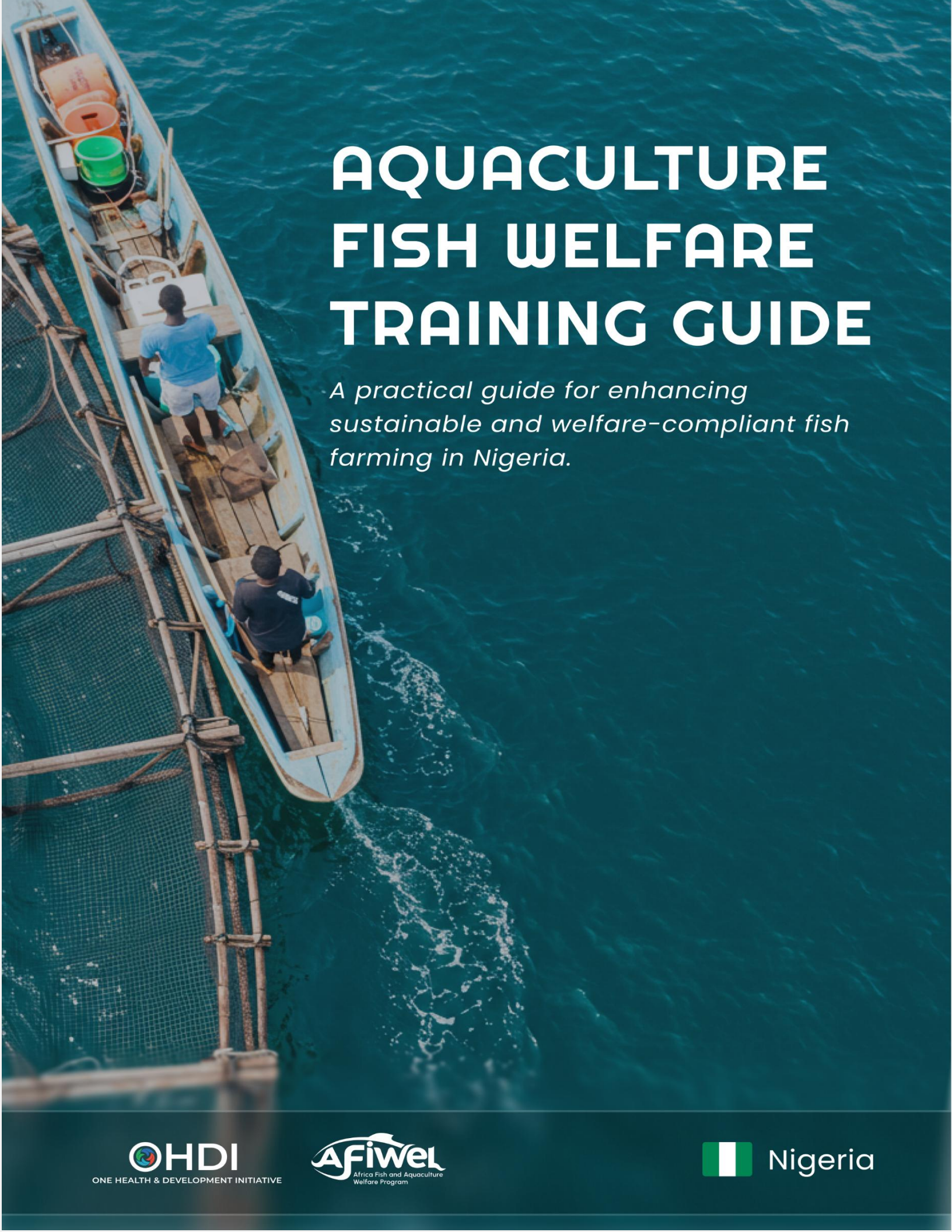

AQUACULTURE FISH WELFARE TRAINING GUIDE

A practical guide for enhancing sustainable and welfare-compliant fish farming in Nigeria.

OHDI
ONE HEALTH & DEVELOPMENT INITIATIVE

AFIWEL
Africa Fish and Aquaculture Welfare Program

Nigeria

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PREFACE

Fish welfare is increasingly recognised as a core component of sustainable and ethical aquaculture. Across Africa, where aquaculture plays a vital role in food security, livelihoods, and economic development, there is growing urgency to embed welfare principles into production systems, policy frameworks, and capacity-building efforts.

The Africa Fish and Aquaculture Welfare (AFIWEL) Program, implemented by One Health and Development Initiative (OHDI), was established to address this need. The AFIWEL program is a pan-African initiative that supports ethical, welfare-driven, safe, and sustainable aquatic life and production systems across Africa. One of its flagship initiatives is the AFIWEL Fellowship, which engages select fisheries and aquaculture professionals and experts in capacity-building, community-building, and field implementation programs to advance fish and aquaculture welfare practices and integrate them into existing sustainable aquaculture frameworks. Through this pan-African fellowship model, the program supports professionals across the continent to lead transformative action in fish and aquaculture welfare through education, stakeholder engagement, and policy advocacy.

This Fish Welfare Training Guide is one of several developed by AFIWEL Fellows. This particular guide has been tailored to the specific aquaculture realities of Nigeria, providing practical, evidence-based knowledge and tools for fish farmers, aquaculture workers, extension officers, animal health professionals, and institutions involved in the fish production value chain.

The content draws from global best practices, scientific insights, and local expertise to ensure that welfare recommendations are both technically sound and contextually relevant. It covers key aspects such as water quality, stocking densities, feeding, handling, transportation, health management, and humane slaughter, all anchored in the principles of good welfare practices: freedom from pain, distress, discomfort, and suffering.

As you explore this guide, we invite you to reflect on the broader goal it serves, which is to promote responsible aquaculture systems that protect animal welfare, support livelihoods, and ensure long-term environmental sustainability. We hope it will be a valuable resource in your efforts to improve fish health, welfare, productivity and sustainability outcomes in Nigeria and across Africa.

With best regards,

The AFIWEL Program Team

One Health and Development Initiative (OHDI)

LIST OF ACRONYMS

Acronym	Meaning
ASC	Aquaculture Stewardship Council
ASPC	American Society for the Prevention of Cruelty to Animals
CIWF	Compassion in World Farming
CVON	Chief Veterinary Officer of Nigeria
DVPCS	Department of Veterinary and Pest Control Services
FAO	Food and Agriculture Organisation of the United Nations
FMARD	Federal Ministry of Agriculture and Rural Development
GDP	Gross Domestic Product
HSUS	Humane Society of the United States
IPCC	Intergovernmental Panel on Climate Change
MDA	Ministries, Departments, and Agencies
NGO	Non-Governmental Organisation
NOAA	National Oceanic and Atmospheric Administration
OIE	World Organisation for Animal Health (former acronym, now WOAH)
OWI	Operational Welfare Indicators
RAS	Recirculating Aquaculture Systems
RSPCA	Royal Society for the Prevention of Cruelty to Animals
SDG	Sustainable Development Goal
TWG	Technical Working Group
WOAH	World Organisation for Animal Health (formerly OIE)

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MODULE 1: OVERVIEW OF AQUACULTURE IN NIGERIA

Definition and Scope of Aquaculture

What is Aquaculture?

Aquaculture is derived from two words- aqua, which means water, and culture, which means to grow or cultivate. Hence, it is the regulated cultivation or growing of organisms in water for the purposes of food production, recreation, commerce, and scientific research (Garner, 2016). In other words, aquaculture refers to the farming of aquatic organisms, such as fish, shellfish (molluscs, crustaceans) and aquatic plants. Farming involves intentional interventions in the rearing process to enhance production, such as stocking, feeding, protection from predators, and ensuring health and welfare, among others. It also implies that cultivated stock is owned by individuals or corporate entities (FAO, 2011).

Water as an environment for culturing could be either freshwater or saltwater (marine). Fish aquaculture, a form of farming, refers to the cultivation of fish in various aquatic environments. Hence, fish farming (pisciculture) refers to the culturing of fish as food. Furthermore, aquaculture could be regarded as the breeding, growing, and harvesting of fish and other aquatic plants. Aquaculture serves as an environmentally sustainable source of food and commercial products, contributing to healthier ecosystems and aiding in the restoration of threatened or endangered aquatic species in the wild. This has facilitated the expansion of fish farming in coastal and marine waters, driven by the increasing global demand for seafood (NOAA, 2022).

Types of Aquacultures

Based on the features of the water environment in which aquatic organisms are being raised, aquaculture is divided into three categories, namely freshwater

aquaculture, brackish water aquaculture and marine/saltwater aquaculture (mariculture).

A. Freshwater Aquaculture: This is a type of aquaculture that involves farming of aquatic animals and plants in a freshwater environment with no salt. It entails growing aquatic animals and plants in earthen ponds, concrete tanks, reservoirs, rivers and raceways. This type of farming supports only aquatic organisms inhabiting a freshwater environment; common species include tilapia, catfish, and carp. It also supports an integrated farming system that combines fish farming with other agricultural activities, such as rice cum fish farming and poultry cum fish farming systems, which could be monoculture or polyculture.

B. Brackish water Aquaculture: In this case, it comprises a mixture of seawater and freshwater, usually with salinity less than 30 ppt. Examples of such farming systems include tidal earthen ponds, pens and cages in estuaries, creeks, backwaters, and mangrove waterways, which are commonly found in coastal states in Nigeria, namely Lagos, Ogun, Ondo, Edo, Delta, Bayelsa, Rivers, Akwa Ibom and Cross River. Culturable fish species in brackish water habitats include mullets (*Liza* sp*),* tarpon (*Megalops atlanticus*), Tilapia (*Sarotherodon melanotheron*, *Tilapia guineensis*), Catfish (*Chrysichthys nigrodigitatus*, *Bagrus bayad*), Snapper (Lutjanus spp*),* and grunter (*Pomadasys spp)* (Anyanwu *et al*., 2007).

C. Marine Aquaculture/Mariculture*:* This typically involves the farming of aquatic organisms in seawater or saline water environments, such as oceans or coastal areas. Examples include floating cages, rafts, and artificial reefs. Farmed species include shrimp, mussels, oysters and salmon. This type of aquaculture is not common in Nigeria, despite being naturally gifted with a long coastline, which lies along the shores of the Atlantic Ocean (NIWA, 2023). Marine aquaculture remains underutilised, except for a few investors who have recently ventured into it in states like Lagos and Bayelsa.

Importance of Aquaculture in Nigeria

Aquaculture is significantly important in Nigeria in the following ways;

- ***Source of Protein****:* It provides a sustainable source of protein and means for essential nutrients needed for the growing population.
- ***Food Security****:* Aquaculture is an integral part of food security, as farming will ensure adequate food security for the teeming population.
- ***Economic Growth:*** It provides means of livelihood for citizens of the country through the generation of income and revenue through domestic sales and exports.
- ***Conservation:*** It protects the aquatic environment from being overfished or exploited.

Historical Background of Aquaculture in Nigeria

Early Development and Practices: From a historical point of view, aquaculture in Nigeria started from 1939 to 1945 when Britain conducted a study to evaluate aquatic resources in Nigeria (Adewumi and Fagbenro, 2010). This later developed into the establishment of Panyam Carp Farm in 1950, which was under the Federal Fisheries Services, later renamed the Federal Department of Fisheries. Subsequently, fish farms spread across the country, including those in Onikan, Lagos State; Funtua, Kaduna State; Etinam, Cross River State; Kano State; and Benin, Edo State. Community-owned fish farms were also established at Onitsha, Ijebu-Ode, Oyo, and Sokoto for the extensive culture of Tilapia, Catfish, *Chrysichthys sp*., and Carp (Dada, 1976).

Growth and Milestone: Between 1960 and 1965, aquaculture in Nigeria began to gain momentum with the support of the FAO, with the culturing of species such as pink prawn (*Penaeus durorarum*), tilapia (Tilapia spp.), and common carp (*Cyprinus carpio*) (FAO, 1969). Thereafter, in 1968, the production of brackish water aquaculture emerged in Lagos State. This led to the continuous growth of the

aquaculture industry, with the establishment of fish ponds and fish farms throughout the country. The growth and development in this sector enticed many people to venture into the business, and recently, aquaculture has become one of the fastest-growing farming industries (Kaleem, 2021). Fish aquaculture: Aquaculture production in Nigeria contributed to the increase in global production, rising from 0.07% in 1995 to 0.21% in 2022 (Oboh, 2022).

Current Status of Aquaculture in Nigeria

Production Statistics and Trends: The FAO (2024) report stated that aquaculture production increased from 26,000 tonnes in 2000 to 259,000 tonnes in 2022, with a 11.2% regional share in total production, making Nigeria the top producer in sub-Saharan Africa and the second-largest producer in Africa after Egypt. However, in 2022, a fall to below its 2020 production level, following a recovery in 2021, was experienced in Nigeria (Figure 1).

Key Aquaculture Species in Nigeria: Globally, key aquaculture species farmed include finfish (carps, catfishes, cichlids (tilapia), salmonids, milkfish, largemouth black bass, snakeheads, sea breams and porgies), crustaceans (penaeid shrimps, red swamp crayfish, Chinese mitten crabs, river prawns and swimming crabs), molluscs (oysters, clams, cockles and arkshells, sea mussels, constricted tagelus and scallops), other animals (soft-shell turtles, Japanese sea cucumber, frogs and edible jellyfish) and seaweed or algae (red algae, brown algae and cyanobacteria) (FAO,2024). However, out of the listed aquaculture species, Nigeria has focused on majorly indigenous species like catfishes (African catfish - *Clarias gariepinus*, sharptooth catfish *Heterobranchus longifilis*, hybrid of the two catfish species - Heteroclarias), tilapia species (*Oreochromis niloticus*, *O. mossambicus*, *O. aureus*, *Sarotherodon galilaeus*, *S. melanotheron*, and *Coptodon rendalli*), and exotic species like carps (common carp, *Cyprinus carpio*) and other emerging species like *Pangasius* sp (Dada, 1976; FAO, 2022). *C. gariepinus*, *H.*

longifilis, hybrid Heteroclarias, C. carpio, and *O. niloticus* are fish species currently contributing to the growth of the industry, with African catfish being the most widely cultured and most popular fish species across the country (54% annual production), which made Nigeria the highest producer of African catfish in the world (FAO, 2023).

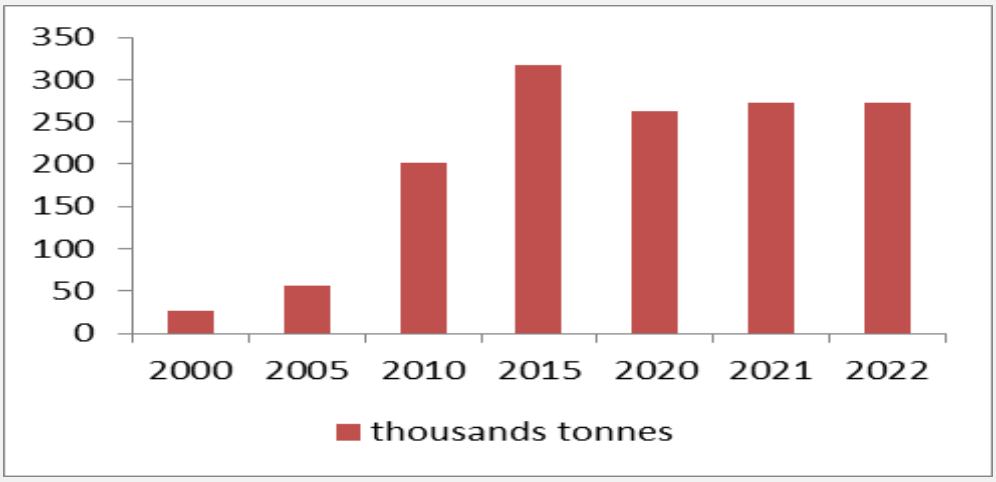

Figure 1 Aquaculture production and trends in Nigeria (Source: FAO. 2024. FishStat: Global aquaculture production 1950–2022)

Socioeconomics and Contributions to Gross Domestic Product: Nigeria's aquaculture tremendously contributed to the economy of the country through income generation, generation of employment and promoting food security through the provision of fish as a source of protein. Data indicate that over 10 million Nigerians are recently engaged in various aquaculture value chains (S and P, 2021). According to the National Bureau of Statistics, aquaculture contributed 3.24% to Nigeria's GDP, indicating a promising venture. Fish are largely consumed in Nigeria; however, local production (fisheries 75%, aquaculture 25%) alone cannot commensurate with demand; hence, a deficit of about 2.5 million tonnes is being augmented through importation of fish (FAO, 2023).

Aquaculture Practices and Systems

Production Systems: Generally, there are three production systems which depend on the size and level of production in the farming system. They include extensive (open system), semi-intensive (semi-open system), and intensive (closed system) systems.

1. Extensive/Open Aquaculture System: This type of aquaculture involves farming of aquatic organisms in natural waterways such as rivers, estuaries and marine zones. The aquatic organisms farmed are left to feed on natural food from their environment. The advantages of this system are that it requires no human intervention for management practices, as aquatic organisms are left to fend for themselves; no physical water exchange is needed, as this process occurs naturally; and it is cost-effective, as it eliminates feeding costs for the aquatic organisms being farmed. Extensive aquaculture systems are commonly practised in developing countries and rural environments with constrained infrastructures (FAO, 2020). Key features of this system (Greenhalgh, 2022) include:

- Large ponds ranging from 1 to 5 ha in area are used for farming.
- Stocking density > 0.5 pcs/sq m (Fish), >5pcs/sq m (Shrimp).
- No supplemental feeding or fertilisation is provided.
- Harvest – 500 to 2,000kgs/ha.
- The least managed form of farming system.

Examples of this system include open-water cage systems (floating cages in lakes or oceans with natural feeding of fish), traditional earthen ponds where fish feed on natural productivity, and seaweed farming in an open marine environment.

2. Semi-intensive or Semi-open System: This is a mixed fish farming system in which fish species are fed with artificial feeds and also rely on natural productivity for feeding, ensuring a balance between them. It requires moderate human intervention in its management practices. Farming is often done in controlled

environments, such as ponds, tanks, or enclosures, with higher production rates than extensive systems. This system is being maintained for water quality parameters, stocking density, water exchange and feeding. It is commonly used in both freshwater and coastal aquaculture for species like tilapia, catfish, shrimp and carp (FAO, 2020). This system is commonly practised in Nigeria's aquaculture. Key features of this system include:

- Involves medium ponds (0.5 to 1 hectare in area).
- Stocking density ranges from 10000 to 15000 fish/ha, 5 to 10 pcs/sqm (Shrimp).
- Feeding with both natural and supplementary.
- Harvest – 2500 to 10000 kg (Fish) and 1500 to 2500kg (Shrimp).

3. Intensive or Close System: This is a highly controlled farming system with monitored water exchange and management of the farmed species. It isolates and manages the farmed species from the external environment, allowing for monitored and precise control over water quality, temperature, and other parameters. It is commonly practised in tanks, raceways or specialised enclosures. It requires a high-input and high-output system, whereby aquatic organisms are cultured with a heavy reliance on external feed, energy, and technology. Examples of this system include high-density cage culture in water bodies with maximum feeding and management, fish hatcheries with intensive breeding facilities for fry and fingerlings, and indoor tank systems with controlled environments and advanced water quality management (Greenhalgh, 2022). Key features of this system include:

- Well-managed form of fish farming.
- Maximum production of fish from a minimum quantity of water.
- Involves small earthen ponds/tanks/raceways with very high stocking density (10-50 fish/m^3 of water).

Culture Systems in Nigeria's Aquaculture

Aquaculture systems in Nigeria are farmed in various culture media, depending on the availability of resources such as species, water, technology, time and stocking density and ultimately production goals in every region of the country. Various culture systems employed in Nigeria include natural, semi-natural, and constructed systems in order to achieve sustainable fish production. The culture systems include earthen ponds, fish tanks (made of plastic, fibreglass, and tarpaulin), cage culture, recirculatory systems, reservoirs, and dams (Ozigbo *et al*., 2014).

