophication and state its main cause.

Explain how algal blooms affect fish in aquatic systems.

3.3 Food Chains, Food Webs, and Trophic Levels

3.3.1 Structure of aquatic food chains and webs

A food chain is a linear sequence showing the transfer of energy from one organism to the next, starting with primary producers. In a typical aquatic food chain: phytoplankton are consumed by zooplankton, zooplankton by small fish, small fish by larger predatory fish, and so on to apex predators. A **food web** is more realistic, capturing the multiple feeding connections between species within a community.

Food webs illustrate that most fish are not confined to a single trophic pathway but feed on multiple prey items, making the web more stable and resilient to the loss of any single species. In Nigerian aquatic systems, food webs connect diverse primary producers (including macrophytes and phytoplankton), through multiple invertebrate and fish consumers, to apex predators such as the Nile perch (Lates niloticus) in some northern lakes.

Fill in the blank: A food ________ is more realistic than a food chain because it captures multiple feeding connections between species.

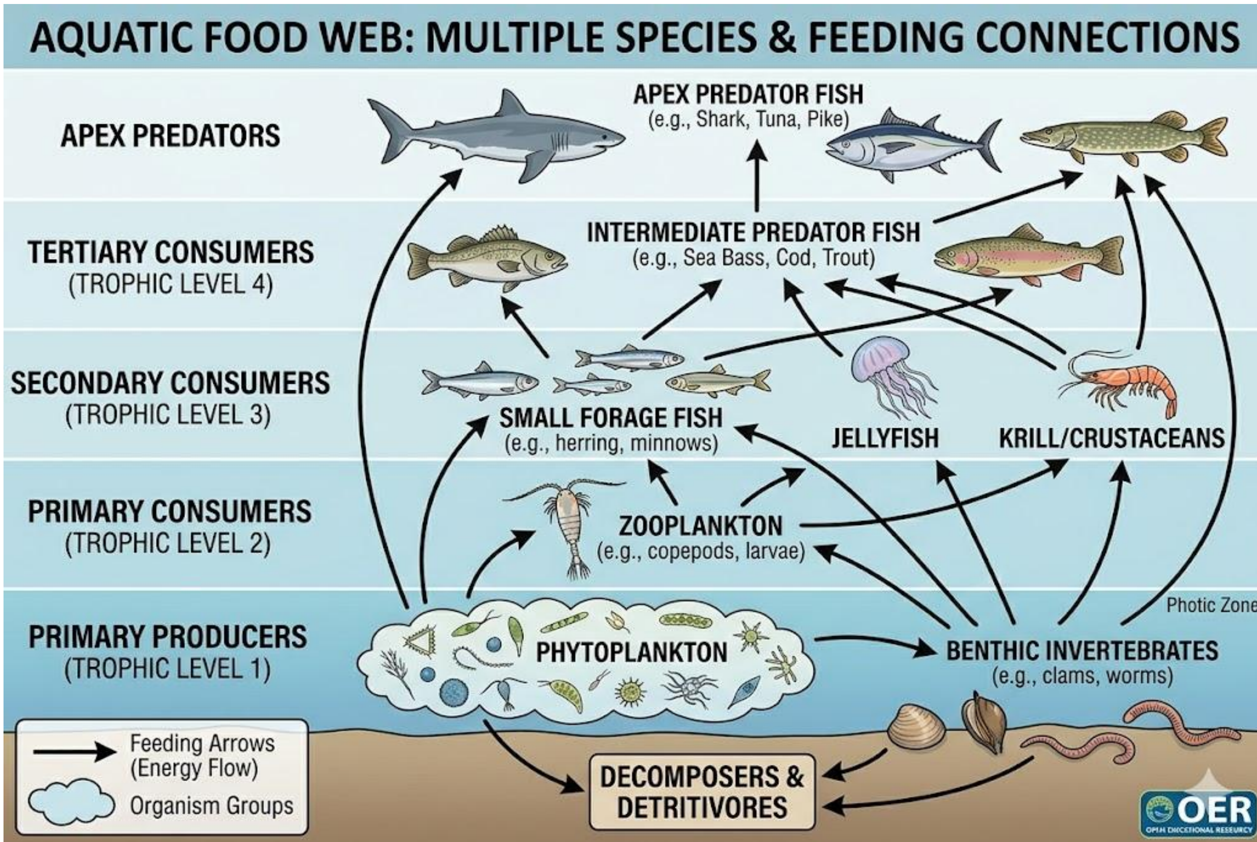


Figure 3.4: Aquatic food web showing multiple feeding connections among producers, invertebrates, and fish species

3.3.2 Trophic levels and energy transfer efficiency

Trophic levels represent the feeding position of an organism in a food web. Level 1 comprises producers (phytoplankton, macrophytes); Level 2 comprises primary consumers (zooplankton, herbivorous fish); Level 3 comprises secondary consumers (small carnivorous fish); and higher levels comprise apex predators. Most fish do not occupy a single fixed trophic level but shift trophic position with age and diet.

Energy transfer efficiency between trophic levels averages about ten per cent, meaning that for every 100 units of energy fixed by phytoplankton, only about 10 reach herbivorous fish and only 1 reaches the first level of carnivores. This constraint limits food chain length and means that fisheries targeting higher trophic levels (large predatory fish) will always be smaller in maximum yield than those targeting lower levels (sardines, anchovies, tilapia).

Fill in the blank: For every 100 units of energy at the producer level, only about ________ units reach the first level of carnivores.

Trophic Level	Examples of Organisms	Approximate Energy Transfer	Explanation
Producers	Algae, phytoplankton, aquatic plants	~100% (base energy input)	Capture solar energy through photosynthesis, forming the foundation of the food web.
Primary consumers	Zooplankton, small crustaceans	~10%	Feed on producers; only a fraction of energy is transferred upward.
Secondary consumers	Small fish, jellyfish	~1%	Consume herbivores; energy transfer decreases due to metabolic losses.
Tertiary consumers	Larger predatory fish (e.g., tuna)	~0.1%	Feed on smaller carnivores; energy available is greatly reduced.
Apex predators	Sharks, humans, seabirds	~0.01%	Top of the food chain; receive the least energy due to cumulative losses.

Table 3.1: Trophic levels in aquatic ecosystems with examples and approximate energy transfer

3.3.3 Food and feeding habits of fish

Fish feeding habits are classified by the types of food they consume. **Herbivores** such as tilapia (Oreochromis spp.) feed mainly on algae and aquatic plants. **Omnivores** such as carp and many catfishes consume both plant and animal material. **Carnivores** such as pike, Nile perch, and most large predatory fish feed primarily on other fish and invertebrates. **Detritivores** feed on organic debris and are important in benthic systems.

Food and habitat selection are closely linked. Feeding specialisation determines the trophic level a species occupies and its position in the food web. In Nigerian fisheries, the diversity of feeding types among commercially important species, from herbivorous tilapia in shallow lakes and ponds to carnivorous croakers and snappers in coastal marine waters, reflects the broad range of production pathways that Nigerian aquatic systems support.

Fill in the blank: Fish that feed mainly on algae and aquatic plants are classified as ________.

Feeding Category	Examples (Nigerian Fish Species)	Explanation
Herbivores	*Tilapia zillii* (Redbelly tilapia)	Feed mainly on algae and aquatic plants, supporting energy transfer from producers.
Omnivores	*Clarias gariepinus* (African catfish)	Consume both plant material and animal prey, adapting to diverse food sources.
Carnivores	*Lates niloticus* (Nile perch)	Predatory fish that feed on smaller fish and invertebrates, regulating populations.
Detritivores	*Chrysichthys nigrodigitatus* (Bagrid catfish)	Feed on organic matter and decomposing material, contributing to nutrient recycling.

Box 3.2: Classification of fish by feeding habit with examples from Nigerian species

Pilot questions 3.3

Distinguish between a food chain and a food web.

List the four trophic levels in an aquatic ecosystem and give one example for each.

Explain why fisheries targeting low trophic levels can sustain higher yields than those targeting high trophic levels.

Classify the following fish by feeding habit: tilapia, Nile perch, and catfish.

Explain how a fish's feeding habit determines its position in the food web.

3.4 Species Interactions

3.4.1 Predation and its ecological effects

Predation is an interaction in which one organism (the predator) kills and consumes another (the prey). It is one of the most powerful forces shaping fish community structure. Predators reduce prey abundance directly and indirectly influence the behaviour, distribution, and morphology of prey species. In aquatic ecosystems, predation often structures entire communities through trophic cascades, in which changes in predator abundance ripple down through lower trophic levels.

A classic example of a trophic cascade is the reduction of a top predator, which releases prey fish from predation pressure, allowing them to increase in abundance and intensify grazing on zooplankton, which in turn causes phytoplankton to increase. Understanding predation dynamics is critical for fisheries management because the commercial harvest of predatory fish is itself a form of predation removal that can have cascading consequences for the wider aquatic community.

Fill in the blank: A ________ cascade occurs when changes in predator abundance affect prey, which in turn affect organisms at lower trophic levels.

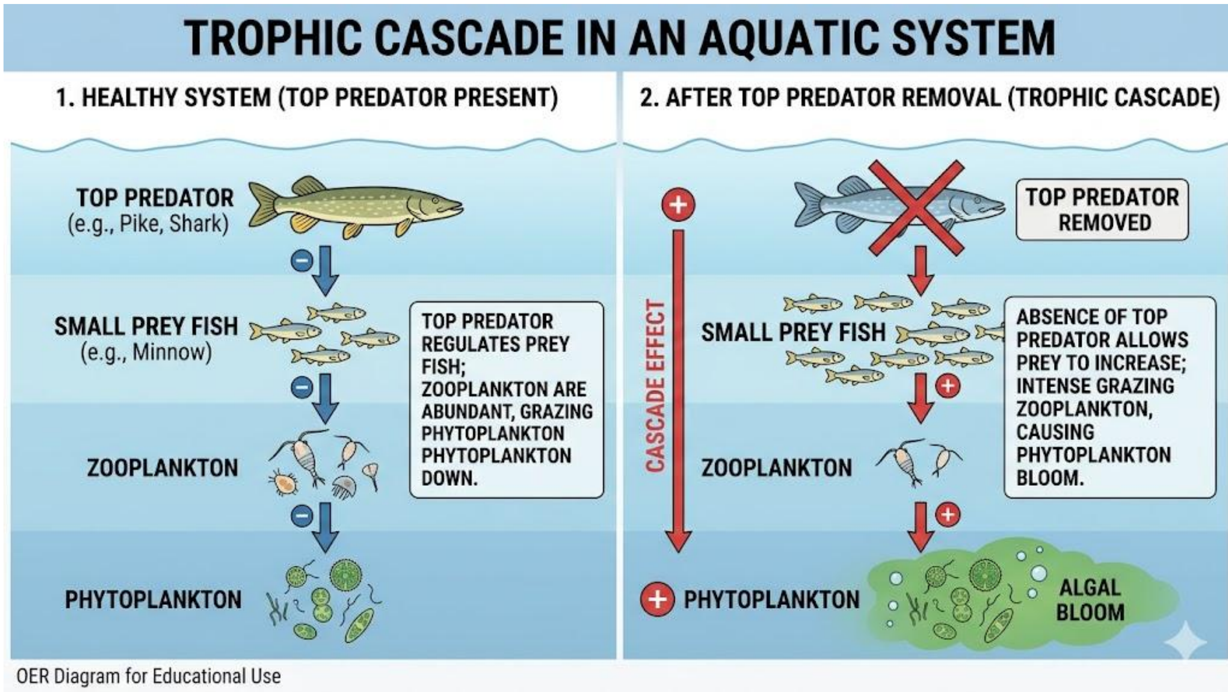


Figure 3.5: Trophic cascade showing how removal of a top predator affects lower trophic levels in an aquatic food web

3.4.2 Competition and resource use

Competition occurs when two or more species require the same limited resource, such that the use of that resource by one reduces its availability to the other. **Interspecific competition** between different species can lead to competitive exclusion or niche differentiation, as discussed in Series 2. **Intraspecific competition** among members of the same species is a key density-dependent mechanism regulating population size and is one of the forces that drives populations towards their carrying capacity.

In fisheries, competition for food and space determines the growth rates, condition, and survival of fish. Heavy stocking of aquaculture ponds or overfishing of some species while sparing others can shift competitive balances in ways that alter community composition. In multispecies fisheries such as those operating in the Niger Delta, understanding competitive interactions between commercially targeted species is important for predicting how harvesting one species will affect the others sharing the same food resources.

Fill in the blank: Competition among members of the same species is called ________ competition and is a key density-dependent regulator of population size.

Type of Competition	Definition	Examples in Fish Communities
Interspecific	Competition between individuals of different species for the same resources.	Tilapia and catfish competing for food in shared habitats; sardines and anchovies competing for plankton.
Intraspecific	Competition among individuals of the same species for limited resources.	Nile perch competing with other Nile perch for prey fish; tilapia competing for nesting sites.

Box 3.3: Interspecific and intraspecific competition in fish communities

3.4.3 Mutualism, commensalism, and parasitism

Mutualism is an interaction that benefits both species. In aquatic systems, cleaner fish such as cleaner wrasses remove parasites and dead tissue from larger fish, benefiting both parties. **Commensalism** benefits one species without affecting the other; for example, small fish that shelter in the tentacles of jellyfish gain protection without apparent harm to the jellyfish. **Parasitism** benefits the parasite at the expense of the host; fish lice, monogenean flukes, and internal helminths are common fish parasites that reduce host growth and survival.

Parasitism is particularly significant in fisheries ecology because high-density cultured fish populations provide ideal conditions for parasite transmission, making parasite management a major concern in aquaculture. Ectoparasites reduce the growth and market value of farmed fish, while endoparasites can affect reproductive success and survival. Understanding these interactions provides a more complete picture of the forces regulating fish abundance in both wild and cultured systems.

Fill in the blank: An interaction that benefits one species while the other is unaffected is called ________.

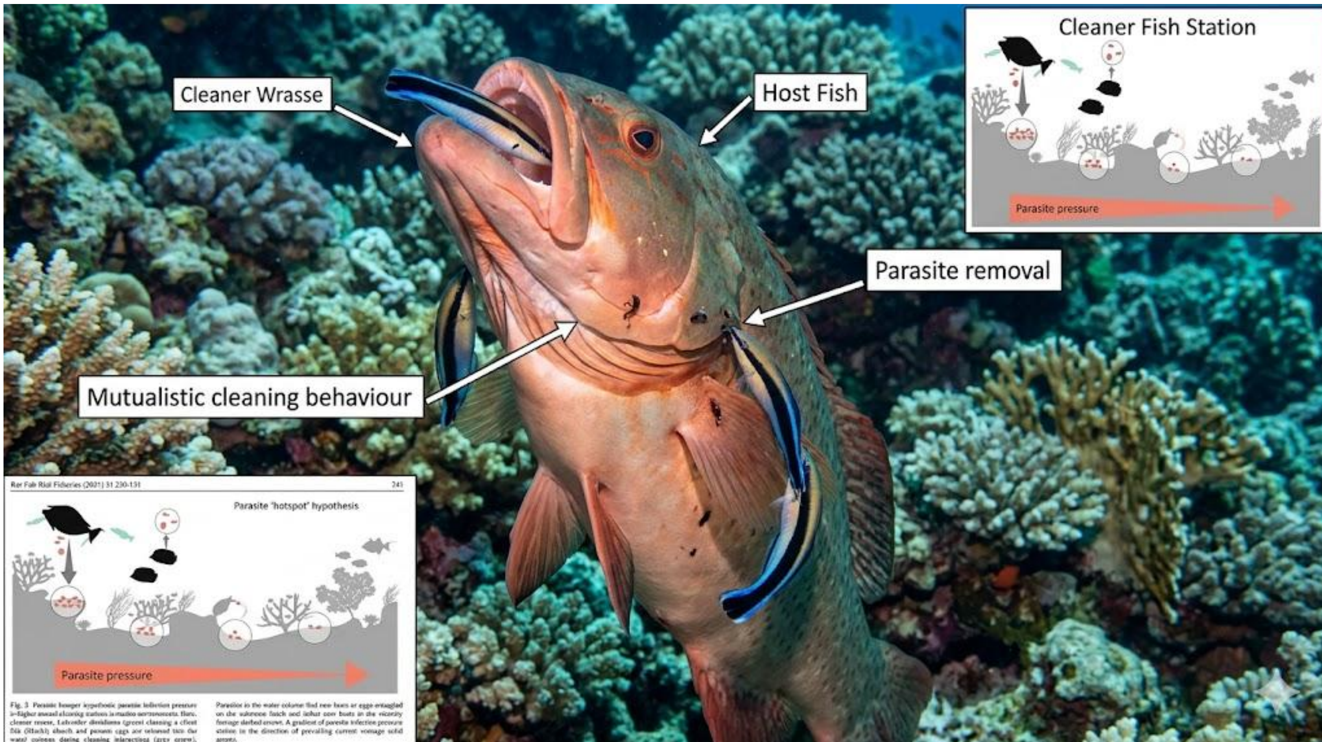


Plate 3.3: Cleaner fish removing parasites from a larger host fish, illustrating mutualism in an aquatic ecosystem

Pilot questions 3.4

Define predation and explain its role in shaping fish community structure.

Explain what a trophic cascade is and give one example.

Distinguish between interspecific and intraspecific competition.

Explain how competition for food affects the growth and survival of fish.

Distinguish between mutualism, commensalism, and parasitism, giving one aquatic example of each.

Series Summary

This Series has examined aquatic production, the roles of plankton and benthos, food chain and web structure, and species interactions. We began with primary and secondary production, establishing how organic matter is generated and transferred through trophic levels, and identified the abiotic and biotic factors that regulate production. We then explored phytoplankton and zooplankton ecology, the functions of benthic communities, and the processes of eutrophication and nutrient cycling, illustrating their significance for Nigerian water bodies.

