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FAA 410
INFORMATION AND COMMUNICATIONS TECHNOLOGIES IN FISHERIES AND AQUACULTURE
AQUACULTURE MANAGEMENT SYSTEM
WATER QUALITY
Temperature 28.4 °C
pH 7.6
Dissolved Oxygen 5.6 mg/L
Ammonia 0.02 mg/L
FEED MANAGEMENT
Feed Used
FISH GROWTH
STOCK SUMMARY
WATER QUALITY MONITOR
POND MONITORING
Live Data
ICT TOOLS IN FISHERIES AND AQUACULTURE
Data Collection
Data Analysis
Communication
Decision Support
Record Keeping
GIS MAPPING FOR FISHERIES MANAGEMENT
REMOTE SENSING AND DRONE TECHNOLOGY
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Course code: FAA 410

Course title: Information and Communications Technologies in Fisheries and Aquaculture

Course credit load: 2 Units

Series 1: Roles and Applications of ICT in Fisheries and Aquaculture

Series outline

Part 1.1: Introduction to ICT in Fisheries and Aquaculture

Sub Part 1.1.1: Definition and scope of ICT in fisheries and aquaculture

Sub Part 1.1.2: Historical development of ICT adoption in the fisheries sector

Sub Part 1.1.3: Overview of ICT infrastructure and components

Part 1.2: Roles and Benefits of ICT

Sub Part 1.2.1: ICT for data collection and fisheries monitoring

Sub Part 1.2.2: ICT for communication and market information

Sub Part 1.2.3: ICT for resource management and decision support

Part 1.3: Hardware and Software in Fisheries and Aquaculture

Sub Part 1.3.1: Key hardware tools used in fisheries and aquaculture

Sub Part 1.3.2: Categories of software used in fisheries management

Sub Part 1.3.3: Connectivity and network infrastructure

Part 1.4: Challenges and Opportunities of ICT Adoption

Sub Part 1.4.1: Barriers to ICT adoption in fisheries and aquaculture

Sub Part 1.4.2: Opportunities created by ICT in the sector

Sub Part 1.4.3: ICT policy and institutional frameworks in Nigeria

Introduction

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Information and Communications Technology (ICT) has transformed virtually every sector of the global economy, and fisheries and aquaculture are no exception. From the use of GPS and sonar by fishing vessels to mobile phone applications that connect fish farmers to markets and extension services, ICT tools now pervade the full length of the fisheries and aquaculture value chain. Understanding how these technologies work, what they offer, and what barriers limit their adoption is therefore essential knowledge for any fisheries professional operating in the twenty-first century.

The aim of this Series is to introduce you to the roles, benefits, and challenges of ICT in fisheries and aquaculture, providing a foundation for the more technical content in the Series that follow.

We shall commence this Series by defining the scope of ICT and tracing its development in the fisheries sector. Next, we will examine the specific roles and benefits of ICT for data collection, communication, and resource management. Following that, we will survey the hardware and software tools in common use. Finally, we will wrap up by evaluating the barriers to ICT adoption and the opportunities it creates for fisheries and aquaculture in Nigeria and globally.

Series Learning Outcomes

Upon completing this Series, you should be able to:

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

SLO 1.2 describe the historical development of ICT adoption in the fisheries sector (Linked to Part 1.1),

SLO 1.3 identify the main components of ICT infrastructure used in fisheries and aquaculture (Linked to Part 1.1),

SLO 1.4 explain the role of ICT in fisheries data collection and monitoring (Linked to Part 1.2),

SLO 1.5 describe how ICT improves communication and market information access for fishers and fish farmers (Linked to Part 1.2),

SLO 1.6 explain how ICT supports fisheries resource management and decision-making (Linked to Part 1.2),

SLO 1.7 identify key hardware and software tools used in fisheries and aquaculture (Linked to Part 1.3),

SLO 1.8 describe the barriers to ICT adoption in fisheries and aquaculture (Linked to Part 1.4), and

SLO 1.9 explain the opportunities created by ICT and the policy frameworks that support its adoption in Nigeria (Linked to Part 1.4).

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1.1 Introduction to ICT in Fisheries and Aquaculture

1.1.1 Definition and scope of ICT in fisheries and aquaculture

Information and Communications Technology (ICT) refers to the diverse set of technological tools and resources used to transmit, store, create, share, and manage information. In fisheries and aquaculture, the scope of ICT extends from basic mobile telephony and internet connectivity used by small-scale fishers to sophisticated sensor networks, satellite-based vessel monitoring systems, and computerised stock assessment software used by government agencies and research institutions.

The application of ICT in this sector encompasses hardware devices (computers, smartphones, GPS units, echo sounders), software applications (database management systems, GIS, stock assessment tools), and communication networks (internet, mobile networks, radio). Together these components form an integrated information environment that enables more efficient management of fisheries resources, more informed decision-making, and better access to markets and extension services for producers at all scales.

Fill in the blank: ICT refers to the diverse set of technological tools used to transmit, store, create, share, and _____ information.

Figure 1.1: Diagram showing the main components of ICT in fisheries and aquaculture including hardware, software, and communication networks

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1.1.2 Historical development of ICT adoption in the fisheries sector

The adoption of ICT in fisheries has followed the broader trajectory of technology development globally. Early applications in the 1970s and 1980s were confined to mainframe computers in research institutions for stock assessment calculations and catch database management. The spread of personal computers in the 1990s brought basic data management and GIS capabilities to fisheries departments. The mobile phone revolution of the 2000s was transformative for small-scale fisheries, enabling fishers to communicate with markets and receive weather warnings.

The smartphone era and expansion of mobile broadband from the 2010s onwards dramatically expanded the range of ICT tools available to fishers and fish farmers at low cost. Today, satellite-based Vessel Monitoring Systems (VMS) are mandatory for industrial fishing fleets in many countries, mobile apps connect fish farmers to extension services, and drone and remote sensing technologies are being adopted for aquaculture pond management. In Nigeria, the growth of mobile phone penetration has been the most significant driver of ICT adoption in artisanal fisheries.

Fill in the blank: The _____ phone revolution of the 2000s was transformative for small-scale fisheries, enabling fishers to communicate with markets and receive weather warnings.

Figure 1.2: Timeline showing the key phases of ICT adoption in the fisheries sector from mainframe computers to smartphones and satelite systems

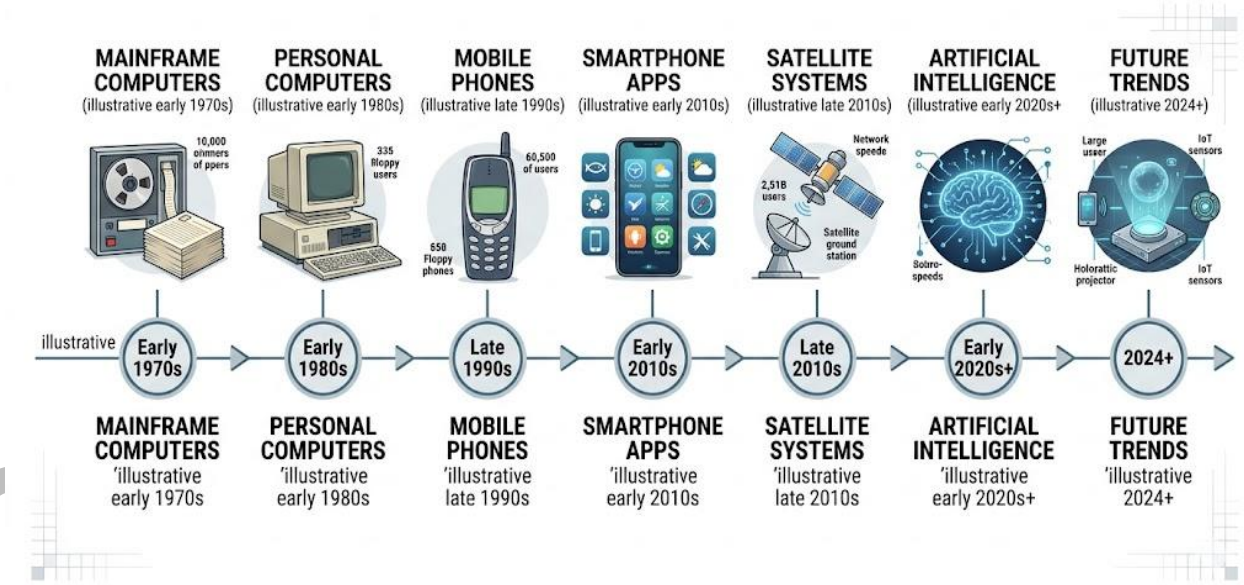

Figure 1.2: Timeline showing the key phases of ICT adoption in the fisheries sector from mainframe computers to smartphones and satellite systems

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1.1.3 Overview of ICT infrastructure and components

ICT infrastructure in fisheries and aquaculture comprises four layers: hardware (the physical devices), software (the programmes running on those devices), data (the information generated and processed), and connectivity (the networks that link devices and users). At the national level, infrastructure includes government fisheries databases, vessel monitoring control centres, and data communication networks. At the farm or vessel level, it includes GPS units, depth sounders, computers, smartphones, and sensors.

Connectivity is the most critical and most variable infrastructure component. In urban and coastal areas with good mobile or internet coverage, connectivity enables real-time data transfer, cloud-based data management, and access to online decision-support tools. In remote fishing communities and rural aquaculture areas, poor connectivity remains a binding constraint on ICT adoption. Bridging this connectivity gap through investment in rural telecommunications infrastructure is a prerequisite for realising the potential of ICT in Nigerian fisheries and aquaculture.

Fill in the blank: The four layers of ICT infrastructure are hardware, software, _____, and connectivity.

Figure 1.3: Diagram showing the four layers of ICT infrastructure in fisheries and aquaculture from hardware at the base to connectivity at the top

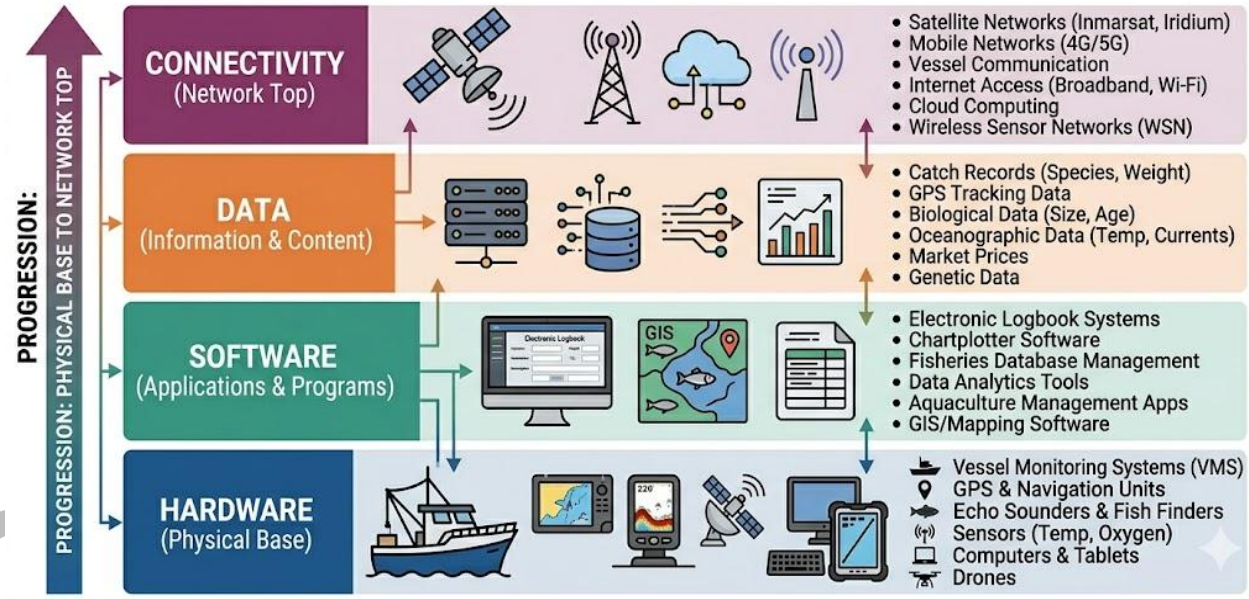

Figure 1.3: Diagram showing the four layers of ICT infrastructure in fisheries and aquaculture from hardware at the base to connectivity at the top

Pilot questions 1.1

Define ICT and state its scope in relation to fisheries and aquaculture.

What technological development of the 2000s most transformed small-scale fisheries ICT use?

List the four layers of ICT infrastructure in fisheries and aquaculture.

Why is connectivity described as the most critical infrastructure component?

Give two examples of hardware and two examples of software used in fisheries.

1.2 Roles and Benefits of ICT

1.2.1 ICT for data collection and fisheries monitoring

Data collection and monitoring are among the most important applications of ICT in fisheries. Electronic logbooks replace paper records on fishing vessels, capturing catch, effort, and position data in real time and transmitting them to fisheries management authorities. Vessel Monitoring Systems (VMS) use GPS and satellite or mobile communication to track the positions of fishing vessels continuously, enabling monitoring of compliance with area closures and licence conditions. Electronic Reporting Systems (ERS) allow fishers to report catches electronically at sea.

In aquaculture, automated sensor systems continuously monitor dissolved oxygen, temperature, pH, and feeding activity in ponds and tanks, generating data streams that allow early detection of water quality problems. Remote sensing and drone imagery are increasingly used to monitor pond conditions, assess vegetation cover, and detect harmful algal blooms across large aquaculture areas. These ICT-driven monitoring tools substantially improve the quality, timeliness, and spatial coverage of fisheries data compared with traditional paper-based methods.

Fill in the blank: Vessel _____ Systems (VMS) use GPS and satellite communication to track the positions of fishing vessels continuously, enabling compliance monitoring.

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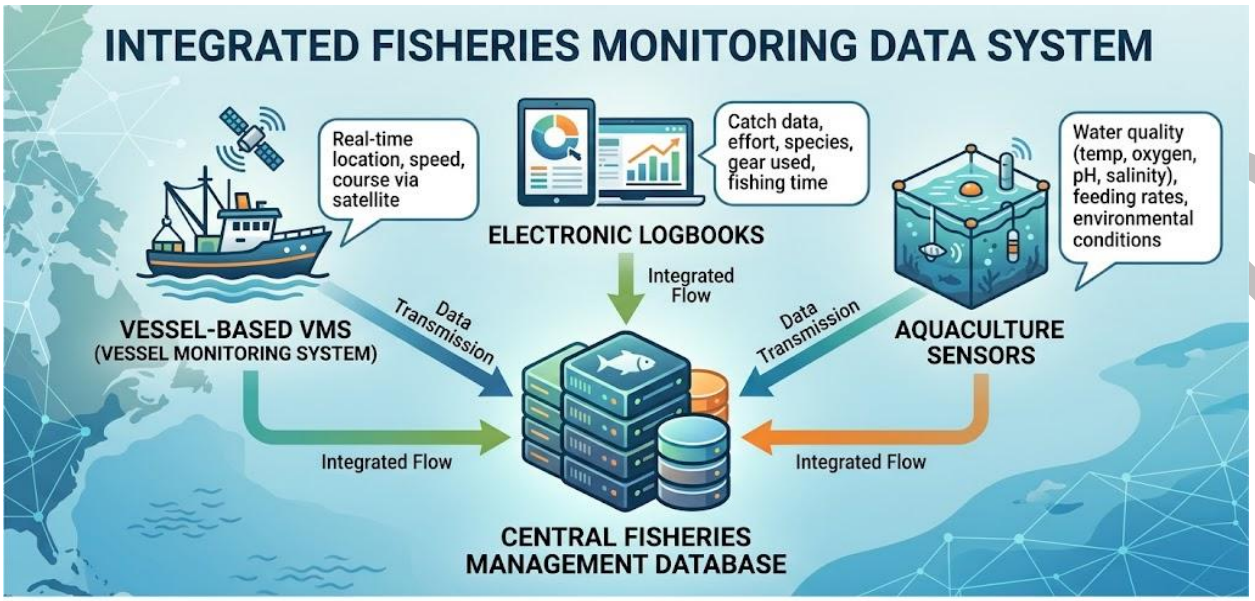

Figure 1.4: Diagram showing how VMS, electronic logbooks, and sensor systems create an integrated data collection system for fisheries monitoring.

Figure 1.4: Diagram showing how VMS, electronic logbooks, and sensor systems create an integrated data collection system for fisheries monitoring

1.2.2 ICT for communication and market information

Market information systems (MIS) delivered via mobile phones and the internet are among the most demonstrably beneficial ICT applications for small-scale fishers and fish farmers. By providing real-time information on fish prices at different landing sites and markets, MIS allows fishers to choose where to land or sell their catch to maximise revenue, reducing information asymmetries that previously favoured traders over producers. Studies in Kerala, India, and in West Africa have documented significant income gains for fishers following the adoption of mobile phones for market communication.

Extension services have also been transformed by ICT. WhatsApp groups, SMS-based advisory services, and dedicated fisheries apps now connect fish farmers and fishers directly with researchers, extension workers, and input suppliers, providing timely advice on disease management, feeding practices, weather and sea conditions, and regulatory information. In Nigeria, mobile-based fish disease diagnostic tools and aquaculture management apps are increasingly available, reducing the isolation of rural fish farmers from technical support.

Fill in the blank: Market information _____ delivered via mobile phones provide real-time fish prices, helping fishers choose where to sell and reducing information asymmetries.

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Plate 1.1: Fish market traders and fishers using smartphones to check prices and communicate with buyers in a Nigerian fish landing site

1.2.3 ICT for resource management and decision support

Decision support systems (DSS) integrate data from multiple sources and apply analytical models to help managers evaluate policy options and predict the consequences of different management decisions. In fisheries, DSS tools combine stock assessment model outputs, economic data, and social indicators to generate management advice on allowable catches, seasonal closures, and gear regulations. Geographic Information Systems (GIS) display spatial data on fishing grounds, protected areas, habitat maps, and vessel positions, supporting evidence-based spatial management.

At the aquaculture level, farm management software integrates production records, feeding data, water quality logs, and financial accounts to produce dashboards showing farm performance in real time. These tools allow farm managers to identify problems early, optimise feeding schedules, and track profitability cycle by cycle. ICT-based decision support therefore raises the quality of management decisions across the sector, from national fisheries management to individual farm operations, by making relevant information available at the right time and in an accessible form.

Fill in the blank: Geographic Information _____ (GIS) display spatial data on fishing grounds, habitat maps, and vessel positions to support evidence-based fisheries management.

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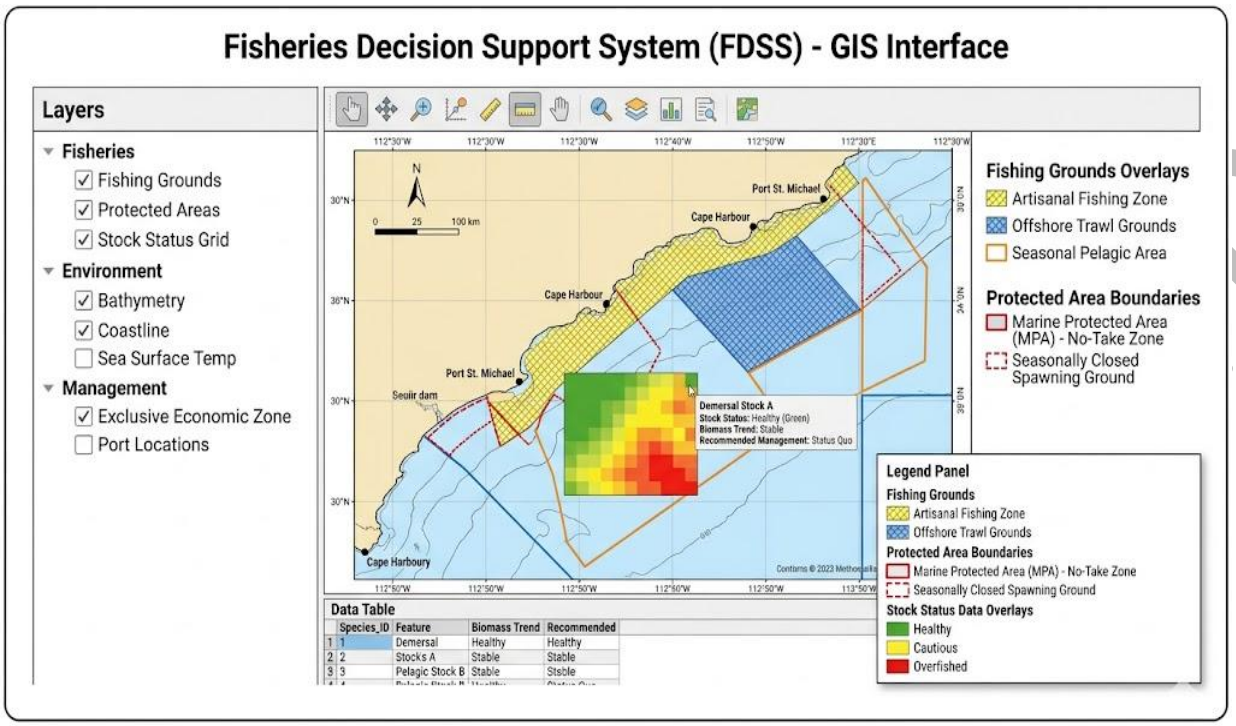

Figure 1.5: Screenshot or diagram of a GIS-based fisheries decision support system showing fishing ground maps and stock status information

Pilot questions 1.2

Define VMS and explain how it supports fisheries compliance monitoring.

Explain how market information systems benefit small-scale fishers.

State two ways ICT has transformed fisheries extension services.

What is a decision support system in fisheries management?

Explain one role of GIS in supporting fisheries resource management.

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1.3 Hardware and Software in Fisheries and Aquaculture

1.3.1 Key hardware tools used in fisheries and aquaculture

Hardware in fisheries and aquaculture encompasses a broad range of physical devices, from basic to sophisticated. At the vessel level, GPS receivers provide accurate position and navigation data; fish finders and echo sounders use acoustic signals to detect fish schools and measure water depth; and radar systems assist with collision avoidance and navigation in poor visibility. Onboard computers and data loggers record catch, position, and operational data automatically during fishing operations.

In aquaculture, key hardware includes water quality sensors (DO meters, pH probes, temperature loggers), automatic feeders with programmable timers and feed dispensing mechanisms, CCTV cameras for security and feeding behaviour monitoring, and drones for aerial surveillance of large pond complexes. At the office and laboratory level, computers, servers, printers, and scientific instruments such as NIR analysers and image analysis systems form part of the ICT hardware inventory. Proper maintenance, calibration, and replacement of hardware are essential for the continuous and reliable functioning of ICT systems.

Fill in the blank: Fish finders and echo _____ use acoustic signals to detect fish schools and measure water depth on fishing vessels.

Plate 1.2: Fishing vessel wheelhouse showing GPS, echo sounder, and onboard computer used for navigation and catch data recording

1.3.2 Categories of software used in fisheries management

Software applications used in fisheries and aquaculture fall into several broad categories. Database management systems (e.g. MS Access, MySQL, PostgreSQL) store and manage large volumes of catch, effort, biological, and economic data. Geographic Information Systems (GIS) such as ArcGIS and the open-source QGIS are used for spatial analysis of fishing grounds, habitat mapping, and marine spatial planning. Stock assessment software packages such as FAO's FiSAT II, MULTIFAN-CL, and Stock Synthesis apply population dynamic models to estimate stock status and MSY reference points.

Aquaculture management software tools such as AquaSoft and FarmHack track production records, feeding schedules, water quality logs, and financial performance. Vessel Monitoring System (VMS) software at the fisheries control centre processes and displays vessel position data on a map interface, generating alerts for vessels entering closed areas. Statistical analysis packages (R, SPSS, STATA) are widely used for processing fisheries data and producing scientific reports. Each software category requires trained users and regular updating to remain functional and secure.

Fill in the blank: Stock assessment software packages such as FAO's FiSAT II apply population _____ models to estimate stock status and MSY reference points.

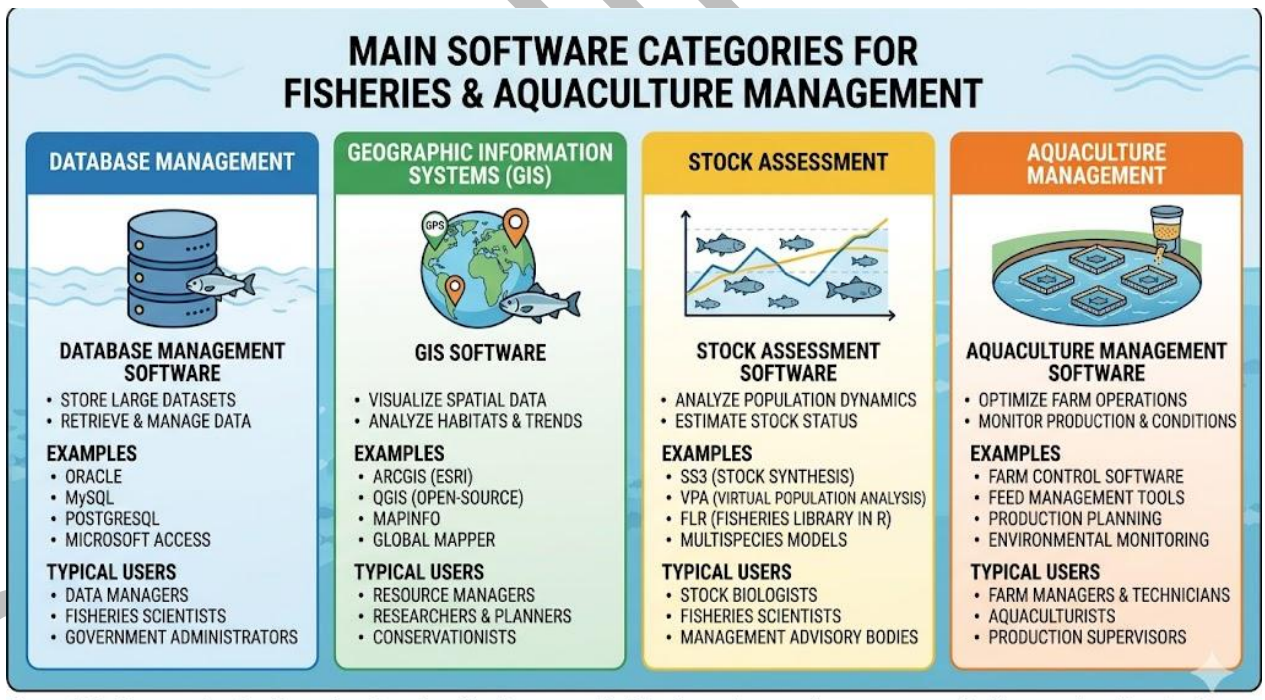

Figure 1.6: Diagram showing the main categories of software used in fisheries and aquaculture management with examples of each category

Figure 1.6: Diagram showing the main categories of software used in fisheries and aquaculture management with examples of each category

1.3.3 Connectivity and network infrastructure

Connectivity infrastructure determines the speed, reliability, and geographic reach of ICT services available to fisheries and aquaculture stakeholders. Mobile broadband (3G, 4G, and increasingly 5G) networks are the dominant means of connectivity for fishers and fish farmers in Nigeria, given the limited reach of fixed-line broadband infrastructure outside major cities. Satellite internet services such as Starlink have recently expanded connectivity options in remote coastal and rural areas, though at higher cost than mobile broadband.

At sea, satellite communication systems provide vessel connectivity beyond the range of mobile networks, enabling VMS data transmission, weather downloads, and voice communication from offshore fishing grounds. Radio communication remains important for safety-of-life communications and in areas beyond both mobile and satellite coverage. In aquaculture, local area networks (LAN) within farms connect sensors, computers, and automated systems. Building adequate connectivity infrastructure is a prerequisite for deploying advanced ICT applications in fisheries, and its expansion in rural Nigeria requires coordinated investment from government and the private sector.

Fill in the blank: Satellite internet services such as _____ have recently expanded connectivity options in remote coastal and rural areas beyond the reach of mobile networks.

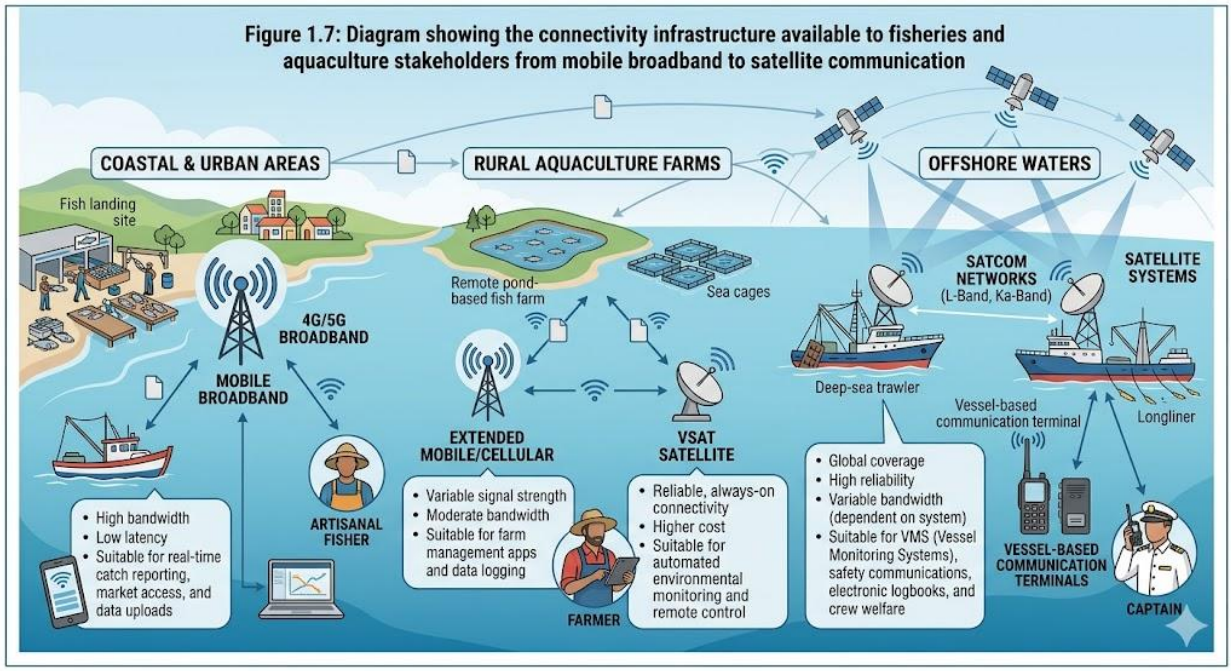

Figure 1.7: Diagram showing the connectivity infrastructure available to fisheries and aquaculture stakeholders from mobile broadband to satellite communication

Pilot questions 1.3

Name three hardware devices used on fishing vessels and state the function of each.

State three categories of software used in fisheries management and give one example of each.

What is FiSAT II and what is it used for?

Explain why mobile broadband is the dominant connectivity option for Nigerian fish farmers.

Describe how satellite communication enables connectivity for offshore fishing vessels.

1.4 Challenges and Opportunities of ICT Adoption

1.4.1 Barriers to ICT adoption in fisheries and aquaculture

Barriers to ICT adoption in fisheries and aquaculture are multiple and interconnected. Limited infrastructure, particularly poor mobile network coverage and unreliable electricity supply in rural and coastal areas, prevents access to ICT services even where devices are available. The cost of hardware devices and data subscriptions may be prohibitive for small-scale artisanal fishers and fish farmers with low and irregular incomes. Low digital literacy, especially among older and less-educated fishers, limits the ability to use ICT tools effectively even when access is available.

Language barriers are significant where ICT applications are available only in English or other non-local languages. Cultural resistance to changing established practices and distrust of data collection systems (for fear that data will be used for taxation or enforcement) can impede adoption. Institutional barriers include the absence of supportive ICT policies, inadequate technical support for users, and a lack of locally relevant content and applications. Addressing these barriers requires coordinated effort by government, development organisations, private sector actors, and fishing communities.

Fill in the blank: Low digital _____ limits the ability of fishers and fish farmers to use ICT tools effectively even when access to devices and networks is available.

Barrier	Description / Impact
Infrastructure gaps	Limited internet connectivity, unreliable electricity, and poor rural network coverage hinder ICT use.

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Barrier	Description / Impact
Cost	High cost of devices, software, and data services restricts access for small-scale operators.
Digital literacy	Low awareness and limited technical skills among fishers and farmers reduce effective ICT adoption.
Language	Many ICT tools are designed in English, limiting accessibility for local users with indigenous languages.
Cultural resistance	Preference for traditional practices and skepticism toward new technologies slow adoption.
Institutional weaknesses	Weak policy frameworks, inadequate extension services, and poor coordination reduce ICT integration.

Box 1.1: Key barriers to ICT adoption in Nigerian fisheries and aquaculture

1.4.2 Opportunities created by ICT in the sector

Despite these barriers, ICT creates significant opportunities for transforming fisheries and aquaculture in Nigeria and Africa. Mobile-based financial services (mobile money) enable fish farmers and fishers to receive payments, access credit, and purchase inputs without needing a bank account or physical banking infrastructure. E-commerce platforms allow small-scale producers to sell directly to urban consumers, reducing the power of middlemen and increasing farm-gate prices. Precision aquaculture using sensors, automated feeders, and data analytics offers significant improvements in feed efficiency and water quality management.

ICT also creates entrepreneurial opportunities for graduates of fisheries and aquaculture programmes. Developing apps and digital platforms tailored to local fisheries needs, providing ICT training and technical support to fishing communities, and building data services for fisheries management agencies are emerging business niches. The growing use of drones for pond surveillance, blockchain for seafood traceability, and satellite imagery for illegal fishing detection all represent sectors where fisheries-trained individuals with ICT skills can build careers and businesses at the intersection of technology and aquatic resource management.

Fill in the blank: E-commerce platforms allow small-scale fish producers to sell directly to urban _____, reducing the power of middlemen and increasing farm-gate prices.

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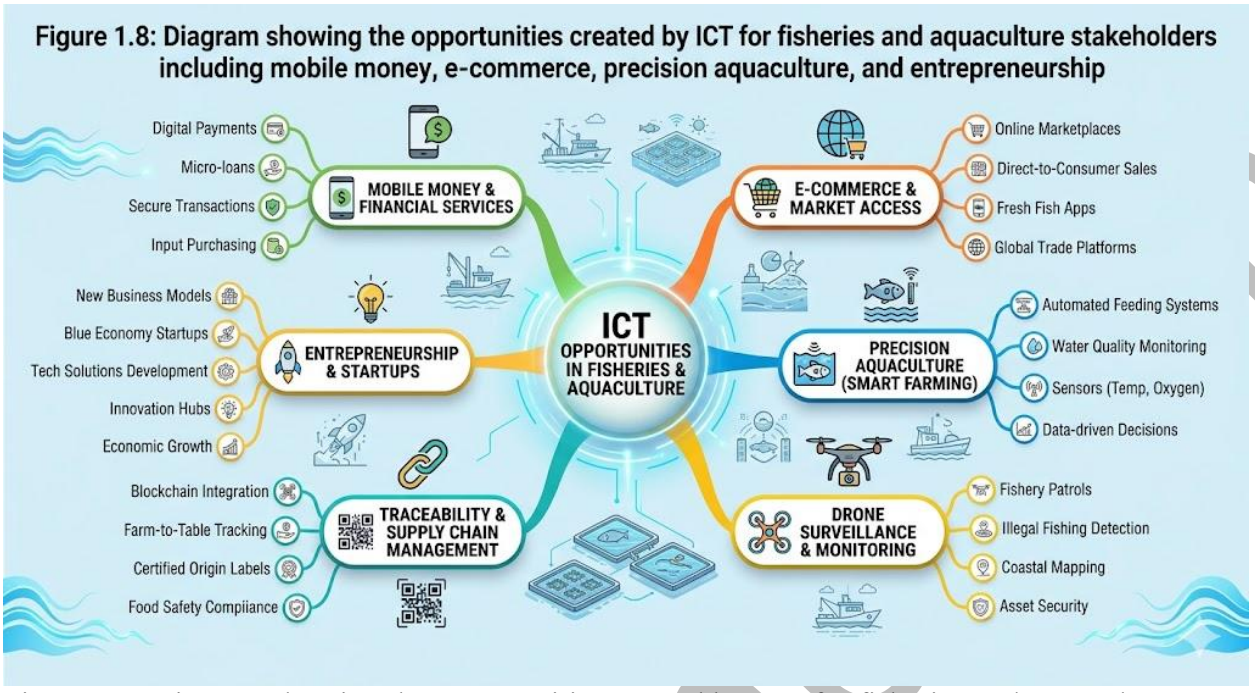

Figure 1.8: Diagram showing the opportunities created by ICT for fisheries and aquaculture stakeholders including mobile money, e-commerce, precision aquaculture, and entrepreneurship

1.4.3 ICT policy and institutional frameworks in Nigeria

Nigeria's ICT policy environment has evolved substantially since the establishment of the National Information Technology Development Agency (NITDA) in 2001 and the liberalisation of the telecommunications sector that drove rapid mobile phone expansion. The National Digital Economy Policy and Strategy (2020-2030) provides a framework for accelerating digital transformation across all sectors including agriculture and fisheries. However, specific ICT policies for fisheries and aquaculture remain underdeveloped, and their integration into fisheries management plans is limited.

Key institutional actors in the ICT-fisheries interface include the Federal Department of Fisheries (FDF), which oversees VMS and the national fisheries data system; NIOMR, which uses oceanographic data and ICT tools in research; and the Nigerian Communications Commission (NCC), which regulates the telecommunications sector and sets connectivity standards. International organisations including FAO and the World Bank have supported ICT deployment in Nigerian fisheries through projects such as the West Africa Regional Fisheries Program (WARFP). Strengthening the ICT policy framework specifically for fisheries and aquaculture is a priority for maximising the sector's potential.

Fill in the blank: The National Information Technology Development _____ (NITDA) was established in 2001 as the principal national body for ICT policy and development in Nigeria.