1. **Earthen Pond:** This is either a natural or artificially dug ground with sole reliance on a soil and water ecosystem to provide a suitable environment for the farmed fish species. This is commonly used for African catfish, Tilapia and Carp, and it is suitable for semi-intensive farming. This is typically used throughout the county.
2. **Fish Tanks:** These are artificially constructed with different materials such as concrete blocks, tarpaulin, plastic and fibreglass. It allows for controlled feed, water quality, and disease management both outdoors and indoors. This is commonly used for intensive aquaculture (small-scale and commercial). It is highly recommended for use due to its ease of management and maintenance, as well as its ability to safeguard against natural disasters such as flooding, which poses a significant challenge to earthen pond aquaculture. Examples of fish species farmed using this media include catfish and their hybrids, which are used throughout the country.
3. **Cage Culture:** This involves the use of floating cages made from netting materials and usually mounted in natural water bodies such as rivers, lakes and reservoirs, and grown until harvest. It is also known as an open system or offshore cultivation, allowing for large-scale production and management. It is suitable for farming tilapia, catfish, and carp, and is commonly found in Lagos State, Oyan Dam in Ogun State, Lake Chad, and the River Niger.

4. **Re-circulatory System (RAS):** This is an example of a closed system aquaculture where breeding of aquatic organisms is done on land in a technologically enhanced enclosure against the natural production in ponds, tanks, and flow-through systems. In this case, water is continuously filtered and reused, ensuring optimum rearing conditions for fish. It can be expensive to purchase and operate, and is usually suited to urban areas of the country for commercial production; therefore, it is only economically viable to farm high-value species in this system.
5. **Reservoirs and Dams:** These are natural water bodies that are artificially created water enclosures, which are managed for extensive or semi-intensive fish culture, usually involving individual, community or commercial farming. There are available areas with dams or reservoirs, such as the Kainji Dam in Niger State, the Oyan Dam in Ogun State, and the Asejire Dam in Oyo State. Common cultured fish species include tilapia and carp.

Figure 2 A semi-intensive, earthen pond aquaculture system

Figure 3 A semi-intensive, concrete tank aquaculture system

Figure 4 An intensive, concrete tank aquaculture system

Challenges Facing Aquaculture in Nigeria

Various challenges hinder the growth and sustainability of aquaculture in Nigeria, especially during the COVID-19 and post-COVID periods, when the country's economy experienced a surge, leading to various crises in the aquaculture sector. The challenges are not limited to, but also extend to various issues, including climate change, feed and input availability, biosecurity issues, disease management, and a lack of policy.

1. **Climate Change:** Climate change is a global concern affecting agricultural productivity due to changes in the weather conditions. Additionally, Nigeria

has been ranked among the ten countries most affected by extreme weather conditions, changes in rainfall patterns, and severe flooding due to heavy rainfall (World Bank Climate Scorecard, 2019). All these have severe consequences for aquaculture practices, as earthen ponds are susceptible to flooding, thereby causing fish loss and a loss of livelihood. This alone has discouraged many farmers from embarking on fish farming in Nigeria.

2. **Feed and Input Availability:** Fish feeding and input are integral aspects of aquaculture production; however, they have become a concern in Nigeria. Catfish production is our major interest in the country and has been challenged by high-cost feeds; fishmeal, in particular, is a major constituent in catfish nutrition and is usually imported. Therefore, the dwindling foreign exchange has skyrocketed the prices of these feeds and inputs. This has negatively affected production, as fish farmers could no longer afford the cost of the fish feed. This is incredibly evident in the production statistics of fish in Nigeria. This challenge has forced fish farmers to use unacceptable feeds like maggot meal and unprocessed poultry waste for aquaculture production in the country.
3. **Biosecurity and Disease Management:** Disease outbreak is a global concern in aquaculture management, causing massive losses. Catfish farming in Nigeria has been hindered by high mortality rates due to disease outbreaks and a lack of technical expertise in disease management on our various farms, resulting in significant economic losses to fish farmers. Therefore, fish health management has been identified as a major setback of aquaculture in Nigeria (next to the availability of drugs and the high costs of quality feed). Aquaculture health management has been recognised as a significant barrier to disease prevention (Mukaila *et al*., 2023).

Future Prospects and Opportunities in Nigeria's Aquaculture

To achieve the SDGs in aquaculture, most especially SDG 1 (Zero hunger), SDG 2 (No poverty), SDG 12 (Responsible consumption and production) and SDG 14 (Life below water), and an increase in aquaculture production in Nigeria, the following recommendations are made:

- **Diversification of Cultured Fish Species:** There is a need for species diversification, focusing on economically the least-cost and widely acceptable fish species that require less fish meal for their nutrition.
- **Technological Advancement:** There is a need for advancement in technology that will address the recent needs for modern aquaculture practices and improved production.
- **Fish Health and Welfare:** The health and welfare of fish should be prioritised and given adequate attention, as this is important for the growth and development of the sector, as well as increasing the yield of fish farming in Nigeria.
- **Strengthened Aquaculture Policy:** Aquaculture policy in Nigeria needs urgent reform and strengthening of its framework to better place aquaculture in Nigeria. Effective policy making and implementation are required by relevant MDAs in achieving the SDGs in the sector.

Questions and Answers

Activity and Discussion

- Introduce yourself, stating your location, cluster group/association/individual and year of production.
- What type of aquaculture do you practice: Production system, culture medium, fish cultured, stocking rate and why the choice?
- What are your success stories, setbacks and other challenges you have identified as a fish farmer in your locality or state? Others (non-farmers)

should discuss why they are taking the course and what benefits they hope to gain from it.

- What can be done differently to achieve growth in aquaculture?
- What is/are the most common fish farming system(s) practised in your area? Why is this system common? Share your personal experiences (if any) with your preferred fish farming system, including the advantages and disadvantages.

MODULE 2: INTRODUCTION TO ANIMAL WELFARE

Overview, History and Trends of Animal Welfare

Animal welfare encompasses the physical, mental, and behavioural well-being of animals. It is a concept rooted in ethics, science, and law, ensuring that animals under human care live free from unnecessary suffering. Though previously marginalised, the field of animal welfare has continued to grow and advance over the last three decades and more due to the increasing recognition and appreciation of the link between animal sentience and animal well-being. Animal welfare has previously focused primarily on health disposition, improved methods for detecting health issues, and animal management (Pinillos *et al.*, 2015). However, it has evolved to include a better understanding of animals' social behaviours, cognitive abilities, and ability to feel and express pain and suffering (Mendl *et al*., 2009; Broom, 2011). The following provides chronological, notable highlights of events in the evolution of animal welfare:

1. **Ancient Civilisations (Prehistoric times - 600 BCE)**
    - Early human societies had varying attitudes toward animals, ranging from reverence and protection to exploitation.
    - Some ancient civilisations, like the ancient Egyptians and Greeks, held certain animals in high regard and established laws to protect them.
2. **Religious Influence (600 BCE - 1800 CE)**

    Religious texts, such as the Old Testament in Judaism and Hindu scriptures, promoted compassion and respect for animals. Philosophers like Pythagoras and, later, Saint Francis of Assisi, advocated for the ethical treatment of animals.

3. **Animal Welfare Movement (1800s)**

   The Industrial Revolution led to increased urbanisation and the adoption of factory farming practices, raising concerns about animal welfare. Influential figures such as Richard Martin and William Wilberforce in Britain campaigned for the welfare of working animals and passed laws against animal cruelty.

4. **Formation of Animal Welfare Societies (19th century)**

   Animal welfare societies, such as the Royal Society for the Prevention of Cruelty to Animals (RSPCA), founded in 1824, emerged to promote animal welfare and enforce laws protecting animals.

5. **Laboratory Animal Welfare (20th century)**
   - Concerns grew regarding the use of animals in scientific experiments, leading to the establishment of regulations and guidelines for the welfare of laboratory animals.
   - Organisations like the American Society for the Prevention of Cruelty to Animals (ASPCA) and the Humane Society of the United States (HSUS) expanded their work to address animal experimentation.
6. **Modern Animal Welfare Movement (Late 20th Century - Present)**
   - Animal welfare concerns expanded to various areas, including factory farming, animal entertainment, and wildlife conservation.
   - Animal welfare legislation and regulations are being enacted globally, focusing on issues such as animal transportation, humane slaughter, and the use of animals in entertainment.
   - Non-governmental organisations (NGOs) and grassroots movements are playing a significant role in advocating for animal welfare and raising awareness about animal cruelty.

However, despite these remarkable improvements in best practices globally, poor animal welfare practices persist and remain a significant challenge. This apparent neglect has been attributed to several reasons, such as poor awareness, inadequate resources, poor policy frameworks, and sociocultural influences [including traditional or religious biases], among other constraints. On a more positive note, animal welfare is also receiving increasing recognition as an important contribution to an interconnected myriad of animal, human, environmental and ecosystem health (One Health), and sustainable development outcomes. This has led to the development of the ongoing 'One Welfare' concept, which encourages interdisciplinary partnerships to improve animal and human welfare simultaneously, incorporating the environmental components of welfare (Marchant-Forde and Boyle, 2020).

For example, improved animal welfare practices can contribute to a reduction in animal diseases and zoonoses in humans (Madzingira 2017), reduce mortality, improve growth, increase feed efficiency and, all in all, improve production performance; foster human and animal bonds that improve human health and social wellbeing (Freisinger, 2021); and positively impact food safety and meat quality (Animal Welfare Institute, 2018). Furthermore, according to CIWF (2020), addressing welfare concerns such as housing and good management practices has positive impacts on animal health, farms' environmental footprint, and economic and social performance. This recognition has stimulated concerted efforts by stakeholders at all levels to improve the welfare of animals, reduce their pain and suffering, and enhance their health and well-being. A central framework guiding animal welfare is the "Five Freedoms", which outline the basic conditions necessary for animals to thrive. Additionally, the domains of animal welfare provide a comprehensive understanding of the factors that influence an animal's quality of life.

The Five Freedoms of Animal Welfare

In the quest for improved animal welfare, a major advancement is the development of the "Five Freedoms of Animal Welfare". The Five Freedoms were developed in 1965 by the UK's Farm Animal Welfare Council and remain a cornerstone of animal welfare globally (Webster, 2001). This has contributed to the recognition, understanding and establishment of good animal welfare systems and practices. The Five Freedoms of Animals are globally validated basic guidelines and indicators used to determine the welfare status of animals, including fish. It has been touted by several in-country and international animal health and welfare organisations, including the World Organisation for Animal Health (WOAH).

The 'Five Freedoms' include:

- Freedom from thirst and hunger.
- Freedom to display natural behaviour.
- Freedom from discomfort.
- Freedom from fear and distress.
- Freedom from disease, pain, and injury (Mellor, 2016).

The following provides a detailed explanation of the Five Freedoms (which apply to fish):

1. **Freedom from hunger and thirst** – meaning the expected provision of adequate measures of food and water is provided in timely, consistent, balanced, and nutritious rations and is devoid of contaminants and free of disease-causing organisms.

2. Freedom to express natural behaviour – This includes the provision of conditions that are not unduly restrictive in which the fish can move around (including swimming and other fish locomotion, vocalising, feeding, and interacting with

other fishes) within the considerable limits of a protected and safe environment, duplicating its natural settings or environment as much as possible and allowing the animals to express their natural instincts and behaviours.

3. Freedom from discomfort – meaning the provision of a comfortable environment that involves a healthy and good-quality water ecosystem and an existence that is devoid of restrictions, unpleasant perceptions, and harsh environmental conditions (including but not limited to rainy, extreme cold or hot weather or water environments, noise, or fearful situations).

4. Freedom from fear and distress – this includes considerate humane treatment of fish in a manner that does not induce fear, anxiety, distress, or other forms of psychological suffering to the animals. It is essential to recognise that while all freedoms have their distinct roles, they logically interconnect and impact one another in various ways. For example, an animal's "freedom from hunger and thirst" contributes to the satisfaction of the other four freedoms.

5. Freedom from pain, injury, and disease – meaning providing adequate care and environmental conditions that are devoid of (but not limited to) any form of infliction of painful or injurious experience, provision of standard fish management practice and biosecurity measures, prompt and quality veterinary care and treatment, and good antimicrobial stewardship.

The Five Domains of Animal Welfare

The Five Domains model, developed by Mellor and Reid (1994), builds on the Five Freedoms, offering a detailed framework for assessing animal welfare. It includes four physical domains and one mental domain (Mellor and Beausoleil, 2015). Although the Five Freedoms of Animal Welfare provide a strong basis for assessing animal welfare standards, a more updated framework, known as the Five Domains of Animal Welfare, has since been established. The five domains include:

- Nutrition

- Environment
- Health
- Behaviour
- Mental

These domains are described as a science-based best practice framework for assessing animal welfare and quality of life. The first four domains provide information about the animal's various experiences, which make up the fifth domain, the mental domain. It allows a distinction to be made between the physical and functional factors that affect an animal's welfare and the overall mental state of the animal arising from these factors. It also recognises that animals can experience feelings, ranging from negative to positive. Over the last 20 years, this framework has been widely adopted by organisations globally as a tool for assessing the welfare impacts of farm animals, research procedures on animals, pest animal control methods, and other interventions in animal lives.

The Royal Society for the Prevention of Cruelty to Animals (RSPCA) shares more details on the value of the Five Domains, explaining that to help ensure animals have 'a good life', they must have the opportunity to have positive experiences, including satisfaction and satiation. To enable this, those responsible for the care of animals need to provide them with environments that not only allow but also encourage animals to express rewarding behaviours. Thus, the Five Domains provide a means of evaluating the welfare of an individual or group of animals in a particular situation, with a strong focus on mental well-being and positive experiences.

Comparing and Integrating the Five Freedoms and Domains

The Five Freedoms and Five Domains frameworks comparatively contain essentially the same five elements. However, the Five Domains explore the mental state of an

animal in more detail and acknowledge that for every physical aspect that is affected, there may be an accompanying emotion or subjective experience that may also affect welfare. This is useful in terms of reinforcing the message that emotional needs are equally important as physical needs for animals. For example, Zoo Aquarium indicates that while they recognise the value of using the Five Freedoms for driving the prevention of negative welfare in animals, they also apply the Five Domains for animal welfare assessment to progress beyond preventing bad animal welfare to include actively promoting positive animal welfare.

Table 1 Comparing Five Freedoms and Five Domains in Animal Welfare

Five Freedoms	**Five Domains**
From hunger and thirst	Nutrition
From discomfort	Environment
From pain, injury and disease	Health
To express normal behaviour	Behavioral interactions
From fear and distress	Mental state/experiences

Source – RSPCA

Key Animal and Fish Welfare Violations

In many countries, it is seen that several violations of the Five Freedoms of Animals occur to varying degrees. Although it may seem like the norm in many places (for example, in Nigeria), animal abuse is getting less accepted across the world, and animal welfare is highly regulated in many countries. Poor welfare practices common in fish and other animals are listed as follows:

- Inhumane transport causes discomfort such as overcrowding, exposure to uncomfortable weather or other environmental factors, and diminished water quality.
- Inhumane slaughter (painful, fearful, or distressing to animals) and inappropriate stunning and slaughter methods.
- Inhumane handling and mutilation practices, especially without anaesthesia (such as eye-stalk ablation in female shrimp or the incision on the abdomen of the male to extract milt for artificial reproduction).
- Inhumane animal training for sports, entertainment, and catch and release of fish during angling for leisure.
- Factory farming, including restrictive or confined housing.
- Lack of quality and timely intervention of veterinary care and treatment (including the use of untrained animal health practitioners).
- Antimicrobial misuse (from self-medication, poor-quality veterinary services or unethical practice) or overuse (to compensate for poor animal welfare-induced immunosuppression).
- Administration of growth hormones, with resultant anatomical and physiological conditions that cause discomfort, pain, and poor health to the animal.
- Inadequate provision of food/water, excessive fasting periods or withdrawal of food and water for manipulative purposes.
- Prolonged periods of feed restriction for fish grading, transport, slaughter, and other farm management practices such as vaccination, which can cause stress, suffering and injuries such as dorsal fin damage.
- Exposing fish to harmful or strenuous conditions during research without proper ethical and welfare considerations.

Legal Frameworks for Animal and Fish Welfare in Nigeria

According to the Animal Protection Index Reports of 2020 for Nigeria, there is no independent law governing animal welfare in Nigeria. However, there are some provisions against it in other related laws. These include the:

1. **The Criminal Code (1990)**, which addresses animal cruelty, and the phrasing of the legal provision in this area seems to acknowledge that animals can suffer both physically and psychologically. It also includes protection for certain groups of animals, such as those used for draught purposes, for which overloading or overworking is prohibited.
2. **Animal Disease Law and Act of 1988** that empowers and provides the mandate for veterinarians to work in their capacities. This law has been amended three times over the course of its existence. The most recent amendment is the Animal Disease (Control) Act (2022), which provides additional safeguards for farm animals, including a cap on the number of animals that can be transported at once to ensure adequate ventilation. The Department of Veterinary and Pest Control Services (DVPCS) under the Federal Ministry of Agriculture and Rural Development (FMARD) oversees animal welfare. In the DVPCS, the Chief Veterinary Officer of Nigeria (CVON), who is the delegate for the World Organisation for Animal Health (WOAH) on animal health and welfare, oversees the Ministry's national WOAH focal point and division for animal welfare. To address the dearth of a comprehensive legal framework for animal welfare in Nigeria, local and international stakeholders have since been engaging the DVPCS and other relevant government MDAs and policymakers in the country.

Challenges in Animal Welfare

These include:

1. **Cultural and Economic Factors:** Perceptions of animal welfare vary globally and are influenced by cultural practices and economic conditions (Broom, 2010).

2. Policy and Enforcement Gaps: Many regions lack comprehensive welfare laws or face challenges in enforcement (OIE, 2022). However, in Nigeria, a holistic and comprehensive animal welfare law and Policy is currently being drafted and is awaiting stakeholders' validation. Generally, this policy is being established to align with the existing Global Animal Welfare Strategy (GAWS). However, although this has been in development since 2016, many of the improvements and revisions made have yet to be implemented or enacted. To support the operationalisation of the policy, resource mobilisation and stakeholder engagement are currently ongoing in the country by the Department of Veterinary PCS, Federal Ministry of Agriculture and Rural Development (FMARD). Additionally, an Animal Welfare Council, along with several related technical working groups (TWGs), has been established. These TWGs include the Aquatic Animal TWG (which is responsible for addressing all issues of fish and aquaculture welfare), the companion animals TWG, the wildlife animals TWG, the animals used in sports TWG, the livestock and production animals TWG, the animals in transit TWG, the animals in research TWG, the awareness and advocacy TWG, and the ethics and Policy TWG.

For Fish Welfare, while there is no independent law governing this in Nigeria, the Inland Fisheries Act of 2010 provides regulations on the practice of aquaculture in the Nigerian inland waters and various culture systems. It is the regulatory document that addresses issues related to fish farm set-up, artisanal fisheries, fish sales, permits for engaging in fishing and fish businesses, prohibited fishing methods, the exercise of powers vested in government officials, recreational fishing, offences, and their penalties.

3. Climate Change: Environmental changes, such as extreme weather and habitat loss, impact animal welfare directly (IPCC, 2022).

Fish Welfare Practices in Cultured Fish Species

Fish welfare practices in some cultured fish species, such as Tilapia, are currently gaining ground and receiving the utmost attention from aquaculture practitioners. Non-governmental organisations and private certification bodies like FAI Academy in developed countries have played an important role in improving aquaculture practices. For some fish species, such as Clarias, tilapia, and salmon, an established body of information exists that considers their welfare needs and proper production standards (Noble *et al.,* 2018). These welfare needs are based on the five fish welfare indicators, which are designed for the fish species to meet specific needs.

Q&A Session

In a facilitator-led training session, fish welfare trainers/facilitators should provide opportunities for trainees to ask questions and engage in discourses on the module while the facilitator provides answers.

If reading the training manual in a personal capacity, you can share your questions in the following ways to receive answers and further support, where necessary:

- Send your questions to contact@animalwelfarecourses.com or info@onehealthdev.org.
- Share your questions on the Discussion Forum on the online training platform for Fish Welfare.

However, globally, there is still a need to improve fish welfare, as it is an emerging field that requires further research on the welfare needs of other fish species.