Following that, we examined food chains and webs, trophic levels and energy transfer efficiency, and the classification of fish by feeding habit. Finally, we discussed the three major categories of species interaction relevant to fish ecology: predation and trophic cascades, competition and its density-dependent effects, and the symbiotic interactions of mutualism, commensalism, and parasitism. By completing this Series, you should now be able to achieve all nine Series Learning Outcomes (SLO 3.1 to SLO 3.9).

Glossary of Terms

Algal bloom: a rapid and excessive increase in phytoplankton abundance caused by elevated nutrient concentrations, often leading to oxygen depletion and fish kills.

Benthic community: the assemblage of organisms living on or in the sediment at the bottom of a water body, including insects, worms, molluscs, and demersal fish.

Commensalism: a species interaction in which one species benefits while the other is neither harmed nor benefited.

Competition: an interaction in which two or more organisms require the same limited resource, such that the use by one reduces availability to the other.

Detritivore: an organism that feeds on dead organic matter (detritus) and contributes to nutrient recycling in aquatic systems.

Eutrophication: the enrichment of a water body with excess nutrients, typically nitrogen and phosphorus, leading to algal blooms, oxygen depletion, and ecosystem degradation.

Gross primary production (GPP): the total amount of organic matter synthesised by primary producers through photosynthesis.

Herbivore: an organism that feeds primarily on plants or algae; in fish ecology, herbivorous species such as tilapia occupy the second trophic level.

Interspecific competition: competition between individuals of different species for the same limited resource.

Intraspecific competition: competition between individuals of the same species; a key density-dependent mechanism regulating population size towards carrying capacity.

Mutualism: a species interaction that benefits both participating organisms.

Net primary production (NPP): gross primary production minus the energy used by producers for their own respiration; the organic matter available to consumers.

Parasitism: a species interaction in which the parasite benefits at the expense of the host, reducing the host's growth or survival.

Phytoplankton: microscopic photosynthetic organisms that drift in the water column and form the base of most aquatic food webs.

Predation: an interaction in which one organism (predator) kills and consumes another (prey); a primary force structuring fish communities.

Primary production: the synthesis of organic matter from inorganic compounds using solar energy; the energy base of all aquatic food webs.

Secondary production: the formation of organic biomass by consumers through the assimilation of food; links primary producers to fish and higher consumers.

Ten per cent rule: the generalisation that approximately ten per cent of energy at one trophic level is transferred to the biomass of the next.

Trophic cascade: an indirect effect in which changes in the abundance of a predator propagate through the food web, affecting organisms at lower trophic levels.

Zooplankton: small animals that drift in the water column and feed on phytoplankton and each other; form the critical link between primary producers and fish.

Concept Check Questions [Series 3]

Objective Questions

Define primary production. (Linked to SLO 3.1)

What percentage of energy is approximately transferred from one trophic level to the next? (Linked to SLO 3.5)

Fill in the blank: Zooplankton form the critical link between phytoplankton and ________ in aquatic food webs. (Linked to SLO 3.2)

The enrichment of water with excess nutrients leading to algal blooms is called ________. (Linked to SLO 3.3)

A species interaction that benefits both organisms is called ________. (Linked to SLO 3.9)

Short-Answer Questions

Distinguish between gross primary production and net primary production. (Linked to SLO 3.1)

Explain the ecological role of benthic communities in aquatic systems. (Linked to SLO 3.2)

Explain what a trophic cascade is, using a specific example. (Linked to SLO 3.7)

Distinguish between interspecific and intraspecific competition, giving one example of each. (Linked to SLO 3.8)

Classify tilapia, Nile perch, and a copepod by trophic level and feeding habit. (Linked to SLO 3.6)

Long-Answer Questions

Analyse the processes of aquatic production and their regulatory factors, explaining how abiotic and biotic conditions determine the productivity of a water body and its capacity to support fish. (Linked to SLOs 3.1, 3.2, 3.3)

Discuss the structure of food chains and webs in aquatic ecosystems, explaining trophic levels, energy transfer efficiency, and the feeding habits of fish, and evaluate their implications for fisheries management. (Linked to SLOs 3.4, 3.5, 3.6)

Evaluate the major categories of species interaction in aquatic systems, explaining how predation, competition, and symbiotic relationships influence fish abundance and community structure. (Linked to SLOs 3.7, 3.8, 3.9)

Answers to Concept Check Questions [Series 3]

Objective Questions

Primary production is the synthesis of organic matter from inorganic compounds using solar energy, carried out mainly by phytoplankton, macrophytes, and benthic algae.

Approximately ten per cent.

Larger consumers (fish).

Eutrophication.

Mutualism.

Short-Answer Questions

Gross primary production (GPP) is the total organic matter synthesised by producers through photosynthesis. Net primary production (NPP) is GPP minus the energy producers use for their own respiration, and represents the organic matter available to consumers.

Benthic communities process organic matter deposited from the water column, recycling nutrients back into the water. They provide food for demersal fish and serve as indicators of water quality and ecosystem health.

A trophic cascade is an indirect effect in which a change in predator abundance ripples through the food web. For example, removing a top fish predator allows prey fish to increase, which intensifies grazing on zooplankton, reducing their abundance and allowing phytoplankton to increase.

Interspecific competition occurs between different species, for example two fish species competing for the same invertebrate prey. Intraspecific competition occurs between members of the same species, for example individuals within a tilapia population competing for territory and food at high density.

Tilapia: second trophic level, herbivore (feeds on algae and plants). Nile perch: third or fourth trophic level, carnivore (feeds on other fish). Copepod: second trophic level, primary consumer (feeds on phytoplankton).

Long-Answer Questions

Basic response: Primary production is driven by photosynthesis in phytoplankton, macrophytes, and benthic algae; it is regulated by light, nutrients (nitrogen and phosphorus), temperature, and grazing. Secondary production links primary producers to fish through zooplankton and other consumers. Eutrophication disrupts production by causing algal blooms and oxygen depletion.

Value-added response: In Nigerian systems, seasonal flooding enhances nutrient inputs and primary production, but agricultural runoff and sewage loading can trigger eutrophication. Understanding the balance between natural and anthropogenic nutrient inputs is essential for managing the productivity of Nigerian fisheries sustainably.

Basic response: Food chains show linear energy transfer from producers through successive consumers. Food webs are more realistic, showing multiple connections. Trophic levels indicate feeding position; only about ten per cent of energy passes to the next level. Fish feeding habits range from herbivory (tilapia) to carnivory (Nile perch).

Value-added response: The ten per cent rule means fisheries targeting lower trophic levels (herbivorous fish, small pelagics) can sustain far greater yields per unit of primary production than those targeting apex predators. Fisheries management should account for the trophic level of target species when setting harvest limits to avoid systemic overexploitation.

Basic response: Predation reduces prey abundance and can trigger trophic cascades. Competition limits population size through density-dependent effects; interspecific competition can lead to competitive exclusion. Mutualism, commensalism, and parasitism represent additional interaction types with varying effects on the participating species.

Value-added response: These interactions do not operate in isolation. In Nigerian multispecies fisheries, removing large predatory fish reduces predation pressure on smaller fish, which then compete more intensively with each other and with juveniles of commercial species. Parasitism in intensively farmed fish highlights the need to manage stocking density to prevent transmission. A holistic understanding of species interactions is essential for sustainable management.

Answers to Pilot Questions [Series 3]

Part 3.1: Aquatic Production and Its Regulatory Factors

Primary production is the synthesis of organic matter from inorganic compounds by photosynthetic organisms. GPP is the total amount synthesised; NPP is what remains after producers use some for respiration and is available to consumers.

Primary production forms the energy base of all aquatic food webs; it determines the total organic matter available to support herbivores, carnivores, and ultimately the fish populations of commercial interest.

Secondary production is the formation of organic biomass by consumers; it links primary producers to fish by converting phytoplankton and plant biomass into animal biomass accessible to carnivorous fish at higher trophic levels.

Any two: light availability; nutrient concentration (nitrogen and phosphorus); water temperature; mixing regime and stratification.

Only about ten per cent of energy at each trophic level is incorporated into the biomass of the next; the remainder is lost as metabolic heat, excretion products, and uneaten organic matter.

Part 3.2: Plankton, Benthos, and Organic Production

Any two: diatoms; dinoflagellates; cyanobacteria.

Zooplankton feed on phytoplankton and each other and are consumed by fish larvae, juveniles, and adults; they form the critical link between primary producers and larger consumers and are important determinants of fish recruitment success.

Any two: process organic matter deposited from the water column; recycle nutrients back into the water; provide food for demersal fish; serve as indicators of water quality.

Eutrophication is the enrichment of a water body with excess nutrients; its main cause is excessive input of nitrogen and phosphorus from agricultural runoff, sewage, or industrial discharge.

Algal blooms reduce light penetration, preventing photosynthesis by submerged plants; when blooms die and decompose, bacteria consume oxygen, causing hypoxia or anoxia that suffocates fish.

Part 3.3: Food Chains, Food Webs, and Trophic Levels

A food chain is a linear sequence of energy transfer from producer to consumer. A food web is a more realistic network showing the multiple feeding connections among many species in a community.

Level 1: producers (phytoplankton, algae); Level 2: primary consumers (zooplankton, herbivorous fish such as tilapia); Level 3: secondary consumers (small carnivorous fish such as juvenile catfish); Level 4: apex predators (large carnivores such as Nile perch).

Because only about ten per cent of energy is transferred between trophic levels, systems based on low-trophic-level species (close to primary production) have far more energy available, supporting greater biomass and higher sustainable yields than systems targeting apex predators.

Tilapia: herbivore (feeds on algae and plants). Nile perch: carnivore (feeds on fish and large invertebrates). Catfish: omnivore (feeds on both plant material and animals).

Feeding habit determines which organisms a fish consumes and is consumed by, placing it at a specific trophic level; a herbivore occupies trophic level 2, a carnivore occupies level 3 or above, and an omnivore may span multiple levels depending on diet composition.

Part 3.4: Species Interactions

Predation is the killing and consumption of one organism by another; it directly reduces prey abundance and indirectly shapes the behaviour, distribution, and morphology of prey species, making it one of the most powerful forces structuring fish communities.

A trophic cascade is an indirect effect of predator abundance change propagating down through the food web. For example, removing a top predator allows prey fish to increase, which over-grazes zooplankton, reducing their abundance and releasing phytoplankton from grazing control.

Interspecific competition is between different species competing for the same resource. Intraspecific competition is between members of the same species for the same resource, and is the key density-dependent mechanism that limits population growth towards carrying capacity.

Competition for food reduces per capita food intake, lowering individual growth rates and body condition; competition for space limits the number of territories available for breeding, reducing reproductive success; together, these effects reduce survival and growth especially at high population densities.

Mutualism: cleaner fish remove parasites from larger fish, benefiting both (example: cleaner wrasse and grouper). Commensalism: small fish shelter in jellyfish tentacles, gaining protection without affecting the jellyfish. Parasitism: fish lice attach to the skin of fish, feeding on mucus and blood and reducing host condition.

References and Attributions [Series 3]

Textual References (Books and External Sources)

Odum, E. P., & Barrett, G. W. (2005). Fundamentals of Ecology (5th ed.). Brooks Cole.

Begon, M., Townsend, C. R., & Harper, J. L. (2006). Ecology: From individuals to ecosystems (4th ed.). Blackwell Publishing.

Reynolds, C. S. (2006). Ecology of phytoplankton. Cambridge University Press.

Welcomme, R. L. (2001). Inland fisheries: Ecology and management. Blackwell Science.

Pitcher, T. J., & Hart, P. J. B. (1982). Fisheries Ecology. AVI Publishing.

FAO (Food and Agriculture Organization of the United Nations). (2025). Guidelines for sustainable fisheries. FAO.

Figures, Plates, Tables, and Boxes

Figure 3.1: Gross and net primary production in an aquatic ecosystem Attribution: AI generated using prompt "Generate a diagram showing how gross primary production is divided into producer respiration and net primary production." Suggested OER search string: "primary production gross net aquatic ecosystem diagram OER".

Figure 3.2: Energy pyramid showing biomass at successive trophic levels Attribution: AI generated using prompt "Generate an energy pyramid showing decreasing biomass from producers through herbivores to carnivores." Suggested OER search string: "energy pyramid trophic levels biomass aquatic OER diagram".

Box 3.1: Key regulatory factors of aquatic primary production Attribution: AI generated using prompt "Generate a text box listing the key abiotic and biotic factors regulating primary production in aquatic systems." Suggested OER search string: "regulatory factors aquatic primary production OER".

Figure 3.3: Phytoplankton and zooplankton in the planktonic food web Attribution: AI generated using prompt "Generate a diagram showing phytoplankton being consumed by zooplankton which are then consumed by fish." Suggested OER search string: "phytoplankton zooplankton planktonic food web diagram OER".

Plate 3.1: Benthic macroinvertebrates in river sediment Attribution: AI generated using prompt "Generate an image showing diverse benthic macroinvertebrates including insect larvae, worms, and molluscs in river sediment." Suggested OER search string: "benthic macroinvertebrates river sediment diversity OER image".

Plate 3.2: Algal bloom on a eutrophic water body Attribution: AI generated using prompt "Generate an image showing a dense algal bloom covering the surface of a lake, illustrating eutrophication." Suggested OER search string: "algal bloom eutrophication lake surface OER image".

Figure 3.4: Aquatic food web with multiple feeding connections Attribution: AI generated using prompt "Generate a diagram showing an aquatic food web with phytoplankton, zooplankton, invertebrates, and fish species connected by feeding arrows." Suggested OER search string: "aquatic food web multiple species feeding connections OER diagram".

Table 3.1: Trophic levels in aquatic ecosystems Attribution: AI generated using prompt "Generate a table listing trophic levels in an aquatic ecosystem with examples and energy transfer percentages." Suggested OER search string: "trophic levels aquatic ecosystem energy transfer table OER".

Box 3.2: Fish feeding habit classification with Nigerian examples Attribution: AI generated using prompt "Generate a text box listing fish feeding categories including herbivore, omnivore, carnivore, and detritivore with examples of Nigerian fish." Suggested OER search string: "fish feeding habits categories Nigerian species OER".

Figure 3.5: Trophic cascade showing effects of top predator removal Attribution: AI generated using prompt "Generate a diagram illustrating a trophic cascade showing how top predator removal leads to changes in prey fish, zooplankton, and phytoplankton." Suggested OER search string: "trophic cascade top predator aquatic system OER diagram".

Box 3.3: Interspecific and intraspecific competition in fish communities Attribution: AI generated using prompt "Generate a text box distinguishing interspecific and intraspecific competition in fish communities with examples." Suggested OER search string: "interspecific intraspecific competition fish communities OER".

Plate 3.3: Cleaner fish removing parasites from a host fish Attribution: AI generated using prompt "Generate an image showing a small cleaner fish removing parasites from a larger host fish." Suggested OER search string: "cleaner fish mutualism parasite removal OER image".

Course code: FAA 306

Course title: Fisheries Ecology

Course credit load: 2 Units

Series 4: Behavioural Ecology of Selected Fish Species

Series outline

Introduction

In the previous Series, we examined how energy flows through aquatic systems and how species interact within food webs. This Series shifts focus to the individual fish, exploring the behaviours that enable fish to feed, reproduce, defend themselves, and move through their environments. Behavioural ecology links individual actions to ecological outcomes, helping us understand how fish populations are organised and how they respond to environmental change and fishing pressure.

The aim of this Series is to describe and analyse the feeding, reproductive, aggressive, predatory, and migratory behaviours of selected fish species, with particular reference to species of ecological and commercial importance in Nigeria and globally.

We shall commence this Series by examining the feeding behaviours of fish, including foraging strategies and selected Nigerian examples. Next, we will explore reproductive behaviour, from mating systems to parental care. Following that, we will study aggressive, territorial, and predatory behaviour alongside anti-predator defences. Finally, we will wrap up with migratory behaviour, covering the types, cues, and examples of fish migration.

Series Learning Outcomes

Upon completing this Series, you should be able to:

SLO 4.1 describe the types of feeding behaviour in fish and the principles of foraging theory (Linked to Part 4.1),

SLO 4.2 explain the feeding behaviour of selected Nigerian fish species (Linked to Part 4.1),

SLO 4.3 describe mating systems, courtship, and spawning behaviour in fish (Linked to Part 4.2),

SLO 4.4 explain life history strategies and parental care in fish (Linked to Part 4.2),

SLO 4.5 describe aggressive and territorial behaviour in fish and explain its ecological significance (Linked to Part 4.3),

SLO 4.6 explain predatory behaviour and the strategies fish use to capture prey (Linked to Part 4.3),

SLO 4.7 describe anti-predator behaviours and defence strategies in fish (Linked to Part 4.3),

SLO 4.8 identify the types and patterns of fish migration (Linked to Part 4.4), and

SLO 4.9 explain the cues and mechanisms of migration in selected fish species (Linked to Part 4.4).