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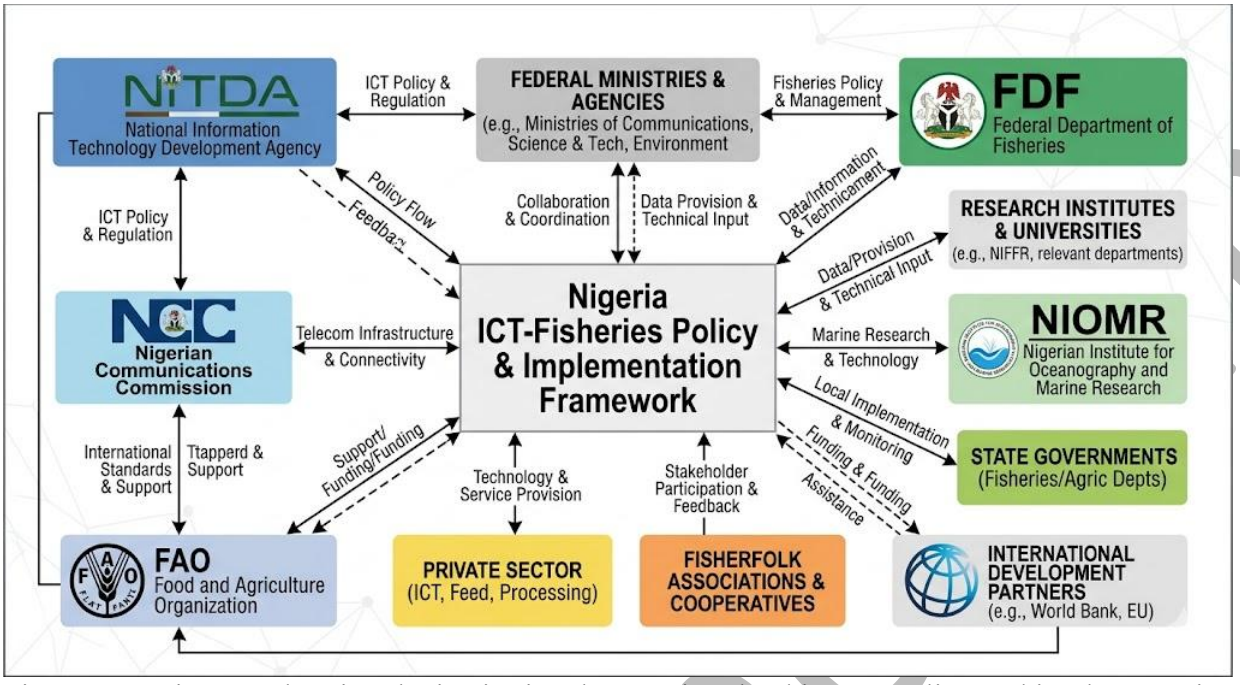

Figure 1.9: Diagram showing the institutional actors involved in ICT policy and implementation for fisheries and aquaculture in Nigeria

Pilot questions 1.4

State four barriers to ICT adoption in fisheries and aquaculture.

Explain how mobile money services benefit small-scale fishers and fish farmers.

Describe one entrepreneurial opportunity at the intersection of ICT and fisheries for a fisheries graduate.

What is NITDA and what role does it play in Nigeria's ICT development?

Name two international organisations that have supported ICT deployment in Nigerian fisheries.

Series Summary

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This Series has introduced the roles, benefits, components, and challenges of ICT in fisheries and aquaculture. We began by defining ICT and its scope, tracing the history of its adoption in the fisheries sector from mainframe computers to smartphones and satellite systems, and describing the four infrastructure layers of hardware, software, data, and connectivity. We then examined the specific roles of ICT in data collection and monitoring (VMS, electronic logbooks, sensors), in communication and market information (MIS, extension apps), and in resource management and decision support (GIS, DSS, farm management software).

Following that, we surveyed the key hardware tools on vessels and in aquaculture facilities, the main categories of fisheries and aquaculture software, and the connectivity infrastructure from mobile broadband to satellite communication. Finally, we evaluated the barriers to ICT adoption including infrastructure gaps, cost, and digital literacy, the significant opportunities ICT creates including mobile money, e-commerce, and entrepreneurship, and the Nigerian ICT policy and institutional landscape. By completing this Series, you should now be able to achieve all nine Series Learning Outcomes (SLO 1.1 to SLO 1.9).

Glossary of Terms

Decision support system (DSS): an ICT tool that integrates data from multiple sources and applies analytical models to help managers evaluate policy options and predict management outcomes.

Digital literacy: the ability to use digital devices, software, and internet services effectively; a key determinant of ICT adoption in fisheries and aquaculture communities.

Electronic logbook: a digital system on fishing vessels that captures catch, effort, and position data in real time, replacing paper-based logbooks and enabling electronic transmission to management authorities.

E-commerce: the buying and selling of goods and services over the internet; increasingly used in fisheries to connect producers directly with consumers, bypassing traditional middlemen.

FiSAT II: FAO-ICLARM Stock Assessment Tools II; a freely available software package used for length-based fish stock assessment, including ELEFAN, catch curve analysis, and yield-per-recruit analysis.

Geographic Information System (GIS): software that captures, stores, analyses, and displays geographically referenced data; used in fisheries for habitat mapping, spatial planning, and vessel monitoring.

Hardware: the physical components of an ICT system, including computers, smartphones, GPS units, sensors, echo sounders, and communication devices.

ICT (Information and Communications Technology): the diverse set of technological tools and resources used to transmit, store, create, share, and manage information, encompassing hardware, software, data, and communication networks.

Market information system (MIS): an ICT-based platform that collects and disseminates current fish prices, supply, and demand information to fishers and traders via mobile phones or the internet.

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Mobile broadband: wireless internet connectivity delivered via mobile telephone networks (3G, 4G, 5G); the dominant connectivity option for fishers and fish farmers in Nigeria.

NITDA: the National Information Technology Development Agency; the principal Nigerian government body responsible for ICT policy, development, and regulation.

Precision aquaculture: the use of sensor networks, automated systems, and data analytics to optimise the management of aquaculture operations, improving feed efficiency, water quality, and production outcomes.

Remote sensing: the acquisition of information about the Earth's surface using satellite or airborne sensors; used in fisheries to monitor sea surface temperature, chlorophyll levels, and habitat conditions.

Satellite communication: communication using satellites in Earth orbit to transmit data, voice, and internet services; enables connectivity for offshore fishing vessels beyond the range of mobile networks.

Software: programmes and operating information that instruct computer hardware to perform specific tasks; includes database management systems, GIS, stock assessment packages, and aquaculture management tools.

Vessel Monitoring System (VMS): a satellite- or mobile-based system that automatically tracks and reports the position of fishing vessels to fisheries control authorities for compliance monitoring.

Concept Check Questions [Series 1]

Objective Questions

Define ICT. (Linked to SLO 1.1)

Which of the following is not a layer of ICT infrastructure? (a) Hardware (b) Software (c) Species diversity (d) Connectivity. (Linked to SLO 1.3)

VMS stands for Vessel _____ System. (Linked to SLO 1.4)

GIS stands for Geographic _____ System. (Linked to SLO 1.6)

Low digital _____ limits the ability of fishers to use ICT tools effectively even when devices and networks are available. (Linked to SLO 1.8)

Short-Answer Questions

Explain how mobile market information systems benefit small-scale fishers. (Linked to SLO 1.5)

Describe two ways ICT is used for monitoring in aquaculture. (Linked to SLO 1.4)

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Identify two hardware tools used on fishing vessels and state the function of each. (Linked to SLO 1.7)

State three barriers to ICT adoption in fisheries and aquaculture. (Linked to SLO 1.8)

Explain one entrepreneurial opportunity created by ICT for a fisheries graduate. (Linked to SLO 1.9)

Long-Answer Questions

Analyse the roles and benefits of ICT in fisheries and aquaculture, explaining its application in data collection and monitoring, market communication, and resource management decision support, with examples from Nigeria and globally. (Linked to SLOs 1.4, 1.5, 1.6)

Evaluate the barriers to ICT adoption in Nigerian fisheries and aquaculture and assess the opportunities that ICT creates, discussing how the national ICT policy framework supports or constrains the potential of digital technology in the sector. (Linked to SLOs 1.8, 1.9)

Discuss the hardware and software tools used in fisheries and aquaculture, identifying the key devices and software categories, explaining the role of connectivity infrastructure, and assessing the challenges of deploying ICT in the Nigerian context. (Linked to SLOs 1.3, 1.7)

Answers to Concept Check Questions [Series 1]

Objective Questions

ICT is the diverse set of technological tools and resources used to transmit, store, create, share, and manage information.

Correct answer: c) Species diversity.

Monitoring.

Information.

Literacy.

Short-Answer Questions

Mobile MIS provide real-time fish price information at different markets via SMS or apps, enabling fishers to choose where to land or sell their catch for the best price. This reduces

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information asymmetries that previously favoured traders over producers, resulting in documented income gains for fishers.

Any two: automated sensor systems continuously monitor dissolved oxygen, temperature, and pH, providing early warning of water quality problems; VMS or GPS tracking monitors vessel positions and movements; drone imagery monitors pond conditions and detects algal blooms across large aquaculture areas; CCTV monitors feeding behaviour and security.

Any two: GPS receiver (provides accurate position and navigation data); echo sounder or fish finder (detects fish schools and measures water depth using acoustic signals); radar (assists with navigation and collision avoidance); electronic logbook (records catch and position data automatically).

Any three: limited infrastructure (poor mobile coverage, unreliable electricity); high cost of devices and data subscriptions; low digital literacy; language barriers (apps available only in English); cultural resistance or distrust of data collection; institutional barriers (lack of supportive policy, technical support, or locally relevant content).

Any one: developing a mobile app for fish price reporting or aquaculture management; providing ICT training and technical support to fishing communities; building data services or dashboards for fisheries management agencies; operating a drone surveillance service for aquaculture farms; developing a blockchain-based seafood traceability platform.

Long-Answer Questions

Basic response: ICT supports data collection through VMS, electronic logbooks, and aquaculture sensors. It benefits communication through mobile MIS that provide fish price information and extension apps. Decision support is provided by GIS for spatial management and DSS tools that combine stock assessment and economic data to advise on catch limits and closures.

Value-added response: The transformative potential of ICT in fisheries is greatest where it addresses the most binding constraints: information asymmetry in markets, data gaps in stock assessment, and isolation of rural producers from technical support. In Nigeria, mobile MIS have already demonstrated measurable benefits for artisanal fishers. The next frontier is integrating data from multiple ICT sources (sensors, VMS, market data, environmental data) into unified fisheries management information systems that support adaptive governance.

Basic response: Barriers include infrastructure gaps, cost, digital literacy, and institutional weakness. Opportunities include mobile money, e-commerce, precision aquaculture, and entrepreneurial niches in app development and drone services. NITDA and the National

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Digital Economy Policy provide the overarching framework, but specific fisheries ICT policies remain limited.

Value-added response: Addressing barriers requires a multi-pronged approach: expanding connectivity infrastructure (public investment in rural mobile coverage, reduced data costs), building digital literacy through school and community training programmes, developing locally relevant and multilingual ICT applications, and creating institutional champions within fisheries agencies to drive digital transformation. The barriers are not insurmountable; many have been overcome in comparable developing-country fisheries contexts through targeted programmes combining technology deployment with community engagement.

Basic response: Hardware tools include GPS, echo sounders, sensors, computers, and drones. Software categories include database management, GIS (ArcGIS, QGIS), stock assessment (FiSAT II), and aquaculture management tools. Connectivity ranges from mobile broadband (dominant in Nigeria) to satellite systems offshore. Challenges include poor rural connectivity, cost, and maintenance capacity.

Value-added response: The gap between hardware availability and effective use is often bridged by software that transforms raw data into actionable information. In Nigerian fisheries, the most impactful near-term investment is in mobile-compatible, locally relevant software applications that work on low-cost smartphones with intermittent connectivity, rather than sophisticated systems requiring stable broadband and trained IT staff. Building local software development capacity, as addressed in Series 3 of this course, is a medium-term priority for sustaining ICT solutions adapted to Nigerian conditions.

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Answers to Pilot Questions [Series 1]

Part 1.1: Introduction to ICT in Fisheries and Aquaculture

ICT refers to the diverse set of technological tools used to transmit, store, create, share, and manage information; in fisheries and aquaculture its scope extends from basic mobile phones used by small-scale fishers to GPS, satellite VMS, and computerised stock assessment software used by management agencies.

The mobile phone revolution of the 2000s most transformed small-scale fisheries ICT use, enabling fishers to communicate with markets and receive weather warnings at low cost.

Hardware, software, data, and connectivity.

Connectivity determines whether devices can exchange data with other systems and access online services; without connectivity, hardware and software cannot deliver their full potential; it is most variable and most often the binding constraint in rural and remote fishing communities.

Hardware: GPS receiver and echo sounder. Software: FiSAT II (stock assessment) and GIS such as QGIS (spatial analysis).

Part 1.2: Roles and Benefits of ICT

VMS is a satellite- or mobile-based system that automatically tracks and reports the positions of fishing vessels to a fisheries control centre; it supports compliance monitoring by alerting authorities when vessels enter closed areas, exceed their licensed fishing grounds, or fish during prohibited periods.

MIS provide real-time information on fish prices at different landing sites and markets via mobile phones; fishers can compare prices and choose where to land or sell their catch to maximise revenue, reducing the information asymmetry that previously allowed traders to buy cheaply from uninformed fishers.

Any two: WhatsApp groups and SMS advisory services connect fish farmers directly with extension workers for timely disease and management advice; mobile apps provide weather forecasts, sea condition data, and regulatory information; e-learning platforms deliver training content to farmers in remote areas.

A DSS in fisheries management integrates data from stock assessments, economic analyses, and social indicators and applies analytical models to help managers evaluate the consequences of different policy options such as quota levels, gear regulations, or area closures.

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GIS displays spatial data on fishing grounds, protected area boundaries, habitat types, and vessel positions, enabling managers to identify spatial conflicts, monitor compliance with area closures, and design marine protected areas and spatial management measures based on evidence.

Part 1.3: Hardware and Software in Fisheries and Aquaculture

Any three: GPS receiver (provides accurate position and navigation); echo sounder or fish finder (detects fish schools and measures depth acoustically); radar (navigation and collision avoidance in poor visibility); electronic logbook system (records catch, effort, and position data automatically).

Any three: database management systems e.g. MySQL (store and manage catch and biological data); GIS e.g. QGIS or ArcGIS (spatial analysis and mapping); stock assessment software e.g. FiSAT II (population dynamic models); aquaculture management software e.g. AquaSoft (production records, feeding, water quality).

FiSAT II is the FAO-ICLARM Stock Assessment Tools II software package; it is used for length-based fish stock assessment applying methods including ELEFAN for growth parameter estimation, catch curve analysis for mortality estimation, and yield-per-recruit analysis for management reference points.

Fixed-line broadband infrastructure reaches only major cities in Nigeria; mobile broadband networks (3G, 4G) have much wider geographic coverage including coastal and peri-urban areas; smartphones compatible with mobile broadband are affordable and widely owned by fish farmers and fishers; mobile broadband therefore provides the most accessible and cost-effective connectivity for the majority of the sector.

Satellite communication systems on vessels transmit position, catch, and other data to shore stations via communication satellites in Earth orbit; this enables VMS data transmission, weather downloads, and voice or data communication from fishing grounds hundreds of kilometres offshore, well beyond the range of mobile network base stations.

Part 1.4: Challenges and Opportunities of ICT Adoption

Any four: limited infrastructure (poor mobile coverage, unreliable electricity); high cost of devices and subscriptions; low digital literacy; language barriers (apps only in English); cultural resistance or distrust; absence of supportive ICT policies for the fisheries sector; lack of locally relevant content.

Mobile money services allow fish farmers and fishers to receive payments electronically, send money to input suppliers, and access credit through digital lending platforms without

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requiring a physical bank account or branch; this is transformative in rural and coastal areas where formal banking infrastructure is absent.

Any one example with explanation: developing a mobile app for fish disease diagnosis or farm management generates recurring subscription revenue; providing ICT training workshops for fishing communities is a scalable service business; building a data portal or dashboard for a fisheries management agency is a consultancy opportunity; operating a drone surveillance service for aquaculture farms generates service fees.

NITDA is the National Information Technology Development Agency, established in 2001; it is the principal government body responsible for ICT policy formulation, development, and regulation in Nigeria, overseeing the implementation of the National Digital Economy Policy and coordinating ICT development across sectors including agriculture and fisheries.

Any two: FAO (supports ICT tools including FiSAT II, FishBase, and e-learning platforms, and has funded projects such as the West Africa Regional Fisheries Program); World Bank (has provided financing for fisheries ICT infrastructure including VMS deployment in Nigeria under the WARFP project).

References and Attributions [Series 1]

Textual References (Books and External Sources)

FAO (Food and Agriculture Organization of the United Nations). (2015). Monitoring the performance of the common fisheries policy. FAO Fisheries and Aquaculture Technical Paper No. 589. FAO.

Aker, J. C., & Mbiti, I. M. (2010). Mobile phones and economic development in Africa. Journal of Economic Perspectives, 24(3), 207-232.

Jensen, R. (2007). The digital provide: Information technology, market performance, and welfare in the South Indian fisheries sector. Quarterly Journal of Economics, 122(3), 879-924.

World Bank. (2019). Digital technology in agriculture: Taking stock of the evidence and getting practical. World Bank Group.

Federal Ministry of Communications and Digital Economy. (2020). National digital economy policy and strategy for a digital Nigeria. Federal Government of Nigeria.

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

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Figures, Plates, Tables, and Boxes

Figure 1.1: ICT components in fisheries and aquaculture Attribution: AI generated using prompt "Generate a diagram showing the three main ICT component categories in fisheries: hardware, software, and communication networks with examples." Suggested OER search string: "ICT components fisheries aquaculture hardware software networks diagram OER".

Figure 1.2: Timeline of ICT adoption in the fisheries sector Attribution: AI generated using prompt "Generate a horizontal timeline showing key phases of ICT adoption in fisheries from mainframe computers to mobile apps and satellite systems." Suggested OER search string: "ICT adoption fisheries timeline milestones OER diagram".

Figure 1.3: Four layers of ICT infrastructure in fisheries Attribution: AI generated using prompt "Generate a layered diagram showing the four ICT infrastructure layers in fisheries: hardware, software, data, and connectivity with examples." Suggested OER search string: "ICT infrastructure layers fisheries aquaculture diagram OER".

Figure 1.4: VMS, electronic logbooks, and sensor data flow diagram Attribution: AI generated using prompt "Generate a diagram showing how vessel monitoring systems, electronic logbooks, and aquaculture sensors feed data into a central fisheries management database." Suggested OER search string: "VMS electronic logbook aquaculture sensors fisheries monitoring data flow OER diagram".

Plate 1.1: Fishers using smartphones at a Nigerian landing site Attribution: AI generated using prompt "Generate an image showing fish traders and fishers at a Nigerian landing site using smartphones to check market prices." Suggested OER search string: "Nigerian fish landing site fishers smartphones market prices OER image".

Figure 1.5: GIS-based fisheries decision support system Attribution: AI generated using prompt "Generate a diagram showing a GIS-based fisheries decision support system interface with fishing grounds, protected area boundaries, and stock status overlays." Suggested OER search string: "GIS fisheries decision support system coastal map OER diagram".

Plate 1.2: Fishing vessel wheelhouse with GPS and echo sounder Attribution: AI generated using prompt "Generate an image of a fishing vessel wheelhouse showing GPS, echo sounder, and onboard computer." Suggested OER search string: "fishing vessel wheelhouse GPS echo sounder onboard computer OER image".

Figure 1.6: Software categories used in fisheries and aquaculture management Attribution: AI generated using prompt "Generate a diagram showing the main categories of software used in fisheries and aquaculture management with examples." Suggested OER search string: "fisheries aquaculture software categories database GIS stock assessment OER diagram".

Figure 1.7: Connectivity infrastructure for fisheries stakeholders Attribution: AI generated using prompt "Generate a diagram showing connectivity options from mobile broadband in coastal areas to satellite systems offshore for fisheries and aquaculture." Suggested OER

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search string: "fisheries aquaculture connectivity infrastructure mobile satellite OER diagram".

Box 1.1: Barriers to ICT adoption in Nigerian fisheries Attribution: AI generated using prompt "Generate a text box listing the key barriers to ICT adoption in fisheries and aquaculture including infrastructure, cost, digital literacy, and institutional factors." Suggested OER search string: "barriers ICT adoption fisheries aquaculture Nigeria OER".

Figure 1.8: ICT opportunities for fisheries and aquaculture Attribution: AI generated using prompt "Generate a diagram showing the key opportunities created by ICT in fisheries including mobile money, e-commerce, precision aquaculture, and entrepreneurship." Suggested OER search string: "ICT opportunities fisheries aquaculture mobile money e-commerce precision OER diagram".

Figure 1.9: Institutional actors in Nigeria's ICT-fisheries policy landscape Attribution: AI generated using prompt "Generate a diagram showing the key institutional actors in ICT policy and implementation for fisheries in Nigeria including NITDA, NCC, FDF, NIOMR, and FAO." Suggested OER search string: "Nigeria ICT fisheries institutional actors policy framework OER diagram".

Course code: FAA 410

Course title: Information and Communications Technologies in Fisheries and Aquaculture

Course credit load: 2 Units

Series 2: Computer Applications and FAO Tools in Fisheries

Series outline

Part 2.1: Common Computer Applications in Fisheries and Aquaculture

Sub Part 2.1.1: Spreadsheets and database applications

Sub Part 2.1.2: Statistical and analytical software

Sub Part 2.1.3: Geographic Information Systems in fisheries

Part 2.2: FAO Software Applications for Fisheries

Sub Part 2.2.1: FiSAT II and length-based stock assessment tools

Sub Part 2.2.2: FishBase, FishStatJ, and fisheries databases

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Sub Part 2.2.3: FAO e-learning platforms and digital resources

Part 2.3: Mobile Applications in Fisheries and Aquaculture

Sub Part 2.3.1: Overview of fisheries and aquaculture mobile apps

Sub Part 2.3.2: Apps for fish identification, disease diagnosis, and management

Sub Part 2.3.3: Developing and deploying apps for local fisheries needs

Part 2.4: Data Management and Visualisation

Sub Part 2.4.1: Fisheries data collection and entry systems

Sub Part 2.4.2: Data cleaning, validation, and management best practices

Sub Part 2.4.3: Data visualisation and reporting for fisheries management

Introduction

The effective use of computer applications and digital tools is now a core professional competency for fisheries scientists, aquaculture managers, and fisheries administrators. From spreadsheets used to track farm production records to sophisticated FAO-developed stock assessment packages used by national fisheries agencies, computer applications permeate every level of the sector. Understanding which tools are available, what they do, and how to use them effectively is therefore an essential part of professional preparation for fisheries and aquaculture graduates.

The aim of this Series is to introduce you to the principal computer applications used in fisheries and aquaculture, with particular attention to FAO-developed tools, mobile applications, and data management and visualisation techniques.

We shall commence this Series by surveying common computer applications including spreadsheets, databases, statistical software, and GIS. Next, we will examine the suite of FAO tools available for stock assessment, fisheries databases, and e-learning. Following that, we will study mobile applications for fish identification, disease diagnosis, and farm management. Finally, we will wrap up with the principles of fisheries data management, validation, and visualisation.

Series Learning Outcomes

Upon completing this Series, you should be able to:

SLO 2.1 describe the main computer applications used in fisheries and aquaculture including spreadsheets, databases, statistical tools, and GIS (Linked to Part 2.1),

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SLO 2.2 explain the role of GIS in fisheries management and describe key GIS applications (Linked to Part 2.1),

SLO 2.3 describe FAO software applications for stock assessment and explain how FiSAT II is used (Linked to Part 2.2),

SLO 2.4 explain the purpose and content of FishBase, FishStatJ, and other FAO fisheries databases (Linked to Part 2.2),

SLO 2.5 describe the FAO e-learning platforms and digital resources available for fisheries professionals (Linked to Part 2.2),

SLO 2.6 identify mobile applications used in fisheries and aquaculture and describe their functions (Linked to Part 2.3),

SLO 2.7 explain how mobile apps are developed and deployed for local fisheries needs (Linked to Part 2.3),

SLO 2.8 describe best practices for fisheries data collection, entry, cleaning, and validation (Linked to Part 2.4), and

SLO 2.9 explain data visualisation principles and describe how fisheries data are presented for management decision-making (Linked to Part 2.4).

2.1 Common Computer Applications in Fisheries and Aquaculture

2.1.1 Spreadsheets and database applications

Spreadsheet applications such as Microsoft Excel and the open-source LibreOffice Calc are the most widely used computer tools in fisheries and aquaculture. They are used to record catch and effort data, calculate growth and mortality parameters, manage farm production records, track financial accounts, and perform simple statistical analyses. Their combination of ease of use, flexibility, and built-in calculation functions makes them accessible to fisheries professionals at all levels.

Database management systems (DBMS) such as Microsoft Access, MySQL, and PostgreSQL provide more robust solutions for managing large volumes of fisheries data. Unlike spreadsheets, DBMS enforce data structure and integrity, support multiple simultaneous users, and allow complex queries across linked data tables. National fisheries agencies use DBMS to manage catch reporting systems, vessel registration databases, and observer programme records. Skills in both spreadsheets and databases are fundamental competencies for any fisheries professional.

Fill in the blank: Microsoft _____ and LibreOffice Calc are the most widely used spreadsheet applications in fisheries and aquaculture for recording and analysing data.

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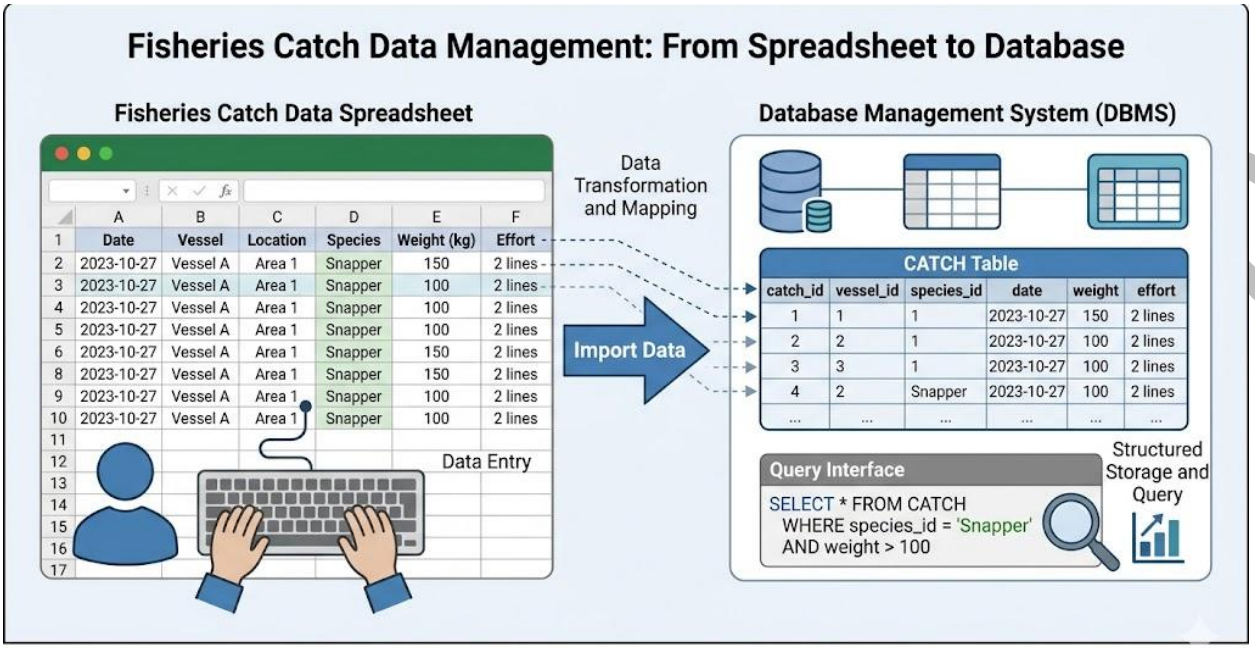

Figure 2.1: Screenshot or diagram showing a fisheries catch data spreadsheet and a linked database interface.
Figure 2.1: Screenshot or diagram showing a fisheries catch data spreadsheet and a linked database interface

2.1.2 Statistical and analytical software

Statistical software packages are essential for analysing fisheries and aquaculture data. R is a free, open-source statistical computing environment widely used in fisheries science for data analysis, population modelling, and visualisation. It has a large library of specialised packages for fisheries applications including the TropFishR package for tropical fish stock assessment and the ggplot2 package for publication-quality graphics. Python is increasingly used for data science tasks in fisheries, particularly when combined with machine learning libraries.

Commercial statistical packages such as IBM SPSS and Stata are used in social and economic analyses of fisheries and aquaculture, including value chain studies and household surveys. SAS is widely used in research institutions for multivariate analysis and experimental design. For routine analyses, Microsoft Excel's built-in statistical functions and the Analysis ToolPak add-in provide an accessible starting point for fisheries students and practitioners who do not yet have programming skills. Familiarity with at least one statistical package is expected of fisheries professionals at the graduate level.

Fill in the blank: R is a free, open-source statistical computing environment with specialised fisheries packages such as _____ for tropical fish stock assessment.

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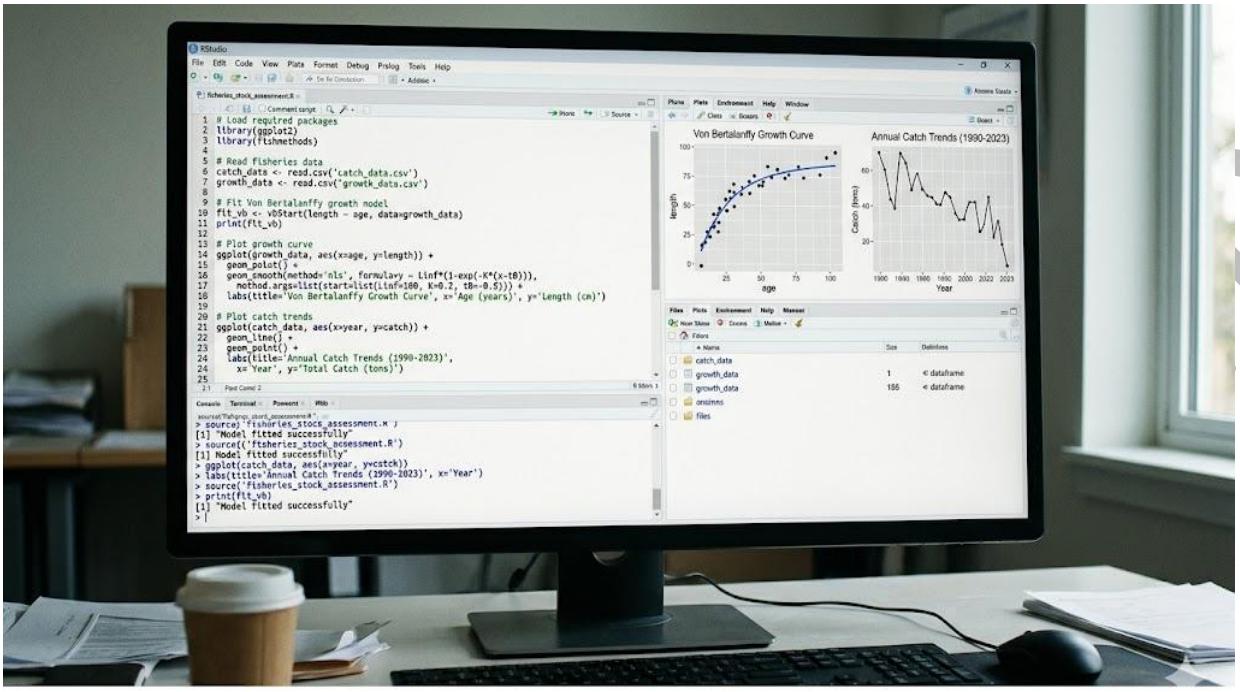

Plate 2.1: Computer screen showing R statistical software with a fisheries stock assessment script and output graphs
Plate 2.1: Computer screen showing R statistical software with a fisheries stock assessment script and output graphs

2.1.3 Geographic Information Systems in fisheries

Geographic Information Systems (GIS) are software tools that capture, store, analyse, and display data that are geographically referenced. In fisheries, GIS is used for mapping fishing grounds and effort distributions, displaying stock assessment results spatially, identifying critical habitats such as spawning and nursery areas, supporting marine spatial planning, and monitoring vessel compliance with area closures. The two most widely used GIS platforms are the commercial ArcGIS and the free, open-source QGIS.

QGIS has become the platform of choice in many developing-country fisheries agencies because it is freely available and has an active development community producing fisheries-specific plugins. Key GIS operations in fisheries include overlaying vessel position data from VMS on habitat maps, calculating area-standardised catch rates across fishing zones, and producing maps of stock distribution and fishing intensity for management reports. Basic GIS proficiency, including layer management, spatial queries, and map production, is a valuable skill for fisheries scientists and managers.

Fill in the blank: _____ is a free, open-source GIS platform widely used in developing-country fisheries agencies as an alternative to commercial ArcGIS software.

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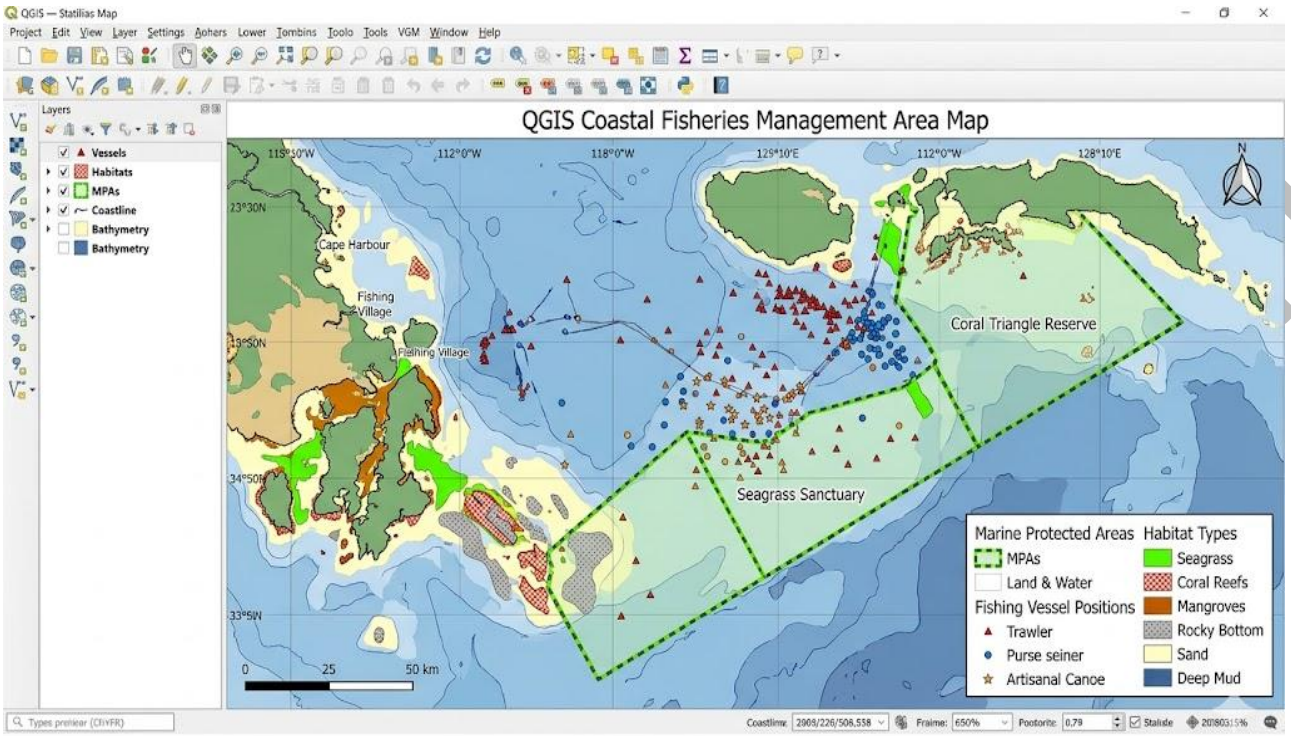

Figure 2.2: QGIS map showing fishing vessel positions overlaid on habitat and protected area boundaries in a coastal fisheries management area

Figure 2.2: QGIS map showing fishing vessel positions overlaid on habitat and protected area boundaries in a coastal fisheries management area

Pilot questions 2.1

State two uses of spreadsheet applications in fisheries and aquaculture.

What advantage does a database management system have over a spreadsheet for managing fisheries data?

Name two statistical software packages used in fisheries and state one use of each.

Define GIS and state two fisheries applications.

Why is QGIS preferred over ArcGIS in many developing-country fisheries agencies?

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2.2 FAO Software Applications for Fisheries

2.2.1 FiSAT II and length-based stock assessment tools

FiSAT II (FAO-ICLARM Stock Assessment Tools II) is a freely available software package developed by FAO and ICLARM (now WorldFish) for the stock assessment of tropical fish using length-frequency data. Its principal analytical modules include ELEFAN (Electronic Length Frequency Analysis) for estimating von Bertalanffy growth parameters, catch curve analysis for estimating total mortality, yield-per-recruit analysis for evaluating fishing pressure, and cohort analysis. It runs on Microsoft Windows and is available for free download from the FAO website.

FiSAT II has been widely applied to stock assessment of commercial species in Nigerian and West African fisheries including croakers, tilapia, and catfish in the absence of reliable age data. Its ELEFAN module fits the von Bertalanffy growth function directly to length frequency histograms, making it particularly suited to data-limited tropical fisheries where otolith ageing is not routinely conducted. Other FAO length-based tools include the Length-Based Spawning Potential Ratio (LB-SPR) method, which estimates stock status from length data alone without requiring growth parameters.

Fill in the blank: FiSAT II's _____ module estimates von Bertalanffy growth parameters by fitting a growth curve directly to length frequency histograms without requiring age data from hard parts.