Discussions

- Reflect on the topic of animal welfare generally. Were you aware of the concept of "animal welfare" before now? Did you consider it important in the management of animals? Have you ever thought about animal welfare in your daily activities? How do you think animal welfare can achieve better production outcomes or better food quality? Can you provide an example where you know that implementing animal welfare practices has also improved human well-being and environmental health?
- Discuss general animal welfare practices and violations in Nigeria. Which of the animal welfare violations listed are common in Nigeria?
- What can be done to address and prevent poor animal welfare practices in Nigeria?
- Discuss your thoughts and feedback on the animal welfare legal framework in Nigeria. Is this enough? Are there gaps? Recommendations?
- What can be done to push for the establishment and implementation of the Animal Welfare Law (Including fish welfare) in Nigeria? How can you support this?

MODULE 3: INTRODUCTION TO FISH WELFARE

Overview and Definition of Fish Welfare

In recent years, the importance of fish welfare has gained recognition as a key factor in promoting a healthier, more sustainable, and ethical world. Prioritising fish welfare in global aquaculture contributes to ocean conservation, reduces the risk of disease outbreaks, and enhances the quality of life for billions of fish. Fish welfare is an emerging field of significant importance in aquaculture, fisheries management, and ecological conservation. Fish welfare is defined as the physical, physiological, and behavioural well-being of fish, reflecting a growing recognition of their sentience and the ethical obligation to minimise suffering while promoting sustainable practices (Huntingford *et al.*, 2006). It has gained prominence due to increased consumer awareness, regulatory frameworks, and research into the impacts of welfare on fish health, productivity, and ecological balance.

Importance of Fish Welfare Practices

Fish welfare is a crucial consideration in aquaculture, fisheries, and conservation due to its ethical, economic, and ecological implications. The growing recognition of fish as sentient beings capable of experiencing pain and stress has led to increased advocacy for their humane treatment (Sneddon *et al.*, 2014). Ensuring fish welfare not only fulfils ethical obligations but also contributes to sustainable development goals, particularly those related to responsible production, consumption, and life below water (FAO, 2020). The importance of fish welfare includes the following:

- **Ethical Considerations**: Scientific evidence demonstrates that fish possess the capacity for pain perception and exhibit behaviours associated with distress (Braithwaite, 2010). These findings have spurred calls for welfare practices

that minimise suffering during capture, transport, handling, and farming. Ethical treatment aligns with societal values and supports the credibility of fisheries and aquaculture industries (Huntingford *et al*., 2006).

- **Economic Impacts:** Improving fish welfare directly influences the economic viability of aquaculture operations. Stress and poor welfare conditions increase susceptibility to diseases, resulting in higher mortality rates, reduced growth performance, and economic losses (Conte, 2004). Conversely, welfare-friendly practices enhance fish health, yield, and product quality, benefitting both producers and consumers.
- **Ecological Sustainability:** Fish welfare plays a significant role in maintaining ecological balance. Overfishing, bycatch, and harmful practices such as blast fishing not only harm fish populations but also disrupt aquatic ecosystems (Browman *et al.*, 2019). Implementing welfare measures helps preserve biodiversity and promotes sustainable fishing practices that safeguard ecosystem services.
- **Policy and Consumer Demand:** Consumers are increasingly demanding ethical and sustainable seafood, creating a market-driven incentive for improved welfare standards (Nielsen *et al*., 2020). Regulatory bodies and certifications, such as those by the Aquaculture Stewardship Council, emphasise welfare as a criterion for sustainability, encouraging compliance and innovation in the industry.
- **Sustainable Development**: Welfare considerations align with global sustainable development goals, ensuring responsible production and consumption practices within the fisheries and aquaculture sectors (FAO, 2020). Therefore, the improvement of aquaculture management practices is a key element in making the current food system less damaging and more aligned with the UN's 2030 Sustainable Development Goals, which encompass poverty, hunger, environmental sustainability, responsible production and consumption, economic growth, and life below water. The

Fish Welfare Initiative believes that the SDGs can only be achieved if fish welfare is incorporated as a fundamental principle of aquaculture operations.

Five Pillars of Fish Welfare

The welfare of fish is influenced by various factors, including environmental conditions, handling practices, stocking densities, and water quality (Ashley, 2007). Poor welfare conditions can lead to stress, disease outbreaks, and compromised growth, which in turn affect aquaculture productivity and the sustainability of wild fish populations. Stress in fish, often measured by cortisol levels and behavioural changes, is a critical indicator of welfare status (Ellis *et al.*, 2012).

In aquaculture, maintaining fish welfare is not only an ethical imperative but also a practical one, as improved welfare standards have been linked to better growth rates, disease resistance, and product quality (Conte, 2004). To assess fish welfare holistically, researchers and farmers commonly integrate multiple types of welfare indicators. They are either operational welfare indicators (OWI) used on farms by trained farmers or laboratory welfare indicators (LABWI) that require laboratory or other analytical facilities to provide information or validate OWI observations (Noble et al., 2018). Therefore, according to the Aquatic Life Institute, there are five OWI indicators that serve as a guide to understanding fish welfare and the welfare of other aquatic animals. They include:

1. Environmental enrichment
2. Feed composition
3. Space requirements and stocking density
4. Water quality
5. Stunning and slaughter

Fish Welfare and Ethical Considerations in Aquaculture

Fish welfare and ethical considerations in aquaculture are gaining global attention due to increasing concerns about animal rights, sustainability, and the ethical responsibilities of the aquaculture industry. These considerations encompass a wide range of factors aimed at ensuring the physical and mental well-being of fish, promoting sustainable practices, and addressing societal expectations for ethical food production. They include:

1. **Animal Rights and Sentience:** Recognising that fish are sentient beings capable of experiencing pain and stress and ensuring ethical treatment throughout their lifecycle.
2. **Sustainability:** Adopting environmentally responsible practices to reduce impacts on ecosystems.
3. **Transparency and Accountability:** Communicating welfare standards and practices to stakeholders and consumers and adhering to international guidelines and certifications like Aquaculture Stewardship Council (ASC).
4. **Cultural and Societal Perspectives:** Acknowledging cultural values surrounding fish and aquaculture and balancing economic goals with ethical responsibilities.

Fish Welfare in Nigerian Aquaculture

Fish welfare is a growing concern in Nigeria, as the aquaculture sector plays a significant role in food security, livelihoods, and economic development.

Challenges to Improved Fish Welfare

Despite progress, challenges remain in defining and quantifying fish welfare due to interspecies variability and limited standardised methodologies. Research and policy efforts are therefore essential to address these gaps, enhance welfare standards, and support the transition to more ethical and sustainable practices in

the fisheries and aquaculture sectors. Aquaculture in Nigeria is largely practised by smallholder farmers who often lack access to technical knowledge and resources to implement welfare-friendly practices (FAO, 2021). Common challenges include:

- **Overcrowding:** Overstocking ponds increases competition for oxygen and feed, leading to stress and poor health.
- **Water Quality Issues:** Inadequate water management results in high ammonia levels, low dissolved oxygen, and temperature stress.
- **Poor Nutrition:** Many farmers use substandard or insufficient feed, compromising fish growth and immune response.
- **Handling and Transport:** Rough handling and prolonged transport conditions cause physical injuries and stress, significantly reducing survival rates.
- **Environmental Challenges:** Environmental factors are critical to fish welfare. Pollution from agricultural runoff, industrial waste, and oil spills has degraded aquatic ecosystems in Nigeria (Erondu and Anyanwu, 2005). Additionally, climate change has introduced erratic rainfall patterns, extreme temperatures, and water scarcity, all of which exacerbate stressors on fish populations (IPCC, 2022).
- **Legal and Policy Framework:** While Nigeria has policies addressing fisheries and aquaculture, explicit guidelines for fish welfare are minimal. While some state fisheries edicts, such as those in Ogun and Edo States, recognise the importance of employing best practices in aquaculture, they lack enforceable provisions for welfare standards. Strengthening these frameworks and aligning them with international standards, such as those outlined by the World Organisation for Animal Health (WOAH) at the national level, is crucial for promoting ethical and sustainable practices in fish aquaculture.

Strategies for Improving Fish Welfare in Nigeria

These include:

1. Capacity Building: Training farmers on best practices for fish husbandry, water quality management, and humane handling techniques.

2. Policy Development and Enforcement: Developing specific regulations addressing welfare issues and ensuring their implementation at all levels of the aquaculture value chain.

3. Research and Innovation: Promoting research on fish behaviour, welfare indicators, and stress mitigation technologies.

4. Stakeholder Collaboration: Engaging policymakers, farmers, researchers, and advocacy groups to prioritise welfare in national aquaculture programmes.

5. Public Awareness Campaigns: Educating consumers on the importance of welfare-friendly aquaculture to drive demand for ethically produced fish.

Q&A Session

In a facilitator-led training session, fish welfare trainers/facilitators should provide opportunities for trainees to ask questions and engage in discourses on the module while the facilitator provides answers.

If reading the training manual in a personal capacity, you can share your questions in the following ways to receive answers and further support, where necessary:

Send your questions to contact@animalwelfarecourses.com or info@onehealthdev.org.

Discussions

- What fish welfare challenges are you facing or will you face on your farm?
- To what extent have you understood the benefits of fish welfare practices?
- Briefly discuss if you have been motivated in this session. If yes, how will you introduce fish welfare into your farm production?

MODULE 4: GROWING SYSTEMS AND FISH WELFARE

Overview of Growing Systems in Fish Aquaculture

Establishing a fish aquaculture farm or fish farm requires careful consideration of several factors to ensure its success, uphold fish health and welfare, and achieve sustainability. These factors include the location of the farm, as well as the selection of a suitable culture medium, such as earthen ponds, tanks, or recirculatory systems. Before setting up a fish farm, it is crucial to assess various requirements, including protocols, regulations, and guidelines. In developed countries, specific guidelines and regulatory frameworks must be followed before establishing a fish farm. These guidelines ensure compliance with environmental, health, and operational standards (www.noaa.org).

In Nigeria, the process is slightly flexible. Aspiring fish farmers must decide on the type of fish to grow and the culture system to use. They then choose a suitable location, which could be within their household or on rented land. Planning begins with determining the necessary equipment, such as fibreglass tanks, tarpaulin tanks, plastic tanks, or materials for digging earthen ponds. Each choice impacts the farm's setup and operations, making it crucial to plan effectively and consider all aspects of the farming system. The factors include the following:

1. Environmental Considerations
2. Fish Welfare and Health
3. Infrastructure and Resources
4. Regulatory and Ethical Compliance

Other considerations include market research (demand, pricing, and competition), financial viability (profitability and sustainability), and training and technical knowledge (fish behaviour and disease management).

1. Environmental Considerations: These include site selection (water availability, soil type, and accessibility), water quality management (temperature, pH, and oxygen levels), and environmental impact.

- ***Site Selection:*** The following key considerations must be adhered to when selecting a site or location for the fish farm:
    - ***Water Availability:*** Water availability is an essential component in fish aquaculture. A reliable source of clean and adequate water is crucial. Additionally, the quality and quantity of water have a direct impact on fish health and growth.
    - ***Soil Type:*** This is important when choosing an earthen pond system; clayey soil is ideal as it helps retain water and prevent seepage.
    - ***Accessibility:*** The farm should be located near markets or transportation routes to reduce logistics costs.
- ***Water Quality Management:*** Water quality parameters should be monitored, and proper management of water quality parameters is an essential component in this regard. Constant monitoring of water quality parameters such as temperature, pH, dissolved oxygen, and ammonia levels ensures that fish live in an environment conducive to their health. Poor water quality can lead to stress, disease outbreaks and high mortality rates.
- ***Environmental Impact Assessment:*** This is important in ensuring the location of the fish farm does not negatively impact the environment. Implement practices that reduce pollution and promote sustainability in your farm site selection.

2. Fish Welfare and Health: These include the type of fish species that will be grown or reared (suitability to the environment), culture or growing system (space, oxygenation, and natural-like conditions), feed and nutrition (balanced diet and feeding practices), and risk management (disease prevention and stress minimisation).

- **Type of Fish Species:** Choose species that are well-suited to the local climate, market demand, and available culture systems. Common species include catfish, tilapia, and carp. Ensure a steady supply of high-quality feed appropriate for the selected fish species. Proper feeding practices minimise waste and promote growth.
- **Culture/Rearing System:** Decide on the farming method, such as earthen ponds, tanks (fibreglass or tarpaulin), cages, or recirculatory aquaculture systems (RAS). The choice depends on land availability, budget, and management expertise.
- **Risk Management:** Plan for risks such as disease outbreaks, theft, extreme weather, and fluctuating market prices. Insurance and diversification can help mitigate these risks.

3. Infrastructure and Resources: In setting up a fish farm, this consideration is essential as it measures the output of the fish farm. A good fish farm with adequate infrastructure and resources will have good output and productivity, compared with a farm that lacks infrastructure and resources in the management of the farm. These include infrastructure and equipment (ponds, tanks, aerators, and filters), financial planning (budget for setup and operations), and the availability of inputs (feed, fingerlings, and equipment). Invest in the right infrastructure, such as water pumps, aerators, tanks, and feed storage facilities, whereas the choice of equipment depends on the type of culture system. Develop a detailed budget covering initial setup, operational costs, and contingencies. Allocating funds for proper equipment, feed, and disease management ensures the farm can maintain high welfare standards for the fish. Also, securing adequate funding ensures smooth operations on the farm.

4. Regulatory and Ethical Compliance: In establishing a farm, it is crucial to take into consideration legal and regulatory requirements (permits, health standards) and welfare standards (humane handling, ethical practices) in your farm.

Obtaining necessary permits or licences from local authorities and the government is very necessary. Compliance with environmental regulations and health standards is essential, especially in developed countries. In Nigeria, adhering to each state's fisheries laws is pertinent to the success and sustainability of the fish farm.

Growing / Rearing Systems

A growing culture or rearing system is a facility or medium where fish species are raised in fish farming practices. Aquaculture employs various growing systems, ranging from traditional pond systems to advanced technologies like Recirculating Aquaculture Systems (RAS). Each system has unique advantages and challenges that affect fish welfare and the sustainability of production. Choosing appropriate growing systems and adopting best management practices are vital for maintaining the health and well-being of farmed fish. Future research should focus on species-specific welfare indicators, innovative system designs, and strategies to reduce stress and enhance productivity.

In Nigeria, various types of culture media, rearing systems, and growing systems have been introduced in Module One of this training guide. Various systems in Nigeria include earthen ponds, concrete tanks, plastic tanks, tarpaulin tanks, net hapas, cages and pens, recirculatory systems and flow-through systems. The choice of using any of these systems solely relies on the type of fish species to be reared and the stage of production, which can be fish hatchery, grow-out production, or broodstock development. This module will describe each system and its welfare considerations for optimal growth and sustainability in fish aquaculture.

General Considerations for Improved Welfare in a Fish Culture System

Improved welfare in fish culture systems involves ensuring the physical and behavioural needs of the fish are met, which will enhance their growth, wellbeing and productivity. When all these measures are implemented, the sustainability of the aquaculture sector is achieved. The key considerations are as follows:

- The fish culture medium or rearing system should be constructed in a way that prevents physical damage to the body of the fish, such as fins or skin.
- Use a rearing system that best suits the fish species' needs.
- While fish remain in their culture systems or enclosure, they are allowed to grow in an environment that has the same features as their natural environment; thus, providing environmental enrichment helps simulate natural habitat and reduce stress and promote natural behaviour.
- The rearing systems should be designed in a way that allows for efficient water flow and waste removal.
- The rearing system should be able to protect the fish from predators and prevent the escape of farmed fish.
- The culture medium should allow for the implementation of biosecurity measures to prevent disease outbreaks and early detection of diseases and stress.
- When culturing fish that require special precautions, such as noise pollution and disturbance, the rearing system should allow for these considerations.
- Train farm staff on best practices in fish welfare and aquaculture management for the rearing system and fish species.

Common Growing Facilities in Nigeria and Welfare Considerations

Earthen Ponds

An earthen pond is a water body that is either natural or artificial. It is constructed either manually or mechanically through the excavation of soil to create a basin

for retaining water. In aquaculture, earthen ponds are a traditional method for raising fish. They can be filled with fresh water from different sources, such as groundwater, surface water, or wells. An earthen pond is described as a type of earthen medium used for collecting and holding water, featuring dikes and a bottom soil layer to minimise seepage. Earthen ponds could arise from natural enclosures such as reservoirs and dams, which are naturally prepared to hold water for both aquatic animals and plants (Omowunmi, 2016). Earthen ponds can be reinforced with either tarpaulin or concrete, resulting in either a tarpaulin pond or a concrete pond. The reinforcement is usually done to protect the earthen pond from environmental effects that could affect the productivity of the pond.

Figure 5 An earthen pond in South-West Nigeria

Figure 6 Tarpaulin-reinforced earthen pond

Welfare Considerations in Earthen Pond

1. **Soil**
    - Serves as a vessel for holding water and minimising seepage.
    - Determines site suitability, pond productivity, water quality, and species selection.
    - Influences construction costs and duration.
2. **Water Sources**
    - Include rivers, streams, springs, wells, boreholes, rainwater, and underground water.
    - Determines water quality, pond size, structure, and treatment needs.
    - Affects pond siting, species selection, and pond depth.
3. **Topography**
    - Influences pond type, earthwork volume, and labour costs.
    - Affects inlet/outlet placement, dike slopes, and pond arrangement.
    - Determines methods of pond filling and drainage.
4. **Climatological Factors**
    - Includes meteorological and hydrological data.
    - Helps estimate dike height, pond size, and location.

    - Influences pond depth, especially in coastal areas.
5. **Vegetation**
    - Can serve as an indicator of soil properties, particularly in coastal regions.

Welfare Issues in Earthen Pond

- **Proper site selection** is crucial for water retention and preventing overflow. A clayey soil with more than 65% clay and a pH range of 6.5 to 8.5 is preferable.
- **Adequate water availability** is necessary, but should be controlled to avoid continuous overflow.
- **Expert advice** is essential in site selection, design, and construction to prevent failures.
- **Poor site investigation and improper construction** are major causes of pond failures.
- **Lack of qualified pond designers** is a significant issue, especially in Nigeria.
- **Past failures** due to unqualified practitioners discourage new investors in fish farming.
- **Sorting and cropping fish** can cause stress, as fish are often removed from water for long periods.
- **Throwing fish into ponds** disorients them and affects their welfare.
- **Cannibalism and predation** are common in earthen ponds, especially in polyculture systems.
- **Earthen ponds are vulnerable** to pollution, poor sanitation, and disease transmission between fish and humans.
- **Soil enrichment risks** include overdosing, water quality deterioration, fish mortality, and pathogen introduction, posing **One Health concerns**.

Fish Tanks

Tank aquaculture is a method of raising aquatic organisms in enclosed tanks, providing better control over environmental conditions, reducing disease risks, and optimising water quality. It is a viable alternative to open-water farming, especially in areas with temperature fluctuations, salinity variations, water scarcity, land constraints, or strict environmental regulations. They are of various types, which depend on the specific requirements and preferences of each type. The characteristics of each growing system are based on shape, function, size, material composition, and mobility. They include concrete tanks (made of concrete blocks), fibreglass tanks (made of fibreglass material), plastic tanks (made of plastic in various shapes and sizes), and tarpaulin tanks (made of tarpaulin material). Rearing fish in tanks allows for flexibility in terms of space and facilitates easy harvesting, and it is generally less prone to flooding compared to earthen pond rearing systems.

1. Concrete Tanks: Concrete tanks are typically built using reinforced concrete for added strength. Their construction is typically carried out by highly skilled professionals in construction engineering, utilising cement and blocks in an appropriate mixture with water. Concrete tanks are typically categorised into three types: stagnant, free-flow, and water recirculatory concrete tanks. This rearing system is commonly used in urban areas in Nigeria, and it is a common feature of urban agriculture (Oyetola *et al*., 2022).

Figure 7 Recirculatory Tank in North Central Nigeria

Figure 8 Stagnant Concrete Tank in North Central, Nigeria

Welfare Considerations and Concrete Tanks

- Concrete tanks require the use of cement and blocks. This must be treated before use in fish farming.

- Concrete tanks are economical and therefore allow for much use in urban farming, and when considering the cost implications of fish farming.
- Concrete tanks possess very good stability and can withstand environmental factors like strong winds. They are capable of withstanding high stocking density.