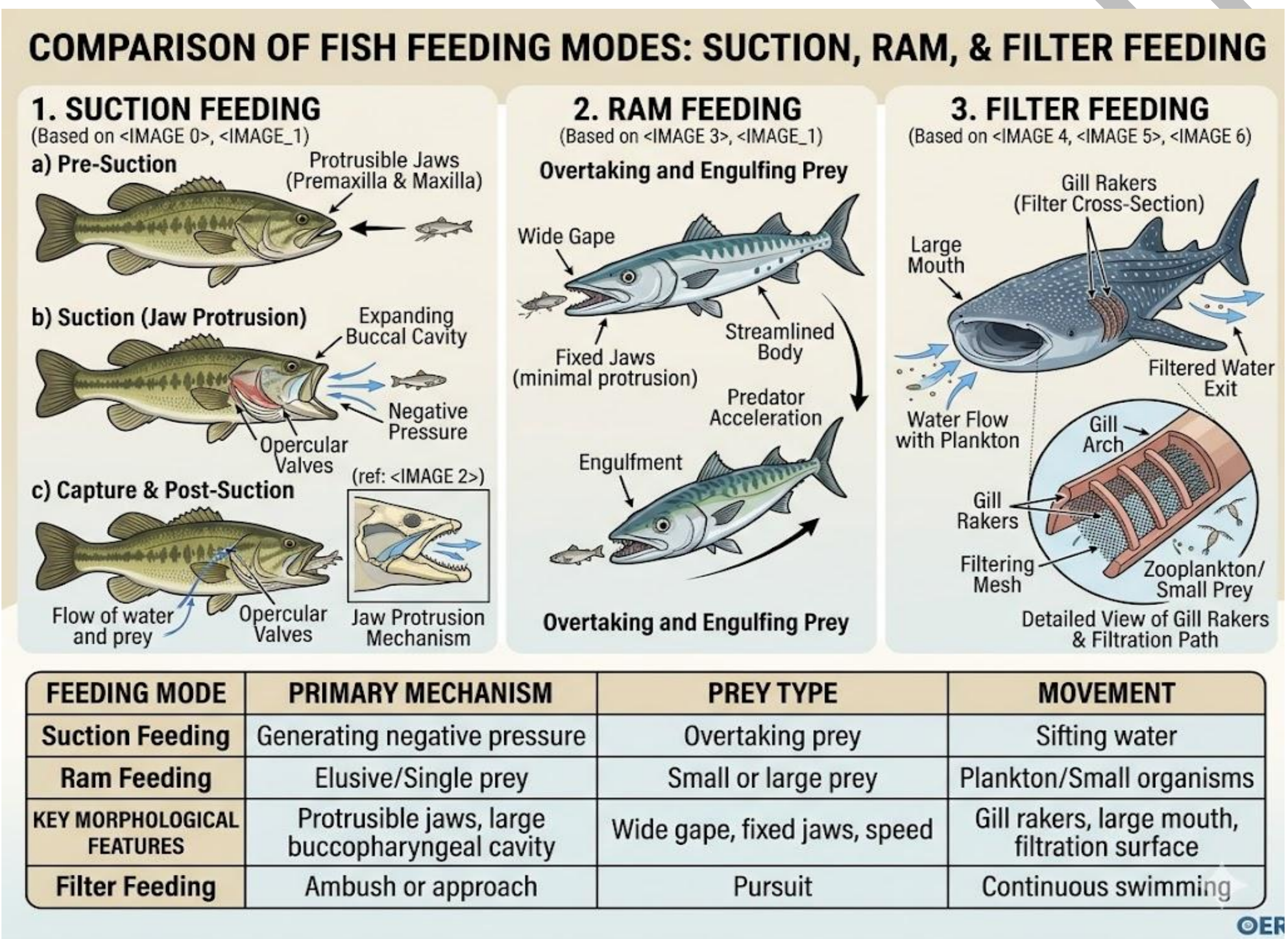
4.1 Feeding Behaviour of Fish

4.1.1 Types of feeding behaviour in fish

Feeding behaviour encompasses all activities associated with food acquisition, from prey detection through to capture and ingestion. Fish show considerable diversity in feeding modes. **Suction feeders** create a rapid inflow of water to draw prey into the mouth. **Ram feeders** overtake prey by swimming rapidly. **Filter feeders** such as tilapia collect suspended particles by passing water through gill rakers.

These modes are tied to body morphology: suction feeders have protrusible jaws; ram feeders have streamlined bodies and wide gape; filter feeders possess fine, closely spaced gill rakers. Feeding behaviour is also influenced by time of day, temperature, prey availability, and competition. Many species shift diet seasonally as prey availability changes.

Fill in the blank: Fish that create a rapid inflow of water to draw prey into the mouth are called ________ feeders.



FEEDING MODE	PRIMARY MECHANISM	PREY TYPE	MOVEMENT
Suction Feeding	Generating negative pressure	Overtaking prey	Sifting water
Ram Feeding	Elusive/Single prey	Small or large prey	Plankton/Small organisms
KEY MORPHOLOGICAL FEATURES	Protrusible jaws, large buccopharyngeal cavity	Wide gape, fixed jaws, speed	Gill rakers, large mouth, filtration surface
Filter Feeding	Ambush or approach	Pursuit	Continuous swimming

Figure 4.1: Diagram showing three feeding modes in fish: suction feeding, ram feeding, and filter feeding

4.1.2 Foraging strategies and optimal foraging theory

Optimal foraging theory predicts that natural selection favours individuals that maximise net energy intake per unit of foraging time. A fish is expected to select prey that provide the highest energy return relative to the effort of catching them, and to leave a food patch when its return rate falls below the average available elsewhere.

In practice, fish modify foraging behaviour in response to predation risk: staying in shelter and accepting lower food intake to avoid exposure is known as the foraging-predation risk trade-off. Social foraging in schools increases prey detection rates in many species. Understanding foraging strategies helps predict how fish populations respond to changes in prey availability caused by habitat change or competition.

Fill in the blank: Optimal foraging theory predicts that fish maximise their net ________ intake per unit of foraging time.

Principle	Explanation
Energy maximisation	Fish aim to maximise net energy gain by selecting prey that provides the most energy relative to effort.
Prey selection	Fish choose prey based on size, abundance, and ease of capture to optimise feeding efficiency.
Patch use	Fish decide how long to remain in a feeding area before moving to another, balancing energy intake with search costs.
Foraging–predation risk trade-off	Fish balance the need to feed with the risk of being preyed upon, often modifying behaviour in risky habitats.

Box 4.1: Key principles of optimal foraging theory applied to fish

4.1.3 Feeding behaviour in selected Nigerian species

Nile tilapia (Oreochromis niloticus) is primarily a filter feeder and algal scraper, but also consumes invertebrates and plant material. This dietary flexibility contributes to its success across a wide range of habitats and makes it highly suitable for aquaculture throughout Nigeria.

The African catfish (Clarias gariepinus) is a nocturnal opportunistic predator and scavenger that feeds on invertebrates, small fish, plant material, and carrion. It uses chemoreception and tactile barbels to locate food in dark or turbid water, exploiting food resources unavailable to visually oriented species. In Nigerian floodplain systems, tilapia, catfish, and other species occupy distinct feeding niches, reducing direct competition.

Fill in the blank: The African catfish uses chemoreception and tactile ________ to locate food in dark or turbid water.

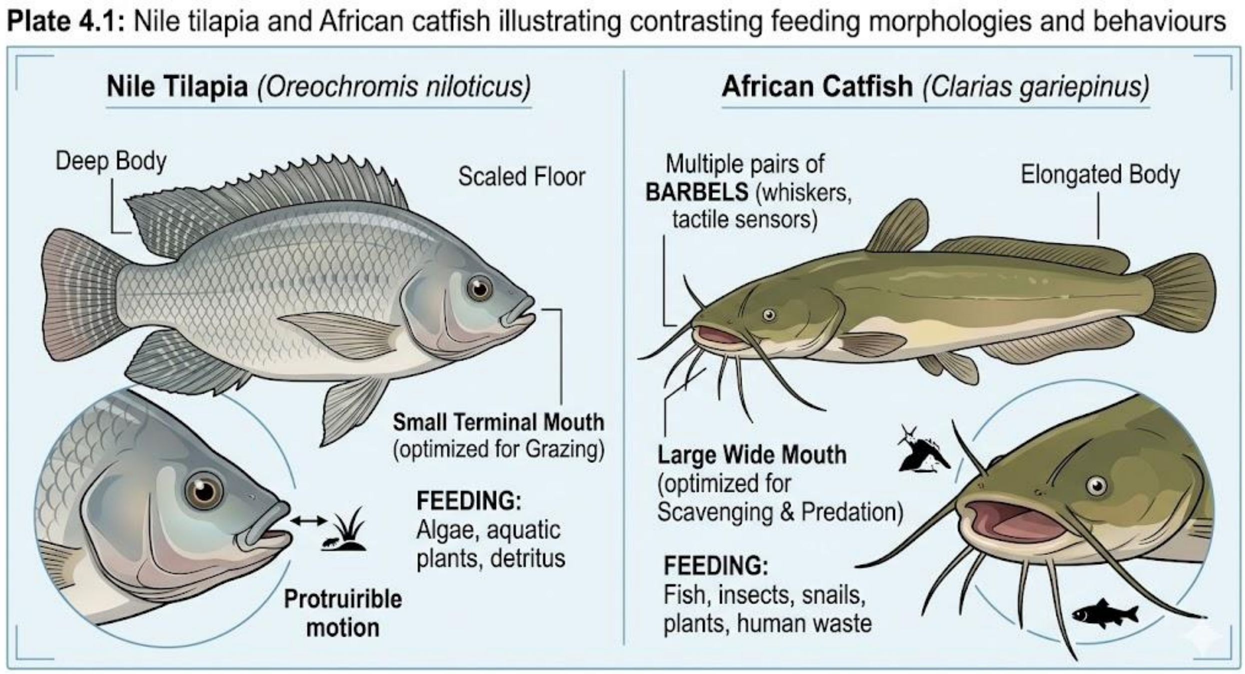


Plate 4.1: Nile tilapia and African catfish illustrating contrasting feeding morphologies and behaviours

Pilot questions 4.1

Define feeding behaviour and name three feeding modes found in fish.

Explain the principle of optimal foraging theory.

What is the foraging-predation risk trade-off?

Describe the feeding behaviour of Nile tilapia.

How does the African catfish locate food in turbid water?

4.2 Reproductive Behaviour of Fish

4.2.1 Mating systems and courtship behaviour

Mating systems describe the pattern of pairing between males and females. Fish exhibit monogamy (one male, one female), polygyny (one male, multiple females), polyandry (one female, multiple males), and promiscuity (no lasting pair bonds). The system of a species is shaped by the costs and benefits of mate guarding, resource distribution, and relative parental investment.

Courtship behaviour precedes mating and serves to attract, assess, and synchronise the reproductive readiness of potential partners. It typically involves visual displays, colour changes, sound production, or chemical signals. In cichlids such as tilapia, nest building and fin displays by the male signal fitness to females. Synchronisation of gamete release is critical because eggs and sperm are viable for only short periods.

Fill in the blank: Courtship behaviour serves to attract, assess, and ________ the reproductive readiness of potential mating partners.

Plate 4.2: Male cichlid displaying courtship colours and behaviour to attract a female

4.2.2 Spawning behaviour and life history strategies

Spawning behaviour refers to the release and fertilisation of eggs. Open-water spawners such as herrings and sardines release eggs directly into the water column. Substrate spawners deposit eggs on rocks, vegetation, or sand. Mouth brooders carry fertilised eggs in the buccal cavity until hatching.

Life history strategies vary from r-selected species, which produce many small eggs with little parental investment and short lifespans, to K-selected species, which produce few large eggs with high parental investment and long lifespans. Sardines are r-selected; large predatory fish such as Nile perch are more K-selected. These differences have major implications for the resilience of fish populations to harvesting pressure.

Fill in the blank: Fish that produce many small eggs with little parental care are described as ________-selected.

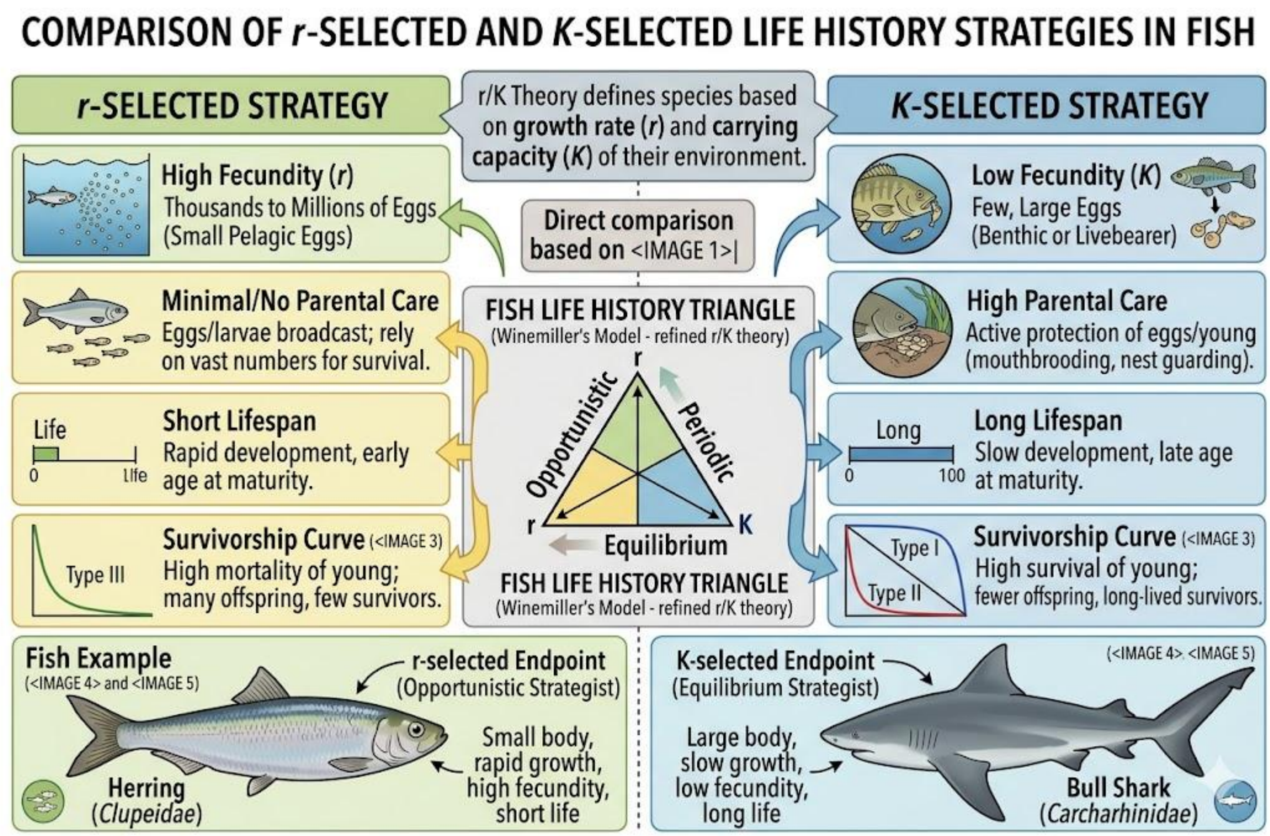


Figure 4.2: Diagram comparing r-selected and K-selected life history strategies in fish

4.2.3 Parental care in fish

Parental care includes any behaviour that increases offspring survival at a cost to the parent, ranging from simple nest guarding to elaborate mouth brooding. It is most developed in species with small clutch sizes, consistent with K-selection. In Nigerian freshwater systems, mouth-brooding tilapia (Oreochromis and Sarotherodon species) carry fertilised eggs and free-swimming fry in the buccal cavity, protecting them from predation.

Nest-guarding behaviour is observed in many catfish species, where parents defend eggs until hatching. The degree of parental care is a major determinant of offspring survival; species with intensive parental care produce fewer but more viable offspring than those that broadcast eggs without guarding. Understanding parental care helps predict the vulnerability of species to disturbance during critical reproductive periods.

Fill in the blank: Fish that carry fertilised eggs in the mouth until hatching are called mouth ________.

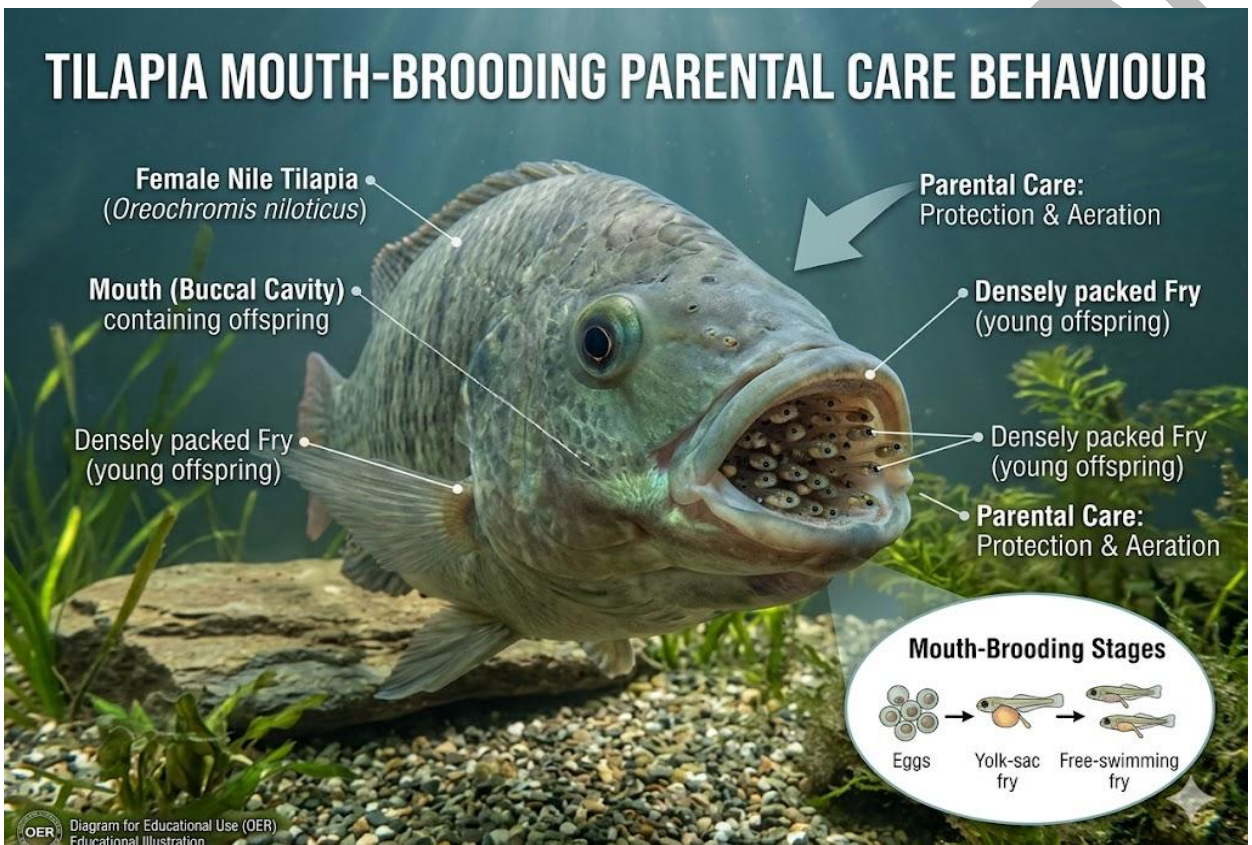


Plate 4.3: Female tilapia mouth brooding her eggs or fry in the buccal cavity

Pilot questions 4.2

Name two mating systems found in fish and give one example of each.