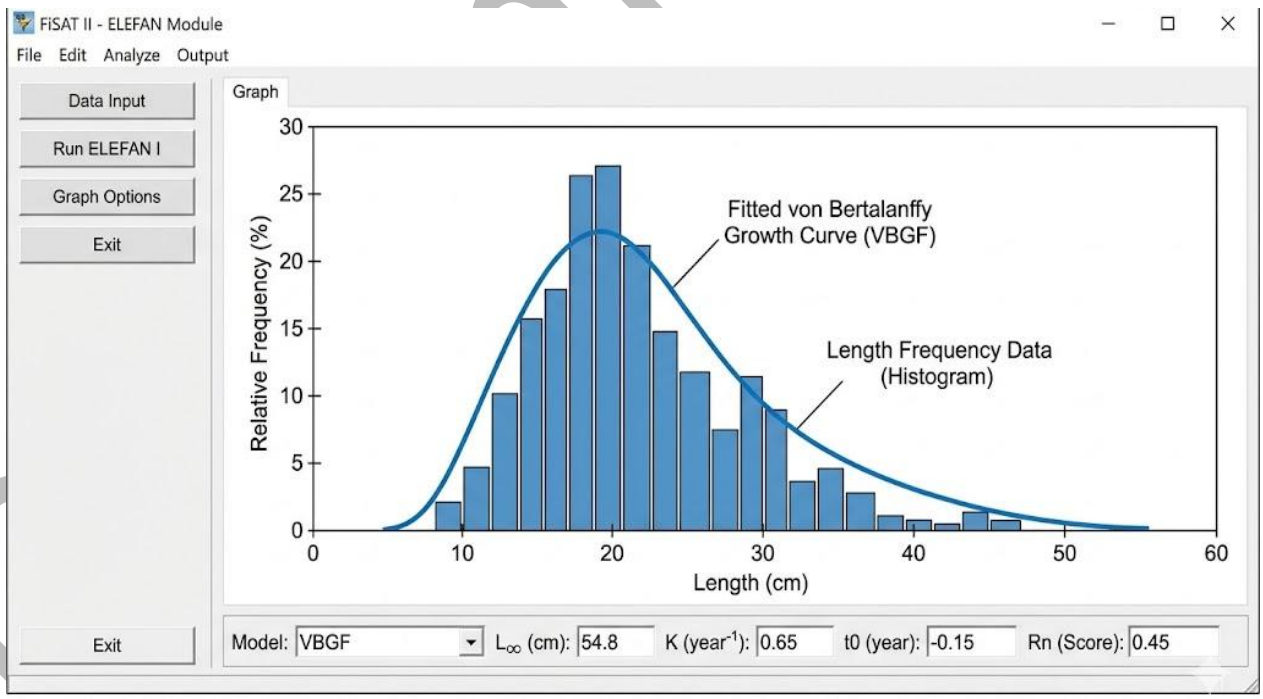

Figure 2.3: FiSAT II software interface showing the ELEFAN module with a length frequency histogram and fitted growth curve

Figure 2.3: FiSAT II software interface showing the ELEFAN module with a length frequency histogram and fitted growth curve

2.2.2 FishBase, FishStatJ, and fisheries databases

FishBase (www.fishbase.org) is the world's largest online database of biological information on fish species, covering more than 35,000 species. It provides species identification information, life history data including growth parameters, reproductive data, diet, and distribution maps, making it an essential reference for fisheries scientists conducting stock assessments, ecological studies, and fish identification. FishBase is freely accessible online and is actively maintained by a global network of collaborators.

FishStatJ is the FAO global fisheries statistics software that allows users to query, analyse, and visualise FAO's global catch and aquaculture production databases, which contain data from all FAO member countries from 1950 to the present. It produces tables and graphs showing national, regional, and global capture fisheries and aquaculture production trends and is an essential reference for fisheries economists, policy analysts, and students preparing reports on national or global fisheries status. Both tools are freely available and require no specialised technical skills to use.

Fill in the blank: _____ is the world's largest online database of biological information on fish species, providing growth parameters, distribution maps, and life history data for over 35,000 species.

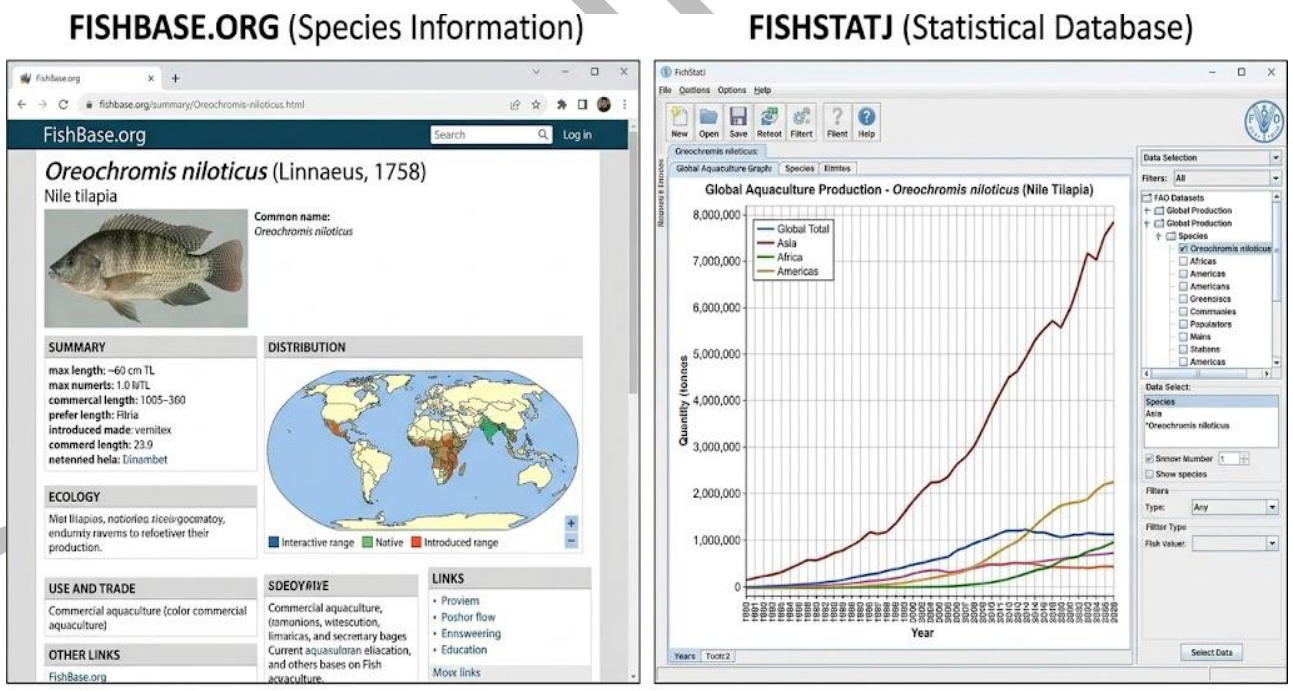

Figure 1. FISHBase.org showins informaion ctad:: fishbase.org/summary/tile screensshots, on FISHSTATJ Aquaculture Production -*Oreochromis niloticus* (Nile Tilapia).

Figure 2.4: Screenshot showing the FishBase species information page for Oreochromis niloticus and the FishStatJ trend graph interface

2.2.3 FAO e-learning platforms and digital resources

FAO provides a substantial portfolio of freely accessible e-learning resources for fisheries and aquaculture professionals. The FAO e-learning Academy (www.fao.org/elearning) offers self-paced online courses on topics including fisheries management, aquaculture, food safety, and value chain analysis. The courses are available in multiple languages and lead to certificates of completion. FAO's eLearning courses on fisheries stock assessment and the Code of Conduct for Responsible Fisheries are particularly relevant to this course.

Beyond formal e-learning courses, FAO makes available a large library of technical manuals, guidelines, and datasets freely downloadable from its website and the FAO Document Repository. The FIGIS (Fisheries and Resources Monitoring System) online portal provides species profiles, stock assessment summaries, and fisheries country profiles for all FAO member states. The Aquatic Commons digital library aggregates research and grey literature on fisheries and aquatic sciences. These resources collectively provide fisheries students and professionals with free access to a comprehensive knowledge base that would otherwise require expensive subscriptions.

Fill in the blank: The FAO _____ Academy provides free, self-paced online courses on fisheries management, aquaculture, and related topics in multiple languages.

Figure 2.5: Screenshot of the FAO e-learning Academy website homepage showing available fisheries and aquaculture courses

Figure 2.5: Screenshot of the FAO e-learning Academy website homepage showing available fisheries and aquaculture courses

Pilot questions 2.2

What is FiSAT II and for what type of fisheries data is it most suited?

Explain what the ELEFAN module in FiSAT II does.

What information can be found in FishBase?

Explain the purpose of FishStatJ and who uses it.

State two types of free FAO digital resources available to fisheries professionals.

2.3 Mobile Applications in Fisheries and Aquaculture

2.3.1 Overview of fisheries and aquaculture mobile apps

Mobile applications (apps) have become an important ICT tool for fisheries and aquaculture because they run on widely available smartphones, work offline or with intermittent connectivity, and can be tailored to specific user needs. Fisheries apps span a wide range of functions including fish species identification, catch reporting, weather and sea condition monitoring, fish price checking, feed management, water quality logging, and financial record keeping. Many are available free of charge from app stores.

FAO and partner organisations have developed several fisheries-specific apps. The FAO FishFinder app assists with species identification using photographs and biological descriptions. The Fish-i Africa platform tracks fishing vessel activity in East African waters. The AquaCalc app assists with aquaculture calculations including stocking density, feeding rates, and water volumes. In Nigeria, locally developed apps for catfish farm management and fish price aggregation are increasingly available, reflecting the growing ecosystem of local fisheries app developers motivated by the LO of this course.

Fill in the blank: Mobile applications run on widely available _____, can work offline, and can be tailored to specific user needs in fisheries and aquaculture.

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Plate 2.2: Fish farmer using a mobile app on a smartphone to log water quality parameters and feed quantities at a catfish pond

Plate 2.2: Fish farmer using a mobile app on a smartphone to log water quality parameters and feed quantities at a catfish pond

2.3.2 Apps for fish identification, disease diagnosis, and management

Fish identification apps use photographic databases and increasingly AI-powered image recognition to help fishers, inspectors, and researchers identify species in the field. iNaturalist allows users to photograph organisms and receive species identifications from a global expert community. The SmartFish app assists small-scale fishers in Mexico with catch recording and species identification. SeafoodWatch guides consumers and buyers on the sustainability of fish species for purchase, drawing on FAO and regional stock assessment data.

Fish disease diagnosis apps provide symptom-based diagnostic pathways that guide fish farmers through the identification of common diseases and the appropriate treatment response, reducing the need for specialist veterinary access in rural areas. Farm management apps such as Aquagrow and KoboToolbox (adapted for aquaculture data collection) help farmers track production cycles, feeding schedules, water quality logs, and financial performance on their smartphones. These tools collectively extend the reach of expert knowledge and management support to fish farmers and fishers who would otherwise lack access.

Fill in the blank: Fish disease _____ apps provide symptom-based pathways that guide fish farmers through identifying common diseases and appropriate treatments without specialist access.

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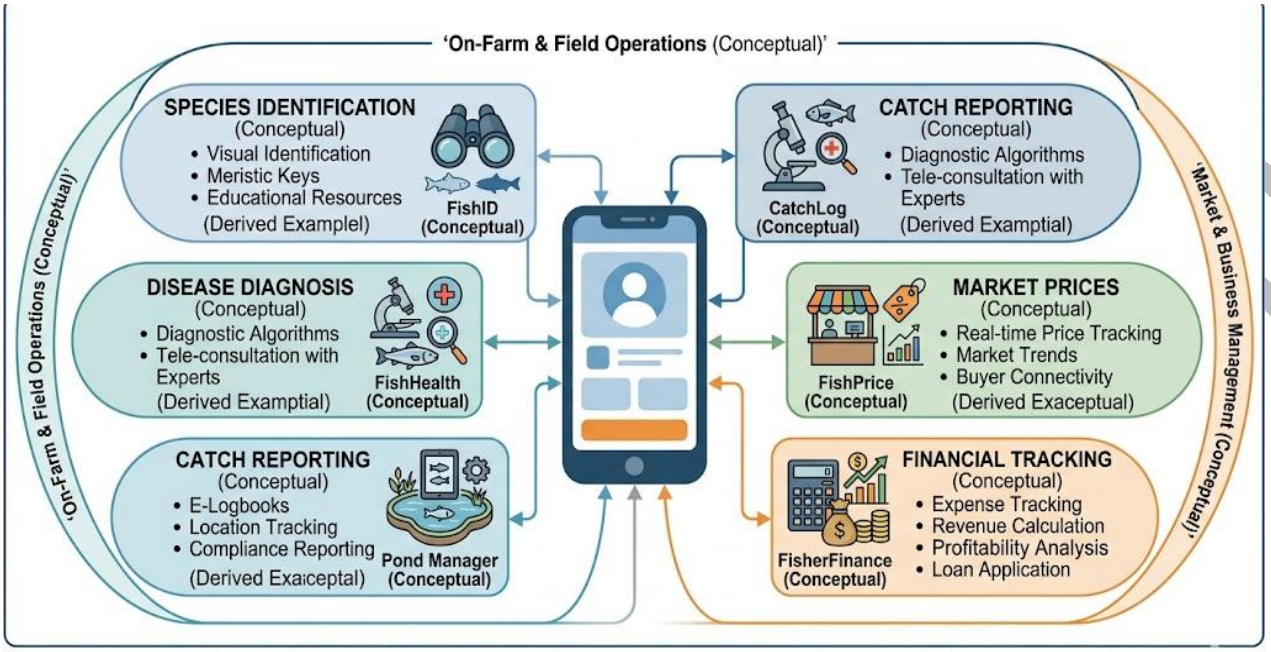

'**Figure 2.6:** Diagram showing the range of mobile app functions available to fishers and fish farmers from identification through disease diagnosis to market and financial management'.

Figure 2.6: Diagram showing the range of mobile app functions available to fishers and fish farmers from identification through disease diagnosis to market and financial management

2.3.3 Developing and deploying apps for local fisheries needs

Developing a mobile app for fisheries begins with a clear problem statement: what specific challenge does the app address, and who are the primary users? User-centred design requires extensive consultation with fishers, farmers, or managers to understand their workflows, language preferences, connectivity constraints, and device capabilities before writing any code. Apps that are designed without this consultation often fail to be adopted because they do not fit the actual needs and context of their intended users.

Technical development involves choosing a platform (Android is dominant in Nigeria due to the prevalence of low-cost Android smartphones), a development framework (MIT App Inventor provides a no-code visual environment suitable for beginners; Flutter and React Native are professional cross-platform frameworks), and a data architecture that supports offline use and synchronisation when connectivity is available. Deployment requires placing the app in the Google Play Store or distributing it as an APK file, followed by user training and an ongoing support and update cycle. Series 3 of this course covers the practical aspects of app development in detail.

Fill in the blank: MIT App _____ provides a no-code visual development environment that allows beginners to build basic Android applications without writing code.

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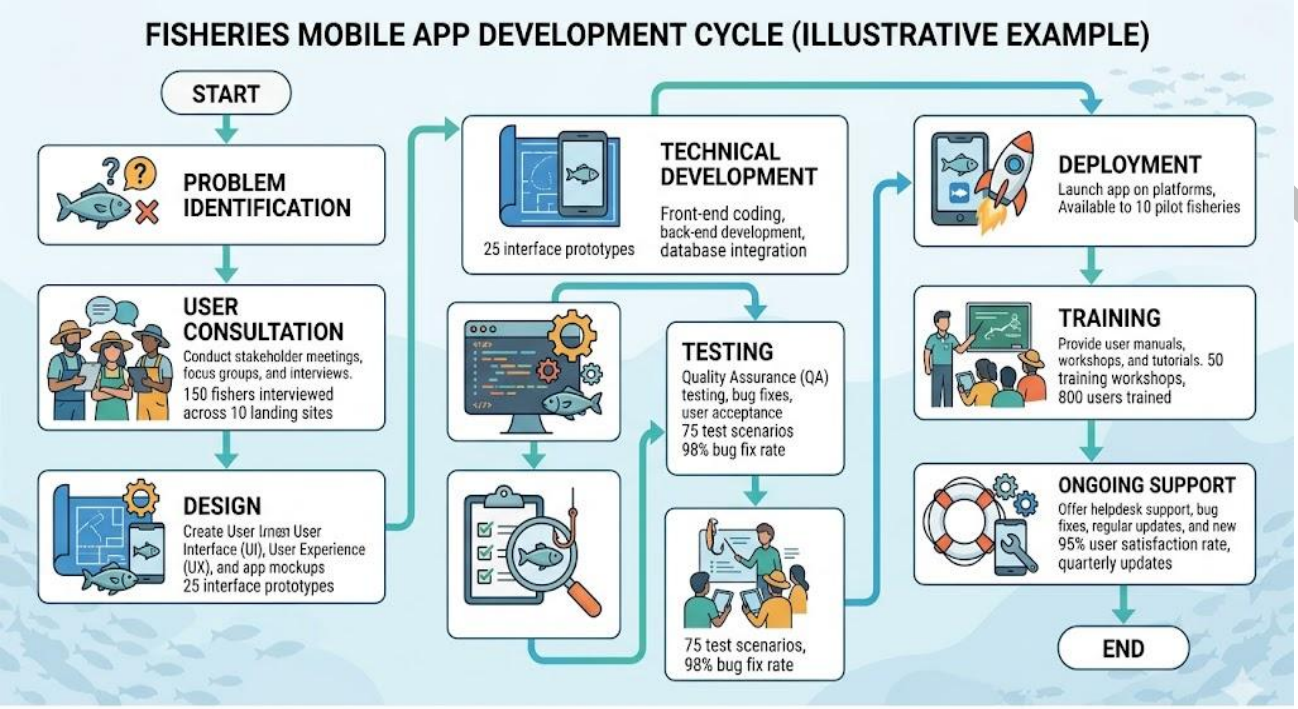

Figure 2.7: Flowchart showing the stages of mobile app development for a fisheries application from problem identification to deployment and support

Figure 2.7: Flowchart showing the stages of mobile app development for a fisheries application from problem identification to deployment and support

Pilot questions 2.3

State three functions that fisheries and aquaculture mobile apps can perform.

Name two FAO-developed or FAO-supported fisheries apps and describe the function of each.

What is iNaturalist and how is it useful for fisheries work?

Explain the first step in developing a mobile app for a fisheries problem.

Why is Android the dominant platform for fisheries app development in Nigeria?

2.4 Data Management and Visualisation

2.4.1 Fisheries data collection and entry systems

Fisheries data collection begins at landing sites, on research vessels, and at aquaculture farms. Traditionally conducted on paper forms, data collection increasingly uses mobile-based digital tools including KoboToolbox, ODK (Open Data Kit), and custom-built apps. These tools allow

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structured data entry directly onto smartphones or tablets, with built-in validation checks (range checks, required fields, skip logic) that prevent many common data entry errors. Collected data are uploaded automatically to a central server when connectivity is available.

Electronic data collection substantially improves data quality compared with paper-based methods by eliminating transcription errors during digitisation, enforcing field-level validation at the point of collection, and providing real-time data availability for analysis. The FAO Data Collection Reference Framework (DCRF) provides a standardised guide for designing national fisheries data collection programmes. In Nigeria, the Federal Department of Fisheries uses a combination of paper-based landing site enumerators and electronic reporting systems, with ongoing efforts to expand electronic data collection across artisanal landing sites.

Fill in the blank: KoboToolbox and ODK (Open Data _____) are mobile data collection tools that allow structured entry on smartphones with built-in validation and automatic upload to central servers.

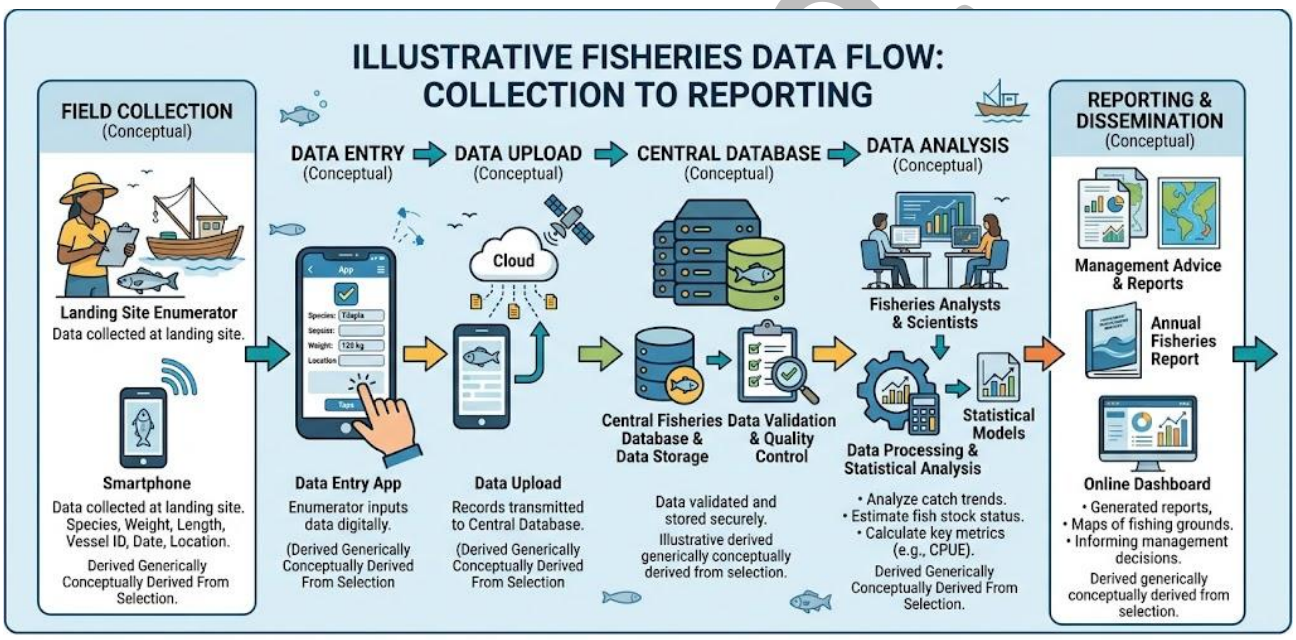

Figure 2.8: Diagram showing the flow of fisheries data from field collection through electronic entry to a central database and analysis system

Figure 2.8: Diagram showing the flow of fisheries data from field collection through electronic entry to a central database and analysis system

2.4.2 Data cleaning, validation, and management best practices

Data cleaning is the process of identifying and correcting errors, inconsistencies, and gaps in a dataset before analysis. Common data quality problems in fisheries datasets include out-of-range values (lengths or weights outside biologically plausible limits), species misidentification codes,

duplicate records, missing values, and inconsistent date or location formats. Each of these errors, if uncorrected, can bias analytical results and produce misleading stock assessment outputs.

Best practices for data management include documenting metadata (information about the data: who collected it, when, where, using what methods), maintaining an audit trail of any changes made to the dataset, storing data in non-proprietary formats (CSV, SQL) to ensure long-term accessibility, and backing up data regularly to multiple locations including cloud storage. Version control systems such as Git allow changes to analysis scripts and data to be tracked over time. These practices are increasingly formalised in data management plans required by research funding agencies and peer-reviewed journals.

Fill in the blank: _____ (information about data including who collected it, when, where, and by what methods) must be documented alongside any fisheries dataset to ensure it can be correctly interpreted and reused.

Best Practice	Description / Purpose
Metadata documentation	Record details about data sources, collection methods, and context to ensure transparency and usability.
Validation	Apply checks and verification procedures to ensure accuracy, consistency, and reliability of datasets.
Non-proprietary formats	Store data in open formats (e.g., CSV, TXT) to ensure accessibility and long-term usability.
Regular backup	Maintain secure and frequent backups to prevent data loss due to system failures or accidents.
Version control	Track changes and maintain historical records of datasets to support reproducibility and accountability.

Box 2.1: Best practices for fisheries data management

2.4.3 Data visualisation and reporting for fisheries management

Data visualisation is the representation of data in graphical form to facilitate understanding, communication, and decision-making. Effective fisheries visualisations include time series plots of catch and effort trends, length frequency histograms, stock status Kobe plots, and spatial distribution maps. These representations communicate complex information far more rapidly and accessibly to managers and stakeholders than tables of numbers or text descriptions alone.

Tools for fisheries data visualisation range from the chart functions built into Excel and R's ggplot2 package to dedicated dashboard platforms such as Tableau Public and the open-source Shiny package in R, which allow interactive web-based visualisations. FAO's Fisheries Global Information System (FIGIS) provides country-level fisheries dashboards. In reporting, visualisations must be accompanied by clear figure captions, appropriate axes and scales, and honest representation of uncertainty. The ability to produce clear, informative visualisations is an increasingly valued skill in fisheries science and management.

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Fill in the blank: The R package _____ allows the creation of interactive web-based data visualisation dashboards for fisheries data without requiring specialist web development skills.

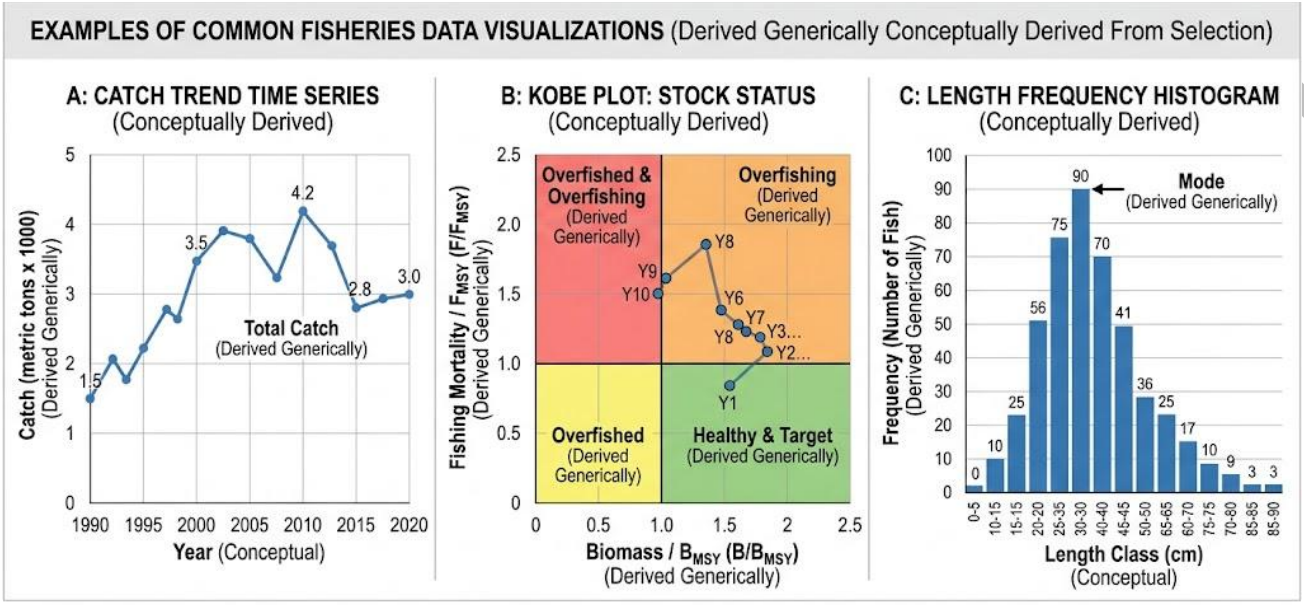

Figure 2.9: Examples of fisheries data visualisations including a catch trend time series, a Kobe plot, and a length frequency histogram (Derived Generically Concceptually Derived From Selection)

Figure 2.9: Examples of fisheries data visualisations including a catch trend time series, a Kobe plot, and a length frequency histogram

Pilot questions 2.4

Name two mobile data collection tools used in fisheries and state one advantage of each over paper forms.

State three common data quality problems in fisheries datasets.

What is metadata and why is it important in fisheries data management?

Name two data visualisation tools used in fisheries and state one type of chart produced by each.

Explain what a Kobe plot shows and why it is useful in fisheries management reporting.

Series Summary

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This Series has surveyed the principal computer applications and digital tools used in fisheries and aquaculture, with particular emphasis on FAO resources, mobile applications, and data management. We began with common computer applications including spreadsheets, databases, statistical software (R, SPSS), and GIS (QGIS, ArcGIS), explaining their respective roles in fisheries data management, analysis, and spatial decision support. We then examined the suite of FAO tools available to fisheries professionals, including FiSAT II for length-based stock assessment, FishBase and FishStatJ as essential biological and statistical reference databases, and the FAO e-learning Academy as a source of free professional development resources.

Following that, we studied mobile applications for fish identification, disease diagnosis, and farm management, explored the range of FAO-supported apps, and introduced the principles of app development for local fisheries needs using platforms such as MIT App Inventor. Finally, we covered fisheries data management and visualisation, describing electronic data collection using KoboToolbox and ODK, data cleaning and metadata documentation best practices, and the use of R Shiny, Tableau, and GIS tools for producing accessible and informative fisheries management reports. 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

ArcGIS: a commercial GIS software platform widely used for spatial analysis, habitat mapping, and fisheries management planning; the industry standard in many professional fisheries organisations.

Data cleaning: the process of identifying and correcting errors, inconsistencies, and gaps in a dataset before analysis to ensure the accuracy and reliability of analytical outputs.

ELEFAN: Electronic Length Frequency Analysis; a module within FiSAT II that estimates von Bertalanffy growth parameters by fitting a growth curve to length frequency data.

FiSAT II: FAO-ICLARM Stock Assessment Tools II; a free software package for length-based tropical fish stock assessment, including ELEFAN, catch curve analysis, and yield-per-recruit modules.

FishBase: the world's largest online database of biological information on fish species, freely accessible at www.fishbase.org and covering more than 35,000 species.

FishStatJ: FAO's global fisheries statistics software tool that allows users to query and visualise FAO global catch and aquaculture production databases from 1950 to the present.

GIS (Geographic Information System): software for capturing, storing, analysing, and displaying geographically referenced data; used in fisheries for habitat mapping, vessel tracking, and spatial fisheries management.

iNaturalist: a citizen science app and platform that allows users to photograph organisms for species identification by a global expert community; useful for fish species identification in the field.

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KoboToolbox: a free, open-source mobile data collection platform that allows structured survey forms to be deployed on smartphones with offline capability and automatic upload to a central server.

Kobe plot: a graphical representation of stock status with B/BMSY on the x-axis and F/FMSY on the y-axis, divided into four colour-coded quadrants indicating combinations of overfished and overfishing status.

Metadata: structured information that describes, explains, and locates a dataset, including details on who collected the data, when, where, and using what methods.

MIT App Inventor: a free, browser-based no-code visual development environment that allows beginners to build Android mobile applications by connecting visual blocks rather than writing code.

ODK (Open Data Kit): a free, open-source suite of tools for mobile data collection; allows structured survey forms to be deployed on Android smartphones for offline data entry and synchronisation.

QGIS: a free, open-source GIS platform available for Windows, Mac, and Linux; widely adopted in developing-country fisheries agencies as a freely available alternative to ArcGIS.

R: a free, open-source statistical computing language and environment widely used in fisheries science; includes specialised packages such as TropFishR for stock assessment and ggplot2 for data visualisation.

Shiny: an R package that allows users to build interactive web-based data dashboards and visualisation tools directly from R code, without requiring HTML or JavaScript programming skills.

TropFishR: an R package providing functions for tropical fish stock assessment methods including ELEFAN growth estimation, catch curve mortality analysis, and yield-per-recruit calculations.

Version control: a system that records changes to files over time, allowing previous versions to be restored and changes to be attributed; Git is the most widely used version control system in fisheries data science.

Concept Check Questions [Series 2]

Objective Questions

Which of the following is a free, open-source GIS platform? (a) ArcGIS (b) QGIS (c) Microsoft Excel (d) FishStatJ. (Linked to SLO 2.2)

FiSAT II stands for FAO-ICLARM Stock _____ Tools II. (Linked to SLO 2.3)

FishBase contains biological information on more than _____ fish species. (Linked to SLO 2.4)

ODK stands for Open Data _____. (Linked to SLO 2.8)

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The R package _____ is used to create interactive web-based data visualisation dashboards. (Linked to SLO 2.9)

Short-Answer Questions

Explain the difference between a spreadsheet and a database management system for fisheries data. (Linked to SLO 2.1)

Describe what the ELEFAN module in FiSAT II does and state why it is suited to tropical fisheries. (Linked to SLO 2.3)

Explain the purpose of FishStatJ and give one example of how it would be used. (Linked to SLO 2.4)

State three best practices for managing fisheries data. (Linked to SLO 2.8)

Explain what a Kobe plot shows and why it is used in fisheries management reporting. (Linked to SLO 2.9)

Long-Answer Questions

Analyse the computer applications and FAO tools available for fisheries stock assessment, explaining the role of spreadsheets, databases, statistical software, FiSAT II, FishBase, and FishStatJ, and evaluating their contribution to fisheries management in data-limited developing-country contexts. (Linked to SLOs 2.1, 2.3, 2.4)

Discuss the role of mobile applications in fisheries and aquaculture, describing the range of app functions available, the FAO-supported tools, and the process of developing and deploying apps for local fisheries needs. (Linked to SLOs 2.6, 2.7)

Evaluate the principles and practices of fisheries data management and visualisation, explaining electronic data collection methods, data cleaning and metadata documentation, and the tools used to produce informative visualisations for fisheries management decision-making. (Linked to SLOs 2.8, 2.9)

Answers to Concept Check Questions [Series 2]

Objective Questions

Correct answer: b) QGIS.

Assessment.

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35,000.

Kit.

Shiny.

Short-Answer Questions

A spreadsheet stores data in a flexible tabular format suitable for small to medium datasets, basic calculations, and charts, but lacks enforced data structure and becomes unwieldy with very large or complex datasets. A DBMS enforces data structure and integrity, supports multiple simultaneous users, allows complex queries across linked tables, and is more appropriate for managing large national fisheries catch reporting or vessel registration systems.

ELEFAN fits the von Bertalanffy growth function directly to length frequency histograms by scoring how well a growth curve passes through the peaks of successive length frequency samples; it requires no age data from otoliths or hard parts. This makes it suited to tropical fisheries where seasonal growth rings in hard parts are often unclear and otolith ageing infrastructure is limited.

FishStatJ allows users to query and visualise FAO's global catch and aquaculture production databases spanning 1950 to the present; it would be used, for example, by a student writing a report on Nigerian fish production trends to download and graph national catch statistics by species and production system over multiple decades.

Any three: document metadata (who collected the data, when, where, and by what methods); store data in non-proprietary formats (CSV, SQL) for long-term accessibility; back up data regularly to multiple locations including cloud storage; use version control (Git) to track changes to datasets and analysis scripts; apply range checks and validation at data entry.

A Kobe plot shows the current status of a fish stock on a two-axis diagram with B/BMSY (biomass relative to the target reference point) on the x-axis and F/FMSY (fishing mortality relative to the sustainable rate) on the y-axis, divided into four colour-coded quadrants; it is used in management reporting because it communicates stock status in a single intuitive visual that non-specialist managers and stakeholders can immediately understand.

Long-Answer Questions

Basic response: Spreadsheets manage routine data; DBMS handle large structured datasets. R provides flexible statistical analysis. FiSAT II applies length-based stock assessment methods (ELEFAN, catch curve, YPR) suited to data-limited tropical fisheries. FishBase supplies biological parameters essential for assessment. FishStatJ provides national and global catch statistics for trend analysis and policy.

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Value-added response: In data-limited contexts such as Nigeria, the combination of FiSAT II applied to landing-site length frequency data and biological parameters sourced from FishBase represents the most practically achievable stock assessment approach for many species. The free availability of these tools removes cost barriers; the remaining constraints are trained users and adequate length sampling programmes. Investing in human capacity to use these tools is therefore a higher priority than procuring new software.

Basic response: Apps for fish ID, disease diagnosis, catch reporting, market prices, and farm management are available. FAO tools include FishFinder and AquaCalc. App development follows a user-centred cycle from problem identification and user consultation through design and technical development to deployment and support. Android dominates in Nigeria; MIT App Inventor is a beginner-friendly platform.

Value-added response: The most impactful fisheries apps in developing countries are those that solve the most binding information problems for their users: real-time market prices for fishers, feed management calculators for fish farmers, and disease diagnosis tools for rural producers without veterinary access. Apps designed through co-creation with target users and tested iteratively with real users before full deployment consistently outperform those designed by technical developers alone. Series 3 of this course provides practical skills in applying these principles.

Basic response: KoboToolbox and ODK enable structured electronic data collection with validation on smartphones. Data cleaning corrects range errors, duplicates, and missing values. Metadata documentation ensures datasets are reusable. Visualisation tools include R/ggplot2, Shiny, and Tableau for catch trends, Kobe plots, and length frequency histograms.

Value-added response: The shift from paper-based to electronic data collection in Nigerian fisheries is well underway but uneven; artisanal landing sites remain predominantly paper-based, creating bottlenecks in data timeliness and quality. The incremental adoption of KoboToolbox by landing site enumerators, combined with automated upload to central databases, could transform the speed and quality of national fisheries statistics at relatively low cost. Effective visualisation of these data in accessible dashboards would then enable managers to use the information for timely decisions rather than historical reporting.

Answers to Pilot Questions [Series 2]

Part 2.1: Common Computer Applications in Fisheries and Aquaculture

Any two: recording catch and effort data; calculating growth and mortality parameters; managing farm production records; tracking financial accounts; performing simple statistical analyses; storing species biological data.

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A DBMS enforces data structure and integrity preventing invalid entries, supports multiple simultaneous users without data corruption, and allows complex queries across linked data tables enabling more sophisticated analyses than are possible in a spreadsheet.

Any two with uses: R (free statistical computing environment used for stock assessment modelling and data visualisation in fisheries); SPSS (commercial statistical package used for social and economic surveys of fisheries communities); Stata (used for econometric analysis in value chain studies); SPSS or SAS (multivariate analysis of experimental aquaculture data).

GIS is software for capturing, storing, analysing, and displaying geographically referenced data; two fisheries applications: mapping fishing grounds and effort distribution; displaying spatial stock assessment results and identifying critical habitats.

QGIS is free and open-source, eliminating licence costs that can be prohibitive for government agencies in developing countries; it has an active development community producing fisheries-specific plugins; it runs on all major operating systems and has a comparable feature set to ArcGIS for most routine fisheries GIS tasks.

Part 2.2: FAO Software Applications for Fisheries

FiSAT II is a free software package for length-based tropical fish stock assessment; it is most suited to fisheries where length frequency data are collected but age data from otoliths or other hard parts are not available, which is typical of many tropical developing-country fisheries.

The ELEFAN module estimates von Bertalanffy growth parameters ($L\infty$, K, and t_0) by fitting a growth curve to length frequency histograms using a scoring function that measures how well the curve passes through successive length frequency peaks; no age data from hard parts are required.

FishBase provides species identification information, life history data including growth parameters ($L\infty$, K, natural mortality), reproductive data, diet descriptions, distribution maps, and ecology information for over 35,000 fish species; it is the primary reference for obtaining biological input parameters for stock assessment models.

FishStatJ allows users to query, analyse, and graph FAO global catch and aquaculture production statistics from 1950 to the present; it is used by fisheries economists, policy analysts, researchers, and students to analyse national and global production trends, compare country performances, and prepare fisheries status reports.

Any two: FAO e-learning Academy courses on fisheries management, aquaculture, and food safety; FAO technical manuals and guidelines available for free download from the FAO Document Repository; FIGIS online fisheries country profiles and stock assessment summaries; Aquatic Commons digital library of fisheries research literature.

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Part 2.3: Mobile Applications in Fisheries and Aquaculture

Any three: fish species identification; catch reporting; weather and sea condition monitoring; fish price checking; feed management; water quality logging; disease diagnosis; financial record keeping.

Any two: FAO FishFinder app (assists with fish species identification using photographs and biological descriptions); AquaCalc app (assists with aquaculture calculations including stocking density, feeding rates, and water volumes); Fish-i Africa platform (tracks fishing vessel activity in East African waters for illegal fishing detection).

iNaturalist is a citizen science app and platform that allows users to photograph organisms and submit them for species identification by a global expert community; it is useful for fisheries work by allowing rapid identification of unfamiliar fish species in the field when reference books or specialist expertise are not available.