Welfare Issues in Concrete Tanks

- Concrete tanks are prone to corrosion over time, particularly in saltwater environments, requiring regular maintenance and occasional resealing.
- Temperature fluctuations can occur if there is an inadequate and inconsistent supply of good-quality water, leading to fish stress and potential mortality. Poor management can lead to the buildup of water pollution, which in turn further increases fish deaths. Additionally, faulty inlet, outlet, or drainage systems, as well as leaks, can cause water loss and a low water level in the tank.
- Aeration is needed because a low level of dissolved oxygen can occur in the tank.
- Concrete tanks are non-flexible and cannot be modified to adapt to other aquaculture needs.

2. Fibreglass Tank: This rearing system is made up of fibreglass material that is used in making a fish tank. It is lightweight, durable, and resistant to corrosion, rust, and deterioration. All these features make it suitable for long-term use in fish aquaculture. Fibreglass is a composite material made of fine glass fibres with a resin, usually polyester, epoxy or vinyl ester (FAO, 2020).

Figure 9 Fibreglass picture (Source: alibaba.com)

Welfare Considerations in Fibreglass Tank

- It allows for different tank designs and sizes.
- It can be customised to ensure that you can adapt the tank to specific fish species and growth stages.
- It is preferred for its high strength-to-weight ratio and cost-effectiveness.
- It can absorb heat, leading to temperature fluctuations that stress fish. Proper shading, insulation and water circulation help mitigate these effects.
- Maintaining optimal water quality is essential.

Welfare Issues in Fibreglass Tank

- Adequate aeration is necessary to maintain dissolved oxygen levels, as oxygen depletion can cause suffocation and increased mortality of fish (Timmons and Ebeling, 2021).

- Ammonia and other waste buildup must be managed through regular cleaning and filtration to prevent toxic conditions in the tank, which can lead to mortality.
- Since it can contain large quantities of fish, overcrowding can result in stress, aggression and susceptibility to disease. Therefore, maintaining species-specific stocking density improves fish welfare and growth. When adequate space is provided for fish, it allows them to exhibit natural swimming behaviours.
- Providing environmental enrichment like artificial plants or hiding spaces can reduce stress and encourage the natural behaviour of fish (Naslund and Johnsson, 2016).

3. Plastic Tanks: This type of rearing system is made up of plastic material of different shapes, sizes and colours for fish farming. The shape includes circular, rectangular and oval, which are suited for the various stages and sizes of the fish species.

Welfare Considerations and Issues in Plastic Tanks

This is similar to the fibreglass tank, except that a black plastic tank is most preferred for fish rearing, as it serves as protection against the sun when it is placed in an open system and allows for good growth of the fish.

4. Tarpaulin Tank: This rearing system is a portable, flexible, and cost-effective fish tank, which is made from durable, waterproof tarpaulin material supported by a metal, plastic, or wooden frame. It is commonly used in aquaculture, particularly in small- and medium-scale fish farming, due to its affordability, ease of setup, and mobility.

Welfare Considerations and Issues in Tarpaulin Tank

This is similar to the fibreglass tank and plastic tank, except that it can be easily torn by sharp objects due to improper handling and is prone to wear and tear if not properly maintained.

Cages

Fish cages are enclosures placed in natural water bodies (such as rivers, lakes, or oceans) or artificial ponds to confine and rear fish while allowing water exchange with the surrounding environment. They are typically made of nets or mesh materials supported by a frame, ensuring that fish remain contained while benefiting from natural water conditions. Fish cage culture is a popular aquaculture system used to increase fish production, especially for species like tilapia, catfish, and carp. It allows for efficient space utilisation, controlled feeding, and ease of monitoring, but it also requires proper site selection, quality materials, and regular maintenance to prevent escapes, disease outbreaks, and environmental degradation.

These are containers made of different mesh sizes, which are mounted within a water body for the purpose of rearing fish species. Cages and pens can be mounted in reservoirs, dams, and in marine and coastal water bodies. The mesh structure allows the clear flow of water in and out of the cage while preventing fish from escaping. There are various shapes and sizes of this rearing system based on the type of cultured fish species, offering versatility and adaptability. Cages could either be fixed, floating, submerged or submersible cages, depending on the location of the cages in the water body (www.planexaquaculture.com).

Figure 10 A square fish cage

Welfare Considerations in Cages and Pens

- Cages must be mounted in water bodies that are free from hindrances and disturbances such as fishing or mining activities.
- The cages must be properly installed by professional aquaculture engineers in order to avoid loss or damage to the cages and the fish.
- Aside from that, there will be no physical water exchange, as it is installed in a water body with continuous movement of water waves, which will facilitate natural water movement; close monitoring of the water quality parameters should be done.
- The cages and pens should be installed in water bodies free from toxic exposure or artificial dumping of hazardous waste into the water bodies.
- Proper feeding of the cultured fish should be done and adequately planned for.

Welfare Issues in Cages

The system is vulnerable to environmental pollution, hazards, and predators, which can stress the fish. Poor-quality materials may lead to structural weaknesses,

allowing predators and unintended species to enter, which can potentially harm farmed fish and introduce diseases. Additionally, conflicts over waterway usage and upstream activities may disrupt maintenance and disturb the fish. This system is common in coastal areas in Nigeria.

Recirculating Aquaculture Systems (RAS)

RAS are highly controlled systems where water is continuously filtered and reused. They reduce environmental impacts and allow precise management of welfare parameters, but require significant investment and expertise. In Nigeria, RAS is very expensive to manage, as it requires constant electricity for its operation. However, this rearing system effectively maintains and regulates fish welfare indicators, ensuring optimal growth and productivity within the system.

Stocking Density and Space in Fish Aquaculture

Artificial conditions in fish aquaculture impose unnatural challenges on fish, such as limited space, abnormal groupings, and inadequate stocking densities. These factors heighten health risks and welfare concerns, including infections, aggression, and competition for food, eventually causing stress and compromising the overall well-being of the fish. Stocking density refers to the number of aquatic organisms (such as fish, shrimp, or other cultured species) stocked per unit area or volume of water in an aquaculture system. It is usually expressed as individuals per square metre (m^2) or cubic metre (m^3), or as biomass per unit volume (kg/m^3). Stocking density is a critical management factor that influences fish growth, survival, water quality, feed utilisation, and overall production efficiency in aquaculture systems (Ellis *et al.*, 2002).

It is calculated as:

Biomass (number of fish species) ÷ volume of water in the growing facility

Welfare Considerations and Stocking Density

The effects of stocking density on fish welfare are complex due to numerous interacting factors, making it difficult to define an optimal density. Recommendations for stocking densities of fish species from different research vary widely, even for the same species and life stage. While farmers can accurately estimate production density, setting strict minimum and maximum levels to ensure welfare remains a challenge. Both excessively low and high densities can negatively impact fish welfare and production.

Therefore, instead of rigid density limits, a more effective approach would be to integrate welfare assessments using operational welfare indicators and good management practices. Regulations should focus on maintaining acceptable levels of key welfare indicators, such as water quality, health, nutrition, and behaviour, alongside economic viability to determine the most suitable stocking density for each species and system (Saraiva *et al.*, 2022). In other words, the authors recommended that determining an appropriate stocking density for fish species (i.e. the optimal range) can only be achieved by considering the welfare aspects of the fish and the good management practices of the farmers, with each production facility and context producing a unique result. The recommended model for calculating the stocking density of a rearing system is illustrated below:

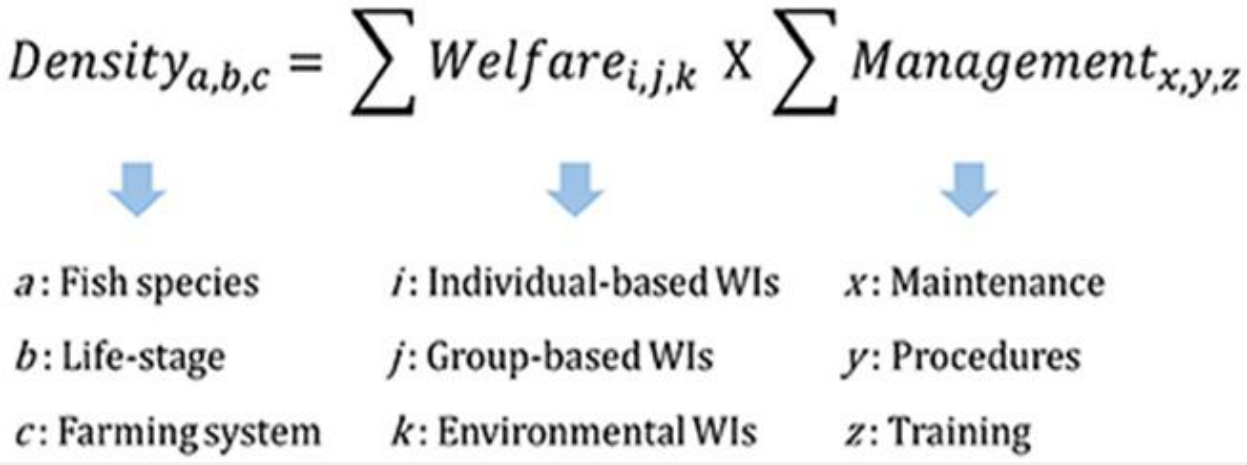

Figure 11 Model representation of the complex components and relations of fish stocking density in terms of fish welfare and good management practices in aquaculture

WI = welfare indicators

Source: Saraiva *et al.* (2022)

Each farmer is requested to calculate his/her stocking density after taking into consideration the welfare indicators of the cultured fish species and after employing the best management practices for optimum growth of the fish. Previous studies on fish species have revealed the welfare indicators of cultured fish species, such as African catfish and tilapia, indicating the recommended range of welfare practices for optimal fish growth. This implies that when culturing your fish and after considering the welfare indicators of your cultured fish and employing best management practices, which resulted in a good feed conversion ratio and optimum growth of fish after production, then the biomass per unit volume of your rearing system will be regarded as your *golden* stocking density of that particular fish you cultured (https://asc-aqua.org/ November, 2024).

Impacts of Growing Systems on Fish Welfare

Stress Factors in Different Systems: Stress can arise from poor water quality, high stocking densities, and handling practices. Each system must address these factors to optimise welfare.

Disease Prevention and Health Management: Growing systems must incorporate biosecurity measures and proactive health management to reduce disease risks and enhance welfare.

Behavioural Considerations: The behaviour of fish, such as swimming patterns and feeding habits, can indicate their welfare. Systems that allow natural behaviours promote better health and productivity.

Q&A Session

In a facilitator-led training session, fish welfare trainers/facilitators should provide opportunities for trainees to ask questions and engage in discourses on the module while the facilitator provides answers.

If reading the training manual in a personal capacity, you can share your questions in the following ways to receive answers and further support, where necessary:

- Send your questions to contact@animalwelfarecourses.com or info@onehealthdev.org.
- Share your questions on the Discussion Forum on the online training platform for Fish Welfare.

Discussion Session

- Discuss each of your current growing systems for your fish farms. What problems are you facing on your farm now?
- Did you do any analysis or evaluation of your farm sites before you decided? Tell us your findings and why you decided on your current system.
- Based on what has been learnt so far, how do you intend to improve the growing system and site of your farm to align with good fish welfare practices?
- Discuss your current stocking density (if you know it).
- Did you consider stocking density before starting your fish farm? How do you determine the optimal stocking density for it?
- Based on what has been learnt so far, what challenges have you been experiencing, and how do you intend to improve your fish farm stocking density going forward?

MODULE 5: WATER QUALITY AND FISH WELFARE

Introduction to Water Quality

Water quality is a fundamental factor influencing the health, growth, and overall welfare of fish in both aquaculture and natural aquatic ecosystems. This is because the first point of contact for fish is water; therefore, water quality is an important welfare indicator for fish growth and well-being. Poor water quality can cause stress, lead to disease outbreaks, and reduce productivity in fish populations (Boyd, 2017). Fish welfare, encompassing both physiological and behavioural well-being, is directly linked to the aquatic environment's chemical, physical, and biological parameters (Ashley, 2007). This module examines the primary water quality parameters that impact fish welfare, including temperature, dissolved oxygen, pH, ammonia, nitrites, nitrates, salinity, turbidity, and microbial load. Additionally, it examines the implications of poor water quality on fish health and provides strategies for maintaining optimal conditions.

Maintaining optimal levels of temperature, oxygen, pH, and other parameters ensures a sustainable aquatic environment. Also, effective management strategies, including routine monitoring, proper filtration, and biosecurity measures, are essential for promoting fish well-being in aquaculture. Recent studies have demonstrated the intricate relationships between various water quality parameters and fish well-being, underscoring the necessity for continuous monitoring and management to ensure sustainable fish production in aquaculture.

Importance of Water Quality in Aquaculture

1. **Growth and Survival of Aquatic Organisms:** Optimal water quality ensures healthy development, feed conversion efficiency, and survival rates of fish. Poor water conditions can cause stress, reduce immunity, and lead to increased mortality.

2. **Disease Prevention:** Good water quality minimises the proliferation of pathogens and parasites, while poor conditions, such as high ammonia and low dissolved oxygen (DO), weaken fish resistance to diseases.
3. **Optimal Feed Utilisation:** When there are proper pH, temperature, and DO levels, these promote efficient digestion and nutrient absorption for the fish. Poor water quality can lead to feed wastage, increased production costs, and water pollution.
4. **Maintenance of Oxygen Levels:** Adequate dissolved oxygen is essential for respiration and metabolic activities of fish. Low oxygen levels (hypoxia) can cause stress, slow growth, and even mass mortality during the rearing process.
5. **Ammonia and Nitrite Management:** Toxic compounds like ammonia and nitrites accumulate from fish waste and uneaten feed, thereby making the water environment unbearable for the fish, which can lead to mass mortalities. Proper water exchange and bio-filtration help prevent toxicity and mortalities.

Key Water Quality Parameters Affecting Fish Welfare in Nigeria

Maintaining optimal water quality is essential for the health and productivity of fish in both natural water bodies and aquaculture systems in Nigeria. Several physicochemical parameters play critical roles in influencing fish welfare. Below is an extensive overview of these key parameters, their impacts, and considerations specific to Nigeria.

1. Temperature

Impact on Fish Welfare: Temperature regulates metabolic rates, growth, reproduction, and immune responses in fish. Deviations from species-specific optimal temperature ranges can lead to stress, reduced growth rates, and increased susceptibility to diseases.

Welfare Considerations: Nigeria's tropical climate results in high ambient temperatures, which can elevate water temperatures in ponds and rivers (Boyd, 1979). In catfish farming, for instance, water temperatures consistently below 15°C can halt growth and potentially lead to mortality, while temperatures above 26°C can reduce dissolved oxygen levels, causing stress and possible death (afrimash.com).

Welfare Improvements (Ekubo and Abowei, 2011):

- Shading: Implementing shading structures over ponds can help moderate water temperatures.
- Depth Management: Maintaining adequate pond depths can help counteract temperature fluctuations.
- Water Exchange: Regularly exchanging pond water with cooler sources can help maintain optimal temperatures.

2. Dissolved Oxygen (DO)

Impact on Fish Welfare: Dissolved oxygen is vital for fish respiration. Low DO levels can cause stress, reduce feeding efficiency, impair growth, and lead to mortality.

Welfare Considerations: Factors such as high stocking densities, excessive organic matter, and elevated temperatures can deplete DO levels in Nigerian fish ponds. Dissolved oxygen levels below 1.5 mg/L are particularly stressful and can be fatal to fish (afrimash.com).

Welfare Improvements (Bhatnagar and Devi, 2013)

- Aeration: Using mechanical aerators can increase DO levels.
- Stocking Density: Maintaining appropriate fish densities reduces oxygen demand.

- Organic Load Management: Regular removal of uneaten feed and waste prevents oxygen depletion due to decomposition.

3. pH Levels

Impact on Fish Welfare: pH measures the acidity or alkalinity of water. Fish thrive within specific pH ranges, and deviations from these ranges can cause stress, reduce growth, and increase mortality.

Welfare Considerations: For catfish, a common species in Nigerian aquaculture, the optimal pH range is between 6.5 and 7.5. pH levels below 4 or above 8.5 can be lethal (Fathurrahman *et al*., 2020)

Welfare Improvements

- Buffering: Adding agricultural lime can stabilise pH levels.
- Water Source Monitoring: Regularly testing water sources helps detect pH fluctuations.
- Avoiding acidic runoff: Preventing runoff from acidic soils or contaminated areas from entering ponds.

4. Ammonia and Nitrite Concentrations

Impact on Fish Welfare: Ammonia, primarily excreted by fish, is toxic at elevated levels. Nitrite, an intermediate product in the nitrification process, can also be harmful. High concentrations can impair oxygen transport in fish, leading to stress and mortality.

Welfare Considerations: Intensive aquaculture practices can lead to the accumulation of ammonia and nitrites, especially in systems with inadequate biofiltration.

Welfare Improvements (Orobator *et al.*, 2020)

- Biofiltration: Establishing biofilters with nitrifying bacteria to convert ammonia to less harmful nitrate.
- Regular Water Changes: Diluting accumulated wastes through periodic water replacement.
- Feeding practices: Avoiding overfeeding to reduce waste accumulation.

5. Turbidity and Suspended Solids

Impact on Fish Welfare: High turbidity can reduce light penetration, affecting photosynthesis and dissolved oxygen levels. Suspended solids can damage fish gills, impairing respiration (Adewoye and Fawole, 2005).

Welfare Considerations: Erosion, runoff, and uneaten feed contribute to increased turbidity in Nigerian water bodies.

Welfare Improvements

- Erosion Control: Implementing vegetation buffers around ponds to reduce sediment runoff.
- Sedimentation Ponds: Using settling ponds to capture sediments before water enters the main culture areas.
- Proper Feeding: Managing feeding to minimise waste.

6. Heavy Metals and Chemical Pollutants

Impact on Fish Welfare: Heavy metals such as lead, cadmium, and mercury can bioaccumulate in fish, leading to health issues and rendering them unsafe for human consumption (Adewoye and Fawole, 2005).

Welfare Considerations: Industrial activities, especially in regions like the Niger Delta, have led to heavy metal contamination in water bodies.

Welfare Improvements

- Pollution Control: Enforcing regulations to limit industrial discharges into water bodies.
- Regular Monitoring: Testing water and fish tissues for heavy metal concentrations.
- Source Water Protection: Selecting water sources with low contamination levels for aquaculture.

7. Salinity

Impact on Fish Welfare: Salinity affects osmoregulation in fish, which is crucial for maintaining their overall health. Sudden changes can cause stress, reduce growth, and increase mortality (The Fish Site, 2015).

Welfare Considerations: Coastal aquaculture operations may experience fluctuations in salinity due to tidal changes or freshwater influx.

Welfare Improvements

- Species Selection: Culturing species adapted to local salinity conditions.
- Salinity Monitoring: Regularly measuring salinity levels, especially after heavy rains or during dry spells.
- Water Management: Blending freshwater and saltwater to maintain stable salinity levels.

8. Microbial Load and Waterborne Diseases

Impact on Fish Welfare: Elevated microbial loads, including pathogenic bacteria, viruses, and parasites, can lead to disease outbreaks in fish rearing. Such diseases can cause high mortality rates, reduced growth, and significant economic losses in aquaculture operations (Yerima and Olojo, 2017).

Welfare Considerations: Studies have indicated that certain water bodies in Nigeria, such as the Asa River, are bacteriologically contaminated, rendering them unsafe for both aquatic life and human consumption (Adewoye and Fawole, 2005).

Welfare Improvements

- Water Source Selection: Choosing uncontaminated water sources for aquaculture to minimise initial microbial load.
- Regular Monitoring: Implementing routine checks for microbial contaminants to detect and address issues promptly.
- Biosecurity Measures: Establishing protocols to prevent the introduction and spread of pathogens within aquaculture facilities.

Cultured Fish Species in Nigeria and Water Quality Recommendations

Recommended water quality requirements for fish vary for different species, and for the various stages in their life cycles (Oluwarore *et al.*, 2023). Table 2 shows the general water quality parameters required for farmed catfish, tilapia and carp.