Explain the purpose of courtship behaviour in fish.

Distinguish between open-water spawners and substrate spawners.

Explain the difference between r-selected and K-selected life history strategies.

Describe mouth brooding as a form of parental care in tilapia.

4.3 Aggressive and Predatory Behaviour

4.3.1 Aggression and territoriality in fish

Aggression in fish refers to threatening or attacking behaviour directed at competitors or intruders, most commonly in defence of feeding sites, spawning territories, and mates. It is typically settled through display and ritual threat rather than physical combat, reducing injury to both parties. Dominance hierarchies, in which some individuals consistently displace others, are common in social fish species.

Territoriality is the defence of a defined area containing valued resources. Territorial fish such as cichlids and reef fish actively patrol and defend boundaries against conspecifics. Territory size is influenced by resource density and the cost of defence relative to the benefit. In aquaculture, aggression and territoriality reduce growth uniformity in communally raised stocks, making stocking density management important.

Fill in the blank: Territorial fish actively patrol and defend boundaries against ________, other individuals of the same species.

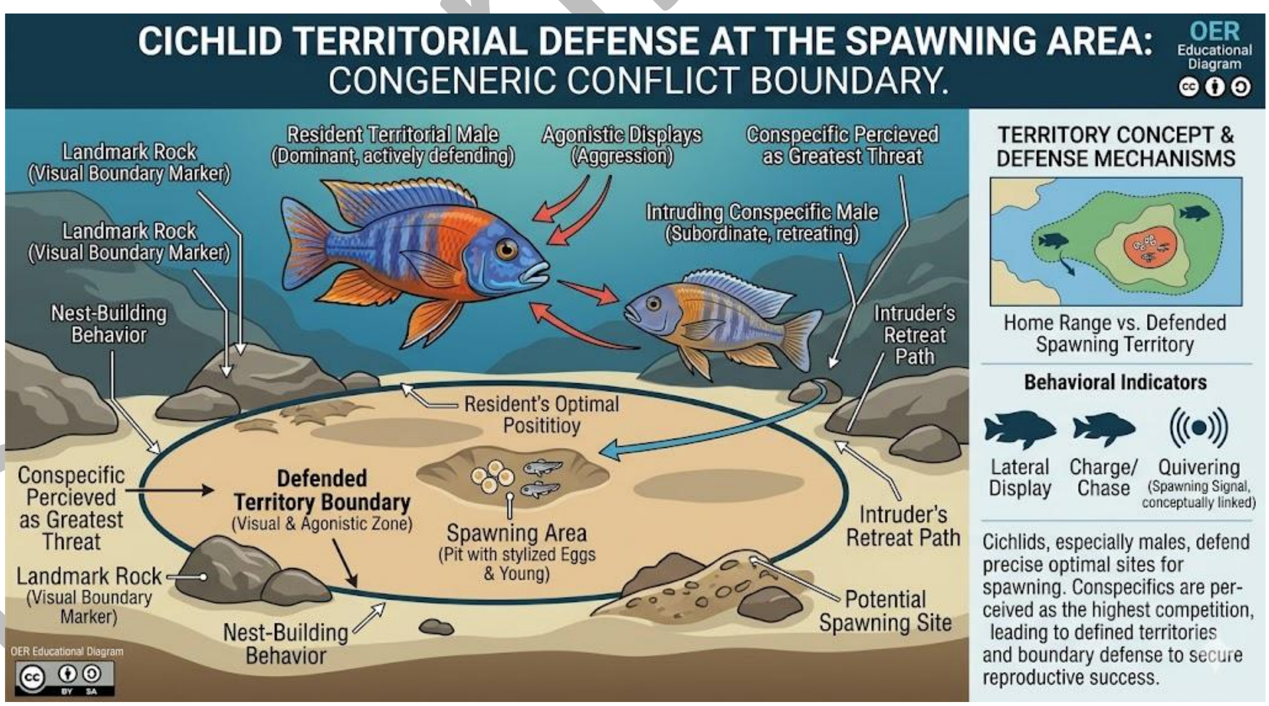


Figure 4.3: Diagram showing a territorial cichlid defending its spawning territory against an intruder

4.3.2 Predatory behaviour and prey capture strategies

Predatory behaviour involves a sequence of prey detection, approach, attack, and capture. Detection relies on vision, lateral line mechanoreception, electroreception (in some species), and olfaction. Ambush predators such as some catfish remain stationary and strike suddenly, minimising energy expenditure. Pursuit predators such as the Nile perch actively chase prey using speed and manoeuvrability.

Prey capture strategies are matched to prey type and habitat. Piscivores herding schooling prey towards the surface before attacking is a cooperative strategy seen in several species. The morphology of the predator, including jaw type, body shape, and fin configuration, reflects the prey capture strategy it has evolved. Understanding predatory behaviour is important for assessing how fishing removes predators and alters community structure.

Fill in the blank: Ambush predators remain ________ and strike suddenly, while pursuit predators actively chase prey.

Plate 4.4: Predatory fish in ambush posture concealed in vegetation ready to strike prey

4.3.3 Anti-predator behaviour and defence strategies

Anti-predator behaviours reduce the risk of being captured. Schooling is one of the most widespread strategies; a large moving school reduces individual predation risk through the

dilution effect (probability of any individual being caught decreases with group size) and the **confusion effect** (a mass of similar moving fish is difficult for a predator to track).

Other strategies include cryptic colouration (camouflage), deimatic displays (startling behaviours such as sudden fin erection), and the C-start escape reflex, in which the body curves rapidly before a powerful acceleration away from a predator strike. Chemical alarm signals released by injured skin warn conspecifics of predator presence. These strategies collectively reduce predation mortality across fish communities.

Fill in the blank: The ________ effect reduces predation risk in schools because the probability of any individual being captured decreases as group size increases.

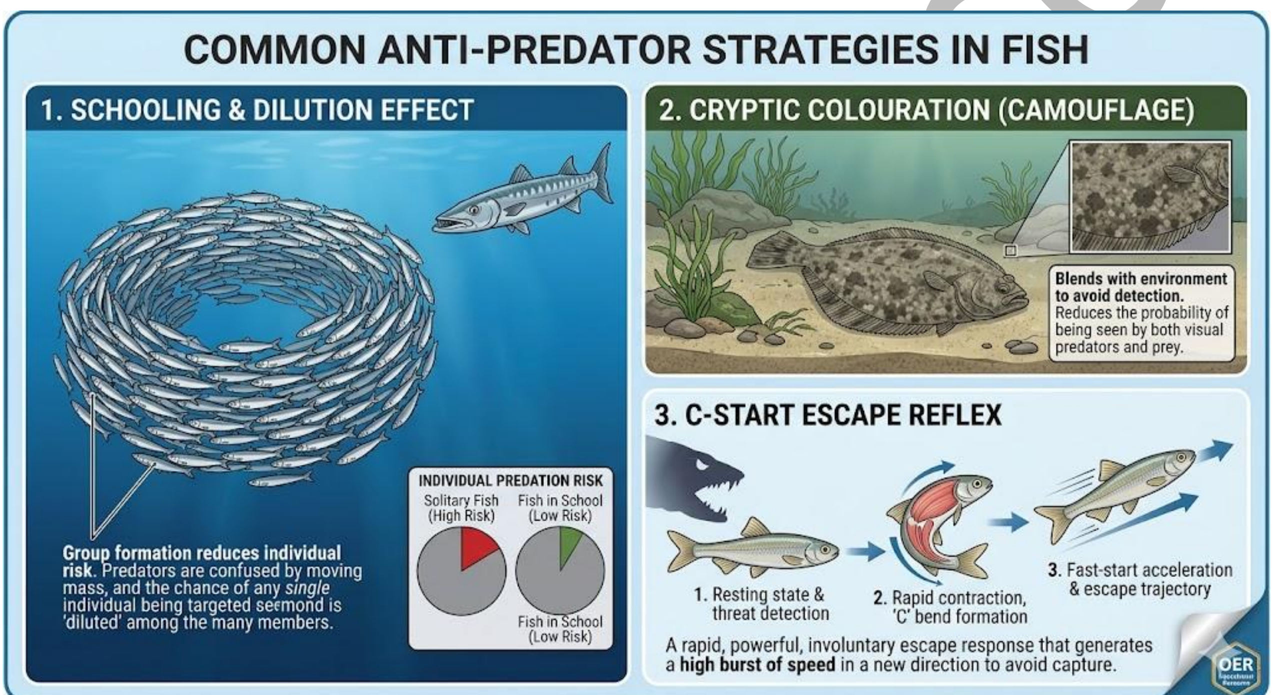


Figure 4.4: Diagram showing anti-predator strategies including schooling, camouflage, and the C-start escape response

Pilot questions 4.3

Define aggression in fish and explain why it is usually settled by display rather than combat.

What is territoriality and what resources do fish typically defend?

Describe the sequence of predatory behaviour in a fish attacking prey.

Distinguish between ambush predators and pursuit predators with one example of each.

Explain how schooling reduces predation risk through the dilution and confusion effects.

4.4 Migratory Behaviour of Fish

4.4.1 Types and patterns of fish migration

Migration is the seasonal, directional movement of fish between habitats, driven by reproductive, feeding, or environmental requirements. Fish migrations are classified by the environments traversed. **Diadromous** species migrate between freshwater and the sea: anadromous species (e.g., salmon) spawn in freshwater and feed in the sea; catadromous species (e.g., freshwater eels) grow in freshwater and spawn at sea.

Potamodromous species migrate entirely within freshwater between river reaches or floodplains. In Nigeria, seasonal migrations of fish between main river channels and adjacent floodplains during the annual flood pulse of the Niger and Benue rivers are among the most ecologically and economically important migratory events, driving the productivity of artisanal floodplain fisheries.

Fill in the blank: Fish that spawn in freshwater and feed in the sea are described as ________.

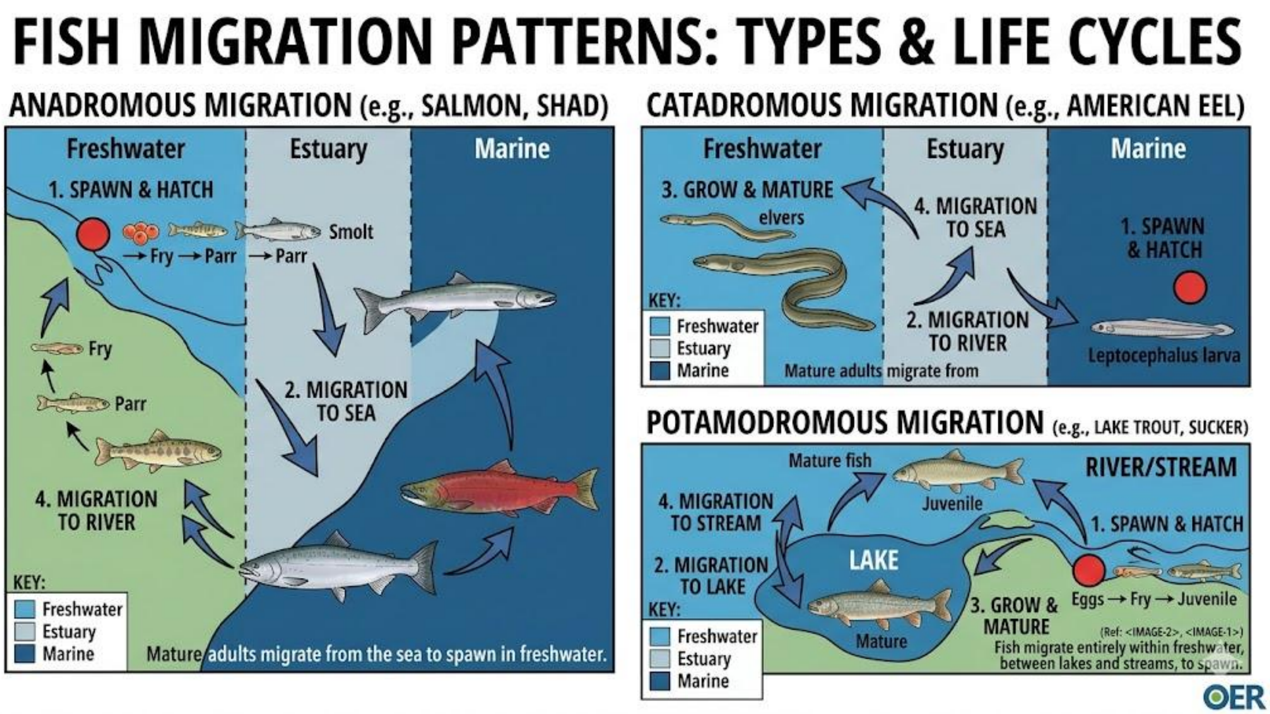


Figure 4.5: Diagram illustrating migration patterns of anadromous, catadromous, and potamodromous fish

4.4.2 Cues and mechanisms of migration

Photoperiod (day length) is among the most reliable cues for initiating seasonal migrations, as it changes predictably throughout the year. **Temperature** triggers migration in many species: warming spring waters stimulate upstream spawning movements and cooling autumn temperatures prompt downstream or offshore movement.

Navigation during migration involves geomagnetic orientation (sensing the Earth's magnetic field), olfactory homing (returning to natal streams by detecting their characteristic chemical signature), and rheotaxis (orientation to water current). Human modification of rivers through dam construction, water abstraction, and pollution disrupts these cues and can prevent fish from completing their migrations, leading to population decline.

Fill in the blank: Salmon return to their natal streams by detecting the characteristic chemical signature through ________ homing.

Cue / Mechanism	Explanation
Photoperiod (day length)	Seasonal changes in light trigger migration timing and reproductive cycles.
Temperature	Shifts in water temperature guide fish toward suitable spawning or feeding grounds.
Geomagnetic orientation	Fish detect Earth’s magnetic field to navigate long distances with precision.
Olfactory homing	Fish use chemical cues and smell to return to natal rivers or spawning sites.
Currents and flow patterns	Water movement provides directional guidance and energy-efficient migration routes.
Social cues	Group behaviour and schooling help coordinate migration among conspecifics.

Box 4.2: Environmental cues and navigation mechanisms used by migratory fish

4.4.3 Migration in selected Nigerian and global species

In Nigeria, characins such as the tiger fish (Hydrocynus forskalii) make lateral migrations from main river channels onto floodplains during the flood pulse of the Niger and Benue rivers, exploiting abundant food resources in temporarily inundated vegetation. These movements are timed to the rise and fall of flood waters and are critical to the artisanal fisheries that depend on stranded fish as floods recede.

Globally, Atlantic salmon (Salmo salar) hatch in freshwater, migrate to sea as smolts, and return to their natal river to spawn. The European eel (Anguilla anguilla) travels from European freshwaters to spawn in the Sargasso Sea, one of the longest known migrations. Both species face severe population declines linked to dam construction, habitat degradation, and overexploitation.

Fill in the blank: During the annual flood pulse in Nigeria, fish move from main river channels onto ________ to exploit temporarily available food resources.

Plate 4.5: Artisanal fishers harvesting fish along receding floodwaters in a Nigerian river floodplain

Pilot questions 4.4

Define migration and distinguish between anadromous and catadromous species.

What is potamodromous migration and why is it important in Nigerian fisheries?

Name two environmental cues that trigger or guide fish migration.

Explain how olfactory homing enables salmon to return to their natal streams.

Explain how dam construction affects fish migration.

Series Summary

This Series has examined the behavioural ecology of fish, covering feeding, reproductive, aggressive, predatory, and migratory behaviours. We began with feeding behaviour, exploring feeding modes, optimal foraging theory, and the contrasting strategies of Nile tilapia and the African catfish. We then studied reproductive behaviour, from mating systems and courtship through spawning strategies, life history trade-offs, and parental care in mouth-brooding cichlids.

Following that, we examined aggression and territoriality, predatory behaviour including ambush and pursuit strategies, and anti-predator defences including schooling, camouflage, and the C-start reflex. Finally, we discussed fish migration, covering the types and patterns of migration, the cues and mechanisms that guide migratory movements, and examples from Nigerian floodplain fisheries and globally important migratory species. By completing this Series, you should now be able to achieve all nine Series Learning Outcomes (SLO 4.1 to SLO 4.9).