The first step is defining a clear problem statement: identifying what specific challenge the app will address and who the primary users are; this requires extensive consultation with intended users (fishers, farmers, or managers) to understand their workflows, language preferences, connectivity constraints, and device capabilities before any technical development begins.

Android dominates in Nigeria because low-cost Android smartphones are far more widely owned by fish farmers and fishers than iPhones; targeting Android therefore maximises the potential reach of a fisheries app to its intended users at the lowest hardware cost.

Part 2.4: Data Management and Visualisation

Any two with advantages: KoboToolbox (advantage: built-in validation checks prevent common entry errors at the point of collection; works offline and uploads when connectivity is available); ODK (advantage: structured form design enforces data consistency across enumerators; free and open-source).

Any three: out-of-range values (lengths or weights outside biologically plausible limits); species misidentification or wrong codes; duplicate records; missing values; inconsistent date or location formats.

Metadata is structured information describing a dataset including who collected it, when, where, and using what methods; it is important because without metadata a dataset cannot be correctly interpreted, compared with other datasets, or reused by different analysts, making it scientifically worthless even if the data itself is of high quality.

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Any two with chart types: R ggplot2 (time series line graphs, length frequency histograms, scatter plots); R Shiny (interactive dashboard visualisations with user controls); Microsoft Excel (bar charts, line graphs); Tableau Public (interactive dashboards); QGIS (spatial distribution maps of catches or vessel positions).

A Kobe plot shows the current stock status on a two-axis diagram (B/BMSY on x-axis, F/FMSY on y-axis) divided into four colour-coded quadrants: green (healthy, not overfished, no overfishing), yellow (overfished or overfishing but not both), and red (overfished and overfishing); it is useful in management reporting because it presents complex stock assessment information in a single intuitive graphic that managers, fishers, and policymakers can understand without needing to interpret raw model outputs.

References and Attributions [Series 2]

Textual References (Books and External Sources)

Gayanilo, F. C., Sparre, P., & Pauly, D. (2005). FAO-ICLARM Stock Assessment Tools II (FiSAT II). FAO Computerised Information Series (Fisheries). FAO.

Froese, R., & Pauly, D. (Eds.). (2025). FishBase. World Wide Web electronic publication. www.fishbase.org.

FAO (Food and Agriculture Organization of the United Nations). (2021). FishStatJ: Universal software for fishery statistical time series. FAO.

Hijmans, R. J., & Elith, J. (2019). Spatial data science with R. GitHub.

World Bank. (2019). Digital technology in agriculture: Taking stock of the evidence and getting practical. World Bank Group.

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

Figures, Plates, Tables, and Boxes

Figure 2.1: Fisheries spreadsheet and database diagram Attribution: AI generated using prompt "Generate a diagram showing a fisheries catch data spreadsheet and a database management system with arrows showing the data relationship." Suggested OER search string: "fisheries catch data spreadsheet database management system OER diagram".

Plate 2.1: R statistical software with fisheries output Attribution: AI generated using prompt "Generate an image of a computer screen showing R statistical software with a fisheries

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analysis script and output graphs." Suggested OER search string: "R statistical software fisheries stock assessment output OER image".

Figure 2.2: QGIS coastal fisheries management map Attribution: AI generated using prompt "Generate a map showing fishing vessel positions overlaid on habitat types and marine protected area boundaries in a coastal fisheries management area." Suggested OER search string: "QGIS fishing vessel positions habitat protected areas coastal map OER".

Figure 2.3: FiSAT II ELEFAN module interface Attribution: AI generated using prompt "Generate a diagram of the FiSAT II ELEFAN interface showing a length frequency histogram with a fitted von Bertalanffy growth curve." Suggested OER search string: "FiSAT II ELEFAN module length frequency growth curve interface OER".

Figure 2.4: FishBase and FishStatJ interface diagram Attribution: AI generated using prompt "Generate a diagram showing the FishBase species page for Nile tilapia alongside the FishStatJ production trend interface." Suggested OER search string: "FishBase FishStatJ FAO fisheries databases interfaces OER".

Figure 2.5: FAO e-learning Academy website Attribution: AI generated using prompt "Generate a diagram showing the FAO e-learning Academy with fisheries and aquaculture courses listed." Suggested OER search string: "FAO e-learning Academy fisheries aquaculture courses website OER".

Plate 2.2: Fish farmer using smartphone app at catfish pond Attribution: AI generated using prompt "Generate an image of a fish farmer at a catfish pond using a smartphone app to record water quality and feeding data." Suggested OER search string: "fish farmer smartphone app water quality feeding catfish pond OER image".

Figure 2.6: Fisheries and aquaculture mobile app categories Attribution: AI generated using prompt "Generate a diagram showing categories of mobile apps for fisheries including species identification, disease diagnosis, catch reporting, and farm management." Suggested OER search string: "fisheries aquaculture mobile apps categories functions OER diagram".

Figure 2.7: Mobile app development flowchart for fisheries Attribution: AI generated using prompt "Generate a flowchart showing the stages of mobile app development from problem identification through user consultation, design, development, and deployment." Suggested OER search string: "mobile app development stages fisheries application flowchart OER".

Figure 2.8: Fisheries data collection and database flow Attribution: AI generated using prompt "Generate a flowchart showing fisheries data flow from field collection on a smartphone to upload to a central database and reporting." Suggested OER search string: "fisheries data collection flow smartphone central database OER diagram".

Box 2.1: Best practices for fisheries data management Attribution: AI generated using prompt "Generate a text box listing best practices for fisheries data management including

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metadata, validation, non-proprietary formats, backup, and version control." Suggested OER search string: "fisheries data management best practices metadata validation backup OER".

Figure 2.9: Fisheries data visualisation examples Attribution: AI generated using prompt "Generate a three-panel figure showing common fisheries data visualisations: a catch trend time series, a Kobe plot, and a length frequency histogram." Suggested OER search string: "fisheries data visualisation catch trend Kobe plot length frequency OER".

Course code: FAA 410

Course title: Information and Communications Technologies in Fisheries and Aquaculture

Course credit load: 2 Units

Series 3: Software and App Development for Fisheries Operations

Series outline

Part 3.1: Foundations of Software Development

Sub Part 3.1.1: The software development life cycle

Sub Part 3.1.2: Programming concepts and languages

Sub Part 3.1.3: Databases and backend systems

Part 3.2: App Development for Fisheries

Sub Part 3.2.1: User-centred design and requirements gathering

Sub Part 3.2.2: No-code and low-code development tools

Sub Part 3.2.3: Building and testing a simple fisheries app

Part 3.3: Web-Based Solutions for Fisheries Management

Sub Part 3.3.1: Web development basics for fisheries applications

Sub Part 3.3.2: Online dashboards and fisheries information portals

Sub Part 3.3.3: Cloud computing and data storage for fisheries

Part 3.4: Deployment, Maintenance, and Entrepreneurship

Sub Part 3.4.1: Deploying and distributing fisheries software

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Sub Part 3.4.2: Maintaining and updating software solutions

Sub Part 3.4.3: ICT entrepreneurship opportunities in fisheries

Introduction

The ability to develop software and applications tailored to the specific needs of fisheries and aquaculture is a high-value skill that opens both professional and entrepreneurial opportunities for fisheries graduates. While Series 2 introduced the computer applications and tools already available in the sector, this Series takes a step further by equipping you with the foundational knowledge and practical skills needed to create new digital solutions to fisheries problems, from simple mobile apps to web-based management portals.

The aim of this Series is to introduce you to the software development life cycle, programming concepts, user-centred design, no-code and low-code tools, web development, and the entrepreneurial pathways that ICT development skills open for fisheries graduates.

We shall commence this Series by establishing foundational concepts in software development including the development life cycle, programming languages, and databases. Next, we will study user-centred app development including requirements gathering and no-code tools. Following that, we will explore web-based fisheries solutions and cloud computing. Finally, we will wrap up with deployment, maintenance, and ICT entrepreneurship.

Series Learning Outcomes

Upon completing this Series, you should be able to:

SLO 3.1 describe the software development life cycle and explain its stages (Linked to Part 3.1),

SLO 3.2 identify common programming languages and explain their relevance to fisheries applications (Linked to Part 3.1),

SLO 3.3 explain the role of databases and backend systems in fisheries software (Linked to Part 3.1),

SLO 3.4 describe user-centred design principles and explain how requirements are gathered for fisheries apps (Linked to Part 3.2),

SLO 3.5 use no-code or low-code tools to design and build a simple fisheries application (Linked to Part 3.2),

SLO 3.6 describe the basic components of web development and explain how they apply to fisheries information portals (Linked to Part 3.3),

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SLO 3.7 explain the use of online dashboards and cloud computing in fisheries management (Linked to Part 3.3),

SLO 3.8 describe the process of deploying and maintaining fisheries software (Linked to Part 3.4), and

SLO 3.9 identify entrepreneurial opportunities in fisheries ICT and explain how to develop a viable business model (Linked to Part 3.4).

3.1 Foundations of Software Development

3.1.1 The software development life cycle

The software development life cycle (SDLC) is the structured process by which software is conceived, designed, built, tested, deployed, and maintained. The classic SDLC stages are: requirements analysis (understanding what the software must do and for whom), system design (defining the architecture and data structures), implementation (writing the code), testing (verifying correctness and usability), deployment (making the software available to users), and maintenance (updating and fixing the software over time).

In fisheries app development, the SDLC is most effective when it is iterative rather than purely sequential. Agile development approaches work in short cycles (sprints), building and testing small increments of functionality with user feedback at each stage. This is particularly valuable in fisheries contexts where users may not be able to articulate all their needs at the outset; seeing and using early prototypes helps fishers and fish farmers identify what works and what needs to change before significant development investment has been made.

Fill in the blank: The software development life cycle begins with _____ analysis, which involves understanding what the software must do and for whom it is intended.

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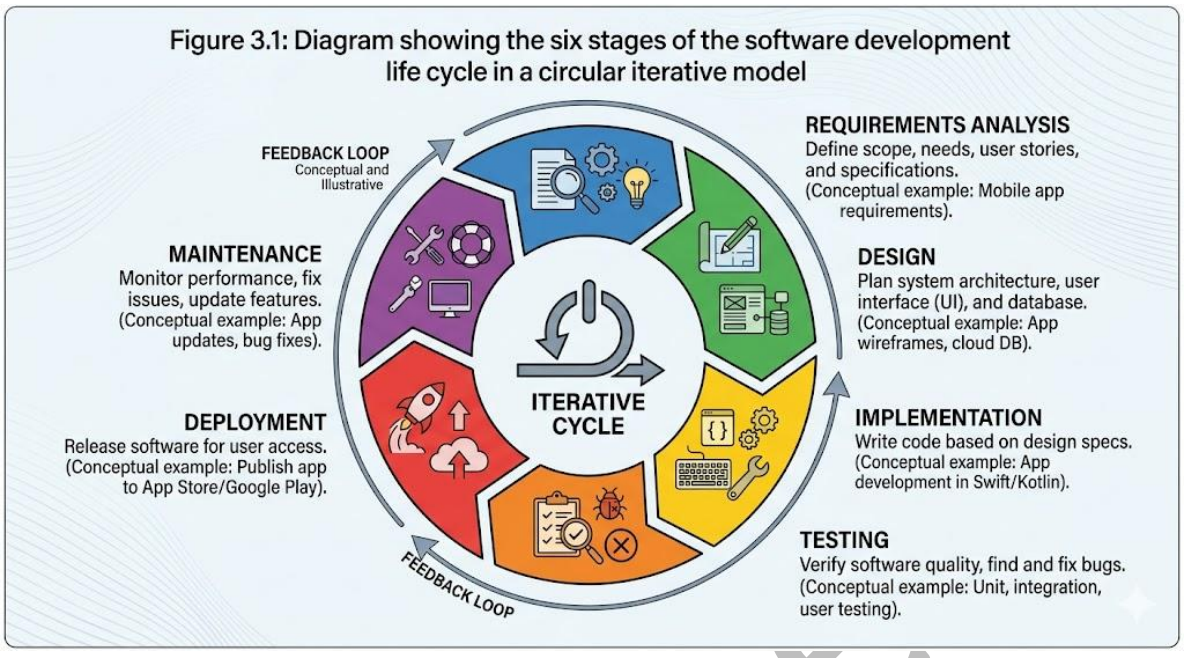

Figure 3.1: Diagram showing the six stages of the software development life cycle in a circular iterative model

3.1.2 Programming concepts and languages

Programming is the process of writing instructions that a computer can execute to perform a specific task. Core programming concepts include variables (named storage for data values), control structures (if-then-else conditions and loops that direct programme flow), functions (reusable blocks of code), and data structures (arrays, lists, and dictionaries for organising data). These concepts underlie all programming languages and are the building blocks of any software application.

For fisheries applications, the most relevant languages are Python (versatile, beginner-friendly, widely used for data analysis and web backends), R (statistical analysis and visualisation), JavaScript (web development and interactive dashboards), and Java or Kotlin (Android app development). SQL is the standard language for querying relational databases and is an essential skill for anyone working with fisheries data systems. Choosing the right language depends on the target platform, the availability of relevant libraries, and the skills of the development team.

Fill in the blank: _____ is a standard language used for querying relational databases and is essential for anyone working with fisheries data management systems.

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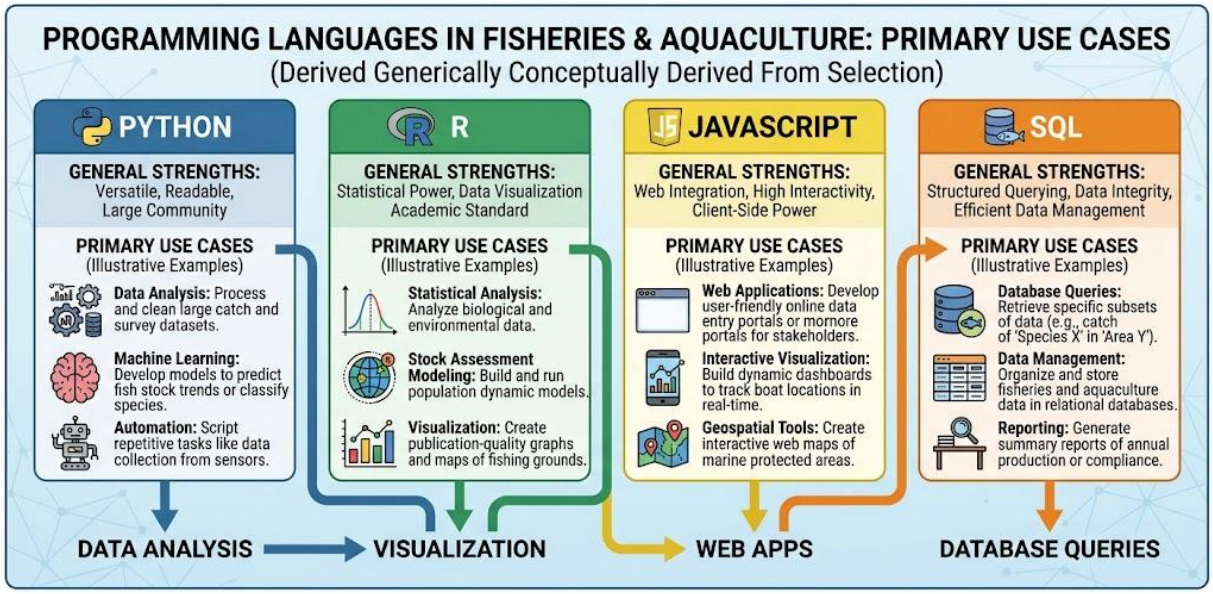

Figure 3.2: Diagram comparing programming languages used in fisheries applications with their primary use cases (Derived Generically Conceptually Derived From Selection)

Figure 3.2: Diagram comparing programming languages used in fisheries applications with their primary use cases

3.1.3 Databases and backend systems

A database is an organised collection of structured data that can be efficiently stored, retrieved, and updated. Relational databases organise data into tables with defined relationships between them, using SQL for data manipulation. In fisheries applications, a relational database might store tables for species, sampling events, catch records, vessel details, and observer data, linked by foreign keys. PostgreSQL and MySQL are the most widely used open-source relational databases in fisheries information systems.

The backend of a software application is the server-side component that handles data processing, business logic, and communication with the database. In a fisheries mobile app, for example, the backend receives data submitted by field enumerators, validates and stores it in the database, and responds to queries from the app interface. RESTful APIs (Application Programming Interfaces) are the standard mechanism through which app frontends communicate with backends over the internet. Understanding the distinction between frontend (what users see) and backend (what processes data) is fundamental to software architecture design.

Fill in the blank: _____ APIs are the standard mechanism through which app frontends communicate with backend servers over the internet in modern web and mobile applications.

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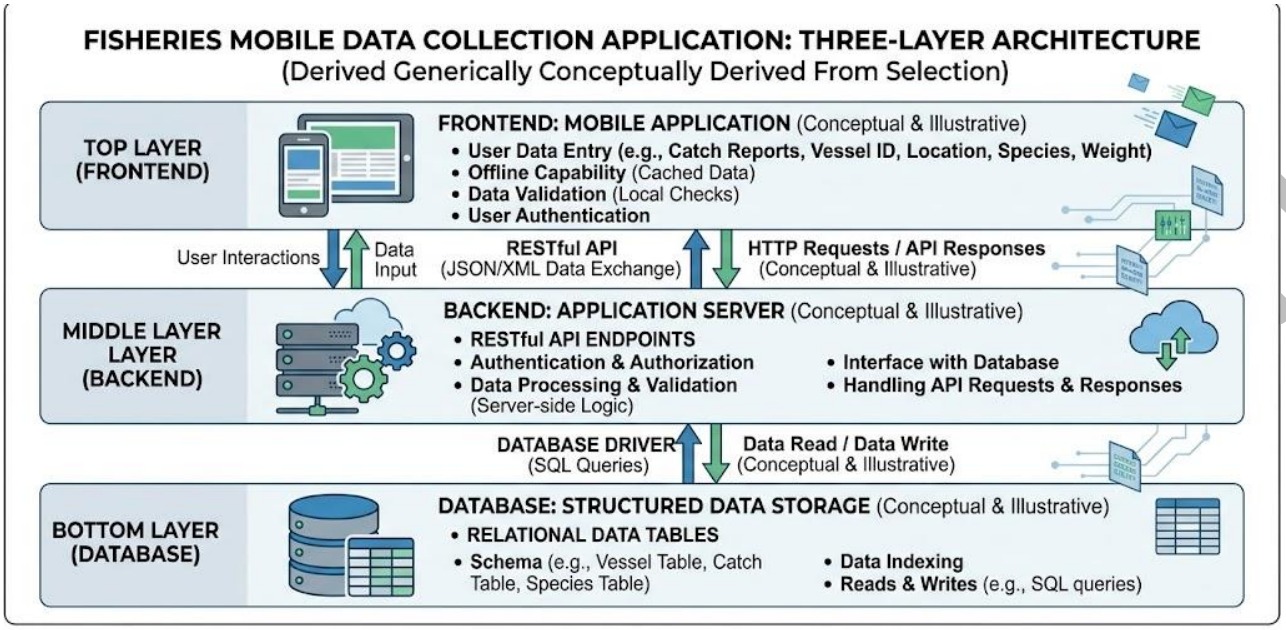

Figure 3.3: Diagram showing the frontend, backend, and database architecture of a fisheries mobile data collection application (Derived Generically Conceptually Derived From Selection)

Figure 3.3: Diagram showing the frontend, backend, and database architecture of a fisheries mobile data collection application

Pilot questions 3.1

List the six stages of the software development life cycle in order.

Explain what agile development means and why it is suited to fisheries app development.

Name four programming languages used in fisheries applications and state one use of each.

What is SQL and why is it important in fisheries data systems?

Explain the difference between the frontend and backend of a software application.

3.2 App Development for Fisheries

3.2.1 User-centred design and requirements gathering

User-centred design (UCD) is an approach to software development that places the needs, preferences, and constraints of the intended users at the centre of every design decision. In

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fisheries app development, this means involving fishers, fish farmers, extension workers, or fisheries officers in the design process from the very beginning. Requirements gathering techniques include structured interviews (asking users what tasks they currently perform and what information they need), observational studies (watching users work to understand their actual workflows), and participatory workshops where users help sketch or prototype the app interface.

A requirements document captures the functional requirements (what the app must do) and non-functional requirements (performance, connectivity constraints, language, device compatibility) before development begins. Wireframes, low-fidelity sketches of the app screens, allow users to review and critique the proposed interface without the cost of building it first. Investing in thorough requirements gathering and design before writing code dramatically reduces the risk of building an app that users will not adopt because it does not fit their actual needs and working context.

Fill in the blank: _____ are low-fidelity sketches of app screens that allow users to review and critique a proposed interface before development begins.

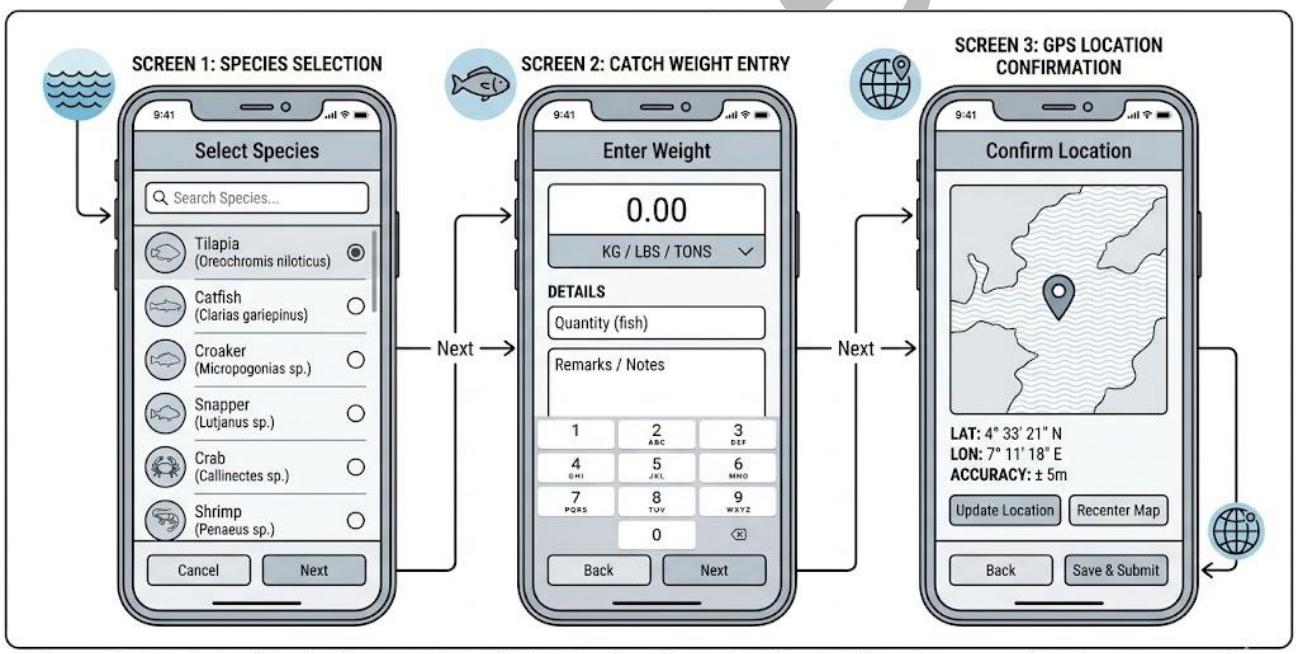

Figure 3.4: Example wireframes for a fisheries landing site data collection app showing screens for species entry, catch weight, and location

Figure 3.4: Example wireframes for a fisheries landing site data collection app showing screens for species entry, catch weight, and location

3.2.2 No-code and low-code development tools

No-code and low-code platforms allow users to build functional software applications without writing conventional programming code, dramatically lowering the barrier to app development

for fisheries professionals without a computer science background. No-code platforms such as MIT App Inventor use visual block-based programming where logic is assembled by connecting graphical blocks representing actions and conditions. Low-code platforms such as OutSystems and Appsmith require some coding for complex functionality but provide drag-and-drop interfaces for most components.

For fisheries data collection, KoboToolbox and ODK (introduced in Series 2) are in effect no-code data collection app builders that allow complex survey forms with skip logic, GPS capture, and photo attachment to be built without programming. Google AppSheet allows spreadsheet data to be turned into a functional mobile app with minimal coding. These tools are particularly valuable for fisheries organisations and researchers in Nigeria who need custom data collection tools quickly and lack dedicated software developers, and they form the practical focus of the skills component of this Series.

Fill in the blank: MIT App _____ is a no-code platform that uses visual block-based programming to allow non-programmers to build Android mobile applications.

Plate 3.1: Student using MIT App Inventor in a browser to build a fisheries data collection app using visual block-based programming

Plate 3.1: Student using MIT App Inventor in a browser to build a fisheries data collection app using visual block-based programming

3.2.3 Building and testing a simple fisheries app

Building a simple fisheries app using MIT App Inventor involves four stages. First, the Designer view is used to set up the screen layout by dragging and dropping interface components (text labels, input fields, buttons, and a map view) onto a virtual phone screen. Second, the

Blocks editor connects these components with logical instructions: when a button is pressed, save the entered data to a list; when another button is pressed, display the list. Third, the app is tested using the live preview on a connected Android phone or the built-in emulator. Fourth, the completed app is exported as an APK file for distribution.

Testing is a critical stage that should involve real users from the target community, not just the developer. Usability testing presents the app to fishers or farm workers without explanation and observes whether they can complete target tasks without assistance. Bug testing checks that all data inputs are stored correctly, that the app handles unexpected inputs gracefully (such as empty fields or very large numbers), and that it functions correctly on devices with varying screen sizes and Android versions. Documented test results guide iterative improvements before the app is finalised for deployment.

Fill in the blank: _____ testing presents the app to target users without explanation and observes whether they can complete tasks without assistance, revealing design problems.

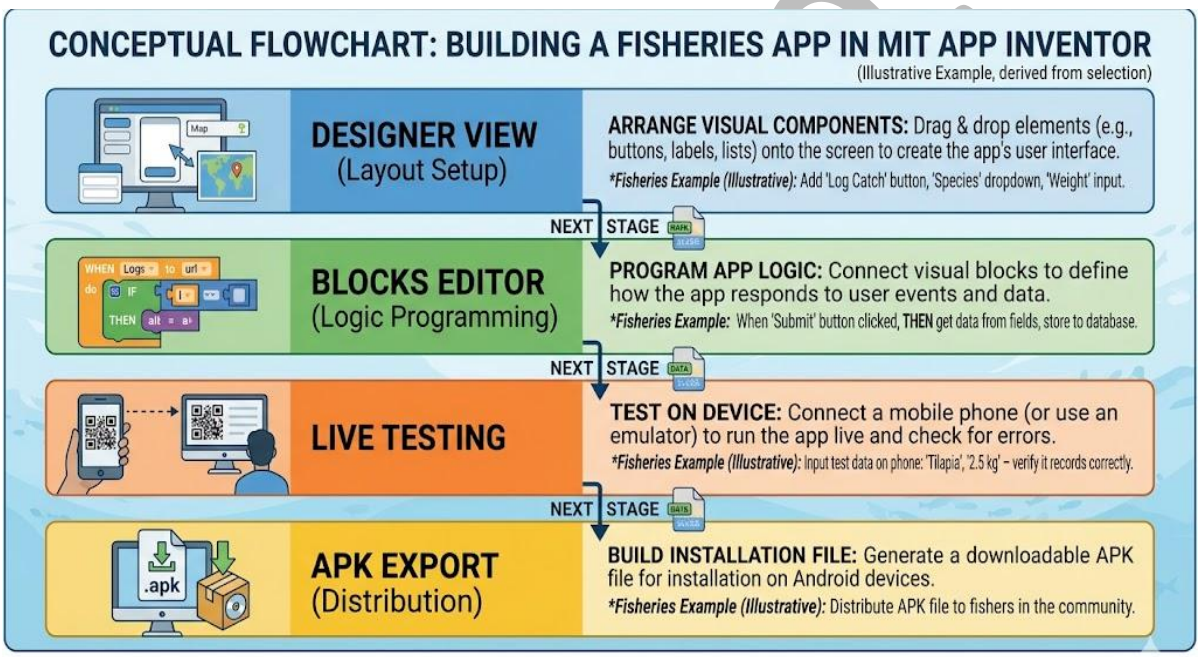

Figure 3.5: Flowchart showing the four stages of **building** a simple fisheries **app in MIT App Inventor** from **design** to testing **and export** (derived generically conceptually derived from selection)

Figure 3.5: Flowchart showing the four stages of building a simple fisheries app in MIT App Inventor from design to testing and export

Pilot questions 3.2

Define user-centred design and explain why it is important for fisheries app development.

Name three requirements gathering techniques used in fisheries app development.

What is a wireframe and how does it reduce development risk?

Distinguish between no-code and low-code development platforms and give one example of each.

Describe the four stages of building a simple app using MIT App Inventor.

3.3 Web-Based Solutions for Fisheries Management

3.3.1 Web development basics for fisheries applications

Web applications run in a browser and can be accessed from any device with internet connectivity, making them highly suitable for fisheries management portals and information systems that need to be accessible to multiple users across different locations. The three core web technologies are HTML (Hypertext Markup Language), which defines the structure and content of web pages; CSS (Cascading Style Sheets), which controls the visual appearance; and JavaScript, which adds interactive behaviour such as responding to user actions and updating page content without reloading.

For fisheries applications, a web developer typically works with a frontend framework (such as React or Vue.js) that organises JavaScript code into reusable components, and a backend framework (such as Django for Python or Node.js for JavaScript) that handles data processing and database communication. Fisheries-specific web applications include national catch reporting portals, vessel registration systems, and stock assessment results dashboards. Understanding the basic architecture of web applications helps fisheries professionals communicate effectively with software developers and evaluate proposed technical solutions.

Fill in the blank: The three core web technologies are HTML (structure), CSS (appearance), and _____ (interactive behaviour).

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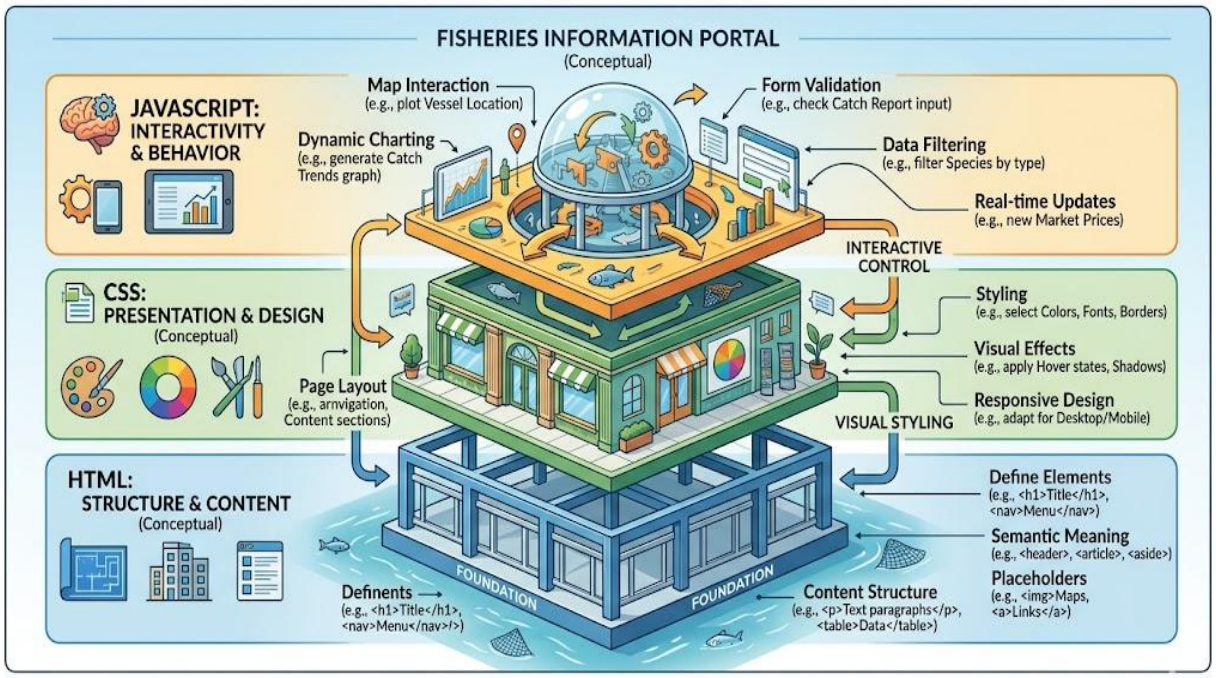

Figure 3.6: Diagram showing the three layers of web development (HTML, CSS, JavaScript) and their respective roles in a fisheries web application (Derived Generically Conceptually Derived From Selection)

Figure 3.6: Diagram showing the three layers of web development (HTML, CSS, JavaScript) and their respective roles in a fisheries web application

3.3.2 Online dashboards and fisheries information portals

Online fisheries dashboards present real-time or regularly updated fisheries data through visual interfaces accessible via a web browser. They typically combine charts, maps, tables, and summary indicators on a single screen, allowing managers to monitor stock status, catch trends, compliance rates, and aquaculture production at a glance. R Shiny, Tableau Public, and Power BI are widely used for building fisheries dashboards. The FAO FIGIS portal and the Global Fishing Watch platform are prominent examples of large-scale fisheries information web systems.

Global Fishing Watch (globalfishingwatch.org) is a publicly accessible online platform that uses satellite AIS (Automatic Identification System) data and machine learning to map fishing vessel activity worldwide in near real time. It has been used by researchers and government agencies to detect illegal fishing, assess fishing effort by country and gear type, and monitor compliance with marine protected area boundaries. Building awareness of such platforms and the ability to extract and interpret data from them is a valuable skill for fisheries students and professionals working on fisheries governance and compliance.

Fill in the blank: Global Fishing _____ is a publicly accessible platform that uses satellite AIS data and machine learning to map fishing vessel activity worldwide.

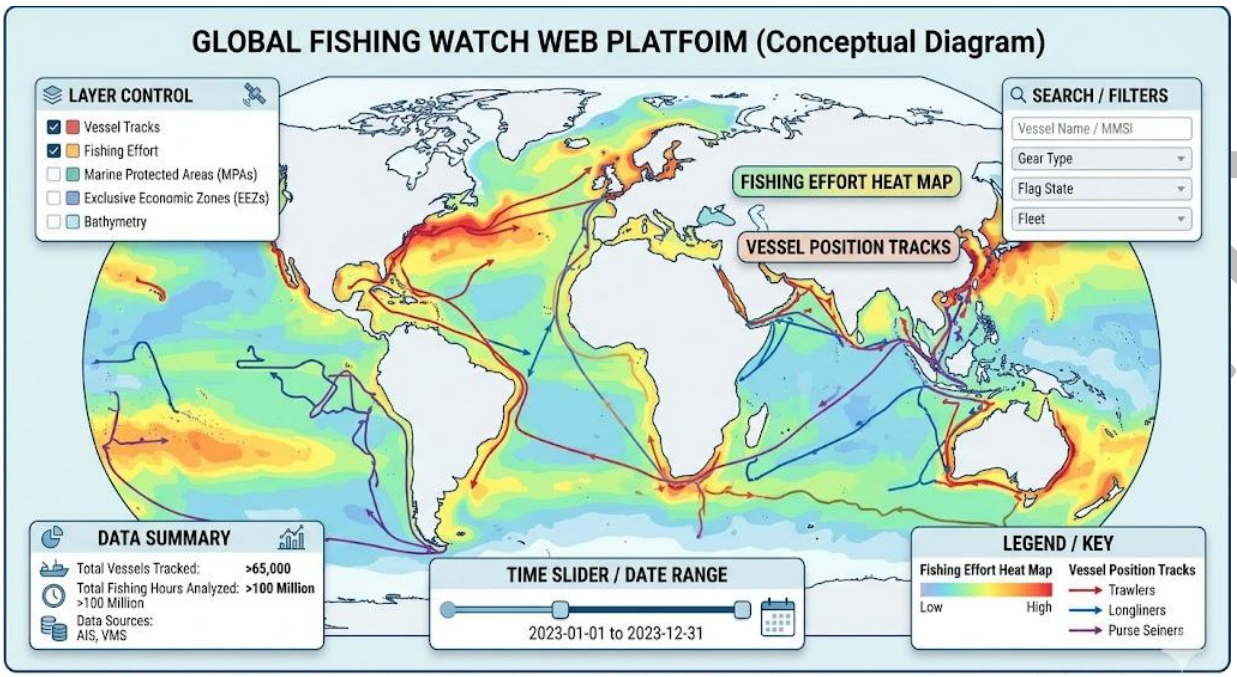

Figure 3.7: Screenshot or diagram of the Global Fishing Watch web platform showing vessel tracking and fishing effort maps

Figure 3.7: Screenshot or diagram of the Global Fishing Watch web platform showing vessel tracking and fishing effort maps

3.3.3 Cloud computing and data storage for fisheries

Cloud computing refers to the delivery of computing services (servers, storage, databases, and software) over the internet from remote data centres rather than from local hardware. For fisheries applications, cloud platforms such as Google Cloud, Amazon Web Services (AWS), and Microsoft Azure provide scalable storage for fisheries databases, computing power for running models, and hosting for web applications, without the capital cost of purchasing and maintaining physical servers.

Cloud storage services such as Google Drive, Dropbox, and OneDrive provide simple, low-cost solutions for backing up fisheries data and sharing datasets between researchers and agencies. Free-tier services from major cloud providers are sufficient for small fisheries data systems and allow developers to build and test applications at no cost. The main considerations when adopting cloud solutions for fisheries data are data sovereignty (ensuring sensitive national fisheries statistics are stored in compliant jurisdictions), connectivity requirements for synchronisation, and long-term cost as data volumes grow.

Fill in the blank: _____ computing delivers server, storage, and software services over the internet from remote data centres, removing the need for local physical servers.