Table 2 Cultured Fish and Water Quality Recommendations

Parameters	Catfish	Tilapia	Carp
Temperature	26°C-32°C (Kashimudddin *et al.*, 2021)	20.2 - 31.7°C (Leonard and Skov, 2022)	28 and 34 °C (Veluchamy *et al.*, 2022)
Dissolved Oxygen (DO)	2.91 and 4.85 mg/L (Boyd and Hanson, 2010)	5 and 7 mg/L (Abd El Hack *et al.*, 2022)	0.5-20 mg/L (Homoki *et al.*, 2021)
pH	6,5-8,5(Fathurrahman	6-8.5 (El-sherif *et*	7-8.0 (Hedarnejad,

	et al., 2020)	*al*., 2009)	2012)
Ammonia	0.34 mg/L (Edward *et al*., 2010)	0.14mg/L (Benli *et al.*, 2011)	0.24 ± 0.06 mg/L, (Heydarnejad, 2012)
Nitrite	1.19 mg/L- (2% of LC50-96h) (de Limai *et al.*, 2011)	0-7 mg/L (Amazon Web Services)	0.18 ± 0.02 mg/L (Heydarnejad, 2012)
Nitrate	400 ppm nitrate (Agricultural Marketing Resource Centre)	5-500 ppm (Sallenave, 2016)	Below 80ppm (Sacramento Koi)
Alkalinity	4.56 mg/L (Baldisserotto and Rossato, 2007)	1.6 to 9.3 mg/L (Colt and Kroeger, 2013)	7.8 ± 0.9 mg/L (Heydarnejad, 2012)
Water hardness	25-50 mg CaCO3 L-1(Copatti *et al.,* 2011)	401.33 mg/L to 634.00 mg/l (Choudhary and Sharma, 2018)	300-500 mg/L CaCO 3 (Rach *et al.*, 2010)

Q&A Session

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- Share your questions on the Discussion Forum on the online training platform for Fish Welfare.

Discussion Session

- Discuss your previous knowledge and experience with good and bad water quality.
- Have you been monitoring water quality? If your response is yes, how have you been doing it?
- Based on what you have learned so far, what issues have you experienced with water quality, and how do you intend to improve the water quality on your farm to align with good fish welfare practice?
- How can you better measure water quality on your farm? What parameters are most important to you?

MODULE 6: FEEDING AND FISH WELFARE

General Principles of Nutrition and Feeding in Fish Welfare

Feeding plays a crucial role in aquaculture, as it directly impacts the growth, health, reproduction, and overall well-being of fish. Fish feeding directly affects the outcome of the production process, as it is what the fish take in the form of feed that will sustain them and improve their growth. The type and quantity of feed provided determine the efficiency of fish farming, which in turn impacts both economic and environmental sustainability. Proper feeding strategies help optimise fish metabolism, reduce waste accumulation in water, and minimise stress, leading to improved survival rates and better-quality fish products (Aljehani *et al.*, 2023). In Nigeria, in aquaculture businesses, fish feeding takes the bulk of the production process and therefore requires critical attention and welfare considerations for the success and sustainability of the aquaculture business.

Relationship between Nutrition and Fish Welfare

Fish welfare is directly connected to nutrition, as an inadequate diet can cause stress and disease susceptibility. Proper feeding supports physiological functions, enhances immune responses, and improves resistance to environmental stressors (EFSA, n.d.). Malnutrition or imbalanced diets lead to deformities, poor growth, and increased mortality rates, highlighting the importance of formulating species-specific diets (Fish Welfare Initiative, n.d.).

Nutritional Composition and Feed Formulation

Fish require essential macronutrients such as proteins, lipids, and carbohydrates, as well as micronutrients like vitamins and minerals, for proper growth and development. Protein is the most critical component, as it supports tissue development, enzyme production, and immune function. Carbohydrates serve as an energy source, while lipids provide essential fatty acids necessary for cellular

functions (Frontiers in Veterinary Science, 2024). Vitamins (A, D, E, K, B-complex, and C) and minerals (calcium, phosphorus, zinc, and iron) are essential for fish metabolic functions. Vitamin C enhances immune function, while vitamin E acts as an antioxidant. Mineral deficiencies can lead to skeletal deformities and impaired physiological processes (Frontiers in Veterinary Science, 2024).

Feed Formulation and Processing

Types of Fish Feeds

They include extruded, pelletized, and mash feeds.

- **Extruded feeds:** These types of feed are highly digestible and stable in water, preventing nutrient leaching. They are usually floating feeds and are commonly available in the market for fish feeding.
- **Pelletized feeds:** These types of feeds are cost-effective and suitable for various fish species and are usually sinking feeds.
- **Mash feeds:** These types of feed are often used for fry and larvae, requiring careful handling to prevent water contamination (Aljehani *et al.*, 2023).

Feeding Practices and Welfare Implications

Proper feeding schedules are crucial in optimising fish growth and welfare. Factors influencing feeding frequency include fish species, age, metabolic rate, and water temperature. Underfeeding results in malnutrition, while overfeeding leads to water pollution and an increased risk of disease outbreaks. Overall, feeding to satiation is advisable for farmers at two feeding regimes, depending on the weather conditions, but preferably in the morning between 8:00 and 9:00 a.m. and in the evening between 5:00 and 6:00 p.m. (Frontiers in Veterinary Science, 2024). Other factors to consider include:

- Strive for the most optimal feeding times and feed quantities and avoid starvation periods exceeding 72 hours.
- Fish must always be provided with sufficient and adequate amounts of feed. This includes avoiding underfeeding or overfeeding them. Insufficient feed can adversely impact their growth, productivity, and welfare, while excessive feed can cause poor water quality, which in turn affects their health and welfare.
- Avoid giving feed in unavailable forms, such as excessively large pellets.
- Avoid feeding in a location where smaller fish are outcompeted, as this can result in poor health and welfare of the affected ones. It is important to grade fish by size in any of your species to achieve a homogenous group and to avoid competition for the smaller fish.
- Make use of skilled personnel in feeding your fish to avoid waste of feeds and irregular growth of fish.
- Store your feeds in a well-ventilated place, away from rodents, moisture and contaminants.

Automatic *vs.* Manual Feeding Systems

Automatic feeders: This reduces feed waste, improves efficiency, and provides precise feeding control.

Manual feeding: This method allows for the observation of fish behaviour but may result in inconsistent feed distribution (Aljehani *et al.*, 2023).

Effects of Underfeeding and Overfeeding on Fish Health

Underfeeding: This leads to weight loss, increased aggression, and higher mortality rates.

Overfeeding: This leads to excessive nutrient buildup in water, which promotes bacterial growth and increases the likelihood of disease outbreaks (EFSA, n.d.).

Behavioural Aspects of Feeding and Welfare Considerations

Feeding behaviour is an indicator of fish welfare. Aggressive feeding can lead to injuries and stress, while poor appetite may signal disease or suboptimal environmental conditions. Monitoring feeding responses helps in adjusting feeding strategies for improved welfare (Fish Welfare Initiative, n.d.).

Fish Feed and Specific Welfare Considerations

Use of Animals for Fish Feed: As sentient beings, a key animal and fish welfare consideration is that the number of animals used for feeding in the supply chain should be minimised to reduce their suffering and limit the reduction and elimination of terrestrial, aquatic and insect animal ingredients. To this end, producers, where possible, must move toward the use of alternative feed products, which have the following characteristics:

1) Have higher feed efficiency ratios that also maintain good nutrition and health,

2) Substitute carnivorous farmed species with herbivorous extractive species.

Use of Chicken Offal or Maggots for Fish Feed: Feeding fish with chicken offal or maggots is highly discouraged and should be subjected to further treatment to destroy potential pathogens before being fed to fish. Apart from being visually unethical for consumption by fish and end consumers (humans and other animals), it poses a high risk of transmitting zoonotic infections with dire health consequences. In future advocacy for country-level and Africa-wide animal and fish welfare regulations, recommendations to ban this practice should be promoted.

Use of Steroid Hormones in Fish Feeds: Many farms in Nigeria are in the habit of using steroid hormones such as testosterone, estrogen, progesterone, and cortisol to stimulate the growth of fish, thereby making the fish grow faster. This practice is

highly discouraged in aquaculture by the FAO and WHO, as these hormones typically have a residual effect on fish and can consequently affect humans who consume such fish. The use of these hormones is strongly discouraged in aquaculture and is contrary to ethical standards.

Innovations In Nutrition and Feeding of Fish

Fishmeal *vs.* Alternative Proteins

Traditionally, fishmeal has been the primary protein source in aquafeeds, but concerns over sustainability have led to the exploration of alternatives. Insect meal, plant-based proteins (such as soy and algae), and single-cell proteins (including bacteria and fungi) are being integrated into diets to reduce dependency on fishmeal while maintaining optimal fish health and welfare (Aljehani et al., 2023).

Feed Additives and Functional Ingredients

Functional additives, such as probiotics, prebiotics, phytobiotics, enzymes, and immunostimulants, are incorporated into feeds to enhance gut health, disease resistance, and nutrient absorption, thereby promoting fish growth (Adegbesan and Yusuf, 2024).

Q&A Session

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- Share your questions on the Discussion Forum on the online training platform for Fish Welfare.

Discussion Session

- Discuss your previous knowledge and experience with good and bad feed. How do you differentiate between good and bad feed for your fish?
- Based on what you have learned, what experiences have you had in the past with sourcing feed for your fish?
- How do you intend to improve the feeding on your farm to align with good fish welfare standards?
- What local alternatives do we have to poor, unethical feeding practices, such as:
    - Use of smaller animals for fish feed,
    - Use of hormones.
    - Use of chicken offal and maggots, and
    - Use of insects?
- How can we innovate on alternative feeding that meets optimal welfare standards for fish production?

MODULE 7: FISH WELFARE DURING HANDLING AND TRANSPORTATION

Overview of Fish Welfare During Handling and Transportation

Ensuring fish welfare during handling and transportation is crucial for maintaining fish health, reducing stress, and minimising mortality. Proper handling techniques and transportation methods not only enhance survival rates but also improve overall aquaculture productivity and sustainability. Fish handling and transportation are critical steps in maintaining the quality and freshness of fish products.

Factors Affecting Welfare During Handling and Transportation of Fish

Several factors influence fish welfare during handling and transportation. They include:

- **Water Quality**: Parameters such as oxygen levels, temperature, pH, and ammonia concentration must be monitored and maintained during fish handling and transport to minimise stress and retain the quality of the fish (Ashley, 2007).
- **Handling Methods**: Not adequately adhering to proper handling methods could have a greater effect on the fish. Excessive handling or rough treatment can cause stress, physical injuries, and mortality (Conte, 2004).
- **Stocking Density and Space**: These are very important factors to consider in fish welfare because overcrowding of fish can lead to low levels or loss of dissolved oxygen, increased accumulation of waste and increased stress in the fish (Harmon, 2009).
- **Transport Duration:** Longer transport times increase the risk of stress and mortality if conditions are not well managed (Ross and Ross, 2008).
- **Species Sensitivity**: Some fish species are more resilient to handling stress than others, requiring species-specific protocols (Barton, 2002).

Handling and Fish Welfare

The capture and handling of fish on a farm is a prerequisite in fish farming, as various activities involving contact with fish will be carried out on the farm. These include sorting, weighing, grading, disease treatment, stocking of fish and slaughter. It is also necessary to move fish between facilities, including transferring them within the rearing system and transporting them between farms for marketing and slaughter (Conte, 2004).

Fish Handling and Welfare Considerations

Fish are very sensitive to handling, and removing them from water requires a critical action to keep the fish alive and stable. Some fish are very sensitive to handling, like Tilapia, while others, like the African catfish, can tolerate rough handling due to their adaptive nature. Animal welfare groups and organisations advise that handling should be kept at an absolute minimum, and removal of fish from water should only be carried out when absolutely necessary, for no longer than 15 seconds, unless under anaesthesia (Humane Slaughter Association, 2005). As a result, it is essential to develop and adopt a less stressful method of fish handling during aquaculture production.

To minimise stress and physical damage during sorting, grading and stocking, the following handling practices should be adopted:

- Avoid rough handling, which can cause physical damage, stress, and injury to the fish. Also, reduce the frequency and duration of handling to limit stress.
- Use soft nets, wet hands, or gloves to prevent skin damage (Harmon, 2009).
- Before transferring fish to a new environment, gradually adjust them to new water conditions.
- Sudden changes in light, temperature, or physical environment should be avoided (Ashley, 2007).

- In some cases, approved anaesthetics or sedatives can help reduce handling stress (Ross and Ross, 2008).

During Fish Processing:

- Store the fish in an insulated container with ice to maintain a temperature below 4°C (39°F) in order to keep the fish fresh.
- Keep the fish moist and covered to prevent dehydration and contamination.
- Process the fish quickly to minimise stress and prevent spoilage during handling.

Transport and Fish Welfare

Transporting fish is a crucial aspect of fish culture. Fry and fingerlings must be transported from the hatchery to the pond for stocking. Brood fish are sometimes transported into the hatchery to spawn. It may even be necessary to transport live harvested fish to the market for sale. Transport of live fish is a multi-step operation that involves the preliminary capture and preparation of the animals, as well as the setup of transport facilities. This is followed by the harvest of the fish, loading, conveyance, including the maintenance of water quality, and unloading at the delivery location. Fish are generally transported in containers of various sizes, such as cans, ceramic or metal pots, wooden or metal buckets, vats, barrels, plastic bags, styrofoam boxes, bottles, jugs, animal skins, and bamboo sections. In fact, almost any clean, waterproof container may be used. Certain containers provide good insulation from heat, for example, wood or styrofoam. Containers like metal or plastic are poor insulators and may have to be wrapped with wet towels or packed with ice to keep temperatures down.

Fish Transport and Welfare Considerations

Fish Transport System: There are two basic transport systems for live fish, the closed system and the open system. A closed system is a sealed container that contains all the necessary requirements for survival within itself. The simplest of these is a sealed plastic bag partly filled with water and oxygen. The open system consists of water-filled containers in which the requirements for survival are supplied continuously from outside sources. The simplest of these is a small tank with an aerator stone (Wedemeyer, 1996). Fish transportation must be done carefully to be successful. A poorly organised effort may easily result in the death of fish. The following factors directly influence fish transport.

1. ***Quality of Fish****:* The quality of fish transported is a decisive criterion. The fish to be transported must be healthy and in good condition. Weakened individuals should be eliminated from the consignment, particularly when the temperature during shipment is high. When the fish are of poor quality, even a significant reduction of fish density in the transport container fails to prevent fish losses. Weak fish are killed at a much higher rate than fish in good condition when the transport time is longer. The fish to be transported, except for the larval stages, should be left to starve for at least a day; if the digestive tract of the fish is not totally cleaned, the possible time of transport is reduced to half, though the conditions may be the same (Ross and Ross, 2008).

2. *Oxygen:* The most important single factor in transporting fish is providing an adequate level of dissolved oxygen. However, having sufficient oxygen in the tank does not necessarily mean the fish are in good condition. The ability of fish to utilise oxygen depends on their tolerance to stress, water temperature, pH, and the concentrations of carbon dioxide and metabolic products, such as ammonia. The crucial factors underlying oxygen consumption by fish in relation to oxygen metabolism during transport are fish weight and water temperature. Heavier fish and those transported in warmer water need more oxygen. For instance, if the

water temperature increases by 10°C (e.g. from 10 to 20°C), oxygen consumption is about doubled. From the point of view of fish transport, for each 0.5°C rise in temperature, the fish load should be reduced by about 5.6%; conversely, for each 0.5°C decrease in temperature, the load can be increased by about 5.6% (Piper *et al.,* 1982). Oxygen consumption also increases in fish due to excitement caused by handling. Excitement increases oxygen demand three to five times (Lusk and Krcál, 1974).

3. ***Tolerance to Transport***: Tolerance of fish to transport is related to their ability to resist or adapt to stressful conditions. Their resistance also changes as they pass through various life stages. Larvae are very delicate, as are brood fish, which are ready to lay eggs. Table 3 below indicates stress tolerance levels of some commonly cultured fish species in Nigeria.

Table 3 Stress tolerance of some commonly cultured fish species in Nigeria

Species	Common Name	Tolerance Level
Oreochromis niloticus	Tilapia	High
Clarias gariepinus	African catfish	High
Heterobrancus bidosalis	Red mud catfish	High
Cyprinus carpio	Common carp	Medium
Heterotis niloticus	African bony tongue	Medium
Bagrus bayad	Silver catfish	High
Gymnachus niloticus	Trunk fish	Low
Chrysichthys nigrodigitatus	Silver catfish	High
Labeo coubie	African carp	Medium

Source: NAERLS (2001)

4. *Presence of Food in the Intestines*: Fish survive transport better if they have no food in their intestines. For this reason, they are not fed for 1 to 2 full days prior to their transportation. Brood stock are often conditioned for transport to spawning facilities by crowding them up in a seine net and releasing them. This procedure is performed over two consecutive days before transferring them from their pond to the hatchery for spawning. The fish stop eating, and this helps them adapt to the stress of artificial spawning. Fish can also be harvested and held in net enclosures or tanks for 24 to 48 hours with clean, preferably gently running, water. The fish pass food out of their intestines and will be in good condition for transport. If the fish have a disease or parasites, they can also be treated easily in tanks before transport.

5. Age and Size of Fish: A lower weight of small fish can be transported per unit volume of water than large fish; therefore, this influences the duration and welfare standards to observe during their transport. Table 4 gives recommendations for transporting different-sized fish in tanks.

Table 4 Quantities of different-sized fish that can be transported in sealed plastic bags (18inch x 32inch) with approximately 7.6 litres of water and pure oxygen

Fish Size	**Duration of Transport**			
	1HR	12 HR	24 HR	48 HR
Newly Hatched Larvae (g/l)	120	80	40	10
1/4-inch (0.64 cm) Fry (g/l)	60	50	40	20
1 inch (2.54 cm) Fingerling (g/l)	120	100	75	40
2-inch (5.08 cm) Fingerling (g/l)	120	105	90	40
3-inch (7.62 cm) Fingerling (g/l)	120	105	90	40
Larger Fish (g/l)	480	180	120	60

Source: ICAAE

Methods Used for Transporting Fish

Various methods are used in the capture and movement of fish within farms, ranging from the use of small nets for individual animals to large nets for the collection of larger fish. Special fish pumps or pipes are also used for fish movement between ponds or to other tanks for treatment. Each of these methods, however, has its associated limitations. For example, the use of nets can easily cause abrasions, damage and loss of scales, and poorly designed pumping systems can also cause fish injury, as they can often be dropped onto hard surfaces at the point of exit from the pipe.

The current popular mode of transportation for catfish in Nigeria involves using modified jerry cans, which are often carried in buses or sometimes placed in the vehicle's booth, emitting smoke containing carbon dioxide or ammonia. The fish may be transported for long distances of up to 6-12 hours, and are often starved to avoid polluting the water. Such a method of transporting goes against standard operating procedures for transporting fish.

Ideal transport systems should include the following:

- Fish should be transported in specially designated vehicles with insulated holding tanks, monitoring apparatus and for very short journeys.
- Fish seeds should be transported in gassed polyethene bags placed in styrofoam boxes to minimise movement shocks during transportation. Before transportation, the receiving tanks must be prepared with high-quality oxygenated water, which will serve as temporary holding tanks. These fish seeds will be observed for approximately a week to ensure that they are free from accompanying parasites/pathogens. After the quarantine period,

they can be transferred to receiving and more permanent holding tanks for onward growth.

Figure 12 Recommended method for Tilapia Transport (closed transport system)

Figure 13 An open transport system (plastic tank)

Q&A Session

In a facilitator-led training session, fish welfare trainers/facilitators should provide opportunities for trainees to ask questions and engage in discourses on the module, while the facilitator provides answers.

If reading the training manual in a personal capacity, you can share your questions in the following ways to receive answers and further support, where necessary:

- Send your questions to contact@animalwelfarecourses.com or info@onehealthdev.org.
- Share your questions on the Discussion Forum on the online training platform for Fish Welfare.

Discussion Session

- How do you currently handle your farmed fish? Please mention all handling methods you use.
- As a fish farmer, have you received training on handling Operational Welfare Indicators (OWIs)? If so, briefly explain who provided it, when it happened, and some examples of how you apply it to your daily routine.
- Based on previous experiences, what is your knowledge of fish transportation? Mention all transportation methods used.
- As a fish farmer, have you received training on transportation OWIs? If so, briefly explain who provided it, when it happened, and some examples of how you applied it before and after live fish transportation.
- Is the person responsible for live fish transportation trained for that purpose? Does this person know how to act in frequently encountered situations and emergencies during transportation?
- How do you intend to improve the handling and transportation of your farmed fish to align with good welfare standards? Are there challenges (e.g.

economic costs, operational on-farm procedures) preventing you from implementing them?