Glossary of Terms

Anadromous: describes fish that spawn in freshwater and feed in the sea; examples include Atlantic salmon.

Anti-predator behaviour: any behaviour that reduces the risk of predation, including schooling, camouflage, alarm responses, and escape manoeuvres.

Catadromous: describes fish that grow in freshwater and migrate to the sea to spawn; examples include freshwater eels.

C-start reflex: a fast-start escape response in which the body curves rapidly into a C-shape before a powerful acceleration away from a predator.

Confusion effect: the difficulty a predator experiences in tracking a single target within a large, moving group of similar-looking prey.

Courtship behaviour: behaviour performed before mating that attracts, assesses, and synchronises the reproductive readiness of potential partners.

Diadromous: describes fish that migrate between freshwater and marine environments as part of their life cycle.

Dilution effect: the reduction in individual predation risk in a group, as the probability of any single individual being targeted decreases with group size.

Filter feeding: a feeding mode in which gill rakers collect suspended particles or plankton from water passing through the mouth.

Foraging-predation risk trade-off: the behavioural compromise in which an animal accepts a lower foraging rate to reduce its exposure to predation.

K-selected: describes species with few offspring, high parental investment, long lifespan, and slow population growth; more vulnerable to overexploitation.

Migration: seasonal, directional movement of fish between habitats, driven by reproductive, feeding, or environmental requirements.

Mouth brooding: a form of parental care in which fertilised eggs and larvae are carried in the mouth of one or both parents.

Optimal foraging theory: the theory predicting that natural selection favours foraging behaviours that maximise net energy intake per unit of foraging time.

Photoperiod: the relative length of daylight in a 24-hour cycle; a key cue used by fish to time seasonal migrations and reproduction.

Potamodromous: describes fish that migrate entirely within freshwater between different river reaches, floodplains, or lakes.

r-selected: describes species with many small offspring, little parental care, short lifespan, and rapid population growth; more resilient to population reduction.

Ram feeding: a feeding mode in which the fish overtakes and engulfs prey by swimming rapidly at it.

Schooling: the coordinated aggregation of fish into a cohesive moving group; provides anti-predator benefits through dilution and confusion effects.

Suction feeding: a feeding mode in which rapid expansion of the buccal cavity creates negative pressure that draws prey into the mouth.

Territoriality: the active defence of a defined area containing valued resources against conspecifics or other competitors.

Concept Check Questions [Series 4]

Objective Questions

Name the three main feeding modes found in fish. (Linked to SLO 4.1)

Fill in the blank: Optimal foraging theory predicts that fish maximise their net ________ intake per unit of foraging time. (Linked to SLO 4.1)

Fish that spawn in freshwater but grow in the sea are described as ________. (Linked to SLO 4.8)

The reduction in individual predation risk in a large school is called the ________ effect. (Linked to SLO 4.7)

Fish that carry fertilised eggs in the mouth until hatching are called mouth ________. (Linked to SLO 4.4)

Short-Answer Questions

Explain the foraging-predation risk trade-off and give one example. (Linked to SLO 4.1)

Distinguish between r-selected and K-selected life history strategies in fish. (Linked to SLO 4.4)

Explain how territoriality affects growth uniformity in aquaculture. (Linked to SLO 4.5)

Describe two anti-predator strategies used by fish. (Linked to SLO 4.7)

Explain how dam construction disrupts fish migration. (Linked to SLO 4.9)

Long-Answer Questions

Analyse the feeding behaviour of fish, explaining the main feeding modes, the principles of optimal foraging theory, and how feeding behaviour differs between selected Nigerian species. (Linked to SLOs 4.1, 4.2)

Discuss the reproductive behaviour of fish, covering mating systems, spawning strategies, life history trade-offs, and parental care, with examples from Nigerian and global species. (Linked to SLOs 4.3, 4.4)

Evaluate the migratory behaviour of selected fish species, explaining the types of migration, the cues and mechanisms used, and the consequences of human disruption of migratory pathways. (Linked to SLOs 4.8, 4.9)

Answers to Concept Check Questions [Series 4]

Objective Questions

Suction feeding, ram feeding, and filter feeding.

Energy.

Anadromous.

Dilution.

Brooders.

Short-Answer Questions

The foraging-predation risk trade-off occurs when a fish accepts a lower energy return to avoid predation risk. For example, a fish may remain in sheltered vegetation accepting smaller prey rather than venturing into open water where food is more plentiful but predation risk is higher.

r-selected fish produce many small eggs, invest little care, mature early, and have short lifespans; they recover quickly after population reduction. K-selected fish produce few large eggs, invest heavily in care, mature late, and have long lifespans; they are more vulnerable to overfishing because recovery is slow.

Dominant individuals defend feeding territories and monopolise food, growing faster than subordinates who are displaced. This creates size inequality within a cohort, reducing productivity. Providing refuges and structural complexity reduces territorial behaviour and improves growth uniformity in farmed fish.

Any two: schooling reduces individual risk through dilution and confusion effects; cryptic colouration makes fish harder to detect; the C-start reflex propels the fish rapidly away from a strike; chemical alarm substances warn conspecifics of predator presence.

Dams block migratory routes, preventing fish from reaching spawning or feeding grounds. They also alter flow regimes, temperatures, and chemical gradients that fish use as navigational cues. Without fish passes, dams cause local extinction of migratory populations by severing access to historical habitats.

Long-Answer Questions

Basic response: The three main feeding modes are suction, ram, and filter feeding, each linked to specific morphological adaptations. Optimal foraging theory predicts energy maximisation per unit foraging time, with adjustments for predation risk. Tilapia is a flexible filter feeder and algal scraper; the African catfish is a nocturnal opportunistic predator relying on chemoreception and barbels.

Value-added response: Dietary flexibility, as shown by both tilapia and catfish, is an adaptive advantage allowing exploitation of multiple food sources as availability changes seasonally. Understanding feeding behaviour informs stocking decisions in aquaculture (complementary niches reduce competition) and helps predict population responses to prey depletion or environmental change.

Basic response: Mating systems include monogamy, polygyny, polyandry, and promiscuity. Courtship synchronises gamete release. Spawning ranges from open-water to substrate and mouth brooding. r-selected species produce many eggs with little care; K-selected species invest heavily in fewer offspring. Tilapia in Nigeria are mouth brooders.

Value-added response: Life history strategy determines vulnerability to exploitation. r-selected species recover quickly after heavy harvest. K-selected large piscivores take years to recover. Management must account for life history in setting harvest limits, protected sizes at capture, and seasonal closures during critical reproductive periods.

Basic response: Migration types include anadromous, catadromous, and potamodromous. Cues include photoperiod, temperature, and olfactory homing. Dam construction blocks routes and disrupts cues. In Nigeria, floodplain migrations of characins and cichlids drive artisanal fisheries productivity.

Value-added response: Loss of migratory connectivity has cascading effects beyond the affected species. In Nigeria, disruption of flood-pulse migrations reduces fish availability to dependent communities, threatening food security. Restoring connectivity through fish passes, regulated flows, and floodplain conservation is a priority for freshwater fisheries management.

Answers to Pilot Questions [Series 4]

Part 4.1: Feeding Behaviour of Fish

Feeding behaviour encompasses all activities associated with food acquisition. The three main feeding modes are suction feeding, ram feeding, and filter feeding.

Optimal foraging theory predicts that natural selection favours individuals that maximise net energy intake per unit of foraging time, selecting prey and patches with the highest energy return relative to search and handling costs.

The foraging-predation risk trade-off is the behavioural compromise in which a fish accepts a lower energy intake to remain in safer areas rather than risking predation in higher-yield but more exposed locations.

Nile tilapia is primarily a filter feeder and algal scraper, but is dietarily flexible and also consumes invertebrates and plant material, contributing to its wide habitat range and suitability for aquaculture.

The African catfish detects dissolved chemical cues from prey through chemoreception and uses tactile barbels around the mouth to locate food items in dark, turbid, or structurally complex environments where vision is unreliable.

Part 4.2: Reproductive Behaviour of Fish

Any two with examples: monogamy (some seahorse species); polygyny (cichlid males holding territories and spawning with multiple females); polyandry (pipefish, where a female deposits eggs with several males); promiscuity (broadcast spawners such as herrings).

Courtship behaviour serves to attract potential mates, allow assessment of mate quality, and synchronise the readiness of both partners so gametes are released simultaneously, maximising fertilisation success.

Open-water spawners release eggs and sperm into the water column where fertilised eggs drift until hatching. Substrate spawners deposit eggs on a specific surface such as rock, sand, or vegetation, where they are often guarded by a parent.

r-selected fish produce many small eggs, invest little parental care, mature early, grow quickly, and have short lifespans. K-selected fish produce few large eggs, invest heavily in parental care, mature late, and have long lifespans.

Female tilapia carry fertilised eggs and free-swimming fry in the buccal cavity, protecting them from predation until they are large enough to survive independently, significantly increasing offspring survival.

Part 4.3: Aggressive and Predatory Behaviour

Aggression is threatening or attacking behaviour directed at competitors or intruders. It is settled by display rather than combat because physical fighting risks injury to both parties; the outcome can be predicted from body size and display intensity without damaging contact.

Territoriality is the active defence of a defined area containing valued resources. Fish typically defend feeding sites, spawning grounds, nest sites, and shelter areas.

A predatory fish detects prey using vision, lateral line, or olfaction; orients and approaches; positions itself for an optimal strike; attacks using suction or ram technique; then captures and ingests the prey.

Ambush predators (e.g., some catfish) remain motionless and strike suddenly with surprise. Pursuit predators (e.g., Nile perch) actively chase mobile prey using speed and agility.

Dilution effect: the probability that any one individual in a large school is the target is lower than for a solitary fish. Confusion effect: the mass of similar moving fish makes it difficult for a predator to focus on and track a single individual, reducing attack success.

Part 4.4: Migratory Behaviour of Fish

Migration is seasonal directional movement between habitats driven by reproductive, feeding, or environmental needs. Anadromous species spawn in freshwater and feed in the sea (e.g., salmon); catadromous species grow in freshwater and spawn at sea (e.g., freshwater eels).

Potamodromous migration is movement entirely within freshwater. In Nigeria it is important because annual flood-pulse migrations of commercial species onto floodplains provide the food base for artisanal fisheries and drive the high seasonal fish yields that communities depend upon.

Any two: photoperiod; water temperature; geomagnetic field; water current direction; chemical composition of water.

Salmon imprint on the specific chemical composition of their natal stream as juveniles; as adults they detect and follow an increasing concentration of this chemical signature as they move upstream, guiding them back to the exact hatching location.

Dams block migratory routes preventing access to spawning or feeding habitats; they alter flow regimes, temperatures, and chemical gradients used as navigational cues; without fish passes or other mitigation, dams cause local extinction of migratory populations.

References and Attributions [Series 4]

Textual References (Books and External Sources)

Begon, M., Townsend, C. R., & Harper, J. L. (2006). Ecology: From individuals to ecosystems (4th ed.). Blackwell Publishing.

Pitcher, T. J. (Ed.). (1993). Behaviour of teleost fishes (2nd ed.). Chapman & Hall.

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Lucas, M. C., & Baras, E. (2001). Migration of freshwater fishes. Blackwell Science.

FAO (Food and Agriculture Organization of the United Nations). (2025). Guidelines for sustainable fisheries. FAO.

Figures, Plates, Tables, and Boxes

Figure 4.1: Three feeding modes in fish Attribution: AI generated using prompt "Generate a diagram comparing suction feeding, ram feeding, and filter feeding in fish." Suggested OER search string: "fish feeding modes suction ram filter OER diagram".

Box 4.1: Principles of optimal foraging theory Attribution: AI generated using prompt "Generate a text box listing the key principles of optimal foraging theory applied to fish." Suggested OER search string: "optimal foraging theory fish principles OER".

Plate 4.1: Nile tilapia and African catfish Attribution: AI generated using prompt "Generate an image showing Nile tilapia and African catfish side by side illustrating feeding morphology differences." Suggested OER search string: "Nile tilapia African catfish Nigerian fish feeding OER image".

Plate 4.2: Male cichlid courtship display Attribution: AI generated using prompt "Generate an image showing a male cichlid performing a courtship display to attract a female." Suggested OER search string: "cichlid courtship display mating behaviour OER image".

Figure 4.2: r-selected versus K-selected life history strategies Attribution: AI generated using prompt "Generate a diagram comparing r-selected and K-selected life history strategies in fish." Suggested OER search string: "r-selected K-selected life history fish OER diagram".

Plate 4.3: Female tilapia mouth brooding Attribution: AI generated using prompt "Generate an image showing a female tilapia mouth brooding her offspring." Suggested OER search string: "tilapia mouth brooding parental care OER image".

Figure 4.3: Territorial cichlid defending spawning territory Attribution: AI generated using prompt "Generate a diagram showing a territorial cichlid defending its spawning area against an intruder." Suggested OER search string: "territorial cichlid defending spawning territory OER diagram".

Plate 4.4: Predatory fish in ambush posture Attribution: AI generated using prompt "Generate an image showing a predatory fish in ambush posture concealed among aquatic vegetation." Suggested OER search string: "predatory fish ambush posture aquatic vegetation OER image".

Figure 4.4: Anti-predator strategies in fish Attribution: AI generated using prompt "Generate a diagram showing schooling, cryptic colouration, and the C-start escape reflex as anti-predator strategies." Suggested OER search string: "anti-predator strategies fish schooling camouflage C-start OER diagram".

Figure 4.5: Migration patterns of anadromous, catadromous, and potamodromous fish Attribution: AI generated using prompt "Generate a diagram showing migration patterns of anadromous, catadromous, and potamodromous fish." Suggested OER search string: "fish migration patterns anadromous catadromous potamodromous OER diagram".

Box 4.2: Environmental cues and navigation mechanisms of migratory fish Attribution: AI generated using prompt "Generate a text box listing environmental cues and navigation mechanisms used by migratory fish." Suggested OER search string: "migration cues navigation mechanisms fish OER".

Plate 4.5: Artisanal fishers at Nigerian floodplain Attribution: AI generated using prompt "Generate an image showing artisanal fishers harvesting fish from receding floodwaters in a Nigerian river floodplain." Suggested OER search string: "artisanal fishing floodplain Nigeria flood pulse OER image".

Course code: FAA 306

Course title: Fisheries Ecology

Course credit load: 2 Units

Series 5: Ecology of Freshwater, Estuarine, and Marine Systems of Nigeria

Series outline

Part 5.1: Ecology of Nigerian Freshwater Systems

Introduction

The previous Series in this course explored ecological principles, population dynamics, production processes, and behavioural ecology at the level of species and communities. This final Series brings those concepts together by applying them to specific aquatic ecosystem types found in Nigeria, examining the ecology of freshwater, estuarine, and marine systems in the national context.

The aim of this Series is to describe the ecology of Nigeria's major aquatic systems, explain the biotic and abiotic factors that characterise each system type, identify the flora, fauna, and fisheries associated with each, and examine the environmental pressures and management challenges facing these systems.

We shall commence this Series by examining the ecology of Nigerian freshwater systems, including rivers, lakes, and floodplains. Next, we will explore the ecology of estuaries, focusing on the ecological functions and biotic communities of Nigeria's coastal transition zones. Following that, we will study the Nigerian marine environment and its biological communities.

Finally, we will wrap up by assessing the major threats to Nigerian aquatic ecosystems and the management approaches used to conserve them.

Series Learning Outcomes

Upon completing this Series, you should be able to:

SLO 5.1 identify and describe the major freshwater systems of Nigeria and their biotic and abiotic characteristics (Linked to Part 5.1),

SLO 5.2 describe the flora, fauna, and fisheries associated with Nigerian freshwater systems (Linked to Part 5.1),

SLO 5.3 define estuaries and explain their physical and ecological characteristics (Linked to Part 5.2),

SLO 5.4 describe the biotic communities and fisheries importance of Nigerian estuaries (Linked to Part 5.2),

SLO 5.5 describe the Nigerian coastal and offshore marine environment and its biological communities (Linked to Part 5.3),

SLO 5.6 explain how marine flora and fauna are utilised and managed in Nigerian waters (Linked to Part 5.3),

SLO 5.7 identify the major threats to Nigerian aquatic ecosystems (Linked to Part 5.4),

SLO 5.8 explain the methods used to assess the biomass of aquatic resources in Nigeria (Linked to Part 5.4), and

SLO 5.9 evaluate management and conservation approaches for Nigerian aquatic systems (Linked to Part 5.4).

5.1 Ecology of Nigerian Freshwater Systems

5.1.1 Major freshwater systems of Nigeria

Nigeria possesses an exceptionally diverse range of freshwater systems. The dominant system is the **Niger-Benue river network**, the largest river system in West Africa, draining most of the country before flowing south through the Niger Delta into the Atlantic Ocean. Other major systems include the Cross River in the southeast, Lake Chad in the far northeast, and numerous seasonal floodplains and reservoirs including the Hadejia-Nguru wetlands and Kainji, Jebba, and Shiroro reservoirs.

These systems span diverse ecological zones from rainforest to semi-arid savanna, producing great variation in hydrological regime, water chemistry, and biotic composition. Together they support hundreds of fish species and millions of artisanal fishers, making the management of their ecological integrity a national food security and livelihood priority.

Fill in the blank: The dominant freshwater system in Nigeria is the Niger-________ river network, the largest river system in West Africa.