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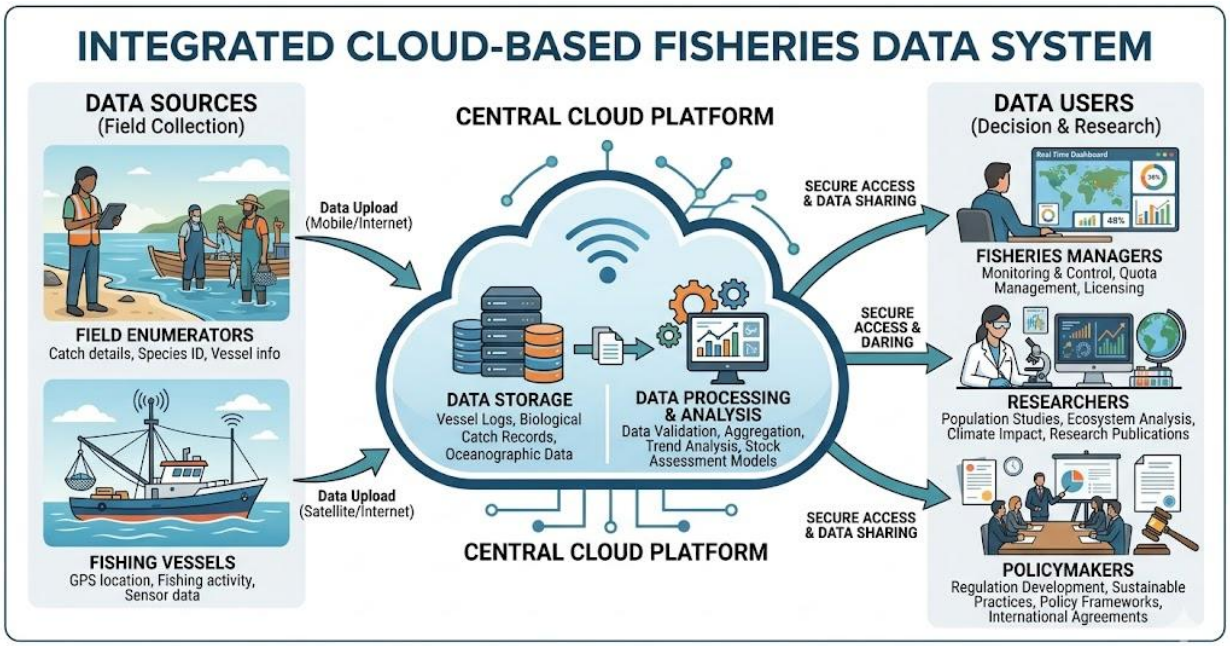

Figure 3.8: Diagram showing how cloud computing supports fisheries data collection, processing, and sharing across multiple users and locations

Figure 3.8: Diagram showing how cloud computing supports fisheries data collection, processing, and sharing across multiple users and locations

Pilot questions 3.3

Name the three core web technologies and state the role of each.

What is an online fisheries dashboard and name two tools used to build one.

Describe what Global Fishing Watch does and how it is used in fisheries governance.

Define cloud computing and give two benefits of using cloud platforms for fisheries data.

What is data sovereignty and why does it matter when choosing cloud storage for national fisheries data?

3.4 Deployment, Maintenance, and Entrepreneurship

3.4.1 Deploying and distributing fisheries software

Deployment is the process of making a completed software application available to its intended users. For Android apps, deployment involves uploading the APK file to the Google Play Store

(which requires a developer account) or distributing it directly as a downloadable file from a website or via messaging platforms such as WhatsApp. Play Store distribution provides automatic update notifications and a trusted installation pathway, but requires a one-time registration fee and compliance with Play Store content policies.

Web applications are deployed by hosting them on a server, either on cloud infrastructure (recommended for scalability and reliability) or on local servers within a fisheries agency. A domain name and SSL certificate are needed to make the application accessible and secure over the public internet. For fisheries data collection apps deployed in areas with limited connectivity, the app must be designed to work offline and synchronise data when a connection is available. Before deployment, a user acceptance testing (UAT) phase verifies that the software meets the agreed requirements in the actual user environment.

Fill in the blank: Before full deployment, a user _____ testing phase verifies that the software meets agreed requirements in the actual user environment.

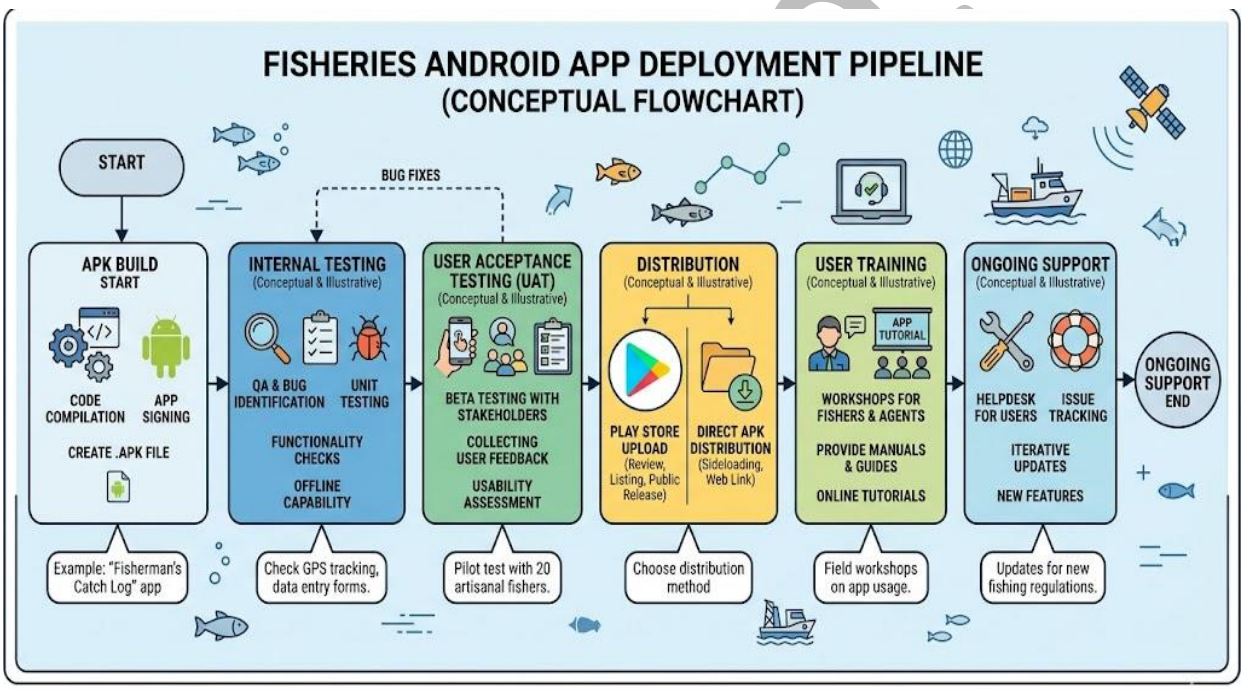

Figure 3.9: Flowchart showing the deployment pipeline for a fisheries Android app from APK build through testing to Play Store release and user training *(Derived Generically Conceptually Derived From Selection)*

Figure 3.9: Flowchart showing the deployment pipeline for a fisheries Android app from APK build through testing to Play Store release and user training

3.4.2 Maintaining and updating software solutions

Software maintenance begins the moment an application is deployed and continues for its entire operational life. Maintenance activities include corrective maintenance (fixing bugs reported by users), adaptive maintenance (updating the app to work with new Android versions,

new device models, or changes in connected APIs), perfective maintenance (adding new features requested by users), and preventive maintenance (refactoring code to reduce complexity and prevent future bugs). A helpdesk or support channel must be established before deployment so users can report problems.

Version control systems such as Git, introduced in Series 2, are essential for managing software updates: each change is committed with a descriptive message, allowing the development history to be reviewed and previous versions to be restored if an update introduces new bugs. Automated testing frameworks allow a suite of tests to be run automatically whenever changes are made, catching regressions before they reach users. Scheduling regular maintenance reviews and allocating a support budget are responsibilities that app developers must communicate to their clients or organisations before deployment.

Fill in the blank: _____ maintenance involves adding new features to an application in response to user requests after the initial deployment.

Type of Maintenance	Description	Fisheries Example
Corrective	Fixes errors or bugs discovered after deployment.	Repairing a mobile app used for fish catch reporting that crashes when uploading data.
Adaptive	Adjusts software to work in new environments or with updated systems.	Updating a fisheries database to integrate with new government reporting platforms.
Perfective	Enhances performance or adds new features based on user feedback.	Improving a fish farm management app by adding water quality monitoring dashboards.
Preventive	Anticipates and prevents future problems by optimizing code and systems.	Regularly updating aquaculture software to prevent data corruption and security risks.

Box 3.1: The four types of software maintenance and their relevance to fisheries applications

3.4.3 ICT entrepreneurship opportunities in fisheries

Fisheries graduates with ICT skills are well positioned to build businesses at the intersection of technology and aquatic resource management. Viable entrepreneurial opportunities include developing and selling subscriptions to aquaculture farm management apps; providing ICT training and digital literacy workshops to fishing cooperatives and farmer associations; building and maintaining fisheries management information systems for state or federal government agencies on a consultancy basis; and developing data services such as market price aggregation platforms or fish quality certification apps.

A viable ICT business in fisheries requires: a clearly identified problem that users are willing to pay to solve; a product or service that demonstrably solves that problem; a sustainable revenue model (subscription fees, service contracts, advertising, or data licensing); and the technical and business skills to build and sustain the enterprise. Fisheries graduates are uniquely positioned to

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identify genuine unmet needs in the sector that technology-only entrepreneurs would miss, and to build culturally appropriate, contextually relevant solutions that gain adoption in fishing communities. The entrepreneurial opportunity is substantial in Nigeria given the size of the fisheries and aquaculture sector and the current low digital penetration.

Fill in the blank: A viable ICT business requires a clearly identified _____ that users are willing to pay to solve and a sustainable revenue model to sustain the enterprise.

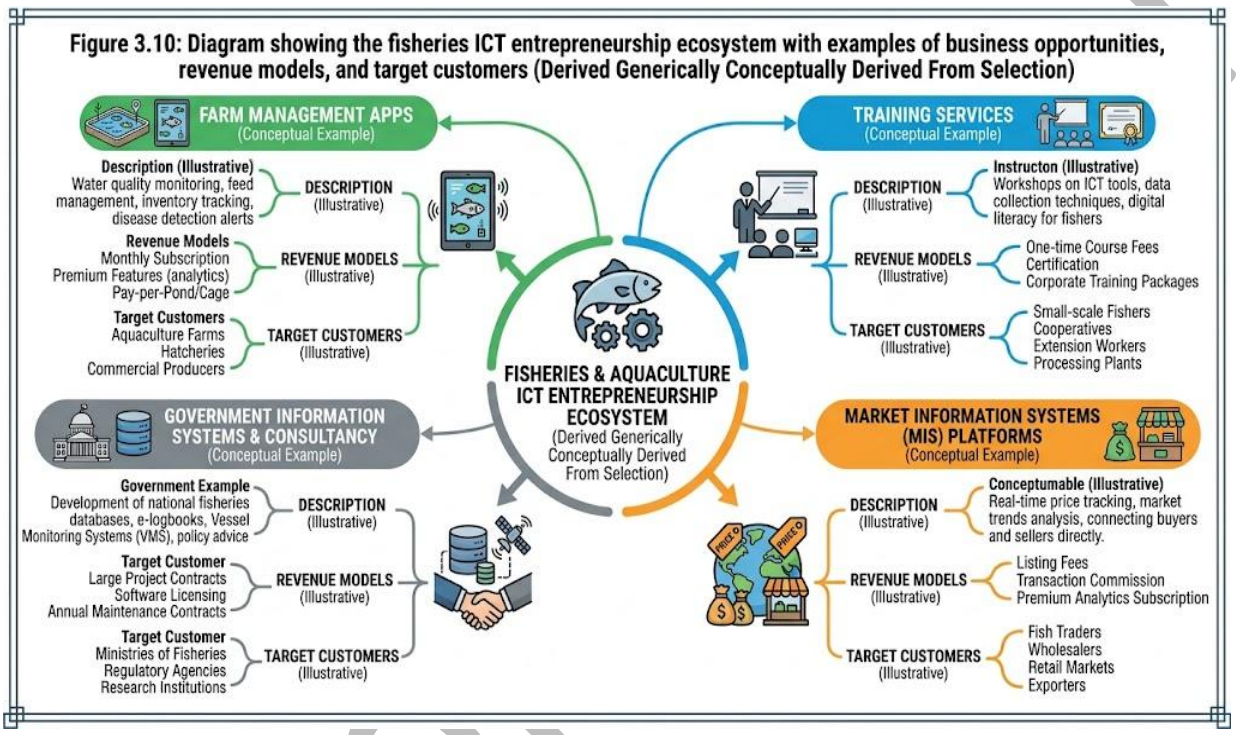

Figure 3.10: Diagram showing the fisheries ICT entrepreneurship ecosystem with examples of business opportunities, revenue models, and target customers

Pilot questions 3.4

Describe two methods of distributing a completed Android app to fisheries users.

What is user acceptance testing and why is it conducted before deployment?

Name the four types of software maintenance and give one fisheries example of each.

Explain why version control is important during software maintenance.

Describe one viable ICT business opportunity for a fisheries graduate and explain its revenue model.

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Series Summary

This Series has equipped you with foundational knowledge and practical skills in software and app development for fisheries operations. We began with the core foundations of software development, covering the SDLC from requirements to maintenance, the programming languages most relevant to fisheries applications (Python, R, JavaScript, SQL), and the database and backend architecture that underpins fisheries information systems. We then studied user-centred design and requirements gathering, the use of no-code and low-code platforms (MIT App Inventor, KoboToolbox, AppSheet), and the four stages of building and testing a simple fisheries app.

Following that, we explored web-based fisheries solutions including the three core web technologies (HTML, CSS, JavaScript), online fisheries dashboards and the Global Fishing Watch platform, and cloud computing as a scalable and low-cost infrastructure for fisheries data systems. Finally, we addressed deployment and distribution strategies for Android apps and web applications, the four types of software maintenance, and the substantial entrepreneurial opportunities available to fisheries graduates with ICT skills. 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

Agile development: an iterative software development approach that builds and tests small increments of functionality in short cycles with continuous user feedback, rather than following a strictly sequential waterfall process.

API (Application Programming Interface): a set of defined rules and protocols through which software applications communicate with each other; RESTful APIs are the standard mechanism for frontend-backend communication in web and mobile applications.

APK (Android Package Kit): the file format used to distribute and install applications on Android devices; generated by app development tools and uploaded to the Google Play Store or shared directly.

Backend: the server-side component of a software application that handles data processing, business logic, and database communication; invisible to the end user but essential for application functionality.

Cloud computing: the delivery of computing services including servers, storage, databases, and software over the internet from remote data centres; enables scalable, on-demand infrastructure without capital investment in physical hardware.

CSS (Cascading Style Sheets): a web technology that controls the visual appearance of HTML web pages, including layout, colours, fonts, and responsive design for different screen sizes.

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Data sovereignty: the principle that data is subject to the laws and governance structures of the country in which it is collected or stored; a consideration when choosing cloud hosting locations for sensitive national fisheries statistics.

Frontend: the client-side component of a software application; the interface that users see and interact with, built using HTML, CSS, and JavaScript for web applications or Java/Kotlin for Android apps.

Git: a distributed version control system that tracks changes to code and data files over time, enabling collaboration, rollback to previous versions, and audit trails for software development projects.

Global Fishing Watch: a publicly accessible online platform that uses satellite AIS data and machine learning to map global fishing vessel activity in near real time; used for fisheries governance, compliance monitoring, and research.

HTML (Hypertext Markup Language): the standard language for structuring and presenting content on the web; defines the elements and layout of web pages accessed through browsers.

JavaScript: a programming language that adds interactive behaviour to web pages and is widely used for building web applications and interactive dashboards; also used for backend development with Node.js.

Low-code platform: a software development environment that provides drag-and-drop components and visual design tools to accelerate development, requiring some coding only for complex or custom functionality.

MIT App Inventor: a free, browser-based no-code platform that allows users to build Android mobile applications using visual block-based programming without writing conventional code.

No-code platform: a software development environment that allows functional applications to be built entirely through visual interfaces and block-based logic without any conventional programming.

Perfective maintenance: software maintenance activities that add new features or improve existing functionality in response to user requests after the initial deployment.

Python: a versatile, beginner-friendly programming language widely used in fisheries science for data analysis, machine learning, web backends, and scripting; the most recommended first programming language for fisheries students.

Requirements document: a formal record of the functional and non-functional requirements of a software application, agreed with stakeholders before development begins; guides the design and testing of the software.

SQL (Structured Query Language): the standard language for creating, querying, and managing relational databases; essential for anyone working with fisheries data management systems.

User acceptance testing (UAT): a testing phase in which intended users verify that a software application meets agreed requirements in the actual operational environment before full deployment.

User-centred design (UCD): a software design philosophy that places the needs, preferences, and constraints of intended users at the centre of every design decision throughout the development process.

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Wireframe: a low-fidelity sketch of an application's screen layout used to communicate and validate the proposed interface with users before technical development begins.

Concept Check Questions [Series 3]

Objective Questions

The first stage of the software development life cycle is _____ analysis. (Linked to SLO 3.1)

Which programming language is standard for querying relational databases? (a) Python (b) HTML (c) SQL (d) CSS. (Linked to SLO 3.2)

A low-fidelity sketch of an app screen layout shown to users before development is called a _____. (Linked to SLO 3.4)

MIT App Inventor uses visual _____-based programming to allow non-programmers to build Android apps. (Linked to SLO 3.5)

The three core web technologies are HTML, CSS, and _____. (Linked to SLO 3.6)

Short-Answer Questions

Explain the difference between agile and sequential (waterfall) software development and state why agile is suited to fisheries app development. (Linked to SLO 3.1)

Describe the role of an API in a fisheries mobile data collection application. (Linked to SLO 3.3)

Explain what user-centred design means and name two requirements gathering techniques. (Linked to SLO 3.4)

Describe what Global Fishing Watch is and how it supports fisheries governance. (Linked to SLO 3.7)

State one viable ICT business opportunity for a fisheries graduate and explain the revenue model. (Linked to SLO 3.9)

Long-Answer Questions

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Analyse the process of developing a mobile app for a fisheries application, explaining the SDLC stages, the importance of user-centred design and requirements gathering, and how no-code tools such as MIT App Inventor enable non-programmers to build functional fisheries apps. (Linked to SLOs 3.1, 3.4, 3.5)

Discuss web-based and cloud-based solutions for fisheries management, explaining the role of the three core web technologies, online dashboards and the Global Fishing Watch platform, and how cloud computing provides scalable infrastructure for fisheries data systems. (Linked to SLOs 3.6, 3.7)

Evaluate the deployment, maintenance, and entrepreneurship dimensions of fisheries software development, explaining deployment strategies, the four types of maintenance, and the business opportunities available to fisheries graduates with ICT skills in Nigeria. (Linked to SLOs 3.8, 3.9)

Answers to Concept Check Questions [Series 3]

Objective Questions

Requirements.

Correct answer: c) SQL.

Wireframe.

Block.

JavaScript.

Short-Answer Questions

Sequential (waterfall) development completes each SDLC stage fully before moving to the next, which works well when requirements are completely known at the start. Agile development works in short iterative cycles with user feedback after each increment, which is better suited to fisheries apps because users (fishers, farmers) often cannot articulate all their needs until they see and use early prototypes.

An API in a fisheries mobile app is the communication interface between the app on the user's phone (frontend) and the server that stores and processes data (backend); when an

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enumerator submits a catch record on the app, the app sends the data to the server via the API, which validates and stores it in the database and sends a confirmation back to the app.

User-centred design places the needs and constraints of intended users at the centre of every design decision; two requirements gathering techniques: structured interviews (asking users what tasks they perform and what information they need) and observational studies (watching users work to understand their actual workflows without relying on self-reporting).

Global Fishing Watch is a publicly accessible online platform that uses satellite AIS data and machine learning to map the activity of fishing vessels worldwide in near real time; it supports fisheries governance by enabling authorities to detect vessels operating illegally in closed areas, assess fishing effort by flag state and gear type, and monitor compliance with MPA boundaries without requiring physical patrol vessels.

Any one example with revenue model: aquaculture farm management app subscription (fish farmers pay a monthly fee to use the app for production records, feeding schedules, and financial tracking); government fisheries data system consultancy (a fisheries agency pays a project fee to design and build a national catch reporting portal and a maintenance retainer for ongoing support).

Long-Answer Questions

Basic response: The SDLC has six stages: requirements, design, implementation, testing, deployment, and maintenance. Agile iterations work best for fisheries apps. UCD involves users throughout design through interviews, observations, and wireframes reviewed before coding. MIT App Inventor enables non-programmers to build and test functional Android apps using block-based logic, building the interface in the Designer view and testing on a connected phone.

Value-added response: The most critical stage is requirements gathering, which determines whether the final app will be adopted. Apps built without adequate user consultation fail because they do not fit the actual workflow or language of their users. The no-code tools available today (MIT App Inventor, KoboToolbox, AppSheet) mean that fisheries graduates can build useful prototype apps to validate a concept before committing to professional development, dramatically reducing the cost and risk of digital solution development in the fisheries sector.

Basic response: HTML structures web content, CSS styles it, and JavaScript adds interactivity. Online dashboards use tools like R Shiny, Tableau, and Power BI; FIGIS and Global Fishing Watch are major fisheries web platforms. Cloud computing provides scalable, low-cost storage and hosting via AWS, Google Cloud, and Azure, with free tiers available for small systems.

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Value-added response: The availability of free-tier cloud services has removed the infrastructure cost barrier for small fisheries ICT projects in Nigeria: a student or small team can deploy a web application on Google Cloud or AWS at zero cost during development and early operation, scaling costs only as user numbers grow. The main capacity gap is not infrastructure but the skills and resources to build, populate, and maintain these systems; addressing this gap is precisely what this course is designed to do.

Basic response: Android apps are deployed via Google Play Store or direct APK distribution; web apps via cloud hosting. User acceptance testing verifies the software meets requirements before release. The four maintenance types are corrective (bug fixes), adaptive (OS/API updates), perfective (new features), and preventive (code refactoring). Entrepreneurial opportunities include app subscriptions, training services, and government consultancy.

Value-added response: The entrepreneurial opportunity for fisheries graduates in Nigerian ICT is particularly large because they combine domain expertise that technology-only entrepreneurs lack with the ICT skills being developed through this course. The most valuable products are those that address the highest-cost information problems in the sector: real-time market price information, rapid disease diagnosis, and reliable production record systems. A fisheries graduate who builds even one of these tools and deploys it successfully to a community of users has created lasting value for the sector and a foundation for a sustainable business.

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Answers to Pilot Questions [Series 3]

Part 3.1: Foundations of Software Development

Requirements analysis, system design, implementation, testing, deployment, and maintenance.

Agile development works in short iterative cycles (sprints), building and testing small increments of functionality with user feedback after each iteration; it is suited to fisheries app development because users often cannot fully articulate their requirements at the start and benefit from seeing and responding to early prototypes before significant investment has been made.

Python (data analysis, machine learning, web backends); R (statistical analysis and visualisation); JavaScript (web development and interactive dashboards); SQL (querying and managing relational databases).

SQL (Structured Query Language) is the standard language for creating, querying, and managing relational databases; it is important in fisheries data systems because national catch databases, vessel registration systems, and observer data are all stored in relational databases that must be queried and maintained using SQL.

The frontend is the user-facing interface of an application (what users see and interact with), built using HTML, CSS, and JavaScript for web apps or Java/Kotlin for Android apps; the backend is the server-side component that processes data, implements business logic, and communicates with the database, invisible to the user but essential for data storage and retrieval.

Part 3.2: App Development for Fisheries

User-centred design places the needs, preferences, and constraints of intended users at the centre of every design decision throughout development; it is important for fisheries apps because users (fishers, farmers, extension workers) have specific workflows, language preferences, and connectivity constraints that are not obvious to developers without deep engagement, and apps that do not fit these realities will not be adopted regardless of technical quality.

Any three: structured interviews (asking users about their current tasks and information needs); observational studies (watching users work to understand actual workflows); participatory workshops where users sketch or prototype the app interface; focus group discussions; analysis of existing paper forms and workflows.

A wireframe is a low-fidelity sketch of an application's screen layout, showing the placement of interface components without detailed visual design; it reduces development risk by allowing users to review and provide feedback on the proposed interface before any code is

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written, preventing the costly mistake of building a technically functional app with an interface that does not match user needs.

No-code platforms allow apps to be built entirely through visual interfaces and block-based logic with no conventional programming (example: MIT App Inventor); low-code platforms provide drag-and-drop components for most functionality but require some conventional coding for complex features (example: OutSystems or Appsmith).

Stage 1: use the Designer view to set up the screen layout by placing interface components (labels, input fields, buttons); Stage 2: use the Blocks editor to connect components with logical instructions (when button pressed, save data); Stage 3: test the app using live preview on a connected Android phone or the built-in emulator; Stage 4: export the completed app as an APK file for distribution.

Part 3.3: Web-Based Solutions for Fisheries Management

HTML (Hypertext Markup Language): defines the structure and content of web pages; CSS (Cascading Style Sheets): controls the visual appearance of web pages including layout, colours, and fonts; JavaScript: adds interactive behaviour such as responding to user actions and updating page content dynamically.

An online fisheries dashboard presents real-time or regularly updated fisheries data through visual charts, maps, and tables accessible in a web browser; two tools for building them: R Shiny (interactive web visualisations built from R code) and Tableau Public (drag-and-drop dashboard builder with public hosting).

Global Fishing Watch is a publicly accessible platform that uses satellite AIS data and machine learning to map the activity of fishing vessels worldwide in near real time; it is used in fisheries governance to detect vessels fishing illegally in closed areas or marine protected zones, to compare fishing effort by country and fleet, and to support evidence-based management decisions without requiring physical patrol vessels in every area.

Cloud computing delivers computing services (servers, storage, databases, software) over the internet from remote data centres; two benefits for fisheries data: scalable storage that grows with data volume without requiring physical hardware investment; built-in redundancy and backup protecting against data loss; accessibility from any location with internet connectivity.

Data sovereignty is the principle that data is subject to the laws and governance structures of the country where it is collected or stored; it matters for national fisheries data because sensitive catch statistics, vessel records, and enforcement data hosted on foreign servers may be subject to foreign laws that conflict with Nigerian sovereignty and data protection obligations.

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Part 3.4: Deployment, Maintenance, and Entrepreneurship

Any two: uploading the APK to the Google Play Store (provides automatic update notifications and a trusted installation pathway but requires a one-time registration fee); distributing the APK directly via a website download or messaging platforms such as WhatsApp (simpler and free but requires users to enable installation from unknown sources and does not provide automatic updates).

User acceptance testing is a phase in which intended users verify that the software meets agreed requirements in the actual operational environment before full deployment; it is conducted to ensure that the software performs correctly under real-world conditions with real users on real devices, catching problems that internal testing by developers may miss.

Corrective maintenance: fixing bugs reported by users after deployment (e.g. fixing a data entry error in a catch recording app); adaptive maintenance: updating the app to work with new Android versions or changed APIs (e.g. updating a VMS app when the satellite provider changes its data format); perfective maintenance: adding new features requested by users (e.g. adding a photo capture function to a fish disease diagnosis app); preventive maintenance: refactoring code to reduce complexity and prevent future problems (e.g. reorganising database structure before scaling up user numbers).

Version control (Git) is essential during maintenance because it tracks every change made to the codebase with a descriptive message and timestamp; if a software update introduces a new bug, the previous working version can be restored instantly; it also allows multiple developers to work on different features simultaneously without overwriting each other's changes.

Any one with revenue model: aquaculture farm management app (fish farmers pay a monthly subscription fee to access the app for production records, feeding schedules, and financial tracking; revenue scales with the number of subscribers); government fisheries information system (a state fisheries agency pays a fixed project fee to develop a catch reporting portal plus a monthly retainer for hosting, maintenance, and support).

References and Attributions [Series 3]

Textual References (Books and External Sources)

Norman, D. A. (2013). The design of everyday things (revised ed.). Basic Books.

Holovaty, A., & Kaplan-Moss, J. (2009). The definitive guide to Django: Web development done right (2nd ed.). Apress.

Kramer, J., & Magee, J. (2006). Software engineering: An introduction. Pearson Education.

Global Fishing Watch. (2025). Global Fishing Watch open data. globalfishingwatch.org.

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World Bank. (2019). Digital technology in agriculture: Taking stock of the evidence and getting practical. World Bank Group.

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

Figures, Plates, Tables, and Boxes

Figure 3.1: Software development life cycle circular diagram Attribution: AI generated using prompt "Generate a circular diagram showing the six stages of the SDLC: requirements analysis, design, implementation, testing, deployment, and maintenance." Suggested OER search string: "software development life cycle SDLC stages circular diagram OER".

Figure 3.2: Programming languages for fisheries applications Attribution: AI generated using prompt "Generate a diagram comparing programming languages used in fisheries: Python, R, JavaScript, and SQL with their primary use cases." Suggested OER search string: "programming languages fisheries applications comparison diagram OER".

Figure 3.3: Fisheries app frontend-backend-database architecture Attribution: AI generated using prompt "Generate a three-layer architecture diagram showing a fisheries mobile app frontend communicating via API with a backend server connected to a database." Suggested OER search string: "fisheries app frontend backend database architecture diagram OER".

Figure 3.4: Fisheries app wireframe screens Attribution: AI generated using prompt "Generate wireframe sketches showing three screens of a fisheries landing site data collection app: species selection, catch weight entry, and GPS location confirmation." Suggested OER search string: "fisheries app wireframe design screens landing site OER".

Plate 3.1: Student using MIT App Inventor Attribution: AI generated using prompt "Generate an image showing a student using MIT App Inventor in a browser to build a fisheries app with block-based programming and phone emulator preview." Suggested OER search string: "MIT App Inventor student fisheries app development no-code OER image".

Figure 3.5: MIT App Inventor build stages flowchart Attribution: AI generated using prompt "Generate a flowchart showing the four stages of building a fisheries app in MIT App Inventor: layout design, block logic, testing, and APK export." Suggested OER search string: "MIT App Inventor fisheries app build stages flowchart OER".

Figure 3.6: Web development layers diagram Attribution: AI generated using prompt "Generate a layered diagram showing HTML, CSS, and JavaScript and their roles in a fisheries information portal." Suggested OER search string: "web development layers HTML CSS JavaScript fisheries portal OER diagram".

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Figure 3.7: Global Fishing Watch platform diagram Attribution: AI generated using prompt "Generate a diagram showing the Global Fishing Watch interface with vessel tracks and fishing effort heat map." Suggested OER search string: "Global Fishing Watch vessel tracking fishing effort heat map OER".

Figure 3.8: Cloud computing for fisheries data Attribution: AI generated using prompt "Generate a diagram showing cloud computing in fisheries with data from field enumerators and vessels uploaded to a cloud platform accessed by managers and researchers." Suggested OER search string: "cloud computing fisheries data storage processing sharing OER diagram".

Figure 3.9: Fisheries Android app deployment pipeline Attribution: AI generated using prompt "Generate a flowchart showing the deployment pipeline for a fisheries Android app from APK build through testing and distribution to user training." Suggested OER search string: "fisheries Android app deployment pipeline flowchart OER".

Box 3.1: Four types of software maintenance Attribution: AI generated using prompt "Generate a text box listing the four types of software maintenance: corrective, adaptive, perfective, and preventive, with fisheries examples." Suggested OER search string: "software maintenance types corrective adaptive perfective preventive fisheries OER".

Figure 3.10: Fisheries ICT entrepreneurship mind map Attribution: AI generated using prompt "Generate a mind map showing fisheries ICT entrepreneurship opportunities including farm management apps, training services, MIS platforms, and government system consultancy." Suggested OER search string: "fisheries ICT entrepreneurship opportunities revenue models OER diagram".

Course code: FAA 410

Course title: Information and Communications Technologies in Fisheries and Aquaculture

Course credit load: 2 Units

Series 4: Artificial Intelligence and Machine Learning in Fisheries and Aquaculture

Series outline

Part 4.1: Introduction to Artificial Intelligence

Sub Part 4.1.1: Definition and scope of artificial intelligence

Sub Part 4.1.2: History and development of AI

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Sub Part 4.1.3: Types of AI and their relevance to fisheries

Part 4.2: Machine Learning Fundamentals

Sub Part 4.2.1: What is machine learning?

Sub Part 4.2.2: Supervised, unsupervised, and reinforcement learning

Sub Part 4.2.3: Key machine learning algorithms and their applications

Part 4.3: AI Applications in Fisheries and Aquaculture

Sub Part 4.3.1: AI for fish species identification and counting

Sub Part 4.3.2: AI for catch monitoring and illegal fishing detection

Sub Part 4.3.3: AI in aquaculture: precision feeding and disease detection

Part 4.4: AI as an Emerging Opportunity

Sub Part 4.4.1: AI tools available for fisheries professionals

Sub Part 4.4.2: Ethical considerations in AI for fisheries

Sub Part 4.4.3: AI entrepreneurship opportunities for fisheries graduates

Introduction

Artificial intelligence (AI) and machine learning (ML) are transforming industries worldwide, and fisheries and aquaculture are no exception. From computer vision systems that automatically identify and count fish species from underwater cameras to satellite-based vessel activity detection algorithms, AI is enabling levels of monitoring, analysis, and management precision that were previously unachievable. For fisheries graduates entering the workforce, understanding AI is no longer optional; it is an increasingly important professional and entrepreneurial competency.

The aim of this Series is to introduce you to the concepts, methods, and applications of artificial intelligence and machine learning in fisheries and aquaculture, and to help you identify the emerging opportunities this technology creates for professional practice and entrepreneurship.

We shall commence this Series by defining AI and tracing its development and types. Next, we will study the fundamentals of machine learning. Following that, we will survey AI applications in fisheries and aquaculture. Finally, we will wrap up with available AI tools, ethical considerations, and entrepreneurial opportunities.

Series Learning Outcomes

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Upon completing this Series, you should be able to:

SLO 4.1 define artificial intelligence and explain its scope and relevance to fisheries and aquaculture (Linked to Part 4.1),

SLO 4.2 describe the history and development of AI and identify the types of AI relevant to fisheries (Linked to Part 4.1),

SLO 4.3 define machine learning and distinguish between supervised, unsupervised, and reinforcement learning (Linked to Part 4.2),

SLO 4.4 describe key machine learning algorithms and explain their application to fisheries problems (Linked to Part 4.2),

SLO 4.5 explain how AI is used for fish species identification and counting in fisheries science (Linked to Part 4.3),

SLO 4.6 describe how AI supports catch monitoring and illegal fishing detection (Linked to Part 4.3),

SLO 4.7 explain AI applications in precision aquaculture including automated feeding and disease detection (Linked to Part 4.3),

SLO 4.8 identify AI tools available to fisheries professionals and explain the ethical considerations in their use (Linked to Part 4.4), and

SLO 4.9 discuss AI as an entrepreneurial opportunity for fisheries graduates (Linked to Part 4.4).

4.1 Introduction to Artificial Intelligence

4.1.1 Definition and scope of artificial intelligence

Artificial intelligence (AI) refers to the development of computer systems capable of performing tasks that normally require human intelligence, such as recognising images, understanding spoken language, making decisions, and identifying patterns in large datasets. AI encompasses a broad range of approaches and techniques, from simple rule-based expert systems to sophisticated neural networks that learn from millions of examples. The scope of AI is widening rapidly as computing power increases and large datasets become available in previously data-poor sectors.

In fisheries and aquaculture, AI is relevant wherever large volumes of data need to be processed rapidly, patterns need to be identified in complex datasets, or decisions need to be made consistently at scale. Examples include identifying fish species from underwater video feeds, detecting anomalous vessel behaviour indicative of illegal fishing in satellite tracking data, predicting aquaculture pond conditions from sensor data, and forecasting future fish stock

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abundance from environmental and catch time series. Understanding the scope of AI helps fisheries professionals identify where it can add the most value in their work.

Fill in the blank: Artificial intelligence refers to computer systems capable of performing tasks that normally require human _____, such as recognising images and identifying patterns in data.

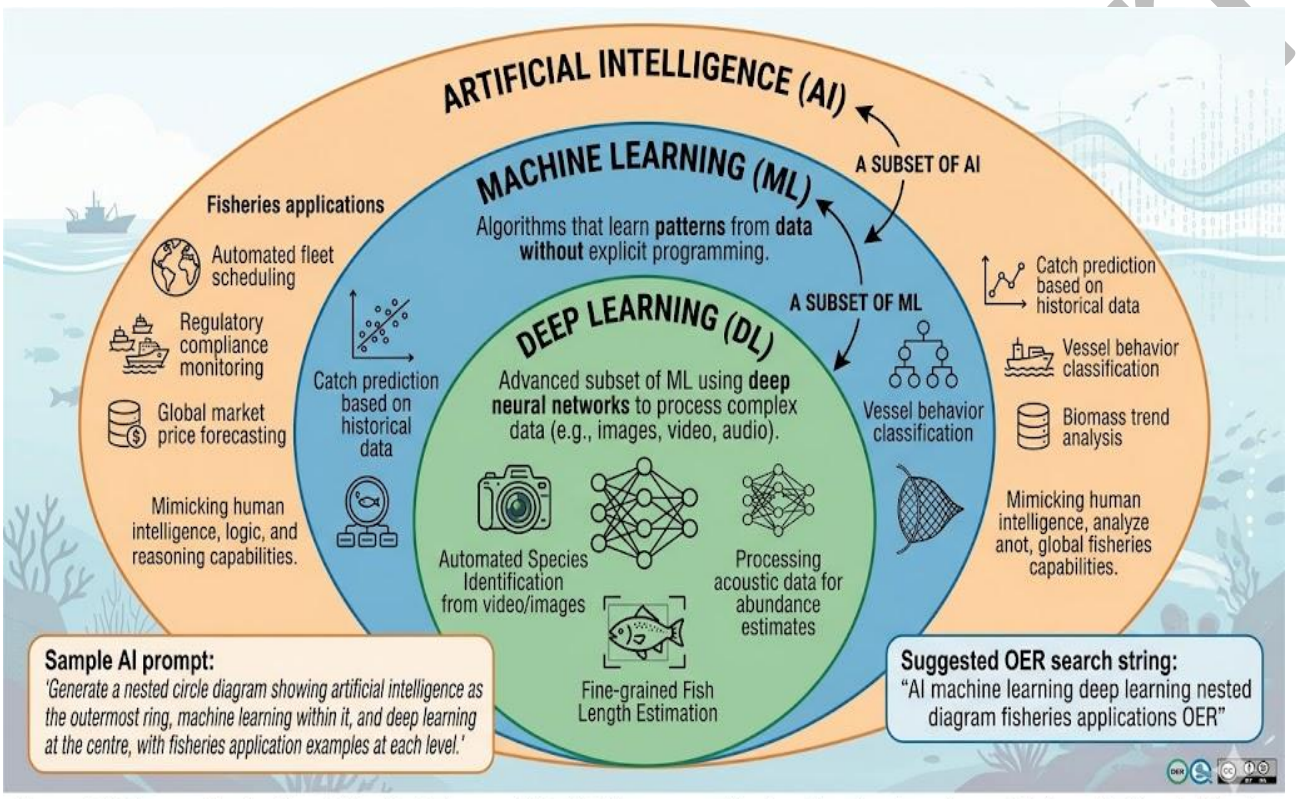


Figure 4.1: Diagram showing the relationship between artificial intelligence, machine learning, deep learning, and their applications in fisheries

Figure 4.1: Diagram showing the relationship between artificial intelligence, machine learning, deep learning, and their applications in fisheries

4.1.2 History and development of AI

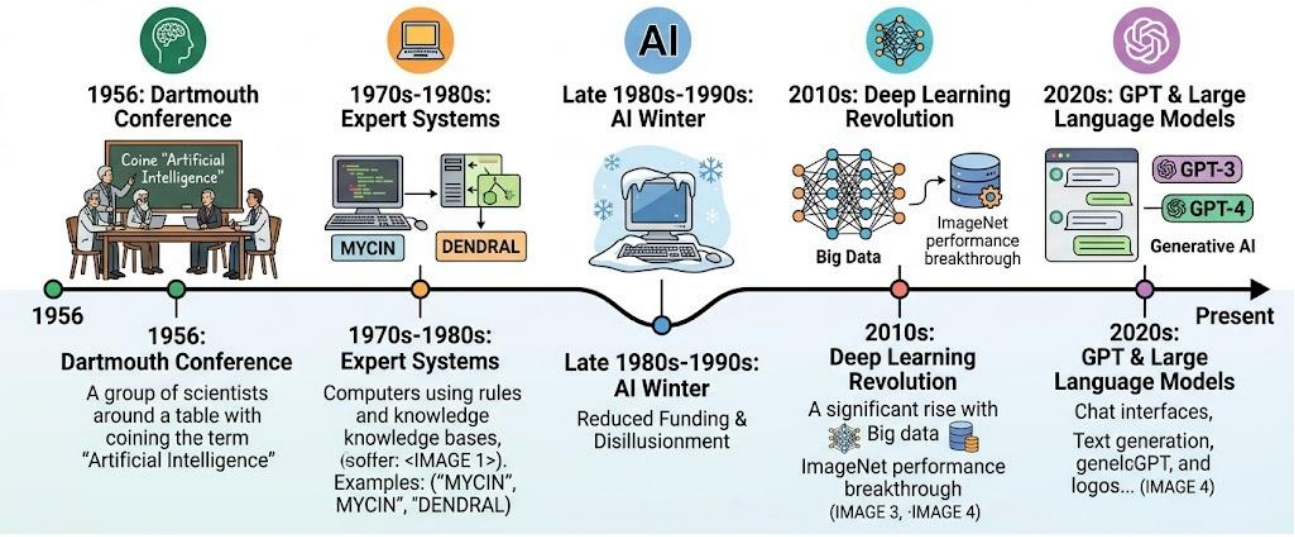
The history of AI spans over seven decades. The field was formally founded at the Dartmouth Conference in 1956, where researchers proposed that all aspects of human intelligence could in principle be precisely described and simulated by machines. Early AI development in the 1950s to 1980s focused on rule-based expert systems that encoded human knowledge as logical rules. These systems achieved notable successes in narrow domains such as medical diagnosis and chess, but struggled with the complexity of real-world problems.