- How can local innovations in transportation be employed to meet optimal fish welfare standards?

MODULE 8 – SLAUGHTERING AND FISH WELFARE

Overview of Fish Slaughtering and Welfare

Fish slaughter is a critical aspect of aquaculture and fisheries, affecting both meat quality and ethical considerations. In Nigeria, fish is a major source of animal protein, and its processing plays a key role as consumers demand healthy fish products, leading to increased demand and boosting the economy of the country. Slaughter is the process used for the killing of animals intended for human consumption (European Council, 2009). However, slaughter methods vary widely, ranging from traditional practices to modern techniques. Fish welfare, particularly during slaughter, has gained attention globally due to increasing awareness of animal welfare and ethical food production. Proper handling and slaughter methods are essential for ensuring minimal suffering, maintaining meat quality, and complying with international standards.

Fish species are slaughtered and killed under different conditions compared to terrestrial animals, primarily due to their aquatic environment. Unlike land animals, fish experience hypoxia (oxygen deprivation) during slaughter, which affects their physiological responses. They also possess unique stress and pain perception mechanisms, which differ from those of mammals and birds. Additionally, fish exhibit species-specific variations in stress tolerance, bleeding efficiency, and post-mortem changes, impacting meat quality. These differences necessitate tailored slaughter methods to ensure humane treatment and product quality. Many commercial fish slaughter methods cause prolonged suffering, exposing fish to pain and distress. Some practices fail to ensure humane treatment, leading to stress and poor welfare before death (European Council, 2009).

Fish are known to be sentient beings; therefore, the welfare rules stipulate that fish shall be spared any distress, avoidable pain, or suffering during their killing and any slaughtering operations. Many known commercial killing methods expose them to

great amounts of suffering over a prolonged period of time, and some of the slaughtering practices (i.e. boiling) are the cause of preventable pain and distress. The percussive, spiking or coring, and electrical stunning followed by the kill method (gill cutting), can be enabled for slaughter (Boyland and Brooke, 2017). Sentience is the animal's capacity to have positive (comfort, excitement) and negative (pain, anxiety, distress, or harm) feelings. Scientific evidence has shown that the major commercial fish species (Wolfe *et al.,* 2019) possess complex neurological substrates supporting pain sensitivity and conscious experiences (Mercogliano and Dongo, 2023).

Fish welfare during slaughter is more than just an ethical concern; according to the One-Health approach, food safety should also include the concept of sentience in relation to fish welfare. The European Commission (2018) has recommended the identification of separate standards for the protection of farmed fish during killing (humane slaughtering methods).

Importance of Humane Slaughtering Practices

Humane slaughter refers to methods that minimise pain and stress before death. Guidelines on fish welfare during stunning and slaughter offered by WOAH's Aquatic Animal Health Code have been developed in developed countries. These guidelines, which emphasise stunning methods that render the fish unconscious before slaughter, have been developed (European Commission, 2018). However, in Nigeria, traditional practices often involve air asphyxiation or direct killing without stunning, raising concerns about welfare and quality. Adopting humane practices can lead to:

1) Improved Fish Meat Quality and Shelf Life: Humane slaughter methods improve meat quality and reduce the risk of spoilage (Fish Count, 2019). It reduces the appearance of soft flesh, gaping, bruising and scale loss, and improves shelf-life when compared to the traditional, less humane slaughter methods (Holmyard,

2017). Humane slaughtering methods yield firmer, translucent fillets with brighter colour, and the onset and severity of rigour are delayed when compared to conventional, less humane slaughter methods (Humane Slaughter Association, 2019).

2) Consumer Preference: Reducing stress at slaughter through humane slaughter methods is also likely to improve eating quality and taste for the consumer, as fish consumers would prefer to eat hygienically and healthily handled fish. Humanely slaughtered fish will boost the international market, as it will enhance the credibility of the fish in terms of adhering to the standard operating procedure for fish slaughter (Fish Count, 2024).

3) Ethical Compliance: Practising humane methods of slaughter improves compliance with existing local and global food processing and safety standards, adhering to ethical treatment of aquatic animals, aligning with global best practices.

Traditional Fish Slaughtering Practices in Nigeria

In Nigeria, traditional methods of fish slaughter have been in existence right from the domestication of fish species. Catfish and tilapia fish have been slaughtered following traditional or "normal" methods, which ordinarily do not consider the sentient nature of fish.

Common Methods of Fish Slaughter

Traditional fish slaughter methods in Nigeria vary by region and include:

1. **Air Asphyxiation**: In this method, the fish are removed from the water and allowed to die through asphyxiation. Fish are left to suffocate in the open air, a common practice in local markets. Air asphyxiation is considered inhumane for fish slaughter because it can take an extended period for fish to die, causing

prolonged suffering. Species such as Nile tilapia (*O. niloticus*) and African sharptooth catfish (*C. gariepinus*) exhibit significant resistance to low-oxygen conditions. Nile tilapia have developed metabolic adaptations that enable them to survive in hypoxic environments by reducing their metabolic rate, thereby conserving energy and prolonging survival during periods of low oxygen availability (Regan *et al.,* 2021). The African sharptooth catfish possesses a specialised suprabranchial air-breathing organ, enabling it to utilise atmospheric oxygen. This adaptation allows the species to withstand hypoxic conditions and survive for extended periods out of water, further prolonging the time to death when subjected to air asphyxiation (Eurofish, 2022). Additionally, the rate at which oxygen is depleted in these fish is influenced by ambient temperature and their activity levels. High temperatures can reduce hypoxia tolerance and alter gill morphology, compromising the fish's ability to extract oxygen and survive under low-oxygen conditions (Mdpi, 2023). Given these physiological adaptations, air asphyxiation is particularly inhumane for species like Nile tilapia and African sharptooth catfish, as it subjects them to prolonged distress before death.

2. Iced Slurry: In this method, fishermen place fish in ice water to slow metabolism, though this does not always lead to immediate unconsciousness. It also increases the time for the onset of rigor mortis and the resolution of rigor. Another advantage is that the water can be drained, and the fish placed in an iced container with their temperature lowered. Additionally, the method immobilises the fish, allowing them to be handled more easily. However, some believe the method is unacceptable since it prolongs the period of consciousness and does not reduce the animals' ability to feel discomfort. Because chilling slows metabolic rate and oxygen needs, it may prolong the duration until death in some instances, with some cold-adapted species taking more than an hour to die.

3. Head Strike: This is also known as manual percussion; this is one of the traditional methods for fish stunning and slaughter. In this method, fish are removed from the water and given a sharp blow to the head. If the blow is strong, the animal is slaughtered. If the blow is weak, the animal is stunned. Worse still is cracking of the skull with a heavy instrument or hitting the skull on a hard surface. After the blow is engaged, the fish usually bleeds. This method may or may not be effective in rendering fish unconscious instantly.

4. Spiking: Another crude traditional method is spiking, also known as "Ikejeme" (which originates from Japan). A sharp spike is inserted into the hindbrain, located slightly behind and above the eye. This action causes instant brain death, ceasing all movement (Sakaguchi, 2020). The procedure can be applied more accurately in large fish due to the larger size of their brains. In smaller fish, the brain may be difficult to locate and destroy. If it is not destroyed, the fish will undergo stress, and some undesirable changes in meat quality may result. For best results, the spike should be placed in a position to penetrate the skull and then pushed quickly and firmly into the brain. The impact of the spike should produce immediate unconsciousness. The spike should then be moved from side to side to destroy the brain. The main disadvantage here is also the unethically violent nature of the method. It is essential to note that manual spiking requires a high level of precision and expertise to be efficient. Therefore, if you must choose between manual percussion (striking) and manual spiking, manual percussion is probably easier to implement effectively because it requires less precision.

Factors Influencing the Use of These Methods in Nigeria

Traditional slaughter practices persist due to:

- **Cultural Norms:** Many fishing communities have used these methods for generations.

- **Lack of Awareness:** Many small-scale fish processors are unaware of humane slaughter alternatives.
- **Economic Constraints:** Modern humane slaughter equipment is expensive and not widely available.
- **Market Demand:** Speed and efficiency often take priority over welfare considerations in high-demand processing environments.

Negative Impacts of Traditional Slaughter Methods

Despite their widespread use, traditional methods present several challenges:

- **Ethical Concerns:** Prolonged suffering in fish before death.
- **Meat Quality Issues:** Stress before slaughter can lead to poorer texture and faster spoilage.
- **International Trade Barriers:** Export markets may reject fish products that do not meet welfare standards.

Modern Slaughtering Techniques and Best Practices

Different fish species require different technical approaches to stunning and killing procedures. Staff must be trained on handling and slaughtering components, and may require adjustments to operational protocols. Animals should only be killed after stunning, and the loss of consciousness and sensibility should be maintained until death (European Council, 2019). However, effective stunning has evident benefits for welfare and product quality, including painless killing, improved flesh quality, delayed rigor mortis, and a longer shelf life (Saraiva et al., 2022). It is crucial to determine if the methods can be either stressful or painful for farmed fish (van de Vis *et al.* 2020).

The modern or commercial methods of humane fish slaughter include electrical stunning, followed by decapitation; percussive stunning using a captive bolt, followed by gill-cutting; the use of carbon dioxide (CO_2) as a stunning method;

and the application of water slurry as a killing method (Mercogliano et al., 2024). However, before considering fish slaughter, it is important to follow pre-slaughter procedures recommended by the Humane Slaughter Association (2019).

Pre-Slaughtering Welfare Considerations

Slaughter and pre-slaughter practices can significantly impact the quality of flesh in farmed fish (Mercogliano *et al.* 2024). The Humane Slaughter Association (2019) gives recommendations for pre-slaughter welfare considerations. These include:

1. **Purging:** This is also referred to as fasting or starving, and it is the method of withdrawing feed from farmed fish prior to slaughter to enable their guts to empty their contents. It reduces the risk of fish contamination during processing and maintains the quality and hygiene of the final products. The recommended time range for purging is 24 to 48 hours to completely empty fish guts while minimising adverse welfare effects. It is also important to note that the minimum duration of fasting needed to achieve gut clearance may vary depending on water temperature.
2. **Crowding**: This is a common husbandry practice in aquaculture, where farmers reduce the water level or increase fish stocking density. It is usually done during harvesting, as a pre-slaughter procedure. However, it exposes fish to a rapidly increasing density, and as a result, oxygen availability and general water quality can decrease quickly. Its adverse effects can be lessened by slowly reducing densities and providing additional oxygen. Additionally, crowding should be carried out gradually in steps (rather than crowding all the fish at once), and fish should not be crowded for more than two hours. Crowding can cause suffering and stress for fish, but with proper management and careful handling, it is possible to minimise stressors. For these reasons, there must always be at least one member of the slaughter team monitoring the crowd pen at all times. It is important that the person

responsible for the welfare of the fish can recognise problems and determine the appropriate action to take to resolve them.

3. **Dewatering:** This is the phase from the crowding to the stunning/slaughter point when the fish are briefly out of water. Most stunning and slaughter methods involve removing fish from the water alive and conscious, which stresses the fish since they are out of their natural environment. To reduce the number of times fish are exposed to air, they should be removed from water, or dewatered, as close to the stunning point as possible. The dewatering process should be designed to gently and promptly move fish to the stunner in the correct orientation. Humane dewatering processes may include using aquatic anaesthetics to sedate fish immediately before their removal from the water, the use of pumps to move fish from the crowd pen, and the use of braille nets.

Modern/Commercial Fish Slaughtering Methods

1. **Percussive Stunning**: This method involves delivering a strong blow to the fish's head, rendering it unconscious before further processing. It is quick and effective when done correctly, reducing stress and pain. Percussion is a stunning method that can be applied manually or automatically through a blow to the fish's head. When the automated percussive method is used, variations in the size of fish within the population can cause a miss-stun in some individuals, and the quality of the fish can be affected. In this case, a further killing method must be applied. Controlling the process requires the presence of well-trained staff at the slaughter facility. The air pressure method used to drive the bolt should be checked to ensure that it is sufficiently high and that the blow is delivered correctly to the head of each fish. Percussion followed by correct gill-cutting causes a rapid state of unconsciousness and insensibility before slaughtering. It is recommended for large fish species, such as catfish and tilapia (Mood *et al.*, 2023; European Commission, 2022).

2. Electrical Stunning: Among the stunning methods is the application of electrical stunning (in water or after fish are removed from the water), which involves passing an electric current through the fish to induce immediate unconsciousness before slaughter (Mercogliano *et al*. 2024). A sufficient current should be passed through the fish's brain using adequate amperage across the electrodes after the fish is removed from the water. The waveform, the stunner orientation, and fish density (kg/L) influence the effectiveness of an electrical stun. Stunning induces a loss of consciousness in fish, but its effectiveness can vary significantly depending on the parameters set (voltage (V), current (A), frequency (Hz), and time of application). To establish the exposure duration to electricity, the main requirement is the time interval between fish leaving the stunner and the killing method (van de Vis et al., 2020). Advantages of this method include;

- Minimal handling stress.
- Improved product quality.
- Potential for automation in larger processing plants.

3. Carbon dioxide narcosis: This slaughter method involves dissolving carbon dioxide in the water before the introduction of the fish. After that, they react violently while their blood rapidly absorbs the gas. The fish may acquire bruises from hitting each other or the sides of the container. The time required to become anaesthetised can vary from less than 4 to more than 100 minutes, and fish may be removed once movement stops, typically after 2-3 minutes. However, there is concern that fish may be rendered immobile by the carbon dioxide before completely losing consciousness and may be bled or eviscerated while still sensible. Also, adding a lot of carbon dioxide to water lowers the pH, making the water very acidic, which causes distress to fish. Some countries have used nitrous oxide ("laughing gas") instead of carbon dioxide, as it does not cause the strong activity seen in fish immersed in carbon dioxide-

saturated water. Nevertheless, the fish recover quickly when removed from contact with the gas.

4. **Ice Slurry and Chilling Methods**: As a killing method, ice water slurry (a mixture of ice and water from 1:2 to 3:1) lowers fish metabolism and reduces activity before slaughter. It is commonly used for rainbow trout, European sea bass and gilthead seabream. The transfer into ice water may lead to asphyxia due to increased fish density without any aeration or oxygen addition to the slurry. The method poses a severe welfare risk and is ineffective in species surviving long periods of anoxia. For example, the rapid drop in temperature has a greater impact than the absence of oxygen in Crucian carp, which is more tolerant to low oxygen levels (van de Vis et al., 2020). Without prior stunning, asphyxiation on ice is considered the worst method in relation to welfare and flesh quality (EFSA, 2009).

5. Exsanguination (Bleeding to death): This is the process whereby an animal bleeds to death. Fish are cut in highly vascular body regions, and the process is stressful and painful unless the animals are first rendered unconscious. One advantage for the industry is that bleeding prevents the fish muscles from turning an unpleasant red colour and acquiring a bloody odour. The main disadvantage is that if stunning is not done before bleeding according to behavioural and neural criteria, fish may remain conscious for 15 minutes or more between the times when major blood vessels have been cut and when they lose consciousness. Bleeding can be accomplished by three major processes: cutting the gills, removing the gills or severing the caudal artery. Alternatively, the heart can be pierced, or the blood vessels in the tail can be severed. The animals die from anoxia, and any struggling, which can range from 4 to 15 minutes, serves to hasten death. However, some species may live longer; for example, eel brains may continue to process information for 13–30 minutes after being decapitated. Additionally, bleeding can be achieved with

decapitation, and while not encouraged due to the unethically violent nature, it provides the most profuse bleeding and the shortest time before loss of consciousness.

6. Use of Anaesthesia (TMS and Metomidate): An advantage of using anaesthesia is that, once fish are anaesthetised, death can be accomplished more easily by other slaughter methods. Another major advantage is that the fish do not undergo stress, which helps to maintain post-harvest quality. However, the use of anaesthetics raises a major concern that some of their compounds may be absorbed into the animal flesh, leaving residual chemical traces in the muscle tissues that would be consumed by humans and animals. Additionally, some species may exhibit adverse reactions to anaesthetics for a short time, as they appear to be irritating. The efficacy of this method may vary depending on the dosage and the species. For example, African Sharptooth Catfish appear to be very resistant to Aqui-S, i.e. they have shown to become paralysed while still being conscious at doses which are known to be lethal to salmonids.

For many species, there are still a lot of uncertainties as to whether chemical anaesthesia actually results in a loss of consciousness or whether it only paralyses fish. For this reason, it is considered that chemical anaesthesia could potentially be humane, but there is too much uncertainty to recommend it. Nevertheless, different countries have different regulations when it comes to pre-slaughter chemical anaesthesia for fish destined for human consumption. Some countries permit it without any withholding period or maximum residue concentration, while others have standards for both aspects. All these points lead back to the uncertainties associated with the use of anaesthesia.

7. Other Stunning and Slaughter Methods include **Salting** to slaughter fish, which is also considered an inhumane method, as it exposes the fish to pain and suffering because death is not immediate; **use of ammonia baths**;

shooting, which is often done for large fish; **using a pneumatic accurate gun,** which can deliver the required velocity for effective stunning.

New stunning methods are proposed to improve the welfare of farmed fish. As an innovative, stunning/killing method, immersion in cold saline (−6◦C, 5% NaCl) is considered an alternative to percussion in rainbow trout (Bordigon *et al.,* 2024). Also, in the same species, electro-narcosis using a current intensity of 400mA is proposed as an alternative to fish immersion in ice water, reducing the stress response and improving flesh quality (Bermejo-Poza *et al.*, 2021). Asphyxiation in the air or an ice slurry, gill cutting, CO_2 addition, exsanguination in ice water, salt baths, or ammonia application are stressful and may induce post-mortem changes in fish meat. Finally, in aquaculture, the uses of more humane methods (percussion and electric stunning) are restricted only to certain fish species (Sneddon, 2020). Tables 8.1 and 8.2 show farmed fish welfare at slaughter and their evaluation for effectiveness.

Table 5 Effective evaluation of current methods of farmed fish welfare at slaughter

Method	Welfare Evaluation
Haemorrhagic decapitation, evisceration, and exsanguination without a prior stunning method	Rejected
Gas exposure immersion in N2/CO2 saturated water	Not recommended for Atlantic salmon and sea bream
Full-automatic percussive stunning	rejected for overly high stunning failure rate
In-water pipeline electrical stunning	Acceptable

followed by the semi-automatic percussive method	
In-water pipeline electrical stunning followed by an efficient killing method	Acceptable
In head-to-body electrical stunning In-water rotating electrical stunning	Acceptable only in freshwater (tilapia and catfish)
Semi-automatic percussive stunning	Acceptable only in freshwater (tilapia and catfish) if the design is adequate and guarantees an air exposure under 15".

Source: WOAH (2022)

Table 6 Comparison between Traditional and Modern Methods

Method	**Effectiveness**	**Welfare Consideration**	**Meat Quality**
Air asphyxiation	Slow, causes distress	Poor	Can lead to rapid spoilage
Head strike	Quick but inconsistent	Moderate	Varies depending on accuracy
Electrical stunning	Instantaneous	High	Preserves texture and

			freshness
Ice slurry	Slow metabolism, but not always effective	Moderate	Prolongs shelf life slightly

Source: WOAH (2022)

Q&A Session

In a facilitator-led training session, fish welfare trainers/facilitators should provide opportunities for trainees to ask questions and engage in discourses on the module, while the facilitator provides answers.

If reading the training manual in a personal capacity, you can share your questions in the following ways to receive answers and further support, where necessary:

- Send your questions to contact@animalwelfarecourses.com or info@onehealthdev.org
- Share your questions on the Discussion Forum on the online training platform for Fish Welfare.

Discussion Session

- Do you slaughter your fish? If yes, what procedure do you currently use?
- Based on what you have learned so far, what mistakes have you made with fish slaughter? Mention which of the slaughter methods you have used.
- How do you intend to improve the slaughter of your fish to align with good welfare standards?
- How can local innovations be adapted to meet optimal welfare standards?