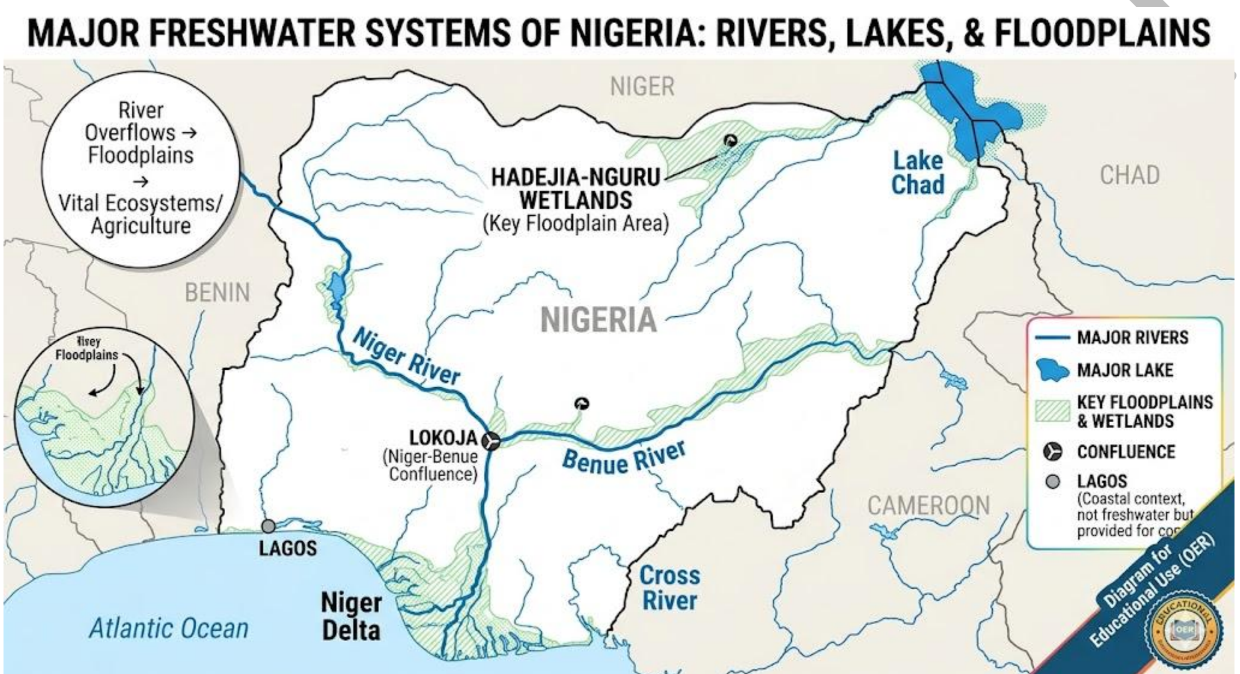

Figure 5.1: Map of major freshwater systems of Nigeria including the Niger-Benue network, Lake Chad, and the Cross River basin

5.1.2 Biotic and abiotic characteristics of Nigerian rivers and lakes

Abiotic characteristics vary greatly with geography and season. Southern rivers are perennial with stable flow, warm temperatures (24-30 degrees Celsius), and high dissolved organic matter from surrounding forest. Northern rivers are highly seasonal, with strong annual flood pulses that periodically inundate adjacent floodplains. The **flood-pulse concept** describes how this seasonal inundation releases nutrients and creates productive shallow-water habitats critical for fish feeding and reproduction.

Biotic communities include diverse macrophyte assemblages, phytoplankton, zooplankton, benthic invertebrates, and rich fish faunas. Riparian vegetation contributes allochthonous organic matter to in-stream food webs, particularly important in forested headwater streams. Lake Chad, despite its fluctuating surface area, supports productive plankton communities underpinning its fisheries.

Fill in the blank: The periodic inundation of floodplains that drives productivity in tropical rivers is described by the ________-pulse concept.

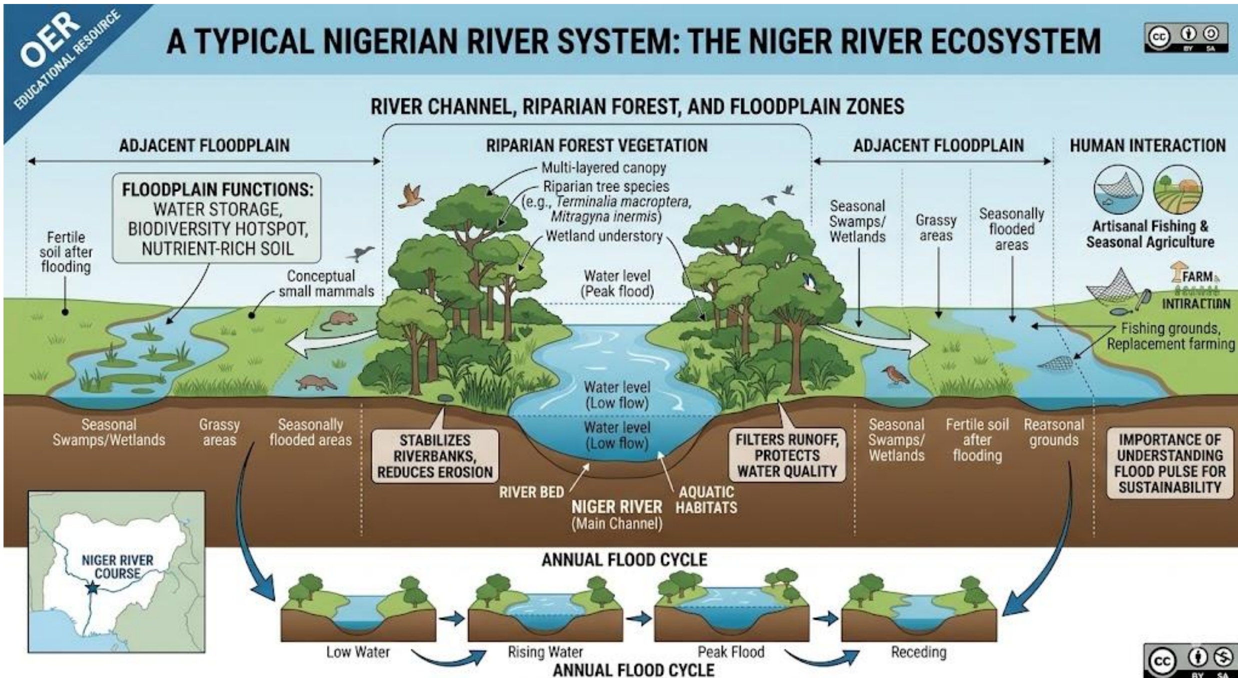

Plate 5.1: The Niger River in Nigeria showing riparian vegetation and floodplain habitat

5.1.3 Flora, fauna, and fisheries of Nigerian freshwater systems

Freshwater flora includes aquatic macrophytes such as water hyacinth (Eichhornia crassipes), water lettuce (Pistia stratiotes), and emergent sedges and grasses, alongside riparian forest trees. Invasive water hyacinth has spread rapidly across Nigerian waterways, blocking navigation, reducing light penetration, and depleting dissolved oxygen, posing a serious threat to freshwater fisheries.

Nigerian freshwater fauna includes over 250 documented fish species. Key commercial species are Nile tilapia (Oreochromis niloticus), African catfish (Clarias gariepinus), mudfish (Heterobranchus spp.), Nile perch (Lates niloticus) in some northern systems, and characins such as the tiger fish (Hydrocynus spp.). Artisanal fisheries are the dominant form of exploitation, supporting millions of livelihoods across the country.

Fill in the blank: The invasive aquatic plant water ________ (Eichhornia crassipes) has spread across Nigerian waterways, reducing oxygen levels and blocking navigation.

Plate 5.2: Artisanal fishing on a Nigerian river showing traditional canoes, nets, and a catch of freshwater fish

Pilot questions 5.1

Name three major freshwater systems found in Nigeria.

Explain the flood-pulse concept and its importance for Nigerian river fisheries.

State two abiotic differences between rivers in the humid south and the semi-arid north of Nigeria.

Name three commercially important freshwater fish species found in Nigerian systems.

Explain one negative ecological effect of water hyacinth invasion in Nigerian waterways.

5.2 Ecology of Nigerian Estuarine Systems

5.2.1 Definition and characteristics of estuaries

Estuaries are semi-enclosed coastal water bodies with a free connection to the sea and measurable freshwater dilution. They are transitional zones between freshwater and marine environments, characterised by strong gradients in salinity, temperature, turbidity, and tidal flow. Salinity varies from near-zero at the freshwater head to near-marine at the mouth, creating distinct zones supporting different ecological communities.

Nigerian estuaries are found along the approximately 850 km coastline, with the most ecologically significant being those of the Niger Delta, Cross River, and Imo River. The Niger Delta estuary is among the largest in Africa, encompassing channels, mangrove forests, tidal mudflats, and open water that together support one of the most productive coastal fisheries in the region.

Fill in the blank: Estuaries are semi-enclosed coastal water bodies with a free connection to the sea and measurable ________ dilution from rivers or land drainage.

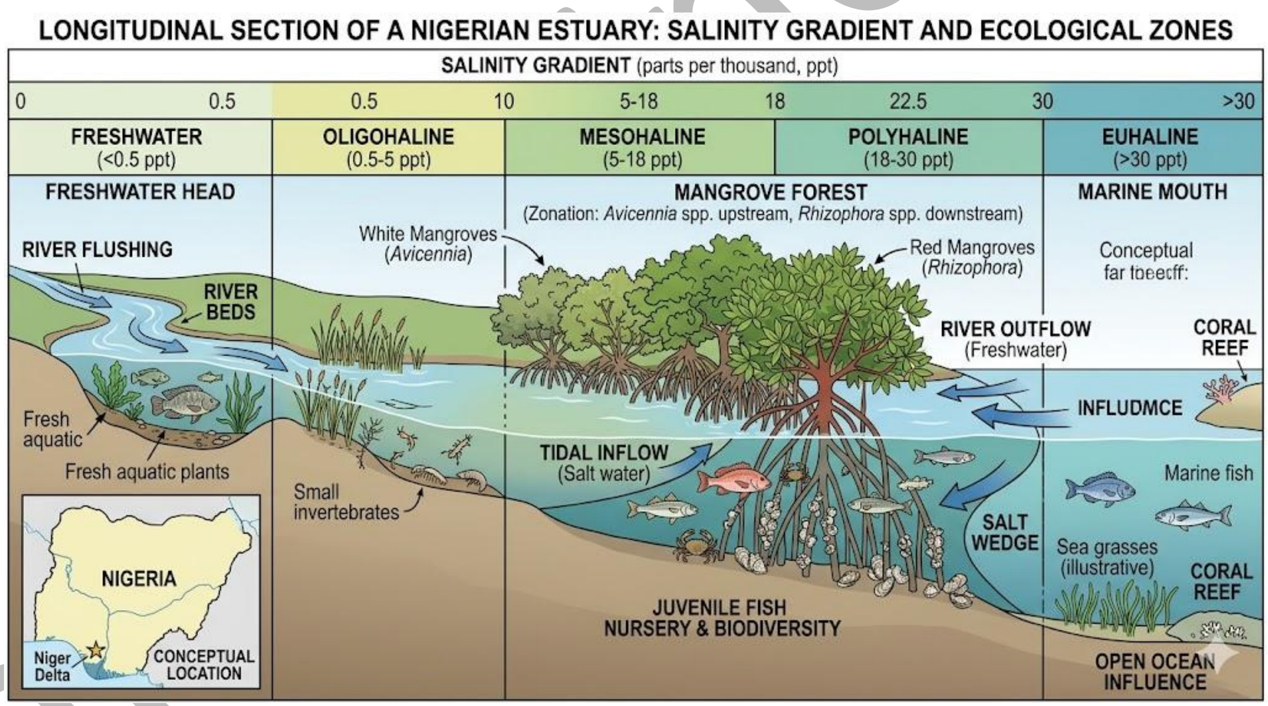

Figure 5.2: Diagram showing the salinity gradient and ecological zones of a Nigerian estuary

5.2.2 Biotic communities of Nigerian estuaries

Mangrove forests dominate the intertidal zones of Nigerian estuaries, particularly in the Niger Delta. The dominant species are Rhizophora racemosa, R. harrisonii, Avicennia germinans, and

Laguncularia racemosa. Mangroves stabilise shorelines, trap sediment, export organic matter to adjacent waters, and provide critical nursery habitat for juvenile fish and invertebrates. Nigeria has one of the largest mangrove areas in Africa.

Estuarine fish communities are characterised by euryhaline species tolerant of wide salinity fluctuations, including mullets (Mugil spp.), croakers (Pseudotolithus spp.), and snappers (Lutjanus spp.). Invertebrate communities include crabs (Callinectes spp.), shrimps (Penaeus spp., Macrobrachium spp.), and oysters (Crassostrea gasar), supporting important artisanal shellfish fisheries and serving as food for commercially targeted fish species.

Fill in the blank: Mangroves provide critical ________ habitat for juvenile fish and invertebrates in Nigerian estuarine systems.

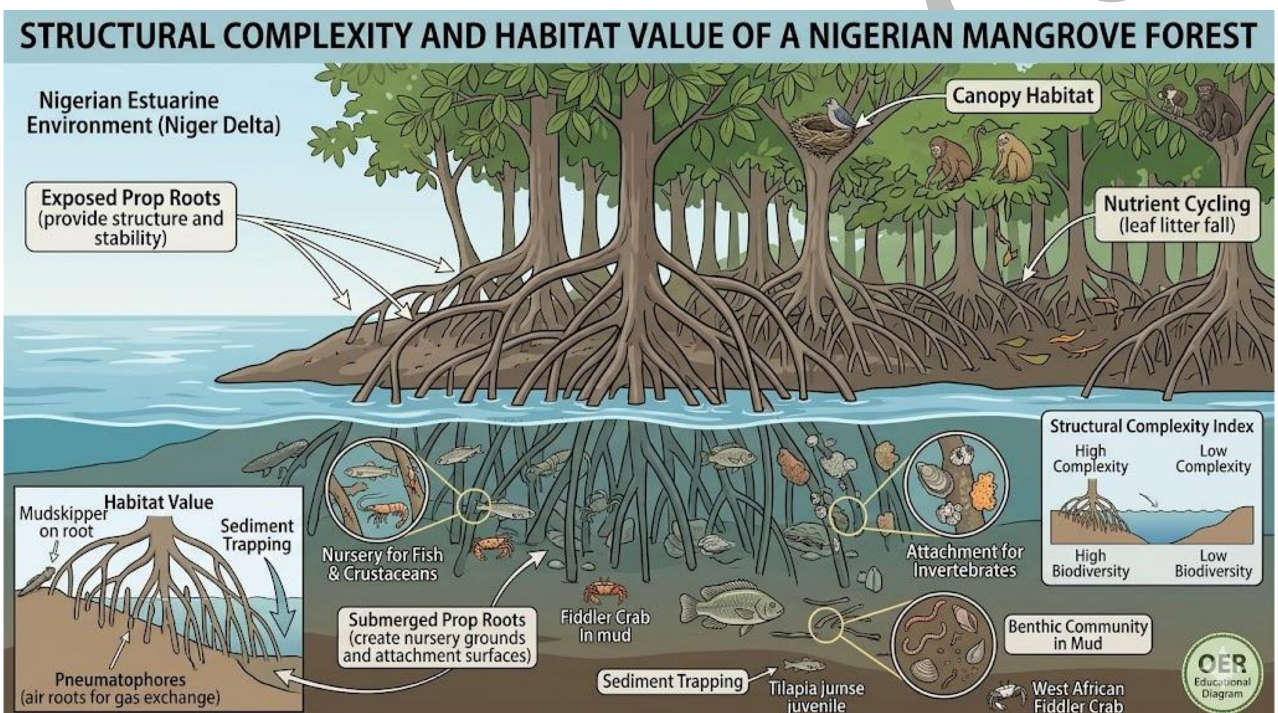

Plate 5.3: Mangrove forest in the Niger Delta showing prop roots and associated estuarine habitat

5.2.3 Ecological functions and fisheries importance of estuaries

Ecological functions of Nigerian estuaries include nutrient processing, sediment trapping, shoreline stabilisation, carbon storage in mangrove biomass and sediments, and support of food webs extending into adjacent marine and freshwater systems. Estuaries export dissolved organic matter and particulate material to the sea, fuelling production in coastal marine zones.

The fisheries importance of Nigerian estuaries is enormous. They serve as nursery grounds for juveniles of marine species recruiting from offshore spawning areas, as feeding grounds for demersal and pelagic fish, and as permanent habitat for resident estuarine species. The Niger

Delta supports one of the most productive artisanal fisheries in West Africa, with Ijaw, Itsekiri, and Urhobo communities depending heavily on fish, shrimp, and crab harvests.

Fill in the blank: Nigerian estuaries serve as ________ grounds for juveniles of marine species that recruit from offshore spawning areas.

Function / Importance	Explanation
Nutrient cycling	Estuaries recycle nutrients between land and sea, supporting high productivity.
Nursery habitat	Provide safe breeding and juvenile development areas for many fish species.
Carbon storage	Mangroves and estuarine vegetation capture and store carbon, mitigating climate change.
Biodiversity support	Estuaries host diverse species, maintaining ecological balance and resilience.
Artisanal fisheries	Support local communities by providing fish and shellfish for subsistence and trade.
Coastal protection	Mangroves and wetlands reduce erosion and buffer against storm surges.

Box 5.1: Key ecological functions and fisheries importance of Nigerian estuaries

Pilot questions 5.2

Define an estuary and describe its main physical characteristics.

Name three dominant mangrove species found in Nigerian estuaries.

Explain two ecological functions of mangroves in Nigerian estuarine systems.

Name two fish and two invertebrate species commercially important in Nigerian estuaries.

Explain why estuaries are described as nursery grounds for marine fish species.