The modern era of AI began with the convergence of three developments: the availability of large digitised datasets (especially from the internet), dramatic increases in computing power (particularly the use of Graphics Processing Units for parallel computation), and advances in

neural network architectures. The deep learning revolution of the 2010s, driven by breakthroughs such as AlexNet in image recognition (2012) and AlphaGo in strategic games (2016), demonstrated that neural networks with many layers could outperform humans on specific tasks. In fisheries, these developments enabled practical applications in image-based species identification and satellite vessel detection from the mid-2010s onwards.

Fill in the blank: The field of AI was formally founded at the _____ Conference in 1956, where researchers proposed that human intelligence could in principle be simulated by machines.

Figure 4.2: Timeline of key milestones in the development of artificial intelligence from 1956 to the present



Sample AI prompt: "Generate a horizontal timeline showing key milestones in AI development from the Dartmouth Con-fience in 1956 through expert systems, the AI winter, the deep learning revolution, and large language models."
Suggested OER search string: "AI development milestones timeline 1956 deep learning OER diagram".

Figure 4.2: Timeline of key milestones in the development of artificial intelligence from 1956 to the present

4.1.3 Types of AI and their relevance to fisheries

AI systems are commonly classified by their breadth of capability and by the nature of their intelligence. **Narrow AI (weak AI)** performs specific tasks within a defined domain, such as identifying fish species from images or predicting ocean temperatures; it cannot generalise beyond its training domain. All current practical AI applications in fisheries are narrow AI. **General AI (strong AI)** would perform any intellectual task a human can, but does not yet exist as a practical technology.

A more practically useful classification distinguishes AI by technique: rule-based systems, machine learning models (which learn patterns from data), and large language models (LLMs) such as ChatGPT that can generate text and answer questions across many domains. In fisheries,

rule-based systems underpin VMS alert systems; machine learning models power image recognition for species ID and anomaly detection in vessel tracking data; and LLMs are beginning to be used for automating report writing and answering fisheries management queries in natural language. Awareness of these distinctions helps fisheries professionals evaluate which AI approach is suited to a given problem.

Fill in the blank: _____ AI performs specific tasks within a defined domain and is the type underpinning all current practical AI applications in fisheries.

Type of AI	Description	Fisheries Example
Narrow AI	AI designed for specific tasks with limited scope.	Mobile app that predicts fish growth rates based on feed input and water quality data.
General AI	Hypothetical AI with human-like reasoning across diverse tasks.	Future systems that could autonomously manage entire aquaculture farms, from feeding to disease control.
Rule-based systems	AI that uses predefined rules and logic to make decisions.	Software that alerts fish farmers when dissolved oxygen drops below safe thresholds.
Machine learning	AI that learns patterns from data to improve predictions and decisions.	Predicting fish disease outbreaks using historical water quality and mortality records.
Large language models	AI trained on vast text data to generate and understand language.	Chatbots that provide farmers with instant advice on feed formulation and best practices.

Box 4.1: Types of AI and their fisheries applications

Pilot questions 4.1

Define artificial intelligence and give two examples of its application in fisheries.

Name two key developments that drove the deep learning revolution from the 2010s.

Distinguish between narrow AI and general AI.

Give one fisheries example of a rule-based AI system.

What is a large language model (LLM) and how might it be used in fisheries management?

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4.2 Machine Learning Fundamentals

4.2.1 What is machine learning?

Machine learning (ML) is a subset of AI in which systems learn to perform tasks by identifying patterns in training data, rather than by following explicitly programmed rules. Instead of a programmer writing rules such as "if the dorsal fin has this shape, the species is X", a machine learning model is trained on thousands of labelled examples of fish images with known species identities, and it learns the features that distinguish species from the data itself. The trained model can then classify new images it has never seen before.

The three essential components of any ML system are: training data (the labelled or unlabelled examples from which the model learns), a learning algorithm (the mathematical procedure that adjusts the model's parameters to fit the data), and a trained model (the output of the learning process, which can make predictions on new inputs). Model performance is evaluated on a held-out test dataset not seen during training, to assess how well the model generalises beyond the training examples. Overfitting, where a model performs well on training data but poorly on new data, is a common challenge in ML that must be actively managed.

Fill in the blank: Machine learning systems learn from _____ data rather than from explicitly programmed rules written by a human programmer.

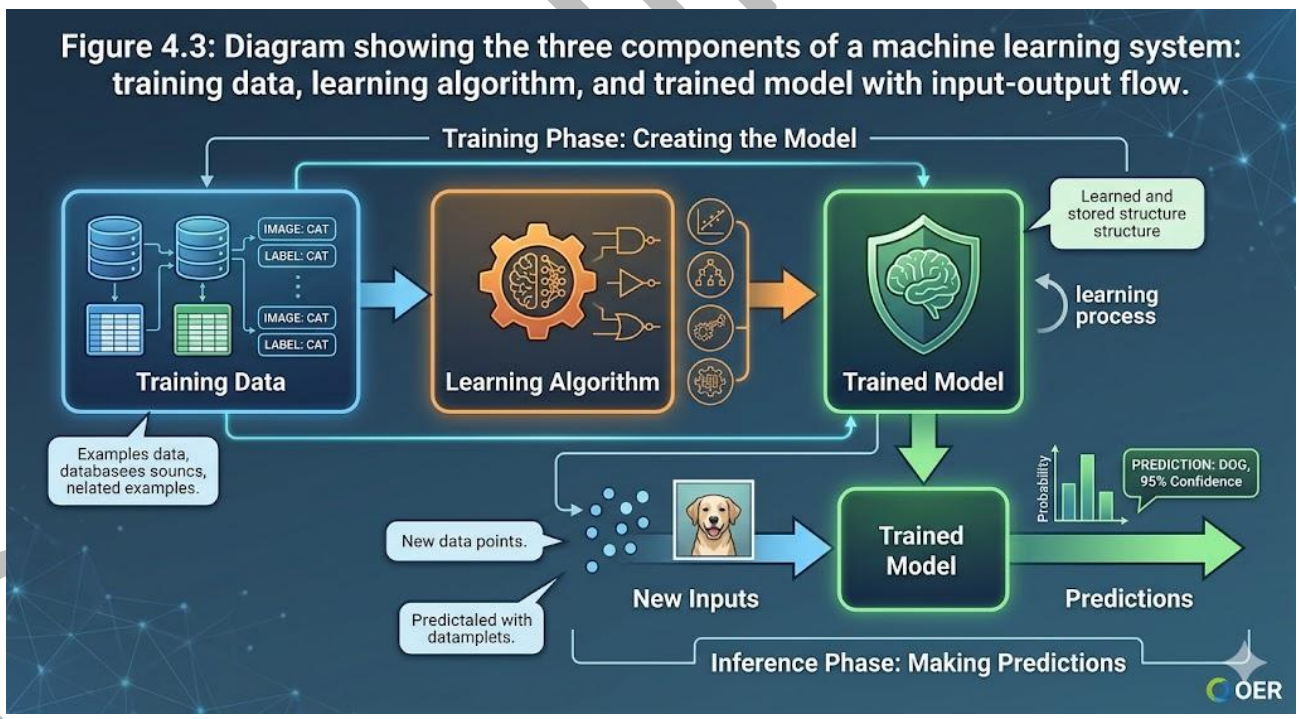


Figure 4.3: Diagram showing the three components of a machine learning system: training data, learning algorithm, and trained model with input-output flow

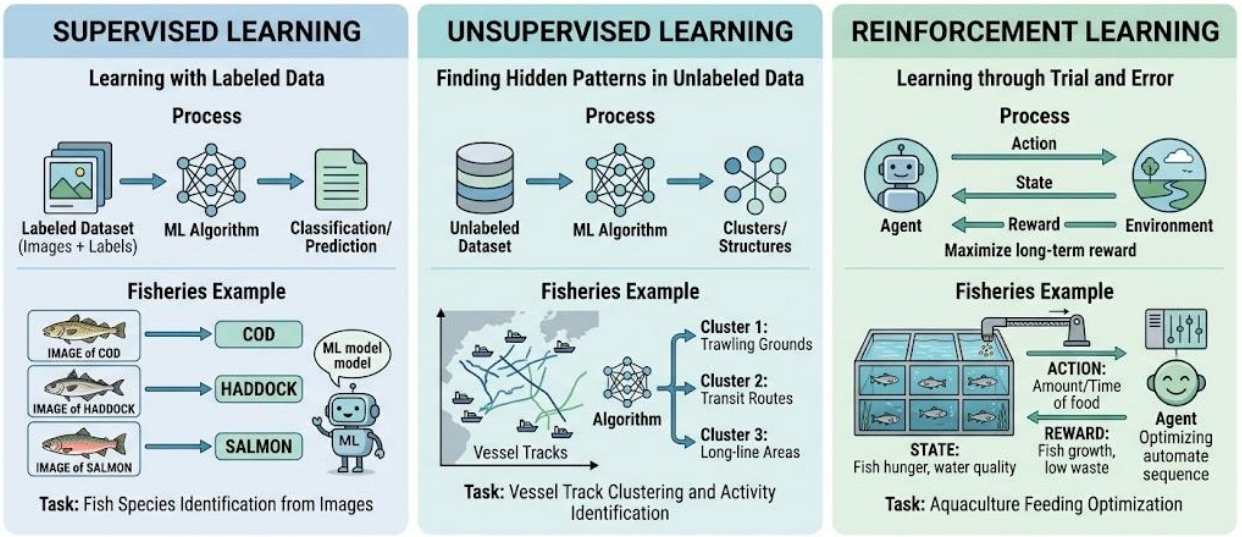
4.2.2 Supervised, unsupervised, and reinforcement learning

Supervised learning trains a model on labelled examples where the correct output is known for each input. A fish species classifier trained on images with known species labels is a supervised learning system. The model learns to map inputs to outputs by minimising the error between its predictions and the true labels. Supervised learning is the most widely used ML approach and underpins most practical fisheries AI applications including species identification and disease detection.

Unsupervised learning finds patterns in data without pre-existing labels, grouping similar examples into clusters or reducing data to fewer dimensions. Clustering vessel tracking data to identify distinct fishing behaviour patterns is an unsupervised learning application.
Reinforcement learning trains an agent to make sequential decisions by rewarding desirable outcomes and penalising undesirable ones; it has been applied to optimise feeding schedules in precision aquaculture systems. Understanding these three paradigms helps fisheries practitioners match the appropriate ML approach to the type of data and problem at hand.

Fill in the blank: _____ learning trains models on labelled examples where the correct output is known, and is the most widely used approach in practical fisheries AI applications.

Figure 4.4: Diagram comparing supervised, unsupervised, and reinforcement learning with fisheries examples of each



Sample AI prompt: "Generate a three-panel diagram comparing supervised learning, unsupervised learning, and reinforcement learning with a fisheries example of each." **Suggested OER search string:** "supervised unsupervised reinforcement learning fisheries examples OER diagram".

Figure 4.4: Diagram comparing supervised, unsupervised, and reinforcement learning with fisheries examples of each

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4.2.3 Key machine learning algorithms and their applications

Decision trees and random forests classify inputs by sequentially applying decision rules; random forests aggregate predictions from many trees for improved accuracy and are used for species classification from morphological measurements and for predicting fish stock status from environmental and fishing variables. **Convolutional neural networks (CNNs)** are the dominant architecture for image recognition tasks; they learn hierarchical visual features directly from pixel data and are used for fish species identification from photographs, underwater video frame classification, and aerial image analysis of aquaculture ponds.

Recurrent neural networks (RNNs) and Long Short-Term Memory (LSTM) networks process sequential data and are used for time series prediction in fisheries, such as forecasting catch levels or water temperature trends. Natural language processing (NLP) models extract information from text, enabling automated analysis of fishing reports, social media monitoring for fisheries compliance, and intelligent search of scientific literature. Large language models (LLMs) represent the current frontier of NLP and are being explored for fisheries report generation and stakeholder communication. For fisheries students, a conceptual understanding of these algorithms enables informed evaluation of AI-based tools and proposals.

Fill in the blank: Convolutional neural _____ (CNNs) are the dominant architecture for image recognition tasks and are used for fish species identification from photographs.

Algorithm	Approach	Fisheries Application Example
Decision Trees	Splits data into branches based on decision rules for classification/regression.	Classifying fish species based on morphological measurements (length, weight, fin shape).
Random Forests	Ensemble of multiple decision trees to improve accuracy and reduce overfitting.	Predicting fish survival rates under varying water quality conditions.
Convolutional Neural Networks (CNNs)	Deep learning models specialized in image recognition and spatial data.	Automated fish counting and species identification using underwater camera images.
Recurrent Neural Networks (RNNs) / LSTMs	Models sequential data and time-series patterns.	Forecasting fish growth trends or predicting seasonal catch volumes based on historical records.
Natural Language Processing (NLP) Models	Processes and understands human language data.	Analyzing fisher logbooks or extension service reports to detect disease trends and management needs.

Table 4.1: Key machine learning algorithms, their approach, and fisheries applications

Pilot questions 4.2

Define machine learning and explain how it differs from rule-based programming.

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What is overfitting in machine learning and why is it a problem?

Distinguish between supervised and unsupervised learning with one fisheries example of each.

What are convolutional neural networks (CNNs) and why are they suited to fish species identification?

Explain one fisheries application of recurrent neural networks (RNNs) or LSTM models.

4.3 AI Applications in Fisheries and Aquaculture

4.3.1 AI for fish species identification and counting

Computer vision AI systems can identify and count fish species from photographs, underwater video, sonar images, and drone footage with accuracy comparable to or exceeding trained human observers. These systems use CNNs trained on large image datasets to classify individual fish by species and in some cases to estimate body length and weight from image dimensions. Deployed on underwater camera rigs at fish passes or trawl sorting conveyors, they enable continuous species-specific catch monitoring that would be impossible with manual observation.

The DeepFish dataset and similar openly accessible annotated fish image databases have accelerated the development of fisheries computer vision models. In Australia, AI-based electronic monitoring systems on fishing vessels use cameras and CNN image recognition to record discards and catch composition automatically, replacing human observers at a fraction of the cost. The iNaturalist platform introduced in Series 2 also uses AI image recognition to assist citizen scientists with species identification. Developing and training these models requires large labelled datasets, which are a significant constraint in data-limited fisheries contexts.

Fill in the blank: _____ vision AI systems use convolutional neural networks trained on annotated image datasets to identify fish species and estimate body size from photographs or video.

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PLATE 4.1:

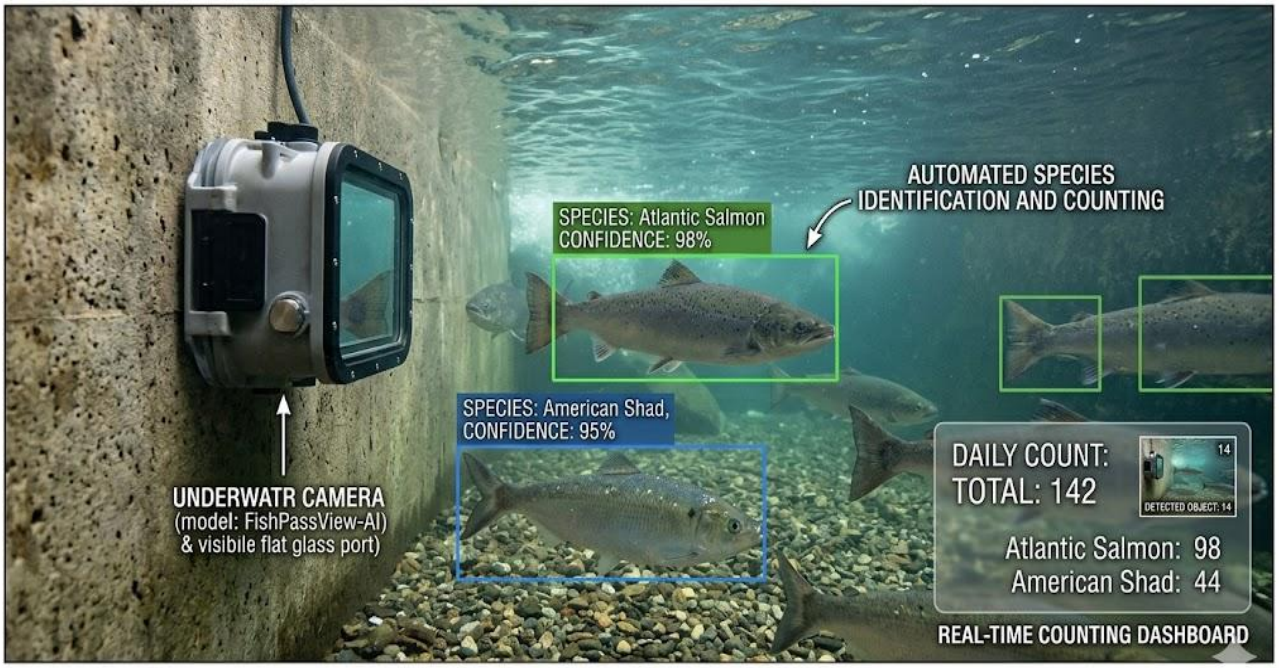

Plate 4.1: Underwater camera system with AI image recognition deployed at a fish pass to identify and count migrating fish species

Plate 4.1: Underwater camera system with AI image recognition deployed at a fish pass to identify and count migrating fish species

4.3.2 AI for catch monitoring and illegal fishing detection

AI-powered catch monitoring systems analyse data from onboard cameras, electronic monitoring devices, and electronic logbooks to verify reported catches, detect discarding, and assess gear compliance. Global Fishing Watch, introduced in Series 3, uses machine learning algorithms applied to satellite AIS data to classify vessel behaviour as fishing or non-fishing, estimate gear type from movement patterns, and detect vessels that appear to be fishing in prohibited areas or without AIS transponders (dark vessels identified by radar or synthetic aperture radar imagery).

Synthetic aperture radar (SAR) satellites can detect vessels even when AIS is switched off, and ML models trained on SAR imagery are used to identify and classify fishing vessels operating without transponders, which is a common indicator of illegal, unreported, and unregulated (IUU) fishing. The combination of AIS tracking, SAR imagery, and ML algorithms has dramatically expanded the ability of fisheries management authorities and NGOs to monitor fishing activity across large ocean areas at relatively low cost, representing one of the most impactful recent applications of AI in fisheries governance.

Fill in the blank: Synthetic aperture _____ (SAR) satellites can detect fishing vessels even when their AIS transponders are switched off, enabling identification of potential illegal fishing activity.

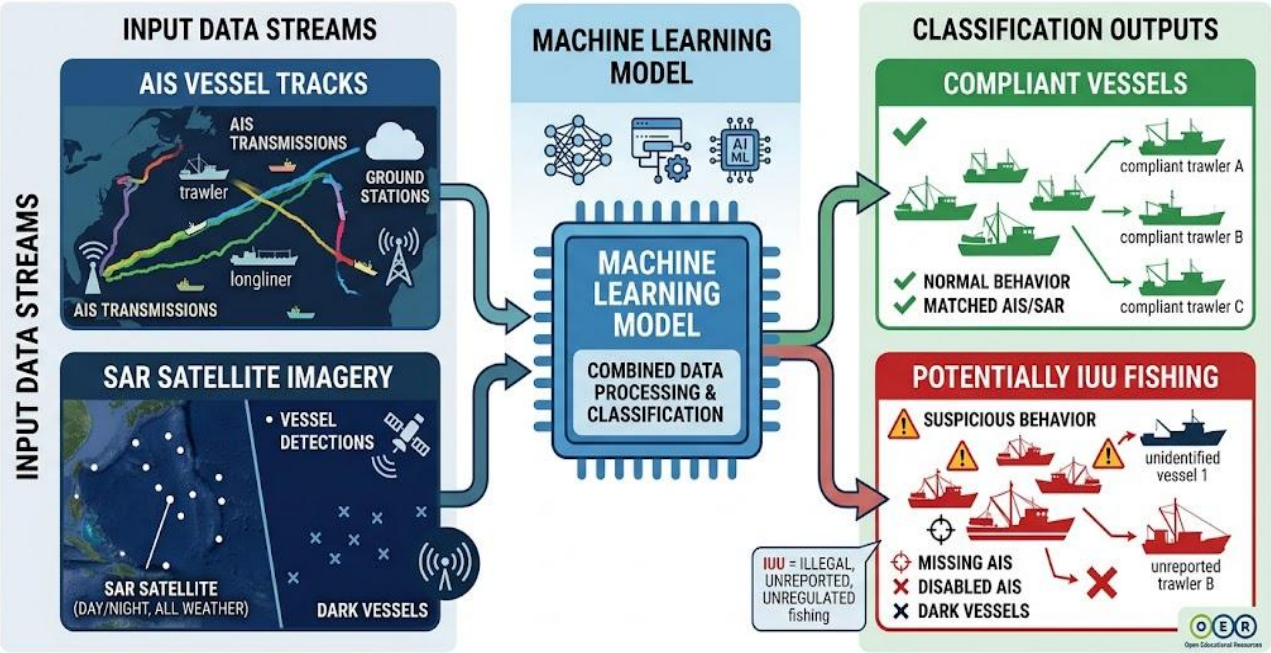

Figure 4.5: Diagram showing how AIS tracking data, SAR satellite imagery, and machine learning combine to detect illegal fishing activity.

Figure 4.5: Diagram showing how AIS tracking data, SAR satellite imagery, and machine learning combine to detect illegal fishing activity

4.3.3 AI in aquaculture: precision feeding and disease detection

Precision aquaculture uses AI to optimise feeding, monitor fish health, and manage pond or tank conditions in real time. Computer vision systems mounted above feeding stations observe fish feeding behaviour and automatically adjust feed dispenser output to match actual appetite, stopping feeding when fish cease responding to pellets. This prevents overfeeding, reduces feed waste and water quality deterioration, and improves feed conversion ratios. Commercial systems such as AquaManager and iFarm deploy these AI-powered feeding systems at industrial scale in salmon and trout farms.

Disease detection AI systems analyse images of fish (from cameras in the water or above pond surfaces) for early visual signs of disease including skin lesions, haemorrhage, abnormal posture, and lethargy. Early detection reduces the time between disease onset and treatment, limiting mortality and improving treatment outcomes. In salmon aquaculture, AI systems monitor for sea lice infestations by counting lice on individual fish from underwater images, guiding targeted treatment decisions. In Nigerian catfish and tilapia farming, the application of precision AI is in its early stages, but low-cost camera and computer vision systems are increasingly accessible.

Fill in the blank: Precision aquaculture AI feeding systems automatically adjust feed _____ to match actual fish appetite, preventing overfeeding and improving feed conversion ratios.

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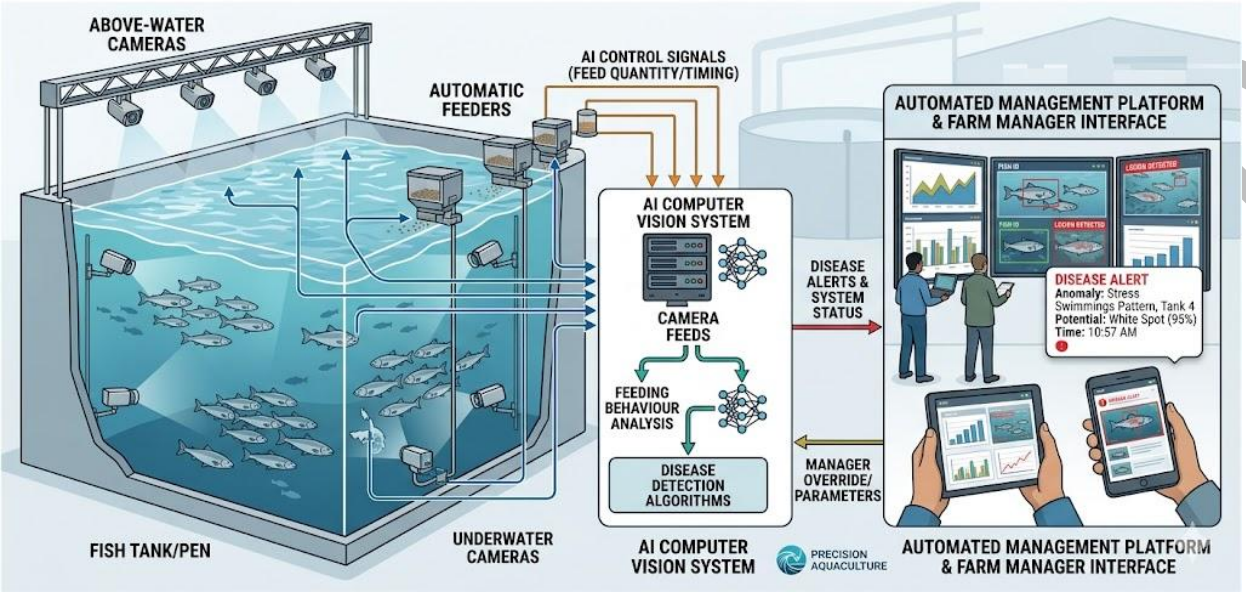
Figure 4.6: Diagram showing an AI-powered aquaculture monitoring system with cameras for feeding behaviour and disease detection connected to an automated management platform



Caption: Figure 4.6: Diagram showing an AI-powered aquaculture monitoring system with cameras for feeding behaviour and disease detection connected to an automated management platform

Pilot questions 4.3

Explain how computer vision AI systems are used for fish species identification and counting.

What is a dark vessel and how is SAR satellite imagery used to detect them?

Describe how AI improves feeding efficiency in precision aquaculture.

Explain how AI disease detection systems work in fish farming.

Name one commercial AI-powered aquaculture management system.

4.4 AI as an Emerging Opportunity

4.4.1 AI tools available for fisheries professionals

A growing ecosystem of AI tools is accessible to fisheries professionals, many of them free or low-cost. Large language models (LLMs) such as ChatGPT (OpenAI), Gemini (Google), and

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Claude (Anthropic) can assist with drafting fisheries reports, summarising scientific papers, generating code for data analysis, answering questions about fisheries regulations, and explaining statistical methods in plain language. These tools do not replace domain expertise but can substantially increase the productivity of fisheries professionals who know how to use them effectively.

Google Teachable Machine and Microsoft Azure Custom Vision allow users to train image classification models on their own photo datasets without writing any code, enabling fisheries researchers to build custom species identification models from photographs collected in the field. The Python machine learning libraries scikit-learn, TensorFlow, and PyTorch provide more advanced tools for building and training models programmatically. For fisheries students, gaining familiarity with at least one LLM tool for everyday productivity and one no-code image classification platform is a valuable starting point for building AI competency.

Fill in the blank: Google Teachable _____ allows users to train custom image classification models on their own photo datasets without writing any code.

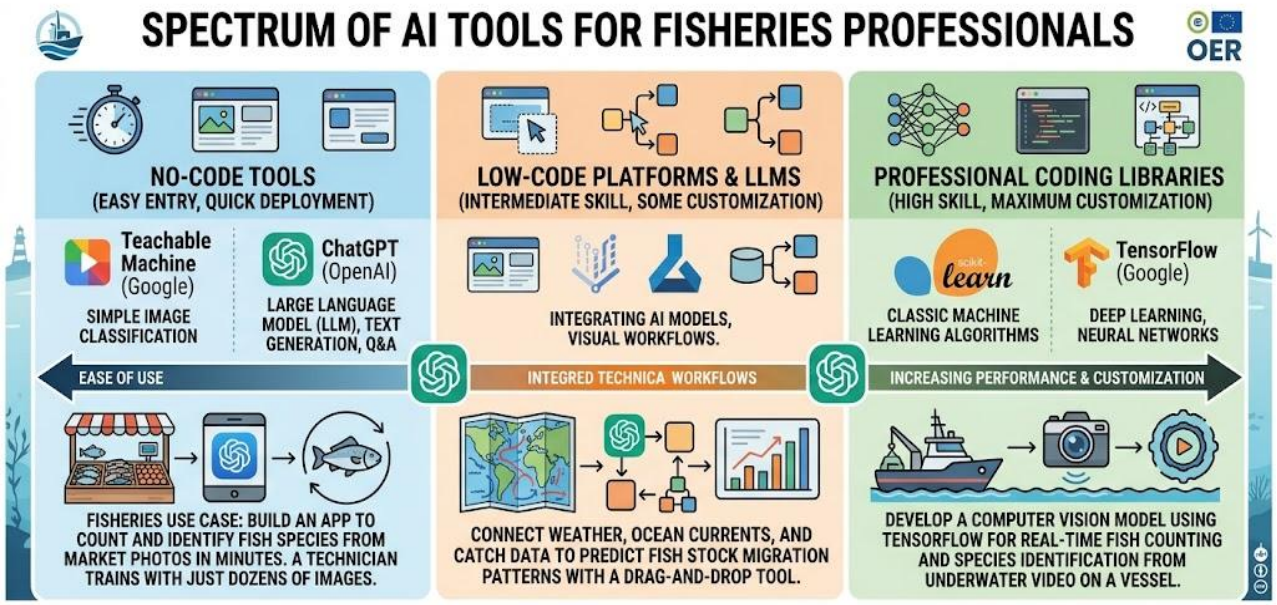

Figure 4.7: Diagram showing the range of AI tools available to fisheries professionals from no-code image classifiers to LLMs and professional ML libraries

Sample AI prompt: "Whew your nceswam hare under a'hand of fisheriers professionals, as sample trochwoure is nannled and learn intewation includes, image, trars, conipteritand fisheries, data, catchwasis."
Suggested OER search string: "https://eacnun.i.h/t/nt/EEl/#124732 fisherie a-nenorate dingrested methods-70030" sample-string," of open educational resourcs for reference.

Figure 4.7: Diagram showing the range of AI tools available to fisheries professionals from no-code image classifiers to LLMs and professional ML libraries

4.4.2 Ethical considerations in AI for fisheries

The deployment of AI in fisheries raises important ethical questions that fisheries professionals must be aware of. Bias in training data is a fundamental concern: if an AI fish

species classifier is trained predominantly on images from one geographic region or one imaging condition, it may perform poorly on fish from other regions or captured under different conditions, producing systematically biased outputs if deployed widely. Similarly, if vessel behaviour classification models are trained on data from specific flag states or gear types, they may produce discriminatory enforcement outcomes.

Transparency and accountability require that AI-driven management decisions should be explainable: when an AI system flags a vessel as potentially engaged in IUU fishing or recommends a reduced catch quota, the basis for that decision must be interpretable by human managers and challengeable by affected parties. Data privacy is a concern where AI systems collect and analyse detailed behavioural data from fishers without clear consent or governance. The use of AI in enforcement contexts, where incorrect classifications can result in serious legal and economic consequences, demands particularly rigorous validation and human oversight in the decision-making process.

Fill in the blank: _____ in AI training data occurs when a model is trained on non-representative examples, causing it to perform poorly or produce discriminatory outputs on under-represented groups.

Ethical Consideration	Description / Purpose
Training data bias	Biased or incomplete datasets can lead to inaccurate predictions and unfair outcomes.
Transparency & explainability	AI decisions must be interpretable so fisheries managers understand how outputs are derived.
Data privacy	Sensitive fisheries and farmer data must be protected from misuse or unauthorized access.
Accountability	Clear responsibility must be assigned for AI-driven decisions affecting livelihoods.
Human oversight	AI systems should support, not replace, human judgment in fisheries management.

Box 4.2: Key ethical considerations in the use of AI for fisheries management

4.4.3 AI entrepreneurship opportunities for fisheries graduates

Fisheries graduates with AI skills are positioned at the intersection of two high-demand competency areas. Entrepreneurial opportunities include building and commercialising fish species identification apps using open-source computer vision models trained on locally collected image datasets; developing AI-powered aquaculture management systems that integrate sensor data with predictive models for optimal feeding and disease alerts; and providing AI-based data analysis services to fisheries agencies and research institutions that lack in-house machine learning expertise.

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The convergence of fisheries domain knowledge with AI skills is particularly valuable in the Nigerian context, where AI tools developed for other geographic and species contexts often perform poorly without local adaptation and where no sufficient local AI talent exists with both fisheries expertise and technical capability. A fisheries graduate who can train a CNN to identify Nigerian commercial fish species from photographs, or build a vessel behaviour anomaly detection system calibrated to Gulf of Guinea fishing patterns, provides value that cannot easily be replicated by either a pure AI engineer or a traditional fisheries manager. This combination creates a compelling entrepreneurial and career opportunity for the current generation of fisheries graduates.

Fill in the blank: Fisheries graduates with AI skills create unique value by combining _____ domain knowledge with technical AI capability, addressing problems that neither pure engineers nor traditional fisheries managers can solve alone.

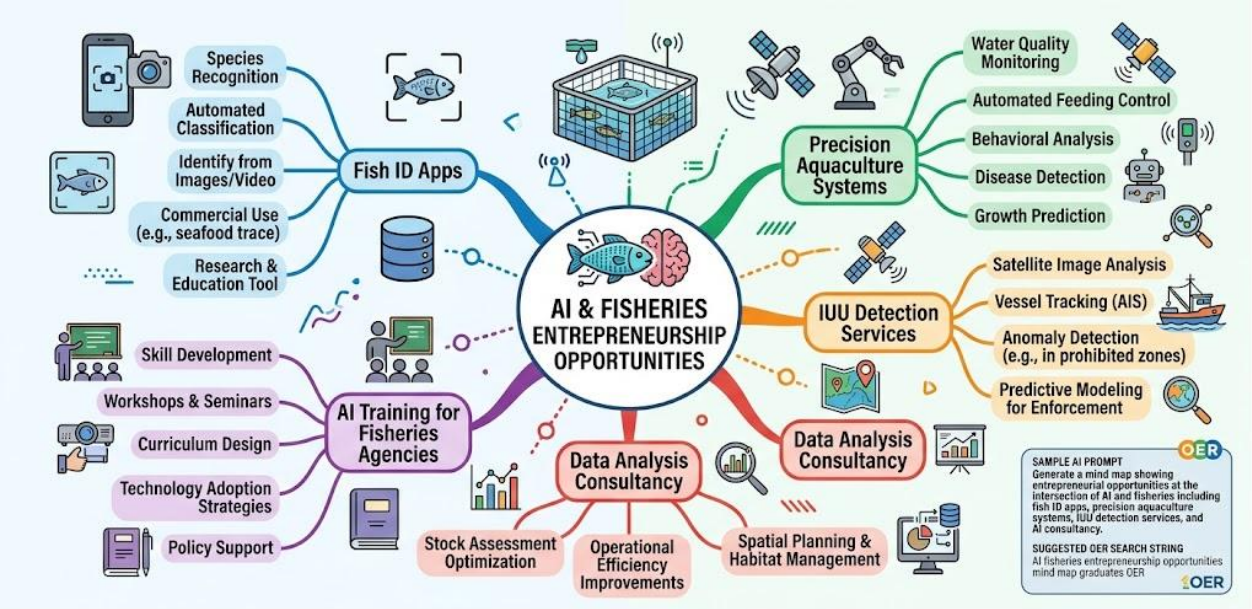

Figure 4.8

Figure 4.8: Mind map showing entrepreneurial opportunities at the intersection of AI and fisheries for fisheries graduates.

Figure 4.8: Mind map showing entrepreneurial opportunities at the intersection of AI and fisheries for fisheries graduates

Pilot questions 4.4

Name three AI tools available to fisheries professionals and state one use of each.

What is training data bias and why is it a concern in fisheries AI applications?

Explain why AI-driven management decisions in fisheries should be transparent and explainable.

Describe one AI entrepreneurial opportunity for a fisheries graduate in Nigeria.

Why is the combination of fisheries domain knowledge and AI skills particularly valuable in the Nigerian context?

Series Summary

This Series has introduced the concepts, methods, and applications of artificial intelligence and machine learning in fisheries and aquaculture. We began by defining AI, tracing its historical development from the 1956 Dartmouth Conference through the deep learning revolution of the 2010s to large language models today, and distinguishing between narrow AI, general AI, rule-based systems, machine learning, and LLMs. We then examined the fundamentals of machine learning, explaining the roles of training data, learning algorithms, and trained models, distinguishing between supervised, unsupervised, and reinforcement learning, and describing the key algorithms including decision trees, CNNs, RNNs, and NLP models with their fisheries applications.