MODULE 9 – ENVIRONMENTAL ENRICHMENT AND FISH WELFARE

Concept of Environmental Enrichment in Aquatic Systems

Shepherdson (1998) defined environmental enrichment as "an animal husbandry principle that seeks to enhance the quality of captive animal care by identifying and providing the environmental stimuli necessary for optimal psychological and physiological well-being". Environmental Enrichment (EE) refers to modifications in captive environments that enhance the well-being of fish by promoting natural behaviours, reducing stress, and improving overall health (Gerber *et. al.* 2015). In aquatic systems, enrichment involves introducing physical structures, optimising social interactions, and providing sensory stimuli that mimic natural habitats. Unlike terrestrial animals, fish require specific environmental modifications due to their unique physiological and behavioural needs. It involves enhancing an animal's living environment to promote species-specific behaviours, mental stimulation, and overall well-being.

In the context of fish, it refers to creating conditions that mimic their natural habitats and encourage natural behaviours. It can include adding structures or modifying rearing units to create a more natural or complex environment that resembles the fish's natural habitat. It may also include any intentional augmentation of complexity in the surroundings of the animal, such as structures made from plants and pebbles, music, unusual foods, and the introduction of various fish species. Furthermore, it may include mimicking colours and introducing varied conditions like dark hiding spots and cooler water areas for them to choose from (Leone and Estévez, 2008; Näslund and Johnsson, 2014). This is particularly relevant in captive settings such as aquaculture farms and public aquariums (Zhang *et al.*, 2020a).

Types of Environmental Enrichment

The different types of environmental enrichments are divided into five (Bloomsmith *et al.,* 1991), and for farmed fish, the main environmental enrichment, according to Näslund and Johnsson (2014), comprises the following:

1. **Social Enrichment:** This is when animals experience the correct amount and type of contact with other fish or animal species. This includes sufficient access for social species and sufficient distance for those that are mutually aggressive or cannibalistic.
2. **Occupational Enrichment:** This includes physical and psychological stimulation that allows for the expression of behaviours that promote psychological well-being. This can involve play, interactive feeding opportunities, and sufficient room to swim freely (Gerber *et al.* 2015).
3. **Physical/Structural Enrichment:** This includes modification of housing environments to include structural complexity, shelter, and visual stimulation. This can include adding silt, sand, or other suitable substrates for incubation to the floor, which allows animals to burrow.
4. **Sensory Enrichment:** It aims at stimulating the fish's senses through the use of different stimuli such as light, sound, or odour, which is a diversity of visual, auditory, olfactory, tactile, and taste stimuli.
5. **Dietary/Nutritional Enrichment:** It involves providing a varied and balanced diet to meet the fish's nutritional needs and promote overall health and well-being. The use of feed is enhanced by the addition of appropriate nutrients, the availability of a suitable amount and variety of food, feeding frequency, and/or the delivery system (Gerber *et al*. 2015).

Why Environmental Enrichment?

The overall aim of environmental enrichment is to improve the husbandry conditions of captive animals, thereby enriching the environment through means

that augment the welfare of the animals held in captivity (Gerber et al., 2015). The purposes of environmental enrichment are to reduce abnormal behaviours, increase behavioural methods, and enable the animal to cope with challenges in a normal way (Chamove and Anderson, 1989). However, abnormal behaviour in farmed fish should be interpreted with caution, and further research is stressed to elucidate the importance of the possibility of expressing natural behavioural patterns (Ashley 2007).

The following goals of environmental enrichment were stated by Young (2003):

1. Increasing behavioural diversity.
2. Reducing the frequency of abnormal behaviour.
3. Increasing the range or number of normal or natural behaviour patterns.
4. Increasing positive utilisation of the environment and increasing the ability to cope with challenges in a normal way (Shepherdson 1989 as modified by Young 2003; Chamove and Moodie 1990).

With the interest of animal welfare as the primary goal, the aims of environmental enrichment include the following, according to Mellen and McPhee (2001);

- Successfully reproducing animals exhibiting adequate parental care as a goal of captive management. Enriched environments enhance adequate care, thereby promoting successful reproduction.
- The identification and reduction of potential sources of chronic stress and/or the enhancement of an animal's ability to cope successfully with acute stress by providing enrichment.
- The reduction or elimination of aberrant behaviours and concurrently provide opportunities for species-appropriate behaviours and activity patterns.
- The rearing of animals for re-introduction or re-stocking purposes appears to be more successful when they are reared under conditions that are

sufficiently rich (and close to the environmental diversity of the habitat they are going to be stocked into, to allow the performance and maintenance of species-appropriate behaviours (modified from Mellen and McPhee, 2001).

Benefits of Environmental Enrichment

The benefits of environmental enrichments for fish welfare are highlighted below:

- It improves post-stocking survival and foraging efficiency, reduces fin damage, and promotes social cohesion in fish farms (Rosburg *et al.*, 2019; Huysman *et al*., 2019).
- It can improve various aspects of fish biology, including aggression, stress, energy expenditure, injury, and disease susceptibility (Arechavala-Lopez *et al*., 2019; Zhang *et al.*, 2020b).
- It can have positive effects on fish physiology, health, survival, and general welfare.
- It improves the physiological state and behaviour of fish, serving as an indicator of their well-being (Oliveira *et al*., 2022). This is because it provides new sensory and motor stimulation to help meet their behavioural, physiological, morphological, and psychological needs, while reducing stress and the frequency of abnormal behaviours. It also increases the spatial use of the tank and enhances the growth rate in fish.
- Environmental enrichment enhances the fish's surroundings to avoid negative welfare (like stereotypical behaviour and chronic stress) and encourages positive welfare (natural behaviour display and positive emotions).

Some examples from scientific and evidence-based resources show the impacts and benefits of environmental enrichment. This includes occupational enrichment,

such as providing opportunities for fish to engage in natural behaviours that can help fish cope with acute stressors (Arechavala-Lopez *et al.,* 2019).

In summary, environmental enrichment has the potential to improve fish welfare in aquaculture by enhancing their well-being, reducing stress, and promoting natural behaviours. It often requires the management of aqua-ecosystems and biodiversity, as well as the use and application of local and traditional knowledge (Aubin *et al.*, 2017).

Species Recommendations for Environmental Enrichment

Catfish

Generally, key recommendations for the environmental enrichment of catfish include the provision of shelter structures and floating pond covers, the use of dark tank colouration, and the provision of feed in dry crumbles at the fingerling stage, with night feeding preferred at the adult stage. As adapted from the Aquatic Life Institute (ALI), key recommendations for environmental enrichment of Catfish have been explained in Table 7.

Tilapia Fish

Environmental enrichment strategies for Tilapia fish species have been studied to improve their behaviour and welfare in captivity. Studies have shown that structural environmental enrichment, such as the use of plant-fibre ropes or physical structures, can enhance cognition, exploratory behaviour, and brain physiological functions in Tilapia fish (Torrezani *et al.*, 2013). Enriched environments have been shown to reduce aggression and increase hierarchical behaviour in Tilapia fish (Arechavala-Lopez *et al.*, 2020). As adapted from the Aquatic Life

Institute (ALI), key recommendations for environmental enrichment of Tilapia fish have been elucidated in Table 8.

Table 7 Environmental Enrichment Recommendation for African sharptooth catfish (Clarias gariepinus)

Enrichment Category	Juvenile	Adult
Enclosure Colouration	For higher survival and better growth in fry, provide black tanks (FishEthoBase).	Not enough information is available currently. Therefore, we default to the species' "natural" conditions at this stage.
Substrate Provision	For the most natural solution, provide vegetation or mud banks (FishEthoBase).	For the most natural solution, provide mud, shale, sand, and vegetation (FishEthoBase).
Lighting	To accommodate the preference for fry and reduce stress in juveniles, provide ≤15 lux. For juveniles, a 24-hour photoperiod is stressful; stress levels decrease and growth increases with shorter photoperiods. Natural photoperiod is 9-15 hours. (FishEthoBase).	For lower aggression under light intensities of 0.002-1.4 µmoles/m2/s, provide blue light. Natural photoperiod is 9-15 hours. Provide access to natural (or at least simulated) photoperiod and daylight (FishEthoBase).

Water Augmentation	For better growth in fry, provide shallower tanks than deeper tanks (14.5 diameter-to-depth ratio or 0.1 m2 x 0.03 m depth) (FishEthoBase).	Provide variations in the direction and the velocity of the water inlet, depending on the life stage. Depth: Provide at least 2-4m, ideally up to 10 m or more, bearing in mind the planned stocking density (FishEthoBase).
Structures	For better growth in juveniles, install bamboo poles in ponds, which probably enable periphyton growth, which serves as additional food (FishEthoBase).	African catfish cultured in a coupled aquaponic system with basil exhibited a reduction in injuries and agonistic behaviour when paired with high plant density compared to low plant density and control conditions (no plants).
Shelter	Shelter structures reduced juvenile cannibalism (Hecht and Appelbaum, 1988; Hossain *et al.,* 1998). Enrichment with shelters probably increases the value for fry, but this may cause attacks and chases to establish territories. (FishEthoBase) Must be carefully	For the most natural solution, provide vegetation or mud banks; alternatively, provide artificial shelters inside the system or outside (e.g., black plastic shade material, black nylon shade cloth netting, aluminium roof plates. (FishEthoBase).

	monitored.	

Table 8 Environmental Enrichment Recommendation for Tilapia Fish Species

Enrichment Category	Juvenile	Adult
Enclosure Colouration	Not enough information is available at this time. Therefore, we default to the species' "natural" conditions at this stage.	Maia and Volpato (2016) demonstrated that it takes at least 10 days of testing to determine the colour preference of Nile tilapia, and that green and blue are the most preferred colours by the species.
Substrate Provision	Enrichment with e.g. river pebbles and plastic kelp models probably increases the value for juveniles, but this may cause more intense fights to establish territories (FishEthoBase). Must be closely monitored.	Males choose to make their nests in sand substrate when compared to other substrates, such as stones. Individuals presented equal frequency of total attacks, whether they were being kept with or without substrates, but fewer highly intense attacks were observed in animals kept with the substrate. For the most natural solution,

		provide sand and mud; alternatively, provide gravel. Bamboo poles also increase growth (FishEthoBase).
Lighting	Increased light intensity (280-1390 lx) reduces aggressive interactions between pairs of juvenile males. Natural photoperiod is 9-15 hours. Provide access to natural (or at least simulated) photoperiod and daylight (FishEthoBase).	Blue light reduces stress by preventing the confinement-induced cortisol response. Natural photoperiod is 9-15 hours. Provide access to natural (or at least simulated) photoperiod and daylight. Avoid 1,400 lux, as it increases aggression compared to 280 lux (FishEthoBase).
Water Augmenta-tion	Depth: Provide at least 2-6m, ideally up to 20m, bearing in mind the planned stocking density. Individuals should be able to choose swimming depths according to life stage and status (FishEthoBase).	Depth: Provide at least 2-6m, ideally up to 20m, bearing in mind the planned stocking density. Individuals should be able to choose swimming depths according to life stage and status (FishEthoBase).
Structures	An enriched environment increases resource value, which in turn prompts more intense fights (FishEthoBase).	Fish cultured in environments enriched with artificial water hyacinth and shelter presented higher latency to trigger confrontations, and the confrontations were less intense in the section with

		enrichment items (Neto & Giaquinto, 2020).
Shelter	An enriched environment increases resource value, which in turn prompts more intense fights (FishEthoBase).	For the most natural solution, provide roots or submerged branches, bushes, or trees; alternatively, provide artificial shelters within the system (e.g. an artificial reef) (FishEthoBase).
Feeding System	Ensure that you provide sufficient feed from approximately 4-8 days after hatching. Self-feeders could prevent stressful food competition (FishEthoBase).	Tryptophan-supplemented food was found to reduce confrontations (Neto and Giaquinto, 2020). Install a self-feeder and make sure all Nile tilapia adapt to it. (FishEthoBase). Provide sand, mud, and bamboo poles so that individuals may search for (FishEthoBase).

Carp Fish

Environmental enrichment recommendations for carp fish species include expanding the range of bred fish, considering the available feed base and biotechnics level. The traditional set of fish recommended for polyculture in north-western regions includes planktophages (peled), benthophages (chir, pyjian, carp), predators (pike perch, pike, trout), phytoplankton, zooplanktophages (white amur and motley carp), herbivorous fish (white cupid), Chudsky whitefish, muksun, and hybrids of peled with chir for nectobentos (Williams *et al.,* 2009). A multi-

coloured gravel substrate, cobbles, and plants can be provided in the hatchery environment (Murtaza *et al.*, 2020). As adapted from the Aquatic Life Institute (ALI), key recommendations for environmental enrichment of Carp fish have been elucidated in Table 9.

Table 9 Environmental Enrichment Recommendation for Carp Fish Species

Common carp (*Cyprinus carpio*)		
Enrichment Category	**Juvenile**	**Adult**
Enclosure Colouration	For lower stress and higher growth, avoid red and black tanks (FishEthoBase).	For lower stress and higher growth, avoid red and black tanks (FishEthoBase).
Substrate Provision	For the most natural solution, provide sand, mud, gravel, and submerged vegetation (FishEthoBase).	For the most natural solution, provide sand, mud, gravel, and submerged vegetation (FishEthoBase).
Lighting	The natural photoperiod ranges from 7 to 17 hours. Provide access to natural (or at least simulated) photoperiod and daylight (FishEthoBase). For lower stress and higher weight in juveniles, prefer 200 over	The natural photoperiod ranges from 7 to 17 hours. Provide access to natural (or at least simulated) photoperiod and daylight (FishEthoBase). Allow the Common carp a resting period at night or in the dark (FishEthoBase).

	80 lux (FishEthoBase).	
Water Augmenta-tion	Depth range: in the wild, found at 0-1.3m, adults up to 25m. Provide at least 1.5m, ideally up to 5m or more, bearing in mind the planned stocking density. Individuals should be able to choose swimming depths according to their life stage (FishEthoBase).	Depth range: in the wild, found at 0-1.3m, adults up to 25m. Provide at least 1.5m, ideally up to 5m or more, bearing in mind the planned stocking density. Individuals should be able to choose swimming depths according to their life stage (FishEthoBase).
Structures	Cover: Avoid complete cover for differences in the daily rhythms (FishEthoBase).	Cover: Avoids completely covering concerns about differences in daily rhythms (FishEthoBase).
Shelter	Juveniles used plants as shelters (FishEthoBase).	For the most natural solution, provide vegetation; alternatively, consider providing artificial shelters both inside and outside the system (FishEthoBase).
Feeding System	Food competition: Ensure sufficient feed is provided from approximately 1-7 days after hatching. To improve stress tolerance,	The most natural solution is to provide food at: 1) varying intervals or 2) constant intervals, but day as well as night, while making sure not to disturb the resting part of the population.

	enrich feed for fry with 4% fructo-oligosaccharides (FishEthoBase).	Alternatively – and for lower stress and higher growth – install a self-feeder and make sure all Common carp adapt to it.

Q&A Session

In a facilitator-led training session, fish welfare trainers/facilitators should provide opportunities for trainees to ask questions and engage in discourses on the module, while the facilitator provides answers.

If reading the training manual in a personal capacity, you can share your questions in the following ways to receive answers and further support, where necessary:

- Send your questions to contact@animalwelfarecourses.com or info@onehealthdev.org.
- Share your questions on the Discussion Forum on the online training platform for Fish Welfare.

Discussion Session

- Have you heard about or tried "Environmental Enrichment" before now? What was your experience like? What enrichments do you (or someone you know) currently use?
- Based on your current knowledge, how do you intend to improve the environmental enrichment of your fish to align with good welfare standards?
- How can local innovations and traditional knowledge in the environment be employed to meet optimal welfare standards?

MODULE 10 – FISH HEALTH AND WELFARE

Overview of Fish Health and Welfare in Nigeria

Fish health is a critical aspect of aquaculture and fisheries, directly impacting productivity, sustainability, and economic viability. Ensuring fish health involves disease prevention, water quality management, nutrition, and stress reduction (Austin and Austin, 2016). Maintaining fish health is crucial for sustainable aquaculture and fisheries. A combination of good management practices, disease monitoring, and preventive strategies can enhance fish welfare and productivity. In Nigeria, the welfare of fish, particularly in terms of their health status, is often overlooked and not given due importance. This is attributed to the limited information available on maintaining and managing fish health. Fish

pathologists are limited; therefore, it becomes difficult to manage fish health due to a lack of adequate information and knowledge.

Fish health can be defined as the absence of disease and the normal functioning and behaviour of the fish (Ducrot *et al.*, 2011). For a fish to be in a proper state of health, effective management practices must have been put in place before such fish can be termed healthy fish or in a state of good health. Hence, welfare considerations are crucial in managing the health of fish, which forms the foundation of fish health management. Healthy fish should eat aggressively when fed during regular feeding regimes, and they should not be visible in the pond except during feeding. A deviation from these is an indication of the unhealthy status of the fish.

The fish environment is surrounded by various pathogenic diseases, including fungi, bacteria and parasites; hence, successful fish health management starts with the prevention of diseases rather than the treatment of diseases. Preventing diseases relies on adequate water quality management, as water is the primary environment for fish and serves as their first point of contact. Disease outbreaks pose a significant threat in aquaculture, resulting in substantial economic losses for farms due to increased mortality, decreased growth and productivity, and higher production costs. Due to its catastrophic impacts on aquaculture, FAO (2020) regarded it as one of the major obstacles to the growth and development of sustainable aquaculture. The major barriers to the effective prevention and control of diseases in fish farms include inadequate aquaculture disease management training, the unavailability of effective drugs within the reach of farmers, the high cost of quality feeds, the high cost of drugs and treatment, and poor financial support. These indicate the need for fish farmers and managers to be well-trained in aquaculture disease management, thereby reducing the occurrence of disease outbreaks and increasing their farms' economic performance.

Factors Affecting Fish Health

Several factors, including stress, environmental conditions, nutrition, pathogen exposure, and management practices, influence fish health. Diseases rarely affect fish under ideal circumstances, but when something in the environment is not right, the fish start to experience various symptoms of illness, which are caused by various factors. These factors include the following:

1. Stress

Stress is a significant contributor to fish diseases, as it suppresses the immune response. Stressors include handling, transport, pollution, and sudden environmental changes (Iwama *et al.,* 2011). Prolonged stress leads to immunosuppression, increasing vulnerability to infections (Tort, 2011). Stress weakens the fish and increases their susceptibility to illness. These stress factors could be either living or non-living. Living sources include parasites, bacteria, fungi, and, least common, viruses. Some normal and obligate bacterial pathogens may cause diseases under stressful environmental conditions.

2. Water Quality

Water quality is the primary determinant of fish health. Parameters such as dissolved oxygen, pH, ammonia, nitrite, and temperature influence fish physiology and immune function (Boyd, 2018). Poor water quality can lead to stress, making fish more susceptible to diseases (Tucker and Hargreaves, 2020). If your fish is sick, the first thing to check is the water quality. Parameters to check include pH, dissolved oxygen, ammonia and nitrite. A water quality kit should always be available on the farm. Low DO, high pH, ammonia and nitrite are capable of causing diseases in fish. Therefore, all these must be checked weekly and recorded for use.

3. Nutrition and Feed Quality

Balanced nutrition is crucial for maintaining fish immunity, promoting growth, and supporting reproduction. Nutrient deficiencies, such as a lack of essential amino acids, vitamins, or minerals, can lead to a poor immune response and increased susceptibility to disease (Gatlin, 2010). Functional feeds enriched with probiotics, prebiotics, and immuno-stimulants have gained popularity in promoting fish health (Ringo *et al.,* 2018). Poor feeding of fish and not supplying them with adequate, nutritious, and well-balanced feeds can reduce their immunity to diseases and thereby increase their susceptibility to pathogenic diseases (Okhueleigbe, 2021).

4. Pathogens and Disease Outbreaks

Fish are susceptible to bacterial, viral, fungal, and parasitic infections. Disease outbreaks often result from stress due to poor handling, overcrowding, or environmental fluctuations (Roberts, 2012). Disease outbreaks are common in Aquaculture globally, and in Nigeria in particular. Therefore, public health officers and epidemiologists should be on alert when disease outbreaks occur and are experienced by fish farmers, in order to manage such diseases effectively.