5.3 Ecology of Nigerian Marine Systems

5.3.1 The Nigerian coastal and offshore marine environment

The Nigerian marine environment comprises warm tropical waters of the Gulf of Guinea, extending from the shoreline across the continental shelf (approximately 200 m depth) to deep offshore waters. The continental shelf is relatively broad off the Niger Delta. Seasonal upwelling of cold, nutrient-rich deep water along sections of the West African coast significantly enhances primary production and supports high fish biomass in productive years.

The physical environment is characterised by warm temperatures (25-30 degrees Celsius), strong seasonal variation in rainfall and river discharge affecting coastal salinity and turbidity, and the Niger plume carrying sediment and nutrients far into offshore waters. These features create a highly productive but spatially variable marine ecosystem supporting both artisanal and industrial fisheries.

Fill in the blank: Upwelling of cold, ________-rich deep water along the West African coast enhances primary production and supports high fish biomass.

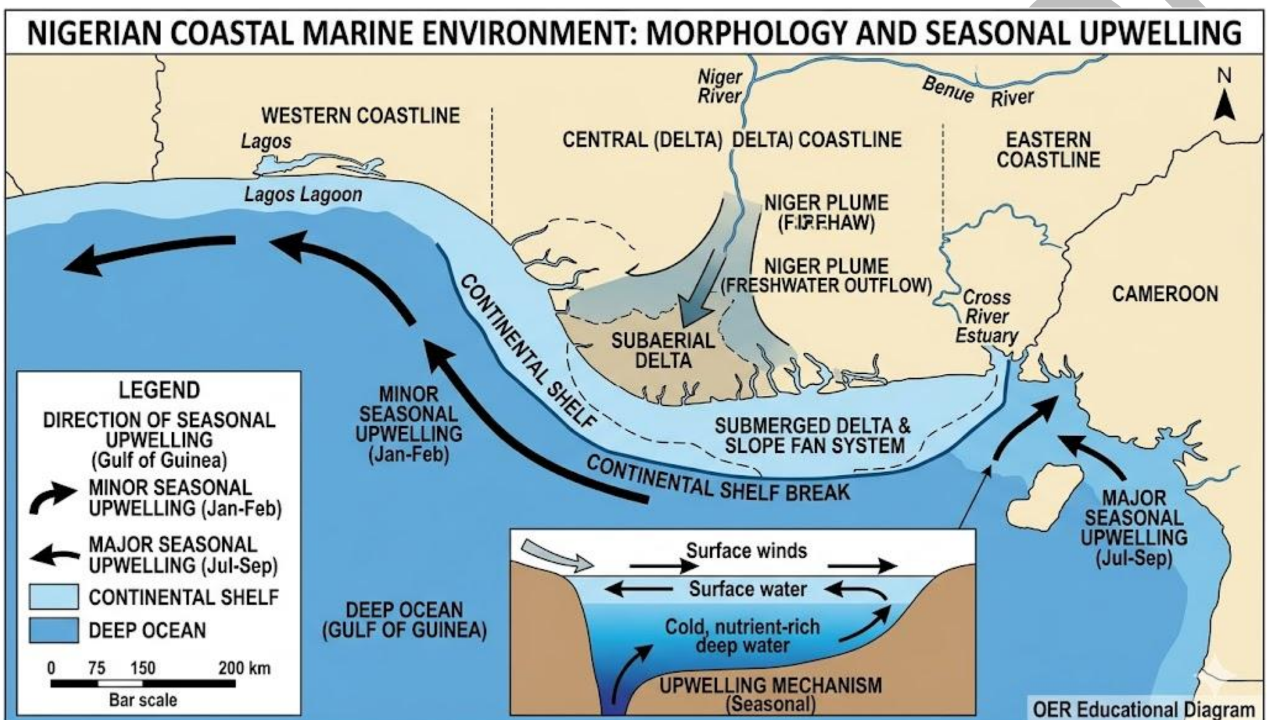

Figure 5.3: Map of the Nigerian coastal and offshore marine environment showing the continental shelf and Niger plume

5.3.2 Marine biota: plankton, benthos, and fish communities

Phytoplankton dominated by diatoms and dinoflagellates form the base of the marine food web, with production enhanced during upwelling. Zooplankton, particularly copepods, are the principal secondary producers and form the food base for small pelagic fish. **Benthic communities** on the continental shelf include polychaetes, bivalves, crustaceans, and echinoderms, supporting the demersal fish communities of commercial importance.

Commercially important small pelagic species include sardinellas (Sardinella maderensis, S. aurita) and bonga (Ethmalosa fimbriata), targeted by artisanal beach seines. Demersal species include croakers (Pseudotolithus spp.), snappers (Lutjanus spp.), groupers, and shrimps exploited by industrial trawlers. Large pelagic species including tuna and swordfish are found in offshore waters and targeted by industrial longliners.

Fill in the blank: Bonga (Ethmalosa fimbriata) and sardinellas are important small ________ species in Nigerian coastal waters.

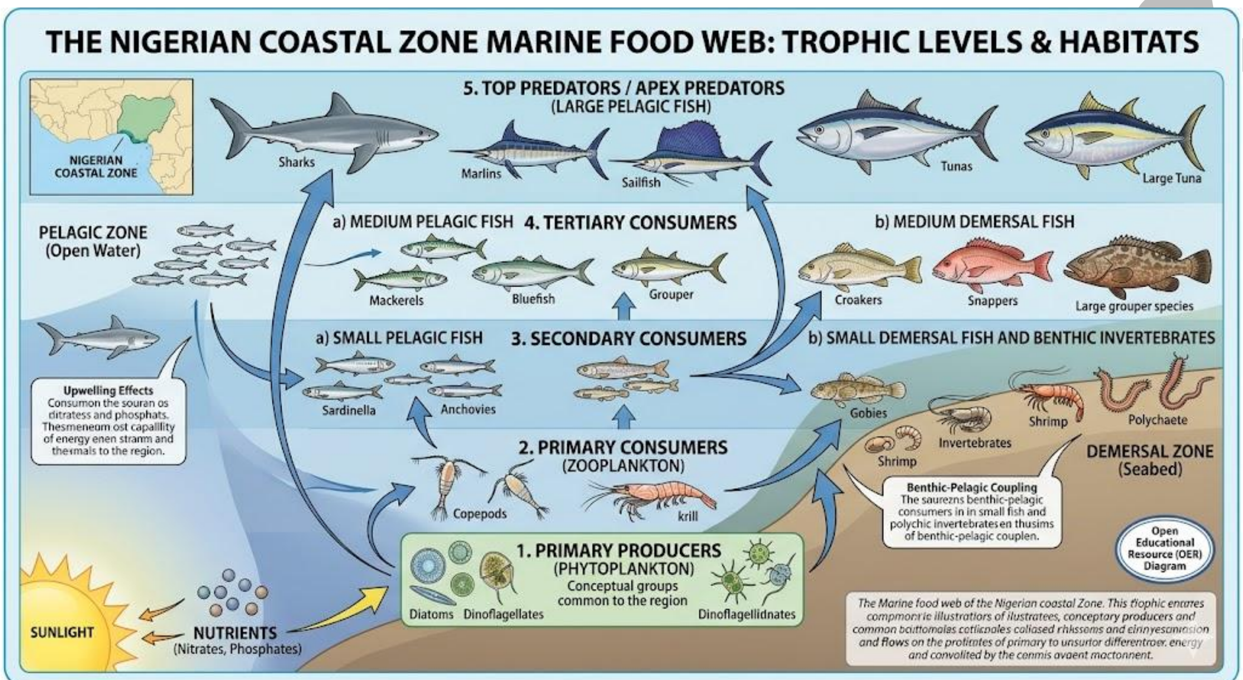

Figure 5.4: Diagram of the Nigerian marine food web from phytoplankton to pelagic and demersal fish communities

5.3.3 Flora and fauna utilisation and management in Nigerian waters

Marine resource utilisation involves both artisanal and industrial sectors. Artisanal fishers using canoes, beach seines, gill nets, and traps operate primarily in coastal and estuarine waters, accounting for the majority of landings by volume. Industrial trawlers operating under licence on the continental shelf target demersal fish and shrimp. Conflicts between the two sectors over fishing grounds and gear interactions are a persistent management challenge.

Management is the responsibility of the Federal Department of Fisheries under the Federal Ministry of Agriculture and Rural Development. Regulatory instruments include vessel licensing, minimum mesh size regulations, closed seasons, and inshore exclusion zones preventing trawlers from operating within defined distances of the coast. Enforcement capacity is limited, and overfishing of key demersal stocks remains a concern requiring strengthened governance and assessment.

Fill in the blank: Management of Nigerian marine fisheries resources is the responsibility of the Federal Department of ________.

Plate 5.4: Industrial trawler and artisanal fishing canoes in Nigerian coastal waters

Pilot questions 5.3

Describe the physical characteristics of the Nigerian marine environment.

Explain how seasonal upwelling affects fish production in the Gulf of Guinea.

Name two commercially important small pelagic and two demersal species in Nigerian marine waters.

Distinguish between the artisanal and industrial fishing sectors in Nigeria.

State two management measures used to regulate Nigerian marine fisheries.

5.4 Environmental Pressures and Conservation of Nigerian Aquatic Systems

5.4.1 Major threats to Nigerian aquatic ecosystems

Oil pollution from decades of crude oil extraction in the Niger Delta has caused widespread contamination of rivers, estuaries, and coastal waters, killing fish, destroying mangroves, and rendering water bodies unfit for artisanal fishing. Overfishing and illegal, unreported, and unregulated (IUU) fishing have reduced stocks of key commercial species below sustainable levels.

Deforestation of riparian and mangrove forests increases sedimentation and reduces habitat complexity. Agricultural runoff causes eutrophication of lakes and slow-flowing rivers. Dam construction blocks fish migrations and alters downstream hydrology. Climate change is already reducing the surface area of Lake Chad and altering rainfall seasonality in ways that affect floodplain fisheries productivity across northern Nigeria.

Fill in the blank: Oil pollution from crude oil extraction has caused widespread contamination in the Niger ________, destroying aquatic habitats.

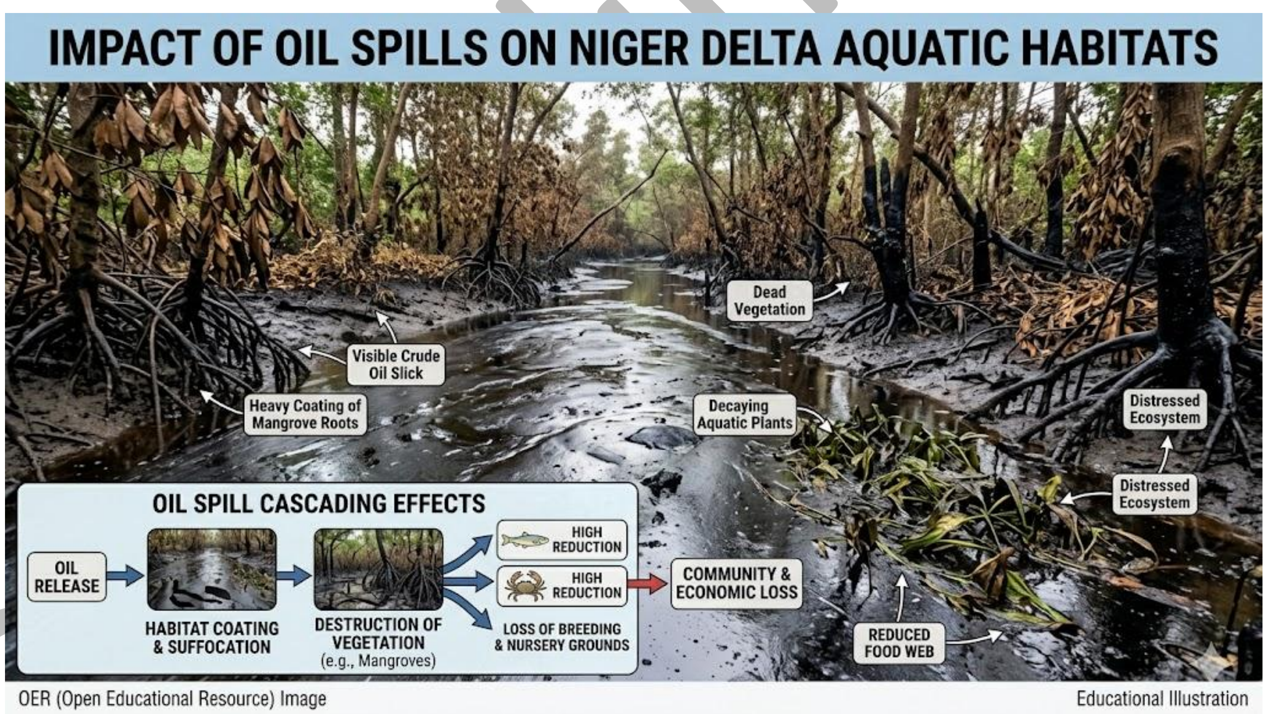

Plate 5.5: Oil-polluted creek in the Niger Delta showing visible oil on the water surface and dead vegetation

5.4.2 Biomass assessment and monitoring of aquatic resources

Biomass assessment is the estimation of the total living mass of a species or community within a defined area. Methods used in Nigerian aquatic systems include trawl surveys, acoustic echo-integration surveys, and catch per unit effort (CPUE) analysis from artisanal and industrial landing data. Trawl surveys provide direct demersal community samples; acoustic surveys are more efficient for estimating pelagic species abundance.

Monitoring programmes track changes in species composition, abundance, and size structure over time, providing data needed to detect overfishing and evaluate management effectiveness. The Federal Department of Fisheries and the Nigerian Institute for Oceanography and Marine Research (NIOMR) carry out periodic assessment surveys. Strengthening the frequency and spatial coverage of these surveys is a priority for evidence-based fisheries management in Nigeria.

Fill in the blank: The Nigerian Institute for Oceanography and Marine Research (_______) carries out periodic fisheries assessment surveys in Nigerian coastal and offshore waters.

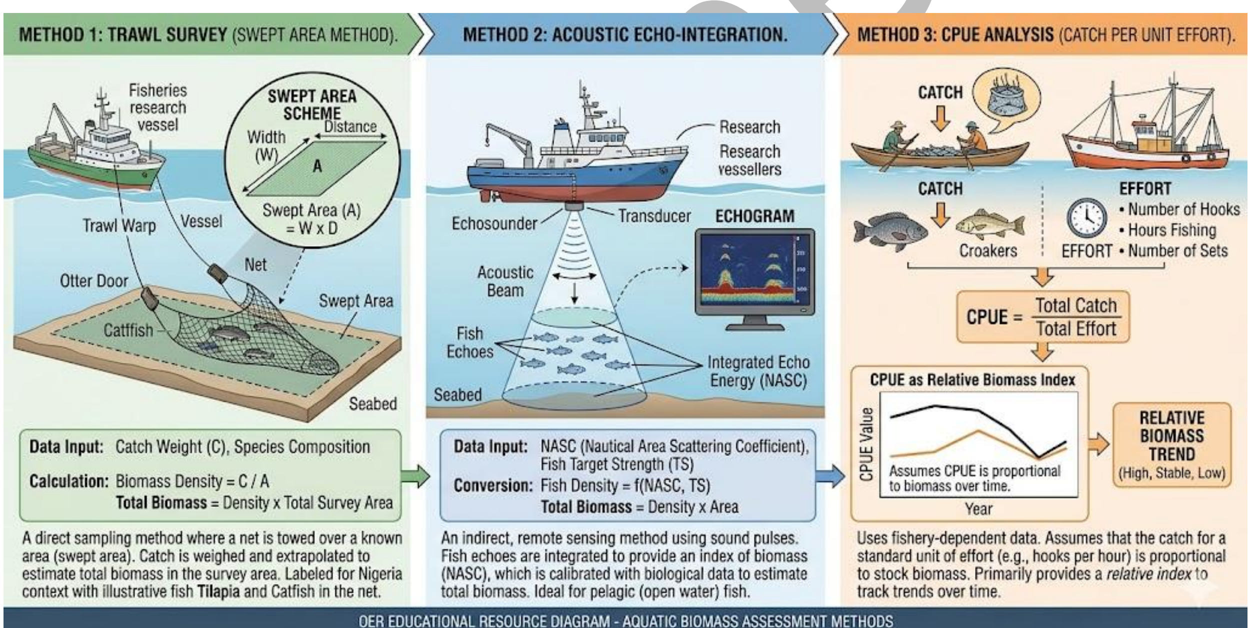

Figure 5.5: Diagram illustrating three methods of biomass assessment used in Nigerian aquatic systems

5.4.3 Management and conservation of aquatic systems in Nigeria

Conservation and management of Nigerian aquatic systems require integrated approaches addressing threats at multiple levels. For freshwater systems, priority actions include protection of riparian and floodplain habitats, regulation of dam operations to maintain environmental flows, and control of agricultural water pollution.

For marine and estuarine systems, priorities include strengthening enforcement of trawling exclusion zones, promoting co-management arrangements with artisanal fishing communities, protecting critical habitats through marine protected areas, and rehabilitating oil-polluted sites in the Niger Delta. International frameworks such as the Abidjan Convention on West and Central African coastal environments provide a basis for regional cooperation. Long-term sustainability requires integrating fisheries ecology into national development planning.

Fill in the blank: Co-management arrangements involve ________ fishing communities in governance decisions alongside government management authorities.

Priority Area	**Explanation**
Habitat protection	Safeguarding rivers, estuaries, mangroves, and marine habitats to maintain biodiversity and ecosystem services.
Co-management	Involving local communities, fishers, and government agencies in shared decision-making for sustainable resource use.
Marine protected areas	Establishing zones where fishing and other extractive activities are restricted to allow stock recovery and ecosystem resilience.
Pollution remediation	Addressing industrial discharge, oil spills, agricultural runoff, and plastic pollution to improve water quality.
Sustainable fishing	Implementing quotas, gear restrictions, and closed seasons to prevent overexploitation of fish stocks.
Climate adaptation	Developing strategies to mitigate impacts of climate change, such as sea-level rise and temperature shifts, on aquatic ecosystems.