Following that, we surveyed AI applications in fisheries and aquaculture, covering computer vision for species identification and counting, AI-powered catch monitoring and IUU detection using AIS and SAR satellite data, and precision aquaculture systems for automated feeding and disease detection. Finally, we examined the ecosystem of AI tools available to fisheries professionals including LLMs and no-code image classifiers, the ethical considerations of training data bias, transparency, and accountability, and the substantial entrepreneurial opportunities available to fisheries graduates who combine domain expertise with AI skills. 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

AIS (Automatic Identification System): a vessel transponder system that broadcasts position, speed, and identity data; used with machine learning to monitor fishing vessel behaviour and detect IUU activity.

Artificial intelligence (AI): the development of computer systems capable of performing tasks that normally require human intelligence, including image recognition, decision-making, and pattern identification in large datasets.

Bias (in AI): systematic error in an AI model caused by non-representative training data, resulting in poor performance or discriminatory outputs for under-represented groups or contexts.

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Clustering: an unsupervised machine learning technique that groups similar data points together without predefined labels; used in fisheries to identify distinct vessel behaviour patterns or habitat types.

Convolutional neural network (CNN): a deep learning architecture that learns hierarchical visual features directly from image data; the dominant approach for fish species identification, disease detection, and aquaculture monitoring.

Dark vessel: a fishing vessel that has switched off its AIS transponder to avoid monitoring; detectable by synthetic aperture radar (SAR) satellite imagery and a key indicator of potential IUU fishing.

Deep learning: a subset of machine learning using neural networks with many layers that can learn complex representations from large datasets; the technology underpinning most current practical AI applications.

General AI (strong AI): a theoretical form of AI capable of performing any intellectual task a human can perform across all domains; does not yet exist as a practical technology.

IUU fishing: illegal, unreported, and unregulated fishing; a major threat to fisheries sustainability increasingly monitored using AI-powered vessel tracking and satellite surveillance systems.

Large language model (LLM): a type of AI trained on vast amounts of text data that can generate, summarise, translate, and answer questions in natural language; examples include ChatGPT, Gemini, and Claude.

Long Short-Term Memory (LSTM): a type of recurrent neural network architecture designed to learn patterns in sequential data; used for time series prediction in fisheries such as catch forecasting.

Machine learning (ML): a subset of AI in which systems learn to perform tasks by identifying patterns in training data rather than following explicitly programmed rules.

Narrow AI (weak AI): AI that performs specific tasks within a defined domain; all current practical AI applications in fisheries are narrow AI.

Natural language processing (NLP): a branch of AI enabling computers to understand, interpret, and generate human language; used for automated fisheries report analysis, regulatory text mining, and chatbot assistants.

Overfitting: a machine learning problem where a model learns the training data too closely and performs poorly on new, unseen data; managed through cross-validation and regularisation techniques.

Precision aquaculture: the use of sensors, computer vision, and AI to monitor and optimise aquaculture operations in real time, improving feeding efficiency, water quality, and disease detection.

Random forest: an ensemble machine learning algorithm that aggregates predictions from many decision trees; used in fisheries for species classification and predicting stock status from environmental variables.

Reinforcement learning: a machine learning paradigm in which an agent learns to make decisions by receiving rewards for desirable outcomes and penalties for undesirable ones; applied to optimise feeding schedules in precision aquaculture.

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SAR (Synthetic Aperture Radar): a satellite imaging technology that can detect objects on the ocean surface regardless of cloud cover or darkness; used to identify fishing vessels that have disabled their AIS transponders.

Supervised learning: a machine learning paradigm in which a model is trained on labelled examples where the correct output is known; the most widely used approach in practical fisheries AI applications.

Teachable Machine: a free Google web tool that allows users to train custom image, sound, or pose classification models without writing any code; useful for building fish species identification models from field photographs.

Training data: the labelled or unlabelled examples used to train a machine learning model; the quality and representativeness of training data is the primary determinant of model performance and fairness.

Unsupervised learning: a machine learning paradigm that finds patterns in data without predefined labels; used in fisheries for clustering vessel behaviour and habitat classification.

Concept Check Questions [Series 4]

Objective Questions

AI was formally founded as a field at the _____ Conference in 1956. (Linked to SLO 4.2)

Machine learning systems learn from _____ data rather than from explicitly programmed rules. (Linked to SLO 4.3)

The dominant deep learning architecture for image recognition tasks is the convolutional neural _____. (Linked to SLO 4.4)

A fishing vessel that has switched off its AIS transponder is called a _____ vessel. (Linked to SLO 4.6)

Google Teachable Machine allows users to train image classification models without writing any _____. (Linked to SLO 4.8)

Short-Answer Questions

Distinguish between narrow AI and general AI and explain which type underpins current fisheries applications. (Linked to SLO 4.2)

Explain the difference between supervised and unsupervised learning with a fisheries example of each. (Linked to SLO 4.3)

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Describe how AI computer vision systems are used for fish species identification. (Linked to SLO 4.5)

Explain what training data bias means and why it is a concern in fisheries AI. (Linked to SLO 4.8)

Describe one entrepreneurial opportunity at the intersection of AI and fisheries for a Nigerian graduate. (Linked to SLO 4.9)

Long-Answer Questions

Analyse the foundations of artificial intelligence and machine learning, explaining the definition and history of AI, the distinction between AI types, and the three ML learning paradigms with fisheries examples of each. (Linked to SLOs 4.1, 4.2, 4.3)

Discuss the applications of AI in fisheries and aquaculture, explaining how computer vision is used for species identification, how AI and satellite data are combined to detect illegal fishing, and how precision aquaculture systems use AI for feeding and disease management. (Linked to SLOs 4.5, 4.6, 4.7)

Evaluate AI as an emerging opportunity for fisheries graduates, identifying the available tools, explaining the key ethical considerations, and assessing the entrepreneurial potential of combining fisheries domain knowledge with AI skills in the Nigerian context. (Linked to SLOs 4.8, 4.9)

Answers to Concept Check Questions [Series 4]

Objective Questions

Dartmouth.

Training.

Network (CNN).

Dark.

Code.

Short-Answer Questions

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Narrow AI performs specific tasks within a defined domain and cannot generalise beyond its training context; general AI would perform any intellectual task a human can perform across all domains but does not yet exist. All current practical AI applications in fisheries are narrow AI, including species identification systems, vessel behaviour classifiers, and precision aquaculture models.

Supervised learning trains a model on labelled examples with known outputs (e.g. a CNN trained on fish images labelled with species identities to classify new fish photographs). Unsupervised learning finds patterns in unlabelled data (e.g. clustering vessel tracking data to identify distinct behaviour patterns such as trawling, longlining, and drifting without pre-labelling each track).

Computer vision AI systems use CNNs trained on large annotated fish image datasets; the CNN learns visual features that distinguish species directly from pixel data; when a new image is presented, the system classifies it to the species whose training examples it most closely resembles; accuracy comparable to human experts has been achieved for common species with sufficient training data.

Training data bias occurs when the dataset used to train an AI model does not adequately represent the full range of conditions, species, or contexts in which the model will be deployed; in fisheries AI, a species classifier trained predominantly on images from one region or under one lighting condition may perform poorly and produce systematically biased classifications when deployed in different conditions, undermining the reliability of management decisions based on its outputs.

Any one with explanation: building a CNN-based fish species identification app trained on photographs of Nigerian commercial species for use at landing sites for catch composition monitoring; developing an AI-powered catfish farm management system that analyses pond sensor data to predict disease outbreaks and optimise feeding; providing machine learning data analysis services to NIOMR or state fisheries agencies for stock assessment or vessel behaviour analysis.

Long-Answer Questions

Basic response: AI is defined as computer systems performing human-intelligence tasks. Founded 1956 (Dartmouth); developed through expert systems, AI winters, and the deep learning revolution of the 2010s driven by big data, GPUs, and neural network advances. Narrow AI underpins all current fisheries applications; general AI does not exist. ML learns from training data; supervised (labelled examples, e.g. species ID), unsupervised (clustering vessel tracks), and reinforcement learning (optimising aquaculture feeding).

Value-added response: The progression from rule-based AI (VMS alerts) to machine learning (image classification, vessel behaviour) to deep learning (CNNs for visual recognition) mirrors the broader history of AI and reflects the increasing availability of fisheries data and computing power. For Nigerian fisheries, the most immediately impactful ML applications

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are those that can work with the data currently being collected: catch composition photographs, landing site surveys, and vessel tracking data from the expanding VMS system.

Basic response: Computer vision CNNs trained on annotated image datasets identify species and estimate sizes from photographs and video. Global Fishing Watch and SAR satellite ML models detect dark vessels and classify fishing behaviour. Precision aquaculture uses camera AI to optimise feeding by observing fish response, and disease detection AI identifies visual symptoms early.

Value-added response: The combination of AIS, SAR, and ML represents a paradigm shift in fisheries surveillance: effective monitoring of large ocean areas no longer requires physical patrol vessels at every location. For Nigeria, participation in these monitoring systems through NIOMR and FDF, and the development of local capacity to interpret their outputs, is essential for effective management of the Gulf of Guinea's shared marine resources and for Nigeria's credibility in international fisheries governance forums.

Basic response: Available tools include LLMs (ChatGPT, Claude), no-code image classifiers (Teachable Machine), and ML libraries (scikit-learn, TensorFlow). Ethical issues: training data bias, transparency, data privacy, accountability for AI-driven decisions, need for human oversight. Entrepreneurial opportunity: Nigerian fisheries graduates uniquely combine domain expertise with AI skills to build locally adapted solutions.

Value-added response: The ethical dimension of AI in fisheries is not abstract; it has direct governance implications. If an AI vessel classification system incorrectly flags artisanal fishers operating in traditional grounds as IUU vessels, the consequences in terms of livelihoods and community trust in management are severe. Ensuring that AI systems used in enforcement are validated on representative local data, are transparent in their decision basis, and have clear human oversight and appeal mechanisms is a governance priority that fisheries graduates with both AI and domain knowledge are uniquely qualified to address.

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Answers to Pilot Questions [Series 4]

Part 4.1: Introduction to Artificial Intelligence

Artificial intelligence refers to computer systems capable of performing tasks that normally require human intelligence such as recognising images, making decisions, and identifying patterns in data; two fisheries examples: identifying fish species from underwater video using computer vision AI; detecting illegal fishing vessel behaviour from satellite tracking data using machine learning.

Any two: availability of large digitised datasets from the internet; dramatic increases in computing power from Graphics Processing Units (GPUs) enabling parallel computation; advances in deep neural network architectures such as CNNs and LSTMs.

Narrow AI performs specific tasks within a defined domain and cannot generalise beyond it; general AI would perform any intellectual task a human can across all domains. All current practical AI systems including those in fisheries are narrow AI; general AI does not yet exist.

Any one: a VMS alert system that fires an alarm when a vessel enters a defined closed area based on GPS coordinates and predefined boundary rules.

A large language model is an AI trained on vast text data that can generate, summarise, and answer questions in natural language; in fisheries management it could be used to automatically draft stock assessment summaries, answer regulatory queries from fishers in natural language, or assist in reviewing and summarising scientific literature.

Part 4.2: Machine Learning Fundamentals

Machine learning is a subset of AI in which systems learn to perform tasks by identifying patterns in training data rather than following explicitly programmed rules; in rule-based programming the developer writes specific conditions for every decision, while in ML the model discovers the relevant patterns and decision boundaries automatically from examples.

Overfitting occurs when a model learns the specific details and noise of its training data too closely, achieving high accuracy on training examples but performing poorly on new, unseen data because it has not learnt generalisable patterns; it is a problem because a fisheries AI deployed in real conditions will encounter examples different from those in training, and an overfitted model will make unreliable predictions.

Supervised learning trains on labelled examples with known outputs (example: CNN trained on fish images with species labels to classify new photographs). Unsupervised learning finds patterns in unlabelled data (example: clustering vessel AIS tracking data to identify distinct fishing behaviour patterns without pre-specifying what the patterns are).

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Convolutional neural networks are deep learning models that learn hierarchical visual features directly from image pixel data through successive convolutional layers that detect increasingly complex patterns; they are suited to fish species identification because species identity is encoded in visual features (shape, colour, fin morphology) that CNNs can learn from labelled training images without requiring manual feature extraction.

RNNs and LSTMs process sequential data in which past values influence predictions of future values; a fisheries application is time series forecasting of catch or environmental variables such as sea surface temperature, where the model learns temporal patterns from historical sequences to predict future values.

Part 4.3: AI Applications in Fisheries and Aquaculture

Computer vision AI systems deploy cameras at fish passes, sorting conveyors, or on fishing vessels; images are analysed by CNN models trained on annotated fish image databases to classify individual fish by species and in some cases estimate body length from image dimensions; the systems can operate continuously without fatigue and process high volumes of fish more consistently than human observers.

A dark vessel is a fishing vessel that has disabled its AIS transponder to avoid monitoring; SAR satellites use radar imaging to detect the physical presence of vessels on the ocean surface regardless of AIS status or cloud cover; ML models trained on SAR imagery can identify and classify vessel types from their radar signatures, enabling detection of dark vessels that are likely engaged in IUU fishing.

Camera systems mounted above feeding stations observe fish swimming and feeding behaviour in real time; CNN models classify whether fish are actively responding to pellets or have stopped feeding; when the AI detects that fish have ceased responding, it stops the automatic feed dispenser, preventing uneaten pellets from accumulating and deteriorating water quality; this matches feed delivery to actual appetite rather than a fixed schedule, improving FCR.

AI disease detection systems use cameras positioned above or within fish tanks to capture regular images of fish; CNN models trained on images of healthy and diseased fish analyse each image for early visual indicators of disease including skin lesions, haemorrhage, abnormal swimming posture, or clustering behaviour; when disease indicators are detected, an alert is sent to the farm manager for investigation and treatment.

Any one: AquaManager; iFarm; Observe Technologies (uses AI video analysis for salmon feeding optimisation); XperSea (uses ML for fish counting and biomass estimation).

Part 4.4: AI as an Emerging Opportunity

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Any three: ChatGPT or Claude LLM (draft fisheries reports, summarise papers, generate analysis code); Google Teachable Machine (train custom image classifiers from field photographs without coding); scikit-learn Python library (build supervised ML models for species classification or stock status prediction); TensorFlow or PyTorch (build and train deep learning models for image recognition); Global Fishing Watch (monitor fishing vessel activity using satellite AIS and ML).

Training data bias occurs when the dataset used to train an AI model does not adequately represent the full range of conditions or groups it will encounter in deployment; in fisheries AI it is a concern because a species classifier or vessel behaviour model trained on data from one geographic region or fishing fleet may produce systematically incorrect outputs when deployed in a different context, potentially leading to biased enforcement or management decisions.

AI-driven decisions in fisheries management have direct legal and economic consequences for fishers and fishing companies; if a vessel is flagged as engaging in IUU fishing or if a quota is set based on an AI stock assessment, the basis for that decision must be interpretable so that management authorities can explain it, fishers can challenge it, and errors can be identified and corrected; opaque AI black-box decisions cannot be held accountable.

Any one with explanation: building a CNN fish species identification app trained on photographs of key Nigerian commercial species (croakers, tilapia, catfish, sardinella) for use by landing site enumerators to improve the accuracy and speed of species composition recording in national catch statistics; revenue from app subscriptions to state fisheries agencies or NGOs conducting monitoring programmes.

Most AI tools developed globally are trained on data from other regions and species contexts and perform poorly on Nigerian fish species and fishing conditions without local adaptation; there is insufficient locally trained AI talent with fisheries domain knowledge; a Nigerian fisheries graduate who understands both the biological context and the AI methodology can bridge this gap, building and adapting AI solutions that are calibrated to local species, fishing patterns, and data conditions in ways that neither pure engineers nor traditional fisheries managers can.

References and Attributions [Series 4]

Textual References (Books and External Sources)

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Zhao, Z. Q., Zheng, P., Xu, S. T., & Wu, X. (2019). Object detection with deep learning: A review. IEEE Transactions on Neural Networks and Learning Systems, 30(11), 3212-3232.

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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 4.1: AI, machine learning, and deep learning nested diagram Attribution: AI generated using prompt "Generate a nested circle diagram showing artificial intelligence as the outermost ring, machine learning within it, and deep learning at the centre with fisheries application examples." Suggested OER search string: "AI machine learning deep learning nested diagram fisheries applications OER".

Figure 4.2: AI development milestones timeline Attribution: AI generated using prompt "Generate a horizontal timeline showing key AI milestones from the Dartmouth Conference in 1956 through expert systems, the deep learning revolution, and large language models." Suggested OER search string: "AI development milestones timeline 1956 deep learning OER diagram".

Box 4.1: Types of AI and their fisheries applications Attribution: AI generated using prompt "Generate a text box listing types of AI including narrow AI, general AI, rule-based systems, machine learning, and LLMs with fisheries examples." Suggested OER search string: "types of AI narrow general rule-based machine learning LLM fisheries OER".

Figure 4.3: Machine learning system components flowchart Attribution: AI generated using prompt "Generate a flowchart showing training data feeding into a learning algorithm to produce a trained model that makes predictions on new inputs." Suggested OER search string: "machine learning components training data algorithm model prediction OER diagram".

Figure 4.4: Supervised, unsupervised, and reinforcement learning comparison Attribution: AI generated using prompt "Generate a three-panel diagram comparing supervised, unsupervised, and reinforcement learning with a fisheries example of each." Suggested OER search string: "supervised unsupervised reinforcement learning fisheries examples OER diagram".

Table 4.1: Machine learning algorithms and fisheries applications Attribution: AI generated using prompt "Generate a table listing machine learning algorithms including decision

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trees, random forests, CNNs, RNNs, and NLP models with fisheries application examples." Suggested OER search string: "machine learning algorithms fisheries applications table OER".

Plate 4.1: Underwater camera AI system at a fish pass Attribution: AI generated using prompt "Generate an image showing an underwater camera system at a fish pass with fish visible illustrating AI species identification and counting." Suggested OER search string: "underwater camera AI fish species identification counting fish pass OER image".

Figure 4.5: AIS, SAR, and ML for illegal fishing detection Attribution: AI generated using prompt "Generate a diagram showing how AIS tracking data and SAR satellite imagery are combined with a machine learning model to detect illegal fishing." Suggested OER search string: "AIS SAR satellite machine learning illegal fishing detection diagram OER".

Figure 4.6: AI precision aquaculture monitoring system Attribution: AI generated using prompt "Generate a diagram showing an AI-powered aquaculture system with cameras connected to a computer vision model controlling feeders and sending disease alerts." Suggested OER search string: "AI precision aquaculture feeding disease detection system diagram OER".

Figure 4.7: AI tools spectrum for fisheries professionals Attribution: AI generated using prompt "Generate a diagram showing the spectrum of AI tools for fisheries professionals from no-code tools through LLMs to professional machine learning libraries." Suggested OER search string: "AI tools fisheries professionals no-code LLM machine learning libraries OER diagram".

Box 4.2: Ethical considerations in AI for fisheries management Attribution: AI generated using prompt "Generate a text box listing ethical considerations in using AI for fisheries management including bias, transparency, data privacy, accountability, and human oversight." Suggested OER search string: "ethical considerations AI fisheries management bias transparency accountability OER".

Figure 4.8: AI-fisheries entrepreneurship mind map Attribution: AI generated using prompt "Generate a mind map showing entrepreneurial opportunities at the intersection of AI and fisheries including fish ID apps, precision aquaculture systems, IUU detection, and AI consultancy." Suggested OER search string: "AI fisheries entrepreneurship opportunities mind map graduates OER".

Course code: FAA 410

Course title: Information and Communications Technologies in Fisheries and Aquaculture

Course credit load: 2 Units

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Series 5: Value Chain Concepts, Methodologies, and Analysis in Fisheries and Aquaculture

Part 5.1: Introduction to Value Chain Concepts

Sub Part 5.1.1: Definition and scope of value chains

Sub Part 5.1.2: Types of value chains in fisheries and aquaculture

Sub Part 5.1.3: Importance of value chains to small-scale fisheries and aquaculture

Part 5.2: Value Chain Methodologies

Sub Part 5.2.1: Overview of value chain methodologies

Sub Part 5.2.2: Sustainable value chain methodology

Sub Part 5.2.3: Value chain mapping

Part 5.3: Data Collection and Value Chain Analysis

Sub Part 5.3.1: Quantitative methods in data gathering for value chain analysis

Sub Part 5.3.2: Functional and economic analysis of value chains

Sub Part 5.3.3: Environmental and social dimensions of value chain analysis

Part 5.4: Value Chain Development and Sustainable Pathways

Sub Part 5.4.1: Upgrading strategies in fisheries value chains

Sub Part 5.4.2: Sustainable pathways in value chain development

Sub Part 5.4.3: Value chain development for small-scale fisheries and aquaculture in Nigeria

Introduction

Value chain analysis has become one of the most important frameworks for understanding how fish and aquaculture products move from producers to consumers, who captures value at each stage, and where interventions are most likely to improve livelihoods, sustainability, and food security. Whether working in research, government, development, or the private sector, fisheries professionals are increasingly expected to understand and apply value chain concepts and analytical tools. This Series provides that foundation.

The aim of this Series is to equip you with a thorough understanding of value chain concepts, the principal methodologies used to study them, the quantitative and qualitative data collection and analysis methods employed, and the development strategies and sustainable pathways that can improve fisheries and aquaculture value chains in Nigeria and beyond.

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We shall commence this Series by defining value chains and examining their types and importance to small-scale fisheries. Next, we will study value chain methodologies including the sustainable value chain approach and value chain mapping. Following that, we will cover data collection methods and functional, economic, environmental, and social analysis. Finally, we will wrap up with upgrading strategies, sustainable pathways, and the Nigerian context.

Series Learning Outcomes

Upon completing this Series, you should be able to:

SLO 5.1 define value chain and explain its scope in fisheries and aquaculture (Linked to Part 5.1),

SLO 5.2 identify the types of value chains in fisheries and aquaculture and explain their characteristics (Linked to Part 5.1),

SLO 5.3 explain the importance of value chain development to small-scale fisheries and aquaculture sectors (Linked to Part 5.1),

SLO 5.4 describe the main value chain methodologies and compare their approaches (Linked to Part 5.2),

SLO 5.5 explain the sustainable value chain methodology and describe how it is applied (Linked to Part 5.2),

SLO 5.6 construct a value chain map for a fisheries or aquaculture product (Linked to Part 5.2),

SLO 5.7 describe quantitative data collection methods used in value chain analysis (Linked to Part 5.3),

SLO 5.8 conduct a functional and economic analysis of a fisheries value chain (Linked to Part 5.3), and

SLO 5.9 explain upgrading strategies and sustainable development pathways for fisheries value chains (Linked to Part 5.4).

5.1 Introduction to Value Chain Concepts

5.1.1 Definition and scope of value chains

A value chain describes the full sequence of activities through which a product passes from its origin to its final consumer, with value being added at each stage. In fisheries, the value chain begins at the point of capture or harvest, moves through handling, processing, and storage, continues through wholesale and retail distribution, and ends at the final consumer. At each node

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in the chain, actors perform functions, incur costs, and earn margins; the difference between cost and selling price at each stage is the value added by that actor.

The scope of value chain analysis extends beyond the physical flow of the product to encompass the flow of information and the governance structures that coordinate actors along the chain. Value chain analysis was popularised by Michael Porter in the 1980s and adapted for agri-food systems by FAO and the World Bank as a tool for identifying constraints to competitiveness, upgrading opportunities, and the distribution of benefits among chain actors. In fisheries and aquaculture, it provides a systems-level perspective on how the sector functions and where interventions can create the most impact.

Fill in the blank: A value chain describes the full sequence of activities through which a product passes from origin to final _____, with value being added at each stage.

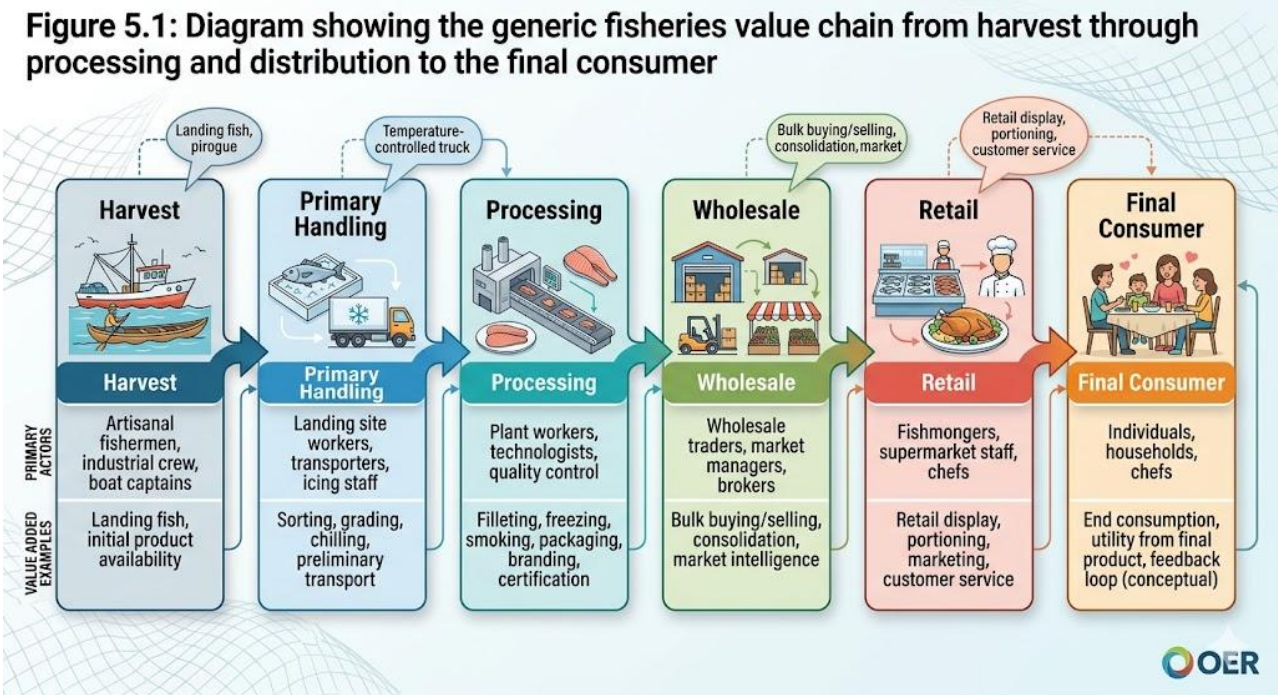

Figure 5.1: Diagram showing the generic fisheries value chain from harvest through processing and distribution to the final consumer

5.1.2 Types of value chains in fisheries and aquaculture

Value chains in fisheries and aquaculture vary in their length, governance structure, and the actors involved. **Short value chains** involve few intermediaries between producer and consumer; a fish farmer selling directly at a market or to a hotel is operating in a short chain. **Long value chains** involve multiple intermediaries including collectors, processors, wholesalers, and retailers and are typical of fish sold to distant urban markets or exported. Short chains generally allow producers to capture a larger share of the final consumer price.

Value chains can also be classified by governance structure. In buyer-driven chains, powerful buyers such as supermarkets or export companies set product standards and exert control over suppliers. In producer-driven chains, processors or cooperatives control quality and branding. In fragmented artisanal chains, no single actor exerts overall coordination and standards are set by local custom. Understanding chain type determines what upgrading strategies are feasible and who the key stakeholders for intervention are.

Fill in the blank: In buyer-_____ value chains, powerful buyers such as supermarkets set quality standards and exert control over upstream suppliers throughout the chain.

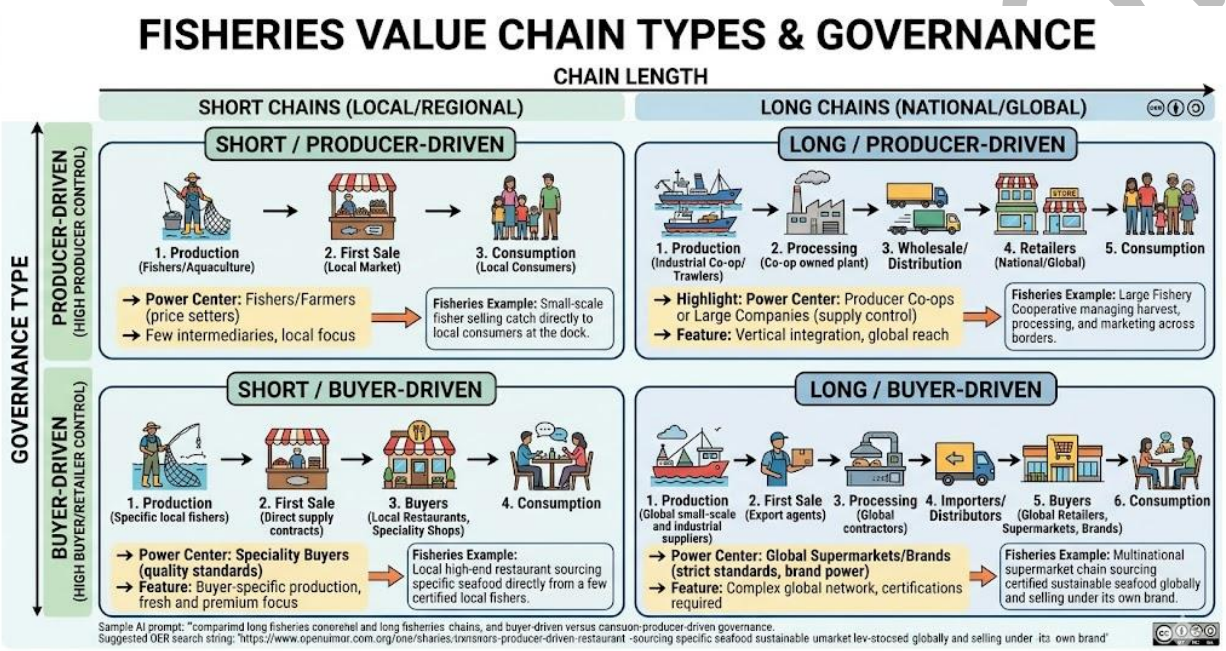

Figure 5.2: Diagram comparing short and long fisheries value chains and buyer-driven versus producer-driven governance

Figure 5.2: Diagram comparing short and long fisheries value chains and buyer-driven versus producer-driven governance

5.1.3 Importance of value chains to small-scale fisheries and aquaculture

Small-scale fisheries and aquaculture producers are often in a weak bargaining position within value chains because they are numerous, geographically dispersed, produce perishable products under time pressure, and lack market information. This creates conditions in which intermediaries capture a disproportionate share of the consumer price while producers receive low and unstable margins. Value chain analysis helps identify where these power imbalances occur and what structural interventions can improve the economic position of small-scale producers.

Value chain development targeted at small-scale producers can improve incomes by reducing post-harvest losses, improving product quality and market access, building collective action through cooperatives or associations, and strengthening links to better-paying market segments.

The FAO Sustainable Value Chain framework explicitly prioritises the integration of small-scale producers into chains that deliver economic, social, and environmental benefits. In Nigeria, where artisanal fisheries provide livelihoods for millions of people, improving value chain performance is a critical development priority linked directly to food security and poverty reduction.

Fill in the blank: Small-scale fishers and fish farmers are often in a weak bargaining position because they are numerous, dispersed, and produce _____ products under time pressure.

Plate 5.1: Women fish processors adding value to artisanal catch through smoking at a small-scale processing site in Nigeria

Pilot questions 5.1

Define value chain and describe the stages of a typical fisheries value chain.

Distinguish between short and long value chains in fisheries.

What is a buyer-driven value chain and how does it affect fish producers?

Explain two reasons why small-scale fish producers are in a weak bargaining position in value chains.

How can value chain development improve the economic position of small-scale fish farmers?

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5.2 Value Chain Methodologies

5.2.1 Overview of value chain methodologies

Several methodological frameworks have been developed for analysing fisheries and agri-food value chains, each with a different analytical focus. The **Porter value chain analysis** focuses on firm-level activities and competitive advantage. The **filière (commodity chain) approach** traces product flows and margins along the chain. The **global value chain (GVC) framework** analyses how chains are governed by lead firms and how developing-country producers can upgrade within them. The **sustainable livelihood approach** examines how households use assets to participate in chains.

FAO and its partners have synthesised these approaches into an operational framework for fisheries and aquaculture value chain analysis that combines economic analysis of margins with assessment of social inclusion, environmental impacts, and governance structures. This integrated approach is increasingly the standard for development-oriented value chain studies in the fisheries sector. Choosing the most appropriate methodology depends on the research question, the resources available, and the intended use of the findings, whether for academic research, policy advice, or project design.

Fill in the blank: The global value _____ (GVC) framework analyses how chains are governed by lead firms and how developing-country producers can upgrade their position.

Methodology	Focus	Unit of Analysis	Fisheries Application
Porter's Value Chain	Internal firm activities and competitive advantage.	Individual firm or enterprise.	Assessing efficiency of fish processing companies and identifying cost-reduction strategies.
Filière Approach	Sequential stages of production and distribution.	Entire commodity chain.	Mapping the flow of fish from capture to consumer in Nigerian markets.
Global Value Chain (GVC)	Governance structures, upgrading opportunities, and global linkages.	International production and trade networks.	Analyzing Nigeria's role in global shrimp exports and identifying upgrading opportunities.
Sustainable Livelihood Framework	Household assets, vulnerability, and livelihood strategies.	Fishing households and communities.	Evaluating how small-scale fishers adapt to shocks (e.g., climate change, market volatility).
FAO Integrated Framework	Holistic view combining economic, social, and environmental dimensions.	Sector-wide, including stakeholders and ecosystems.	Designing policies for sustainable aquaculture development balancing productivity and conservation.

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Table 5.1: Comparison of major value chain methodologies and their analytical focus

5.2.2 Sustainable value chain methodology

The FAO Sustainable Value Chain (SVC) framework is a comprehensive approach designed to assess and develop value chains with the simultaneous goals of economic competitiveness, social inclusion, and environmental sustainability. It defines a sustainable value chain as one in which actors systematically collaborate to achieve long-term social, economic, and environmental goals. The SVC framework is structured around four pillars: economic analysis (costs, margins, competitiveness), social analysis (livelihoods, inclusion, equity), environmental analysis (resource use, emissions, ecosystem impacts), and governance analysis (coordination, standards, power relations).

Applying the SVC methodology involves mapping the chain structure, collecting quantitative and qualitative data from actors at each node, calculating value added and margin distribution, assessing social and environmental performance indicators, and identifying constraints and upgrading opportunities. The methodology is participatory, involving chain actors in the analysis and development of upgrading strategies so that interventions are contextually appropriate and have stakeholder buy-in. In Nigerian fisheries, the SVC approach has been applied to catfish, tilapia, and artisanal marine fisheries value chains in government and donor-funded development projects.

Fill in the blank: The FAO Sustainable Value Chain framework is structured around four pillars: economic, _____, environmental, and governance analysis.

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Figure 5.3: Diagram showing the four pillars of the FAO Sustainable Value Chain framework with example indicators

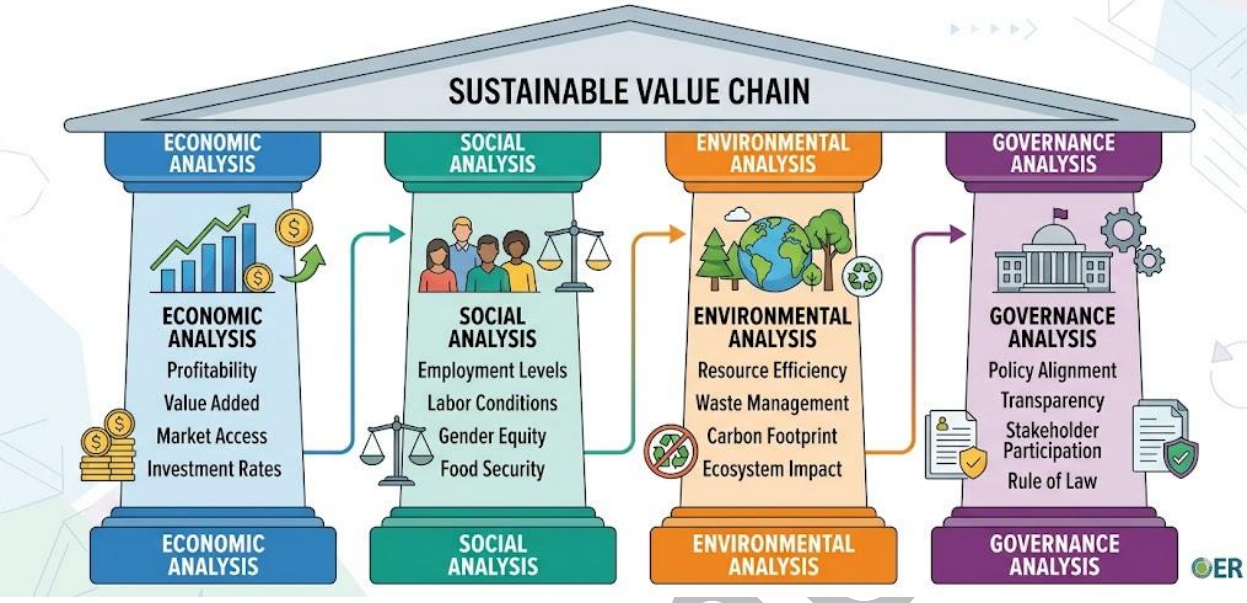

Figure 5.3: Diagram showing the four pillars of the FAO Sustainable Value Chain framework with example indicators

5.2.3 Value chain mapping

Value chain mapping is the graphical representation of a value chain, showing the actors at each node, the product and information flows between them, and the supporting services and enabling environment that shape chain performance. A well-constructed value chain map allows analysts and stakeholders to see the chain as a whole system, identify where actors are concentrated or dispersed, locate bottlenecks and gaps, and pinpoint where interventions would have the most leverage. Mapping is typically the first analytical step in any value chain study.

A fisheries value chain map typically includes: the input supply node (feeds, seed, gear, boats), the production node (farms or fishing vessels), the aggregation or landing node (landing sites, collection points), the processing node (primary and secondary), the distribution and wholesale node, and the retail and consumer node. Supporting service providers (credit, transport, extension, cold chain) and the enabling environment (regulations, infrastructure, research) are shown in separate bands above and below the main chain. Maps are constructed through literature review, key informant interviews, and participatory workshops.

Fill in the blank: Value chain _____ is the graphical representation of chain actors, flows, and supporting services that allows the chain to be understood as a whole system.