Common Fish Diseases

Two main types of diseases affect fish, namely, infectious and non-infectious diseases. Infectious diseases are caused by pathogenic bacteria or viruses that are present in the water or carried by other fish. They are contagious diseases that require special and immediate treatment, including the use of medications and biosecurity measures, to prevent outbreaks. On the other hand, non-infectious diseases are caused by nutritional deficiencies, environmental problems and genetic anomalies. They are usually not contagious, cannot be spread and cannot be cured by medications.

Numerous infectious diseases are significant to global aquaculture, and they are often caused by viruses, bacteria, parasites, fungi, or pests (Cascarano *et al.*,

2021). They have the capacity to spread through the movement of infected host species, have devastating effects on aquaculture productivity, and pose greater challenges for aquaculture development (Subasinghe *et al*., 2009). Diseases that are gradually emerging in catfish production in Nigeria are Furunculosis, a bacterial disease. Other bacterial infections are ascites, necrosis syndrome caused by *Aeromonas sp*, haemolytic syndrome caused by *Enterobacter sp, Staphylococcus sp or Vibrio sp*. White spot disease is caused by the parasitic protozoan *Ichthyophthirius multifiliis*, and other non-infectious diseases can be categorised as environmental, nutritional, and genetic, for example, *Ameloblastic odontoma* (Agbede, 2012).

Generally, common diseases of farmed fish are highlighted below:

1. Common bacterial diseases: These are internal infections which require treatment with medicated feeds with antibiotics approved by the Food and Drug Administration. They could also be external, which often results in skin erosion and ulcerations. They include the following:

- Red Pest characterised by bloody streaks on the body, fins, and/or tail, which may lead to ulceration and possibly fin and tail rot in extreme cases.
- Mycobacteriosis caused by the bacterium *Mycobacterium piscium* and characterised by emaciation, hollow belly, and possibly sores. The leading cause is usually overcrowding or high stocking density in unkept conditions.
- Dropsy caused by *Aeromonas* and characterised by bloating of the body and protruding scales. It affects the kidneys, causing fluid accumulation from renal failure.
- Tail Rot and Fin Rot caused by *Aeromonas* and characterised by disintegrating fins that may be reduced to stumps, exposed fin rays, blood on edges of fins, reddened areas at the base of fins, and skin ulcers with grey or red margins, cloudy eyes. If the tank conditions are not good, an infection can be caused by a simple injury to the fins/tail.

- Ulcer caused by bacteria, *Haemophilus sp* and characterised by loss of appetite and slow body movements.

2. Common fungal diseases: Fungal spores are common in aquatic environments, but do not cause disease in healthy fish. When fish are infected with a bacterial or parasitic infection or are injured as a result of poor handling, the fungi will colonise damaged tissue on the exterior of the fish. Since fungi are a secondary problem, it is essential to identify the underlying cause and address it. Fungal diseases include:

- Mouth Fungus caused by the bacterium *Chondrococcus columnaris* and characterised by white cottony patches around the mouth. It may be fatal due to the production of toxins and the inability to eat.
- *Ichthyosporidium* is a fungus, but it manifests itself internally, primarily attacking the liver and kidneys, and may spread everywhere else. Symptoms include sluggishness, loss of balance, hollow belly, external cysts and sores.
- *Saprolegnia* causes tufts of dirty, cotton-like growth on the skin and can cover large areas of the fish. These fungal attacks often accompany other health issues, such as parasitic infections, injuries, or bacterial infections. Eventually, if left untreated, the fungus will continue to consume the fish until it ultimately dies.

3. Common Parasitic Diseases: These are often caused by small microscopic organisms called protozoans, which live in the aquatic environment. There are different protozoans which infest the gills and skin of fish, causing irritation, weight loss and death. They include the following;

- Argulosis is caused by *Argulus* (Fish louse), which is a flattened mite-like crustacean that attaches itself to the body of the fish. They irritate the host fish, which scrapes itself against objects, may have clamped fins, become restless, and may show inflamed areas where the lice have been.

- Velvet or Rust is a highly contagious and fatal disease characterised by yellow to light brown "dust" on the body, clamped fins, and respiratory distress (breathing hard).
- Anchor Worms (*Lernaea*) are crustaceans whose young are free-swimming and burrow into the skin, go into the muscles and develop for several months before showing, releasing eggs and dying. The holes left behind are ugly and may become infected. The fish scrapes itself against objects, and whitish-green threads may hang out of the fish's skin with an inflamed area at the point of attachment.
- *Erasmus* is a parasite like the anchor worm, but is smaller and attacks the gills instead of the skin. Also, the fish scrapes itself against objects, and whitish-green threads hang out of the fish's gills.
- Fluke infestations also cause the fish to scrape itself against objects, causing the skin to be reddened. In some cases, mucus covers the gills or body, and the gills or fins may be eaten away.
- Nematoda are threadworms that hang from the anus, which can infect just about anywhere in the body, but only show themselves when they hang out of the anus. A heavy infestation causes hollow bellies.
- Leeches are external parasites visible on the fish's skin, which affix themselves to the body, fins, or gills of the fish. Usually, they appear as heart-shaped worms attached to the fish.

4. Other Protozoan Diseases in Fishes are:

- Costia: A rare protozoan disease that causes a milky cloudiness of the skin.
- Hexamita: An intestinal flagellated protozoan that attacks the lower intestine and is characterised by the loss of appetite.
- Ich: A protozoan called *Ichthyophthirius multifiliis,* which is also known as white spot disease. It causes salt-like specks on the body fins, excessive slime, breathing problems, clamped fins, and loss of appetite.

- Neon Tetra disease: This is caused by the sporozoa *Plistophora hyphessobryconis*. It causes muscle degeneration, leading to abnormal swimming movements.
- Glugea and Henneguya, which are sporozoans that form nodular, large cysts on the fish's body and release spores. The fish bloat up, with tumour-like protrusions, and eventually die.
- Whirling Disease: Caused by *Myxosoma cerebralis,* causes blackening of the tail and deformity of the anal region.
- Knot Disease: It is caused by protozoa, *Myxobolus exiguus* and Bio-Disease caused by protozoa *Myxobolus pfeifferi*, with symptoms such as large boils of varying sizes appearing in several parts of the body.
- Myxosporidiosis: It is caused by infection with Myxosorida. Cysts can appear on the body, in internal tissues, and in organs. Infected fish become weak, and their scales may become perforated, causing them to fall off.

5. Viral diseases in Fish: These are difficult to diagnose, and there are no specific medications to treat fish infested with viral diseases. They require special laboratory tests to distinguish between a viral disease and a bacterial disease, as they often appear similar.

- Lymphocystis is a virus which affects the cells of the fish and causes nodular white swellings (cauliflower) on fins or bodies. It can be infectious but is usually not fatal.
- Tumours can be caused by a virus or cancer, but most tumours are genetic. The genetic tumours may be caused by excessive hybridisation, which is common among professional breeders. It is important to note that practically all tumours are untreatable, and if the fish is in distress, it should be culled and slaughtered.

Disease Diagnosis and Management

Disease Diagnosis

The most common diagnostic sign of diseased fish in Nigeria is the death of the fish. When fish die, an average Nigerian farmer generally concludes that the fish in the growing system are diseased before they start any form of diagnosis or treatment. This is usually risky because fish ultimately die due to disease infestation. They usually exhibit signs such as a poor response to feeding, being visible in the water, hanging or gasping for air, scratching their body against the wall of the growing system, skin lesions, and ulceration. All these physical behavioural changes in the fish should alert fish farmers to the onset of diseases in the fish and for necessary treatment by aquatic veterinarians.

Diagnostic Techniques

These include the following:

- **Clinical Observation:** Visual assessment of fish behaviour, lesions, and physical abnormalities (Roberts, 2012).
- **Microscopy:** Identification of parasites and bacteria from skin scrapings and gill biopsies (Noga, 2010).
- **Molecular Techniques:** PCR and RT-PCR are used for rapid pathogen identification (Mishra *et al.*, 2017).
- **Histopathology:** Examination of tissue samples under a microscope for pathological changes (Ferguson, 2006).

Disease Management

Management of disease includes disease treatment, control and prevention (biosecurity measures).

Treatment of Diseases: For many diseases, treatment may vary and include disinfecting of the fish tank, and treatment with antibiotics, metronidazole, copper or malachite green, acriflavine (trypaflavine), para-chloro-meta-xylenol,

thiabendazole, Trichlorofon, potassium permanganate, common salt solution, quinine hydrochloride, quinine sulphate, or quicklime – all in the correct dosage. In other cases, the best course of action is to cull, slaughter, or destroy the infected fish. If unkempt conditions or overcrowding are the suspected cause, it is required to take necessary measures. It is essential to note the following when treatment interventions are being applied to disease conditions in fish:

- Antibiotics may disturb biological filtration in the tank. Therefore, it is also recommended to monitor either ammonia or nitrite levels in the water or use an ammonia remover to ensure that the ammonia level does not exceed the desired limit.
- With larger fish and light infestations, parasites such as lice can be picked off with a pair of forceps.
- Some chemicals used for treatments may pose risks to fish and even human health. Therefore, ensure that they are used in the correct dosage and wear protective clothing and gloves.

Diseases Control and Reporting: Fish disease control are seen in different ways, which include environmental protection, population control, site selection, culture techniques monitoring and sanitation of aquaculture facilities, diagnosis and treatment of diseases of cultured species, avoidance of nutritional diseases, human health epidemiology, prevention of epidemics or mortalities in cultured facilities, formulation and implementation of regulatory measures to control National and International spread of diseases, development of disease resistant strains through genetic selection and hybridisation and individual and mass immunisation of cultured species and biosecurity measures (Bondad-Reantaso *et al*. 2009). The availability of data on diseases in both public and private facilities is in the public interest and important for monitoring the welfare of animals. All farms must record and retain detailed records of disease, treatments, transport, mortality rates, and causes of mortality for all animals in their care. They must actively use these records to further improve conditions within their production. Any disease outbreak should be reported to the appropriate authority, for example, the Department of Veterinary Services or the Department of Fisheries Services in your state of operation.

Disease Prevention Strategies

These include the following:

1. Biosecurity Measures in Fish Health and Welfare Management: Biosecurity is a set of practices to minimise the introduction, establishment and spread of pathogens. It entails a set of consistent and systemised practices that minimise the risk of introducing an infectious disease and/or spreading it to the animals within or outside a farm or facility. It also reduces the risk of diseased animals or infectious agents leaving a facility and spreading to other sites and to other susceptible species (Yanong and Erlacher-Reid, 2012). A lack of a biosecurity plan in the face of a disease outbreak can result in fish morbidity/mortality, increased treatment and diagnosis costs, all of which lead to poor fish welfare, reduced product quality and value, a damaged market reputation, and potential closure of the fish facility. These practices also reduce stress in the animals, making them less susceptible to disease and improving their overall welfare and well-being. According to Yanong and Erlacher-Reid (2012), the major goals of biosecurity are:

- Effective animal management through acquiring healthy fish stocks and optimising their health and immunity through good husbandry.
- Management of pathogens by preventing, reducing, or eliminating pathogens.
- Management of people by educating, training, and managing the movement of staff and visitors.

Many disease agents (live or dead, animate or inanimate) may come in contact with fish or their pond water on farms and have the potential to carry and spread diseases. Farmers need to be prepared to establish biosecurity measures against such agents. These agents include:

- Fomite (inanimate objects), which may be nets, buckets, siphons, footwear, clothing, vehicles, and containers.

- Vectors (living creatures), which may be new livestock, predatory birds, pets and people.
- Direct contact between fish with dead or dying fish, or other aquatic animal, contaminated feed and water sources: on-site sources, water reuse, transportation sources (Sahu *et al.*, 2020).

Benefits of Biosecurity on Fish Farms

Biosecurity can be simply stated as offering protection from exposure to diseases, and it is the most cost-efficient and effective means of disease control available (Aarattuthodiyil and Wise, 2017). Generally, implementing biosecurity measures will be effective in:

- Reducing the risk of disease transmission and minimising the spread of the disease within the same farm or from one farm to another.
- Promoting aquatic animal health.
- Preventing new diseases in ponds.
- Protecting human health (zoonoses, food safety) (Sahu *et al.*, 2020).
- Reducing stress and improving fish welfare and well-being.

Common Biosecurity Measures and Practices

A comprehensive list of good biosecurity measures and practices to be adopted by fish farmers includes the following (Bera *et al*. 2018; Ernst *et al.* 2017):

- Providing a clean, pathogen-free water source at all times for land-based fish farms.
- Restricting the movement of fish from one farm to another, especially from those of poorer health.
- Limiting visits to the fish farm or access to a farm site, i.e. by setting up gates and fences.
- Fixing clear signs to direct traffic within and outside the farm where necessary.

- Establishing and implementing strict sanitary measures such as defining sanitary units, cleaning and disinfection for people entering the farm, using protective and disinfected clothing, foot dips and hand hygiene.
- Restricting the movement of tools and culture organisms.
- Fish stock health should be maintained by keeping stock stress to a minimum level and maintaining optimum water quality.
- Minimise the pest and disease risk associated with stock movements onto, within and off your farm, by maintaining appropriate quarantine procedures during stock movement.
- Minimise the risks of pests and disease entry associated with incoming water through proper treatment.
- Preventing the entry and spread of pests and diseases by assessing all equipment, vessels and vehicles entering the farm through proper biosecurity procedures like disinfection of equipment, controlled use, etc.
- Records should be kept of the workers and visitors, and all the workers should be trained on biosecurity standards.
- Food-borne disease organisms can be minimised by proper handling and storage.
- Implementing pest control management by controlling or eradicating predators, wildlife, scavengers, and other organisms from farm areas.
- Wastewater and solid waste should be treated appropriately before disposal.
- Maintain record for all aspects of biosecurity plan (staff training, workers and visitors' log, inspection, and maintenance of farm infrastructure).
- Regular monitoring, surveillance and audit of the biosecurity measures should be implemented throughout the farm.
- Development and implementation of an appropriate biosecurity management plan (Bera *et al.*, 2018; Ernst *et al.,* 2017).

2. Use of Probiotics and Immunostimulants: Antibiotics are typically administered to fish through feeds, in baths, or via injections (Chowdury *et al.*, 2022). These methods can lead to the accumulation of antibiotic residues in the fish and their aquatic ecosystems. If the proper withdrawal periods are not observed after administering antibiotics, consumers of such fish will ingest antibiotic residues at suboptimal doses, which can facilitate the development of Anti-Microbial Resistance (AMR) and other health risks (Heuer *et al*., 2009; Sapkota *et al*., 2008). A contributing factor to AMR is the use of antibiotics as prophylactics in disease prevention – especially in intensive factory farm settings in aquaculture production (Cabello, 2006). Furthermore, intensive aquaculture, poor animal welfare practices, and poor biosecurity can increase the risk of infection in fish and consequently increase antibiotic use (Cabello, 2006). Furthermore, these residues and resistant bacteria can be transferred between the aquatic and terrestrial animals through the environment and waterways (Chowdury *et al,* 2022).

What is Anti-Microbial Resistance (AMR)?

This is the ability of bacteria, viruses, fungi, and parasites to resist the activity of medications (antimicrobials) designed to kill or inhibit them. These medications include antibiotics, antifungals, antiparasitic drugs, and antivirals. This resistance allows pathogens to survive and grow in the presence of antimicrobials. This leads to an increased treatment period and costs, as well as an increased risk of disease spread, severe infections, and higher mortality rates in terrestrial animals, aquatic species, and humans (WHO, 2021). Although AMR develops naturally over time, antimicrobial misuse and overuse in humans and animals remain a major predisposing factor (Cabello, 2006; Chowdury *et al,* 2022). This inappropriate use is linked to the lack of AMR and antimicrobial stewardship awareness, and the lack of diagnostic capacity in Nigeria and other developing countries

How does AMR spread from Animals to Humans?

Resistant bacteria can spread from animals to humans through the following routes:

- Via contamination of food animals or animal products, e.g. from poor antimicrobial stewardship (misuse or overuse).
- Occupational exposure for farm workers and fish keepers, abattoir workers, veterinary surgeons, and health workers.
- Environmental transfer can also occur upon contamination with resistant bacteria, resistance genes (which can be transferred from resistant pathogens to non-resistant ones), antibiotic residues, and
- Recreational activities, including fishing and swimming.

Impact of AMR

Antimicrobials are essential in intensive animal agriculture and aquaculture. Antibiotics, including oxytetracycline, amoxicillin, and sulphadiazine-trimethoprim, are used extensively in aquaculture to treat or prevent fish diseases, thus maximising productivity (Chowdury *et al.,* 2022). However, misuse and overuse lead to AMR, which causes treatment failure and affects aquaculture fish production and welfare (Schar *et al*., 2020). Also, aquaculture systems with high antimicrobial use may serve as reservoirs for antimicrobial resistance genes, hence facilitating AMR development in animals and humans (Schar *et al.,* 2020). We should also consider that authorised antibiotics for aquaculture species are scarce globally; hence, their efficacies should be maintained.

What Next?

In combating AMR, the FAO action plan on AMR 2016–2020 recommends prudent use of antimicrobials and effective biosecurity practices (FAO). The main recommendations include:

- Prudent and responsible use of antimicrobials to preserve their efficacy.
- Provision of clean, safe, and disease-free aquatic systems to prevent infectious disease incidence and reduce antimicrobial use.
- Proper routine monitoring of resistance during disease outbreaks.
- Proper animal welfare standards should be adopted and maintained as they ensure better immune systems in animals, thus preventing infections, minimising outbreaks, and reducing antimicrobial use.
- Routine removal of antibiotic residues in water via appropriate adsorption techniques, filtration, biological methods, sedimentation, and flocculation (Homem and Santos, 2011).
- Vaccination of aquatic food animals for infectious disease prevention. For example, oral fish vaccines are effective against many aquatic diseases (Newaj-Fyzul and Austin, 2015).
- Probiotics should also be considered in infection prevention and control. For example, probiotics are potential alternatives in controlling pathogens such as *Vibrio harveyi,* a major health threat in aquaculture (Chabrillon *et al.*, 2005).
- Immunostimulants can also be considered for use. Examples include β-1,3 glucans, which are reportedly effective alternatives against various aquatic diseases, such as vibriosis, enteric redmouth, Aeromonas, pasteurellosis, and Hitra disease (Ngamkala *et al.*, 2010).
- Broad-host range phages can also be considered to treat bacterial infections. For example, due to the unavailability of appropriate vaccines, phages were used in salmonids to prevent rainbow trout fry syndrome (RTFS) caused by *Flavobacterium psychrophilum* (Castillo *et al*., 2012).
- Traditional medicinal plants (phtyobiotics) can also be explored as antimicrobial alternatives. Examples include seaweeds, extracts of mango, peppermint, turmeric, jasmine, and neem, which are promising alternatives

for treating bacterial infections caused by aeromonads and *vibrios* in aquatic animals (Newaj-Fyzul and Austin, 2015).

In conclusion, regulatory agencies in Nigeria, such as NAFDAC and VCN, should ensure and regulate the use of synthetic antibiotics and promote the use of natural prebiotics, probiotics and phytobiotics for disease prevention and treatment.

Q&A Session

In a facilitator-led training session, fish welfare trainers/facilitators should provide opportunities for trainees to ask questions and engage in discourses on the module, while the facilitator provides answers.

If reading the training manual in a personal capacity, you can share your questions in the following ways to receive answers and further support, where necessary:

- Send your questions to contact@animalwelfarecourses.com or info@onehealthdev.org.
- Share your questions on the Discussion Forum on the online training platform for Fish Welfare.

Discussion Session

- Do you have any biosecurity protocols or systems on your farm?
- Have you experienced any disease outbreaks on your fish farm before? If you have, share your experience on how you discovered the onset of the disease (e.g. what were the signs), if and how you diagnosed the cause of the disease, and what you did to treat the disease and combat the spread.
- Do you engage qualified professional(s) to provide diagnostic and treatment services for your fish farm? If you do not do so, what is your reason for not doing

so? What are the alternative options you employ? What types of diseases do you encounter in the fish?

- Discuss your current use of antibiotics. Do you consider it currently as antimicrobial stewardship or misuse?
- Do you have a record-keeping system for your fish health, disease reports and antibiotic use?

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