Box 5.2: Key management and conservation priorities for Nigerian aquatic ecosystems

Pilot questions 5.4

State three major threats to Nigerian aquatic ecosystems.

Explain how oil pollution affects aquatic life in the Niger Delta.

Name two methods used to assess the biomass of aquatic resources in Nigeria.

What is the role of NIOMR in Nigerian fisheries management?

State two management measures for the conservation of Nigerian marine and estuarine systems.

Series Summary

This final Series has applied the ecological principles established throughout the course to the specific freshwater, estuarine, and marine systems of Nigeria. We began by describing the major freshwater systems, including the Niger-Benue network, Lake Chad, the Cross River basin, and key floodplains, examining their biotic and abiotic characteristics and the flora, fauna, and artisanal fisheries they support. We then explored Nigerian estuaries, describing their physical characteristics, mangrove-dominated biotic communities, and the ecological functions and fisheries importance of the Niger Delta and other coastal estuarine systems.

Following that, we examined the Nigerian coastal and offshore marine environment, covering biological communities from phytoplankton through small pelagic and demersal fish to large pelagic predators, and the artisanal and industrial sectors that exploit these resources. Finally, we assessed major threats including oil pollution, overfishing, and habitat loss, described biomass assessment and monitoring methods, and outlined management and conservation priorities. By completing this Series, you should now be able to achieve all nine Series Learning Outcomes (SLO 5.1 to SLO 5.9), and the course as a whole will have equipped you with a comprehensive ecological understanding of aquatic systems in Nigeria and their sustainable management.

Glossary of Terms

Abidjan Convention: the Convention for Cooperation in the Protection, Management and Development of the Marine and Coastal Environment of the Atlantic Coast of the West, Central, and Southern Africa Region.

Allochthonous organic matter: organic material originating outside a water body, such as leaves and insects from riparian vegetation; an important energy source in forested headwater streams.

Biomass assessment: the estimation of the total living mass of a species or community within a defined area, using trawl surveys, acoustic surveys, or CPUE analysis.

Bonga (Ethmalosa fimbriata): a commercially important filter-feeding clupeoid fish found in Nigerian coastal and estuarine waters; a major target of artisanal fisheries.

Continental shelf: the gently sloping underwater extension of a continent from the shoreline to approximately 200 m depth; the primary zone of demersal and coastal pelagic fisheries in Nigeria.

Estuary: a semi-enclosed coastal water body with a free connection to the sea and measurable freshwater dilution; characterised by salinity, temperature, and turbidity gradients.

Euryhaline: describes organisms tolerant of a wide range of salinity, enabling survival in estuarine environments where salinity fluctuates with tides and rainfall.

Flood-pulse concept: the ecological concept that seasonal flooding of floodplains by adjacent rivers is the primary driver of productivity, biodiversity, and fisheries in large tropical river systems.

IUU fishing: illegal, unreported, and unregulated fishing; a major threat to the sustainability of Nigerian and global fisheries.

Mangrove: a salt-tolerant tree adapted to intertidal conditions in tropical and subtropical estuaries; dominant species in Nigerian estuaries include Rhizophora and Avicennia. Mangroves provide nursery habitat, stabilise shorelines, and store carbon.

Niger Delta: the delta of the Niger River on the Gulf of Guinea; one of the largest deltas and the largest mangrove ecosystem in Africa, supporting important artisanal fisheries and facing serious oil pollution threats.

NIOMR: the Nigerian Institute for Oceanography and Marine Research; the principal research institution responsible for oceanographic and marine fisheries assessment in Nigeria.

Riparian vegetation: plant communities growing along the banks of rivers and lakes; provides allochthonous organic matter, shading, bank stabilisation, and habitat for aquatic and terrestrial species.

Sardinella: small pelagic clupeoid fish (Sardinella maderensis and S. aurita) among the most commercially important marine species in Nigerian coastal waters.

Upwelling: the movement of cold, nutrient-rich deep water to the ocean surface, enhancing primary production and fish biomass in affected coastal areas.

Water hyacinth (Eichhornia crassipes): an invasive floating macrophyte that has spread across Nigerian waterways, forming dense mats that deplete oxygen, reduce light penetration, and impede fishing.

Concept Check Questions [Series 5]

Objective Questions

Name the largest river system in Nigeria. (Linked to SLO 5.1)

Fill in the blank: The seasonal flooding of floodplains driving river productivity is described by the ________-pulse concept. (Linked to SLO 5.1)

Estuaries are characterised by a gradient from near-zero to near-marine ________. (Linked to SLO 5.3)

The Federal Department of ________ is responsible for managing Nigerian marine fisheries. (Linked to SLO 5.6)

What does IUU fishing stand for? (Linked to SLO 5.7)

Short-Answer Questions

Explain the flood-pulse concept and state one way it supports artisanal fisheries in Nigeria. (Linked to SLO 5.1)

Describe two ecological functions of mangroves in Nigerian estuaries. (Linked to SLO 5.4)

Explain how seasonal upwelling enhances fish production in Nigerian coastal waters. (Linked to SLO 5.5)

State two major threats to Nigerian aquatic ecosystems and briefly explain each. (Linked to SLO 5.7)

Describe two methods used to assess the biomass of aquatic resources in Nigeria. (Linked to SLO 5.8)

Long-Answer Questions

Analyse the ecology of Nigerian freshwater systems, describing the major systems, their biotic and abiotic characteristics, and the flora, fauna, and fisheries they support. (Linked to SLOs 5.1, 5.2)

Discuss the ecology and fisheries importance of Nigerian estuarine and coastal marine systems, explaining the biotic communities and the human pressures they face. (Linked to SLOs 5.3, 5.4, 5.5)

Evaluate the major environmental threats to Nigerian aquatic ecosystems and assess the management and conservation measures needed to sustain these resources. (Linked to SLOs 5.7, 5.8, 5.9)

Answers to Concept Check Questions [Series 5]

Objective Questions

The Niger-Benue river network.

Flood.

Salinity.

Fisheries.

Illegal, unreported, and unregulated fishing.

Short-Answer Questions

The flood-pulse concept states that periodic flooding of floodplains is the primary driver of productivity in large tropical river systems. In Nigeria, the annual inundation of Niger and Benue floodplains releases nutrients, creates feeding and spawning habitats for fish, and concentrates fish during flood recession, sustaining the artisanal harvests that communities depend on.

Any two: stabilise shorelines by trapping sediment; export organic matter to fuel estuarine food webs; provide nursery habitat for juvenile fish and invertebrates; store carbon in biomass and sediments; buffer coastlines from wave energy and storm damage.

Upwelling brings cold, nutrient-rich water to the ocean surface, stimulating phytoplankton growth. Increased primary production supports zooplankton, which in turn supports the schooling small pelagic fish (sardinellas, bonga) that are the main target of coastal artisanal fisheries in the Gulf of Guinea.

Any two: oil pollution from Niger Delta extraction contaminates water and destroys mangroves, killing fish and rendering water bodies unfit for fishing; overfishing and IUU fishing deplete commercial stocks faster than they can recover; agricultural runoff causes eutrophication; dam construction blocks fish migrations and alters downstream flows; deforestation increases sedimentation and reduces habitat complexity.

Any two: trawl surveys (a net is towed over a defined area and the catch used to estimate species composition and density); acoustic echo-integration surveys (echo-sounder transects integrated to estimate biomass); CPUE analysis (catch per unit effort from landing data analysed over time to detect abundance trends).

Long-Answer Questions

Basic response: Nigeria's major freshwater systems include the Niger-Benue network, Lake Chad, the Cross River, and seasonal floodplains. Southern rivers are perennial with stable flow and forest inputs; northern rivers are seasonal with strong flood pulses. Flora includes water hyacinth and riparian forest; key fish species are tilapia, catfish, Nile perch, and characins. Artisanal fisheries are dominant.

Value-added response: The flood-pulse concept is central to freshwater fisheries productivity; annual inundation drives nutrient release, spawning, and the temporal fish concentration that sustains artisanal harvests. Invasive water hyacinth and dam construction are the two greatest contemporary threats to this productivity, highlighting the need for integrated management of both biological and hydrological processes.

Basic response: Nigerian estuaries include the Niger Delta, dominated by mangroves, with euryhaline fish and shellfish communities supporting important artisanal fisheries. Marine systems in the Gulf of Guinea support phytoplankton, zooplankton, small pelagics (sardinellas, bonga), and demersals (croakers, snappers). Both face oil pollution, overfishing, and habitat destruction.

Value-added response: Estuaries serve as nursery grounds for marine fish, making their ecological health fundamental to offshore fisheries productivity. The Niger Delta combines outstanding ecological importance with severe oil pollution, creating an acute conservation challenge. Strengthening mangrove protection, enforcing exclusion zones, and developing artisanal co-management are priority actions for sustaining these systems.

Basic response: Major threats include oil pollution, overfishing, deforestation, agricultural runoff, dam construction, and climate change. Management measures include licensing, mesh regulations, closed seasons, exclusion zones, co-management, marine protected areas, and pollution remediation. NIOMR and FDF carry out biomass assessment through trawl, acoustic, and CPUE methods.

Value-added response: Effective conservation requires integrated ecosystem-based management across the freshwater-estuarine-marine continuum. Strengthening NIOMR's assessment capacity, improving enforcement, engaging artisanal communities in co-management, and remediating Niger Delta habitats are the highest-priority actions. Long-term sustainability demands that fisheries ecology be integrated into national development planning to prevent further habitat destruction.

Answers to Pilot Questions [Series 5]

Part 5.1: Ecology of Nigerian Freshwater Systems

Any three: Niger River, Benue River, Cross River, Lake Chad, Hadejia-Nguru wetlands, Kainji Reservoir, Jebba Reservoir.

The flood-pulse concept states that periodic flooding of floodplains drives productivity in large tropical rivers. In Nigeria, annual inundation of Niger and Benue floodplains releases nutrients, creates nursery and feeding habitats for fish, and concentrates fish during recession, sustaining artisanal harvests.

Any two: southern rivers are perennial with stable flow; northern rivers are highly seasonal with strong flood pulses. Southern rivers have high organic matter inputs from forest; northern rivers drain savanna and semi-arid catchments with lower organic inputs.

Any three: Nile tilapia (Oreochromis niloticus), African catfish (Clarias gariepinus), mudfish (Heterobranchus spp.), Nile perch (Lates niloticus), tiger fish (Hydrocynus spp.).

Water hyacinth forms dense mats blocking sunlight, preventing photosynthesis; as mats decompose, oxygen is consumed causing hypoxia that kills fish; mats impede navigation and net deployment.

Part 5.2: Ecology of Nigerian Estuarine Systems

An estuary is a semi-enclosed coastal water body with a free connection to the sea and measurable freshwater dilution. Characteristics: salinity gradient from near-zero at the head to near-marine at the mouth; tidal influence; high turbidity; strong gradients in temperature and dissolved oxygen.

Rhizophora racemosa, Rhizophora harrisonii, and Avicennia germinans (also Laguncularia racemosa is acceptable).

Any two: provide nursery habitat for juvenile fish and invertebrates; stabilise shorelines by trapping sediment with prop roots; export organic matter fuelling adjacent food webs; store carbon; buffer coastlines from wave energy.

Fish: croakers (Pseudotolithus spp.) and mullets (Mugil spp.) or snappers (Lutjanus spp.). Invertebrates: shrimps (Penaeus spp.) and crabs (Callinectes spp.) or oysters (Crassostrea gasar).

Estuaries provide sheltered shallow-water habitats with abundant food and lower predation pressure than the open sea, making them ideal for the growth and early survival of juveniles of marine fish that spawn offshore and recruit to estuaries.

Part 5.3: Ecology of Nigerian Marine Systems

Warm tropical waters (25-30 degrees Celsius) in the Gulf of Guinea; a broad continental shelf off the Niger Delta; influence of the Niger river plume carrying sediment and nutrients offshore; seasonal upwelling of nutrient-rich deep water along portions of the West African coast.

Upwelling brings cold nutrient-rich water to the surface, stimulating phytoplankton growth and increasing primary production. This supports zooplankton and the small pelagic fish (sardinellas, bonga) that form the basis of coastal artisanal fisheries.

Small pelagics: any two of sardinella (Sardinella maderensis or S. aurita) and bonga (Ethmalosa fimbriata). Demersal: any two of croakers (Pseudotolithus spp.), snappers (Lutjanus spp.), or groupers.

Artisanal fishers use canoes, beach seines, gill nets, and traps in coastal and estuarine waters; they account for the majority of landings by volume. Industrial trawlers are licensed vessels operating on the continental shelf targeting demersal fish and shrimp for commercial markets.

Any two: licensing of industrial fishing vessels; minimum mesh size regulations; closed seasons; inshore exclusion zones restricting trawling within defined coastal distances.

Part 5.4: Environmental Pressures and Conservation

Any three: oil pollution; overfishing and IUU fishing; deforestation; agricultural runoff causing eutrophication; dam construction; climate change.

Oil spills contaminate water and deplete oxygen as oil decomposes; coat mangrove roots killing trees and destroying nursery habitat; render fish unfit for consumption; prevent artisanal fishing in affected areas.

Any two: trawl surveys; acoustic echo-integration surveys; catch per unit effort (CPUE) analysis.

NIOMR is the Nigerian Institute for Oceanography and Marine Research; it carries out periodic fisheries assessment surveys in Nigerian coastal and offshore waters, providing the data needed for evidence-based marine and estuarine fisheries management.

Any two: enforcing inshore trawling exclusion zones; promoting co-management with artisanal fishing communities; establishing marine protected areas; rehabilitating oil-polluted habitats in the Niger Delta.

References and Attributions [Series 5]

Textual References (Books and External Sources)

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Ita, E. O. (1993). Inland fishery resources of Nigeria. FAO/CIFA Occasional Paper No. 20.

FAO (Food and Agriculture Organization of the United Nations). (2018). The state of world fisheries and aquaculture. FAO.

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Figures, Plates, Tables, and Boxes

Figure 5.1: Map of major freshwater systems of Nigeria Attribution: AI generated using prompt "Generate a map of Nigeria showing the major freshwater systems including the Niger River, Benue River, Cross River, Lake Chad, and key floodplains." Suggested OER search string: "Nigeria major freshwater systems rivers lakes map OER".

Plate 5.1: The Niger River with riparian vegetation and floodplain Attribution: AI generated using prompt "Generate an image showing the Niger River with riparian forest vegetation and an adjacent floodplain." Suggested OER search string: "Niger River Nigeria riparian vegetation floodplain OER image".

Plate 5.2: Artisanal fishing on a Nigerian river Attribution: AI generated using prompt "Generate an image showing artisanal fishers on a Nigerian river using canoes and nets with a catch of freshwater fish." Suggested OER search string: "artisanal fishing Nigerian river canoe nets freshwater OER image".

Figure 5.2: Salinity gradient and ecological zones of a Nigerian estuary Attribution: AI generated using prompt "Generate a diagram showing a longitudinal section of a Nigerian estuary from freshwater head to marine mouth, labelling the salinity gradient and main ecological zones." Suggested OER search string: "estuary salinity gradient ecological zones Nigeria OER diagram".

Plate 5.3: Mangrove forest in the Niger Delta Attribution: AI generated using prompt "Generate an image showing a mangrove forest with exposed prop roots in a Nigerian estuary."

Suggested OER search string: "mangrove forest Niger Delta prop roots estuarine habitat OER image".

Box 5.1: Ecological functions and fisheries importance of Nigerian estuaries Attribution: AI generated using prompt "Generate a text box listing the key ecological functions and fisheries importance of Nigerian estuaries." Suggested OER search string: "ecological functions fisheries importance Nigerian estuaries OER".

Figure 5.3: Nigerian coastal and offshore marine environment Attribution: AI generated using prompt "Generate a map showing the Nigerian coastline, continental shelf, Niger Delta, and direction of upwelling in the Gulf of Guinea." Suggested OER search string: "Nigerian coastal marine environment continental shelf Niger plume OER map".

Figure 5.4: Nigerian marine food web Attribution: AI generated using prompt "Generate a diagram showing the marine food web of the Nigerian coastal zone from phytoplankton through zooplankton to pelagic and demersal fish." Suggested OER search string: "Nigerian marine food web phytoplankton pelagic demersal OER diagram".

Plate 5.4: Industrial trawler and artisanal canoes in Nigerian waters Attribution: AI generated using prompt "Generate an image showing an industrial trawler and artisanal fishing canoes in Nigerian coastal waters." Suggested OER search string: "industrial trawler artisanal canoes Nigerian coastal fishery OER image".

Plate 5.5: Oil-polluted creek in the Niger Delta Attribution: AI generated using prompt "Generate an image showing a creek in the Niger Delta with visible crude oil pollution and dead vegetation." Suggested OER search string: "oil pollution Niger Delta creek aquatic habitat destruction OER image".

Figure 5.5: Biomass assessment methods in Nigerian aquatic systems Attribution: AI generated using prompt "Generate a diagram showing three methods of aquatic biomass assessment: trawl survey, acoustic echo-integration, and CPUE analysis." Suggested OER search string: "biomass assessment methods trawl acoustic CPUE Nigeria OER diagram".

Box 5.2: Management and conservation priorities for Nigerian aquatic ecosystems Attribution: AI generated using prompt "Generate a text box listing the key management and conservation priorities for Nigerian aquatic ecosystems." Suggested OER search string: "management conservation priorities Nigerian aquatic ecosystems OER".