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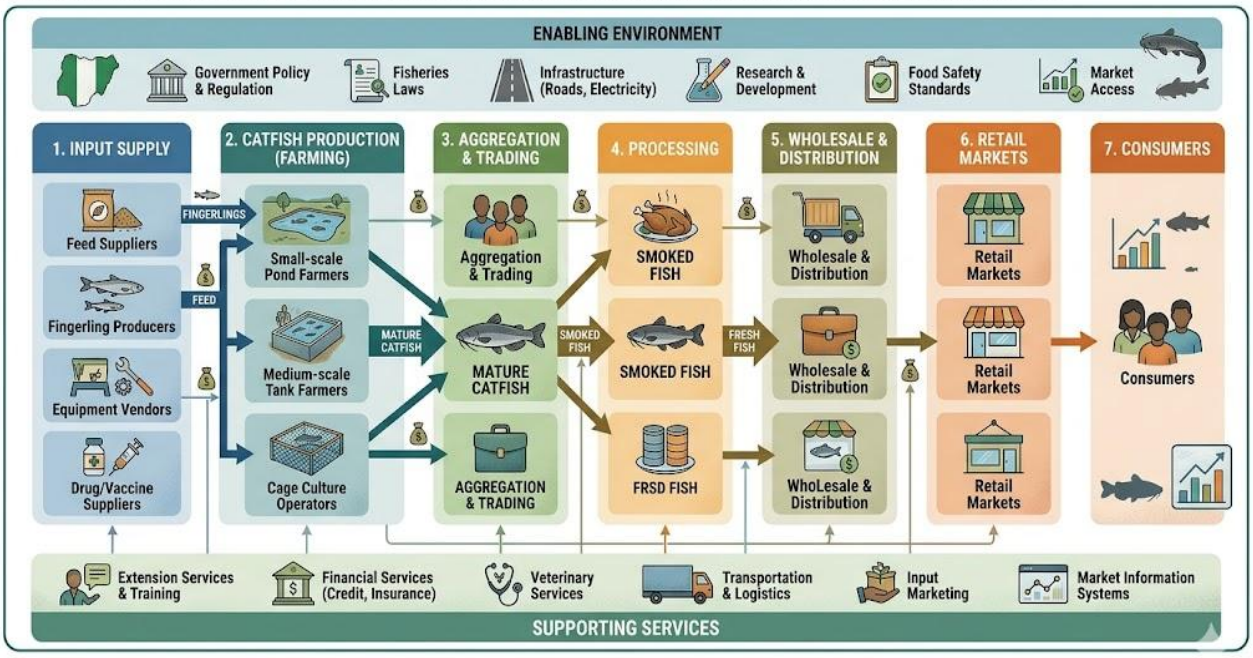
Figure 5.4: Value chain map for the Nigerian catfish value chain showing actors, flows, and supporting services.



Sample AI prompt: "Generate a value chain map for the Nigerian catfish value chain showing nodes from input supply through production, processing, wholesale, and retail with supporting services."
Suggested OER search string: "Nigerian catfish value chain map actors flows supporting services OER".

Figure 5.4: Value chain map for the Nigerian catfish value chain showing actors, flows, and supporting services

Pilot questions 5.2

Name three value chain methodologies and state the main focus of each.

Describe the four pillars of the FAO Sustainable Value Chain framework.

Why is the SVC methodology described as participatory?

Define value chain mapping and explain its purpose.

List the main nodes typically shown in a fisheries value chain map.

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5.3 Data Collection and Value Chain Analysis

5.3.1 Quantitative methods in data gathering for value chain analysis

Quantitative data collection in value chain analysis aims to measure the volumes, prices, costs, and margins at each node of the chain, enabling calculation of value added, margin distribution, and economic efficiency. Key instruments include structured questionnaires administered to chain actors (fishers, processors, traders, retailers) covering production volumes, input costs, purchase and selling prices, labour costs, and transport costs. Stratified random sampling ensures that the diversity of actor types and locations is represented.

Secondary data complement primary surveys: national fisheries statistics provide sector-level volume and value data, market price monitoring systems provide price time series, and published studies provide benchmarks. Post-harvest loss data are collected through direct weighing, observation, and recall surveys at key chain stages. In Nigerian value chain studies, market surveys at major landing sites and fish markets in Lagos, Onitsha, and Maiduguri provide price and volume data combined with farm-level production cost surveys to construct margin analyses across the full chain.

Fill in the blank: Stratified random _____ is used in value chain surveys to ensure that the diversity of actor types and locations in the chain is adequately represented.

Method	Description / Purpose
Structured questionnaires	Standardized surveys used to collect quantitative data from fishers, traders, and processors.
Market price surveys	Regular monitoring of fish prices across markets to track value chain dynamics.
Key informant interviews	In-depth discussions with knowledgeable stakeholders (e.g., fisheries officers, traders) to gain insights.
Focus group discussions	Group-based participatory sessions to explore perceptions, challenges, and opportunities.
Direct observation	On-site monitoring of fishing, processing, and marketing practices to validate reported data.

Box 5.1: Data collection methods used in fisheries value chain analysis

5.3.2 Functional and economic analysis of value chains

Functional analysis identifies the activities performed by actors at each chain node and determines who performs each function, how efficiently they do so, and what constraints they face. Functions in a fisheries value chain include production, sorting and grading, primary processing, packaging, transport, storage, wholesale trading, and retailing. Functional analysis often reveals that some functions are missing, poorly performed, or duplicated, pointing to efficiency gains from restructuring or the introduction of new services.

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Economic analysis calculates the value added, gross margins, and net margins at each chain node, revealing where economic surplus is generated and how it is distributed. Margin analysis compares the share of the final consumer price retained by each actor: in efficient chains farmers or fishers retain a substantial share; in poorly functioning chains intermediaries capture most of the margin. Budget analysis at the enterprise level calculates profitability per unit of product for each actor type, revealing the economic incentives and constraints facing different actors.

Fill in the blank: Margin analysis compares the share of the final _____ price retained by each chain actor, revealing where economic surplus is concentrated in the chain.

Figure 5.5: Stacked bar chart showing margin distribution along the Nigerian smoked catfish value chain from producer to consumer

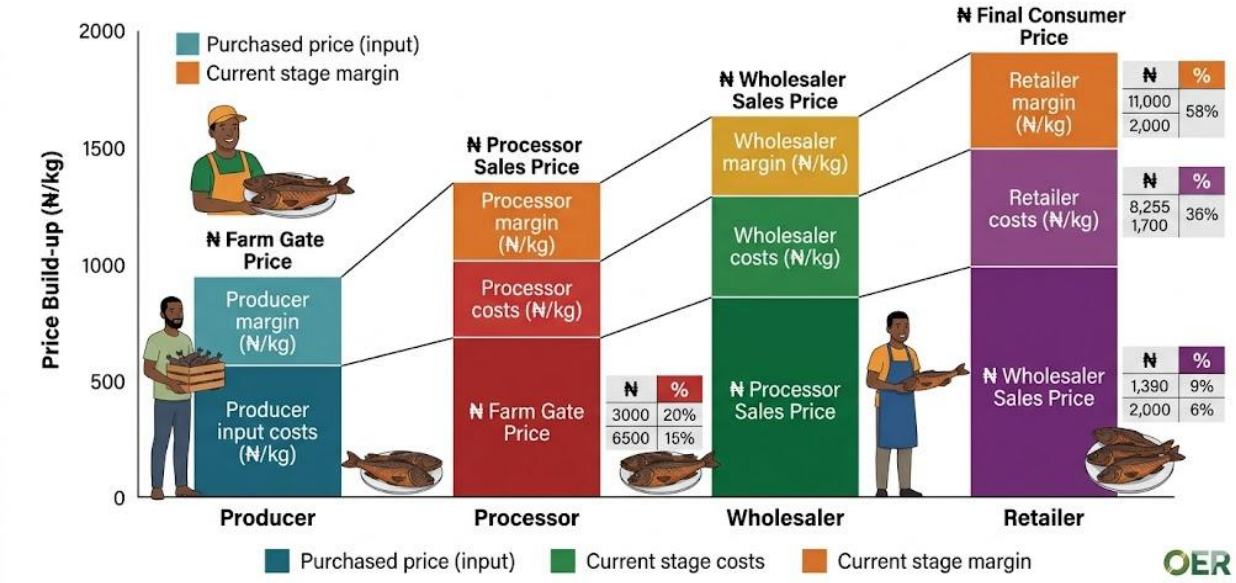


Figure 5.5: Stacked bar chart showing margin distribution along the Nigerian smoked catfish value chain from producer to consumer

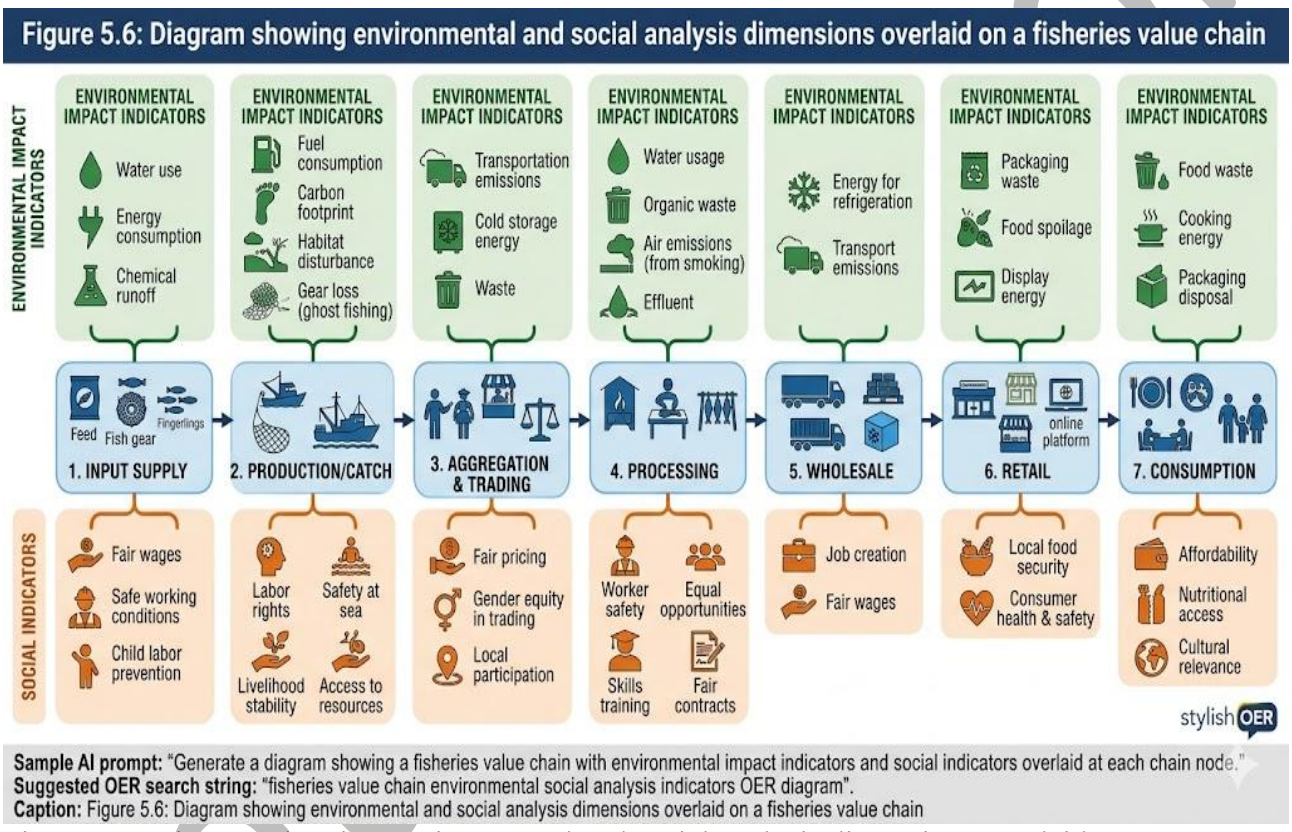
5.3.3 Environmental and social dimensions of value chain analysis

Environmental analysis within the SVC framework assesses the ecological footprint of chain activities, identifying where resource use, pollution, and emissions are concentrated. In fisheries, key environmental concerns include the energy intensity of fishing and processing operations (fuel use in motorised fishing and smoking kilns), post-harvest waste generation, water use and effluent discharge in processing, and the sustainability of input supply chains (particularly fishmeal and fish oil in aquaculture feeds).

Social analysis examines who participates in the chain, how benefits and burdens are distributed across gender, age, and socioeconomic groups, and whether the chain contributes to food security and decent work. In Nigerian fisheries, women dominate fish processing and trading but

are often excluded from access to credit, cold storage, and formal market contracts. Social analysis explicitly maps gender roles and power relations, identifies barriers to women's advancement, and informs equity interventions. Together, economic, environmental, and social analysis provide the evidence base for designing upgrading strategies that are effective and equitable.

Fill in the blank: Social analysis of value chains maps gender roles and _____ relations within the chain, identifying barriers to women's advancement and informing equity interventions.



Sample AI prompt: "Generate a diagram showing a fisheries value chain with environmental impact indicators and social indicators overlaid at each chain node."
Suggested OER search string: "fisheries value chain environmental social analysis indicators OER diagram".
Caption: Figure 5.6: Diagram showing environmental and social analysis dimensions overlaid on a fisheries value chain

Figure 5.6: Diagram showing environmental and social analysis dimensions overlaid on a fisheries value chain

Pilot questions 5.3

State three types of quantitative data collected in a fisheries value chain survey.

Explain what functional analysis of a value chain involves.

Describe what margin analysis shows and why it is important for small-scale fishers.

Name two environmental concerns assessed in fisheries value chain analysis.

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Explain why social analysis of fisheries value chains pays particular attention to gender.

5.4 Value Chain Development and Sustainable Pathways

5.4.1 Upgrading strategies in fisheries value chains

Value chain upgrading refers to the process by which actors improve their competitive position and increase the value they capture. Four main types are recognised. **Process upgrading** improves the efficiency of existing activities, such as adopting improved smoking kilns to reduce fuel use and improve product quality. **Product upgrading** moves to higher-value products, such as shifting from fresh fish to packaged smoked fish or fish cakes.

Functional upgrading involves taking on new chain functions, such as a fisher cooperative moving into direct processing and marketing to capture intermediary margins. **Chain upgrading** involves moving from one chain to a higher-value chain, such as achieving certification for export to premium international markets. For small-scale fisheries in Nigeria, process and product upgrading are the most immediately accessible entry points, while functional upgrading through cooperative action offers significant medium-term potential for increasing producer income shares.

Fill in the blank: _____ upgrading involves moving to higher-value products, such as shifting from fresh fish sales to packaged value-added processed fish products.

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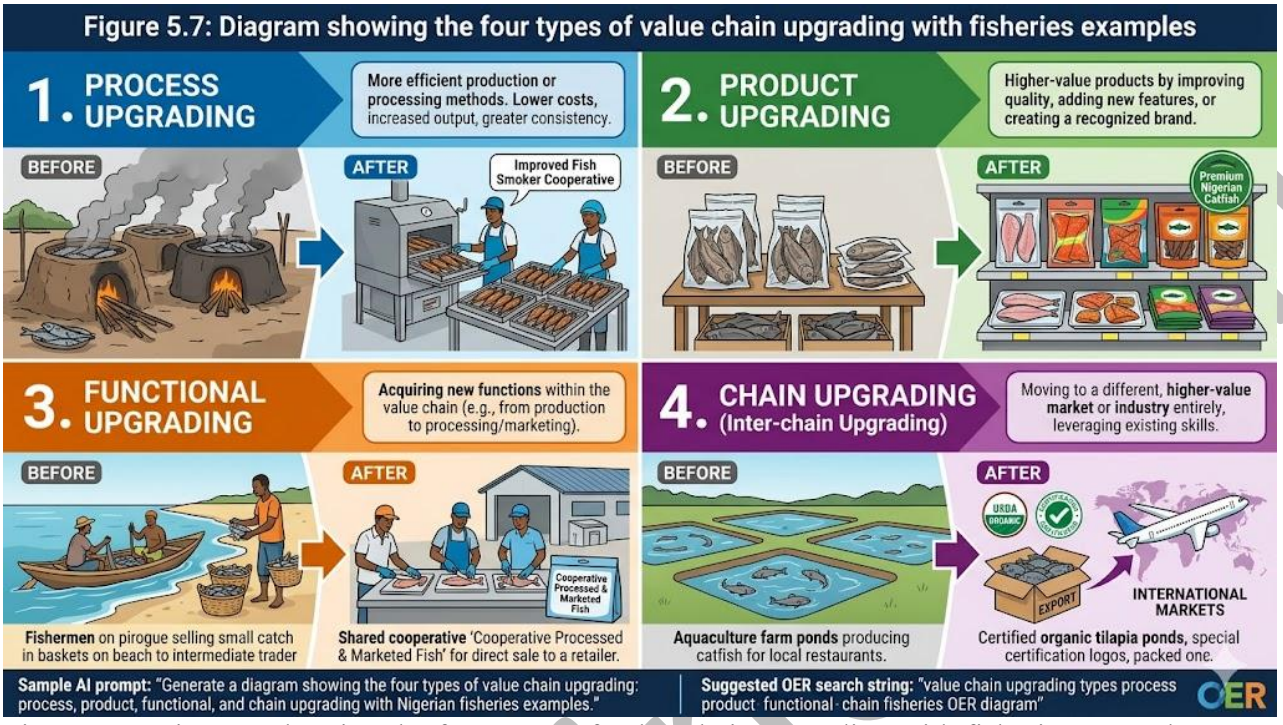

Figure 5.7: Diagram showing the four types of value chain upgrading with fisheries examples

5.4.2 Sustainable pathways in value chain development

Sustainable value chain development seeks pathways that improve economic performance while protecting the environment and enhancing social equity. In fisheries, this means developing value chains that reward sustainable fishing and aquaculture practices, reduce post-harvest losses and waste, improve food safety and quality, ensure fair wages and safe working conditions, and maintain the ecological integrity of the aquatic systems on which the chain depends.

Specific sustainable pathway interventions include linking fishers to certification schemes such as the Marine Stewardship Council (MSC) and Aquaculture Stewardship Council (ASC) that unlock access to premium markets; investing in cold chain infrastructure to reduce post-harvest losses; developing fisheries traceability systems using ICT tools to verify product origin and sustainability claims; and supporting women fish processors to access improved processing technologies and formal finance. These pathways are most effective when they address multiple sustainability pillars simultaneously rather than optimising along a single dimension.

Fill in the blank: The Marine Stewardship _____ (MSC) and Aquaculture Stewardship Council (ASC) are certification schemes that link fisheries producers to premium market segments.

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Figure 5.8: Venn diagram showing sustainable pathway interventions across economic, environmental, and social dimensions of fisheries value chains
Sample AI prompt: "Generate a Venn diagram showing overlapping economic, environmental, and social sustainability zones with sustainable pathway interventions for fisheries value chains."
Suggested OER search string: "fisheries value chain sustainable pathways Venn diagram economic social environmental OER".

Figure 5.8: Venn diagram showing sustainable pathway interventions across economic, environmental, and social dimensions of fisheries value chains

5.4.3 Value chain development for small-scale fisheries and aquaculture in Nigeria

Nigeria's fisheries and aquaculture value chains face several cross-cutting development challenges: high post-harvest losses estimated at 20 to 40 per cent of artisanal catch due to inadequate ice supply, poor handling, and limited cold storage; fragmented market systems with poor price transparency; limited access to formal finance for small-scale producers and processors; inadequate processing and storage infrastructure at rural landing sites; and weak sanitary and phytosanitary (SPS) compliance that restricts access to premium export markets.

Priority development interventions identified in national fisheries strategy documents include investment in ice plants and cold storage at major landing sites, support for women fish processor cooperatives to access improved smoking kilns and working capital, development of a national fish quality and traceability system linked to the FDF licensing framework, promotion of aquaculture intensification to increase domestic supply, and capacity building in value chain analysis skills for fisheries officers. The skills developed in this Series directly support the latter objective and position fisheries graduates to contribute to evidence-based value chain development across the sector.

Fill in the blank: Post-harvest losses in Nigerian artisanal fisheries are estimated at 20 to _____ per cent of the catch, largely due to inadequate ice supply, poor handling, and limited cold storage.

Figure 5.9: Diagram showing the priority value chain development interventions for Nigerian fisheries and aquaculture

Pilot questions 5.4

Name and briefly describe the four types of value chain upgrading.

Give one example of process upgrading in Nigerian artisanal fish processing.

What is functional upgrading and how can a fisher cooperative achieve it?

Name two certification schemes that link fisheries producers to premium sustainable markets.

State two priority value chain development interventions identified for Nigerian fisheries.

Series Summary

This final Series has introduced the concepts, methodologies, analytical tools, and development strategies of value chain analysis as applied to fisheries and aquaculture. We began by defining

value chains and explaining their scope, distinguishing between short and long chains and buyer-driven versus producer-driven governance structures, and explaining why value chain development is particularly important for small-scale fisheries and aquaculture producers in Nigeria. We then examined the principal methodologies including the filière and GVC approaches and the FAO Sustainable Value Chain framework with its four pillars of economic, social, environmental, and governance analysis, and described value chain mapping as the starting point for analysis.

Following that, we covered data collection and analysis methods including quantitative surveys, functional analysis, economic margin analysis, and environmental and social chain assessment with a focus on gender equity. Finally, we examined the four upgrading strategies, sustainable development pathways including cold chain investment, certification, and traceability, and the priority interventions needed for Nigerian fisheries value chain development. By completing this Series and the course as a whole, you should now be able to achieve all nine Series Learning Outcomes (SLO 5.1 to SLO 5.9) and the nine course learning outcomes.

Glossary of Terms

Aquaculture Stewardship Council (ASC): an international certification scheme for responsible aquaculture that verifies environmental and social compliance, enabling producers to access premium markets.

Buyer-driven value chain: a chain governance structure in which powerful buyers such as supermarkets or export companies set product standards and exert control over upstream suppliers.

Chain upgrading: a type of value chain upgrading in which producers move from participation in one chain to a higher-value chain, such as achieving export certification.

Enabling environment: the policies, regulations, infrastructure, and institutional framework that shape conditions for value chain actors; typically shown as a separate band in a value chain map.

Filière approach: a value chain methodology originating in French agricultural economics that traces product flows, margins, and governance along a commodity chain from producer to consumer.

Functional analysis: a component of value chain analysis that identifies the activities performed at each chain node, assesses their efficiency, and identifies missing or poorly performed functions.

Functional upgrading: a type of upgrading in which actors take on new chain functions previously performed by others, such as a cooperative moving into direct processing and marketing.

Global value chain (GVC) framework: a methodology that analyses how internationally coordinated supply chains are governed by lead firms and how developing-country producers can upgrade.

Margin analysis: an economic technique that calculates the share of the final consumer price retained by each actor at each chain node, revealing the distribution of economic surplus.

Marine Stewardship Council (MSC): an international certification scheme for wild-capture fisheries that verifies sustainable fishing practices, enabling access to premium market segments.

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Post-harvest loss: the quantitative or qualitative reduction in fish product between harvest and final consumer; estimated at 20 to 40 per cent in Nigerian artisanal fisheries.

Process upgrading: a type of upgrading that improves the efficiency or quality of existing chain activities, such as adopting improved fish smoking kilns.

Product upgrading: a type of upgrading that shifts production to higher-value products, such as moving from fresh fish sales to packaged value-added processed products.

Sustainable Value Chain (SVC) framework: the FAO integrated methodology for analysing and developing agri-food value chains with goals of economic competitiveness, social inclusion, and environmental sustainability.

Traceability system: a documentation and ICT system that tracks the origin, handling history, and chain of custody of a fish product from harvest to consumer.

Value added: the difference between the cost of inputs at a chain node and the price received for the output; reflects the economic contribution of each actor.

Value chain: the full sequence of activities through which a product passes from origin to final consumer, with value being added at each stage by the actors who perform those activities.

Value chain mapping: the graphical representation of chain actors, flows, supporting services, and enabling environment, used as the starting point for chain analysis.

Value chain upgrading: the process by which chain actors improve their competitive position and increase value captured through process, product, functional, or chain upgrading.

Concept Check Questions [Series 5]

Objective Questions

A value chain describes the full sequence of activities from origin to final _____. (Linked to SLO 5.1)

In a buyer-_____ value chain, powerful buyers set quality standards and control upstream suppliers. (Linked to SLO 5.2)

The FAO Sustainable Value Chain framework has four pillars: economic, social, environmental, and _____ analysis. (Linked to SLO 5.5)

Moving from fresh fish sales to packaged smoked fish is an example of _____ upgrading. (Linked to SLO 5.9)

Post-harvest losses in Nigerian artisanal fisheries are estimated at 20 to _____ per cent of the catch. (Linked to SLO 5.9)

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Short-Answer Questions

Explain why small-scale fishers and fish farmers are often in a weak bargaining position within value chains. (Linked to SLO 5.3)

Describe the purpose of value chain mapping and list four nodes typically shown. (Linked to SLO 5.6)

Explain what margin analysis shows and why it is useful for understanding fisheries value chains. (Linked to SLO 5.8)

Describe the four types of value chain upgrading with a brief fisheries example of each. (Linked to SLO 5.9)

Explain the role of gender in fisheries value chain social analysis. (Linked to SLO 5.8)

Long-Answer Questions

Analyse the principal value chain methodologies used in fisheries and aquaculture, comparing the filière, GVC, and FAO Sustainable Value Chain frameworks, and explaining how value chain mapping is used as the starting point for analysis. (Linked to SLOs 5.4, 5.5, 5.6)

Discuss the data collection and analytical methods used in fisheries value chain studies, explaining quantitative data gathering, functional analysis, economic margin analysis, and environmental and social assessment. (Linked to SLOs 5.7, 5.8)

Evaluate value chain upgrading strategies and sustainable development pathways for fisheries in Nigeria, identifying the types of upgrading available, the sustainable pathway interventions most relevant to the Nigerian context, and the priority development challenges to be addressed. (Linked to SLO 5.9)

Answers to Concept Check Questions [Series 5]

Objective Questions

Consumer.

Driven.

Governance.

Product.

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40.

Short-Answer Questions

Small-scale fishers and fish farmers are numerous and geographically dispersed, making collective bargaining difficult; they produce highly perishable products under time pressure that forces quick sales at whatever price is offered; they lack market information about prices at alternative outlets; and they have limited access to storage, transport, and processing infrastructure that would allow them to hold product or reach better markets.

Value chain mapping graphically represents chain actors, flows, and services allowing the chain to be understood as a whole system, identify bottlenecks, and guide interventions; four nodes typically shown: input supply (feeds, seed, gear), production (farms or fishing vessels), processing (primary and secondary), and wholesale and retail distribution, with supporting services and enabling environment in separate bands.

Margin analysis calculates the share of the final consumer price retained by each actor at each chain node; it reveals where economic surplus is concentrated, whether producers receive a fair share, and which intermediary stages are most profitable; it is useful for identifying power imbalances and targeting interventions to restructure the chain and improve producer income shares.

Process upgrading: improving efficiency of existing activities, e.g. adopting the FTT-Thiaroye kiln to reduce fuel use. Product upgrading: moving to higher-value outputs, e.g. shifting from fresh catfish to packaged branded smoked catfish. Functional upgrading: taking on new chain functions, e.g. a cooperative moving into direct processing and urban market delivery. Chain upgrading: moving to a higher-value chain, e.g. achieving MSC or ASC certification for export.

Women dominate fish processing and trading in Nigerian artisanal fisheries but face systematic exclusion from credit, cold storage, and formal contracts, bearing high risks while capturing limited margins; social analysis maps these gender roles, quantifies income disparities, identifies structural barriers, and informs interventions such as women's cooperative development and targeted finance to advance gender equity.

Long-Answer Questions

Basic response: The filière approach traces product flows and margins along a commodity chain. The GVC framework analyses governance by lead firms and upgrading pathways for developing-country producers. The FAO SVC framework integrates economic, social, environmental, and governance analysis with a participatory methodology. Value chain mapping is the first step, showing actors, flows, services, and the enabling environment as a foundation for all subsequent analysis.

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Value-added response: The choice of methodology should match the research question and intended use. For project design targeting smallholder income, the SVC framework's participatory multi-pillar approach is most appropriate. For policy advocacy on market governance and power, the GVC framework is strongest. For tracking product flows and calculating margins in a specific commodity system, the filière approach is most direct. Most comprehensive studies in Nigerian fisheries combine elements of all three approaches depending on available resources and stakeholder needs.

Basic response: Quantitative surveys measure volumes, prices, and costs at each chain node. Functional analysis identifies chain functions and their efficiency. Margin analysis calculates value added and economic surplus distribution. Environmental analysis covers energy use, waste, and ecosystem impacts. Social analysis examines gender roles, labour conditions, and equity of benefit distribution.

Value-added response: The quality of value chain analysis depends directly on data quality. In Nigerian fisheries, the main challenges are informality of transactions, large numbers of artisanal actors requiring large samples, and seasonal variation requiring repeat surveys. Using digital collection tools such as KoboToolbox substantially improves data quality at manageable cost, and mobile market price systems provide the price transparency that enables rigorous margin analysis without exhaustive field surveys at every chain node.

Basic response: Process upgrading (improved kilns), product upgrading (packaged smoked fish), functional upgrading (cooperative direct marketing), and chain upgrading (MSC/ASC certification). Nigerian sustainable pathways: cold chain investment, women's processor cooperatives, national traceability system, aquaculture intensification. Priority challenges: 20 to 40 per cent post-harvest losses, fragmented markets, limited credit, poor SPS compliance, inadequate infrastructure.

Value-added response: Investment in cold chain infrastructure at artisanal landing sites is the single most transformative intervention for Nigerian fisheries because it simultaneously reduces post-harvest losses, improves quality and food safety, extends market reach, and creates preconditions for all subsequent upgrading. ICT tools developed in Series 1 to 3 of this course, including mobile market price apps and traceability systems, play a critical enabling role by providing price transparency and supply chain information that improve producer bargaining power and enable premium market access.

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Answers to Pilot Questions [Series 5]

Part 5.1: Introduction to Value Chain Concepts

A value chain is the full sequence of activities from origin to final consumer with value added at each stage; typical fisheries stages: input supply, production (capture or harvest), primary handling and aggregation at landing sites, processing, wholesale distribution, retail, and final consumer.

Short value chains involve few intermediaries between producer and consumer, allowing producers to capture a larger share of consumer price (e.g. direct farm sales to a local market); long value chains involve multiple intermediaries including collectors, processors, wholesalers, and retailers and are typical of fish sold in distant urban markets or exported.

A buyer-driven chain is one in which powerful buyers such as supermarkets or export companies set quality standards and exert control over upstream suppliers; it affects fish producers by imposing compliance costs and standards that may exclude small producers lacking resources, or by giving buyers leverage to suppress farmgate prices.

Any two: they are numerous and dispersed making collective bargaining difficult; they produce highly perishable products that must be sold quickly limiting negotiating power; they lack market information about alternative outlet prices; they have limited access to storage and transport that would allow them to wait for better prices.

Value chain development can improve incomes by reducing post-harvest losses through improved handling and storage, improving product quality and market access, building collective action through cooperatives, linking producers to better-paying market segments, and providing market price information through mobile MIS.

Part 5.2: Value Chain Methodologies

Any three: Porter value chain analysis (firm-level activities and competitive advantage); filière approach (product flows and margins along a commodity chain); GVC framework (global chain governance by lead firms and upgrading pathways); sustainable livelihood approach (household asset use and chain participation); FAO SVC framework (integrated economic, social, environmental, and governance analysis).

Economic analysis: costs, margins, value added, competitiveness. Social analysis: livelihoods, inclusion, gender equity, labour conditions. Environmental analysis: resource use, emissions, waste, ecosystem impacts. Governance analysis: coordination mechanisms, standards, power relations among chain actors.

The SVC methodology is participatory because it involves chain actors including fishers, processors, and traders in the analysis process and in developing upgrading strategies,

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ensuring interventions are contextually appropriate, address actual constraints, and have the stakeholder buy-in needed for successful implementation.

Value chain mapping is the graphical representation of chain actors, flows, supporting services, and enabling environment; its purpose is to allow analysts and stakeholders to see the chain as a whole system, identify bottlenecks and power concentrations, and pinpoint where interventions would have the most leverage.

Main nodes: input supply (feeds, seed, gear, boats); production (farms, fishing vessels); aggregation or landing site; processing (primary and secondary); wholesale and distribution; retail and consumer; with supporting services (credit, transport, extension, cold chain) and enabling environment (regulations, infrastructure) in separate bands.

Part 5.3: Data Collection and Value Chain Analysis

Any three: purchase and selling prices at each node; production and transaction volumes; input costs (labour, fuel, ice, packaging); transport costs; post-harvest loss quantities; gross and net margins per unit of product.

Functional analysis identifies the activities performed at each chain node, assesses who performs each function and how efficiently, identifies missing or poorly performed functions that create bottlenecks, and determines what constraints actors face in performing their functions effectively.

Margin analysis calculates the share of the final consumer price retained by each actor at each node; it reveals where surplus is concentrated, whether producers receive a fair share, and which intermediary stages are most profitable; it is important for small-scale fishers because it makes visible the power imbalances in the chain and provides evidence for interventions to improve producer income shares.

Any two: energy intensity of fishing operations (fuel use per unit of catch); energy use in processing (fuelwood for smoking, electricity for refrigeration); post-harvest waste volumes; water use and effluent in processing; sustainability of aquaculture feed input supply chains.

Women dominate fish processing and trading in Nigerian artisanal fisheries but face systematic exclusion from credit, cold storage, and formal contracts, bearing high risks while capturing limited margins; ignoring these dynamics produces a distorted analysis; social analysis maps gender roles, quantifies disparities, and informs interventions to address structural disadvantages that keep female chain actors in low-value activities.

Part 5.4: Value Chain Development and Sustainable Pathways

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Process upgrading: improving efficiency of existing activities (e.g. improved smoking kiln). Product upgrading: moving to higher-value products (e.g. packaged smoked fish). Functional upgrading: taking on new chain functions (e.g. cooperative direct marketing). Chain upgrading: moving to a higher-value chain entirely (e.g. MSC/ASC export certification).

Adopting the FTT-Thiaroye improved fish smoking kiln, which reduces fuelwood consumption by 30 to 50 per cent, lowers PAH emissions, and improves the consistency and shelf life of smoked fish compared with traditional clay kilns.

Functional upgrading involves taking on new functions previously performed by intermediaries; a fisher cooperative achieves it by collectively investing in processing equipment (smoking kilns, cold storage), developing packaging and branding, and establishing direct supply relationships with urban retailers or hotels, thereby capturing processing and trading margins previously earned by middlemen.

Marine Stewardship Council (MSC) for wild-capture fisheries; Aquaculture Stewardship Council (ASC) for farmed fish products.

Any two: investment in ice plants and cold storage at major artisanal landing sites; support for women fish processor cooperatives to access improved kilns and working capital finance; development of a national fish quality and traceability system; promotion of aquaculture intensification to increase domestic supply; capacity building in value chain analysis for fisheries officers.

References and Attributions [Series 5]

Textual References (Books and External Sources)

FAO (Food and Agriculture Organization of the United Nations). (2014). Developing sustainable food value chains: Guiding principles. FAO.

Kaplinsky, R., & Morris, M. (2001). A handbook for value chain research. IDRC.

Porter, M. E. (1985). Competitive advantage: Creating and sustaining superior performance. Free Press.

World Bank. (2013). Fish to 2030: Prospects for fisheries and aquaculture. World Bank Report No. 83177-GLB.

Gereffi, G., Humphrey, J., & Sturgeon, T. (2005). The governance of global value chains. Review of International Political Economy, 12(1), 78-104.

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

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Figures, Plates, Tables, and Boxes

Figure 5.1: Generic fisheries value chain diagram Attribution: AI generated using prompt "Generate a linear flowchart showing the fisheries value chain from harvest through processing and distribution to the final consumer." Suggested OER search string: "fisheries value chain diagram harvest processing consumer OER".

Figure 5.2: Value chain types comparison Attribution: AI generated using prompt "Generate a diagram comparing short and long fisheries value chains and buyer-driven versus producer-driven governance structures." Suggested OER search string: "fisheries value chain types short long buyer-driven producer-driven OER diagram".

Plate 5.1: Women fish processors smoking fish in Nigeria Attribution: AI generated using prompt "Generate an image showing women fish processors smoking fish at a small-scale artisanal processing site in Nigeria." Suggested OER search string: "women fish processors smoking artisanal Nigeria value chain OER image".

Table 5.1: Value chain methodologies comparison Attribution: AI generated using prompt "Generate a table comparing value chain methodologies including Porter, filière, GVC, and FAO integrated framework by focus and fisheries application." Suggested OER search string: "value chain methodologies comparison Porter filière GVC FAO table OER".

Figure 5.3: FAO SVC framework four pillars Attribution: AI generated using prompt "Generate a four-pillar diagram showing the FAO Sustainable Value Chain framework with economic, social, environmental, and governance components." Suggested OER search string: "FAO sustainable value chain framework four pillars diagram OER".

Figure 5.4: Nigerian catfish value chain map Attribution: AI generated using prompt "Generate a value chain map for the Nigerian catfish value chain showing nodes from input supply through production, processing, and consumer." Suggested OER search string: "Nigerian catfish value chain map actors flows supporting services OER".

Box 5.1: Data collection methods for value chain analysis Attribution: AI generated using prompt "Generate a text box listing data collection methods in fisheries value chain analysis." Suggested OER search string: "fisheries value chain data collection methods questionnaire survey OER".

Figure 5.5: Margin distribution bar chart for smoked catfish Attribution: AI generated using prompt "Generate a stacked bar chart showing price build-up and margin distribution along the Nigerian smoked catfish value chain." Suggested OER search string: "fisheries value chain margin distribution bar chart producer consumer OER".

Figure 5.6: Environmental and social analysis on value chain Attribution: AI generated using prompt "Generate a diagram showing a fisheries value chain with environmental and social indicators overlaid at each chain node." Suggested OER search string: "fisheries value chain environmental social analysis indicators OER diagram".

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Figure 5.7: Four types of upgrading diagram Attribution: AI generated using prompt "Generate a diagram showing the four types of value chain upgrading: process, product, functional, and chain upgrading with Nigerian fisheries examples." Suggested OER search string: "value chain upgrading types process product functional chain fisheries OER diagram".

Figure 5.8: Sustainable pathways Venn diagram Attribution: AI generated using prompt "Generate a Venn diagram showing overlapping economic, environmental, and social sustainability zones with sustainable pathway interventions for fisheries value chains." Suggested OER search string: "fisheries value chain sustainable pathways Venn diagram economic social environmental OER".

Figure 5.9: Priority Nigerian fisheries interventions Attribution: AI generated using prompt "Generate a diagram showing priority value chain development interventions for Nigerian fisheries and aquaculture." Suggested OER search string: "Nigerian fisheries value chain development interventions priority OER diagram".

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