AQUACULTURE FISH WELFARE TRAINING GUIDE

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

OHDI
ONE HEALTH & DEVELOPMENT INITIATIVE

AFIWEL
Africa Fish and Aquaculture Welfare Program

Ghana

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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 in leading transformative action for 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 Ghana, providing practical, evidence-based knowledge and tools for fish farmers, aquaculture workers, extension officers, animal health professionals, and institutions involved in 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 Ghana and across Africa.

With best regards,

The AFIWEL Program Team

One Health and Development Initiative (OHDI)

ABBREVIATIONS AND ACRONYMS

AFJ - Aquaculture for Food and Jobs
ALI - Aquatic Life Institute
AMR - Anti-microbial Resistance
AU-IBAR - African Union – Inter-African Bureau for Animal Resources
AWRA - Animal Welfare Research in Africa
CEA - Centre for Effective Altruism
CVON - Chief Veterinary Officer of Nigeria
DVPCS - Department of Veterinary and Pest Control Services
DVS - Department of Veterinary Services
EA - Effective Altruism
EU - European Union
FAO - Food and Agriculture Organisation
FC - Fisheries Commission
FMARD - Federal Ministry of Agriculture and Rural Development
FW - Fish Welfare
FWI - Fish Welfare Initiative
GAWS - Global Animal Welfare Strategy
MDAs - Ministries, Departments and Agencies
NAFDAC - National Agency for Food and Drug Administration and Control
NGO - Non-Governmental Organisation
OHDI - One Health and Development Initiative
Q&A - Questions and Answers
SDGs - Sustainable Development Goals
TWGs - Technical Working Groups
VCN - Veterinary Council of Nigeria
WOAH - World Organisation for Animal Health
WTO - World Trade Organisation

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This module explains the meaning of 'aquaculture' and summarises the common types of aquaculture systems that are practised in Ghana

INTRODUCTION TO FISH AND AQUACULTURE

For fishery and commercial purposes, a fish is any gill-bearing aquatic animal with fins and a backbone or any gill-bearing aquatic organism without a backbone, which is used for food. As aquatic animals, they inhabit both freshwater and marine environments, ranging from rivers and lakes to oceans. Fish is a significant source of protein, providing vital nutrients such as omega-3 fatty acids, vitamins and minerals to millions of people worldwide. The global annual per capita fish consumption is anticipated to reach 21.4kg by 2033 (OECD/FAO, 2024). The growing global demand for fish is a key driver of the rapid expansion of the aquaculture food production sector, now supplying over 50% of the world's fish consumption (FAO, 2023).

Aquaculture

Aquaculture is the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants under controlled conditions. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, and protection from predators. Farming also means individual or corporate ownership of the stock being raised. As wild fish stocks face pressure from overfishing and habitat degradation, aquaculture provides a solution to deliver a stable and sustainable supply of fish. However, it also faces challenges, such as environmental pollution, disease outbreaks, and the need for responsible practices to ensure sustainability.

AQUACULTURE IN GHANA

Fish constitutes 50–80% of the animal protein consumed in Ghana (Sumberg et al., 2016; FAO, 2018a), with a consumption rate ranging from 20 to 25kg/capita/year, higher than the average 14kg for ECOWAS (GNADP, 2024-2028). Ghana's aquaculture sector saw significant growth between 2008 and 2018, with production surging from 5,590 metric tonnes to 76,630 metric tonnes. However, this growth was abruptly interrupted in 2019, as outbreaks of the Infectious Spleen and Kidney Necrosis Virus (ISKNV) and Streptococcus (1a and 1b) in the Volta Basin caused production to plummet to 52,360 metric tonnes (Statista, 2025). The ISKNV and Streptococcus menace significantly impacted cage culture farms, which account for over 60% of annual aquaculture fish production (2021 Annual Performance Report, FC), further contributing to this production decline. Despite this setback, the sector rebounded strongly, reaching 132,680 metric tonnes in 2022 (Statista, 2025).

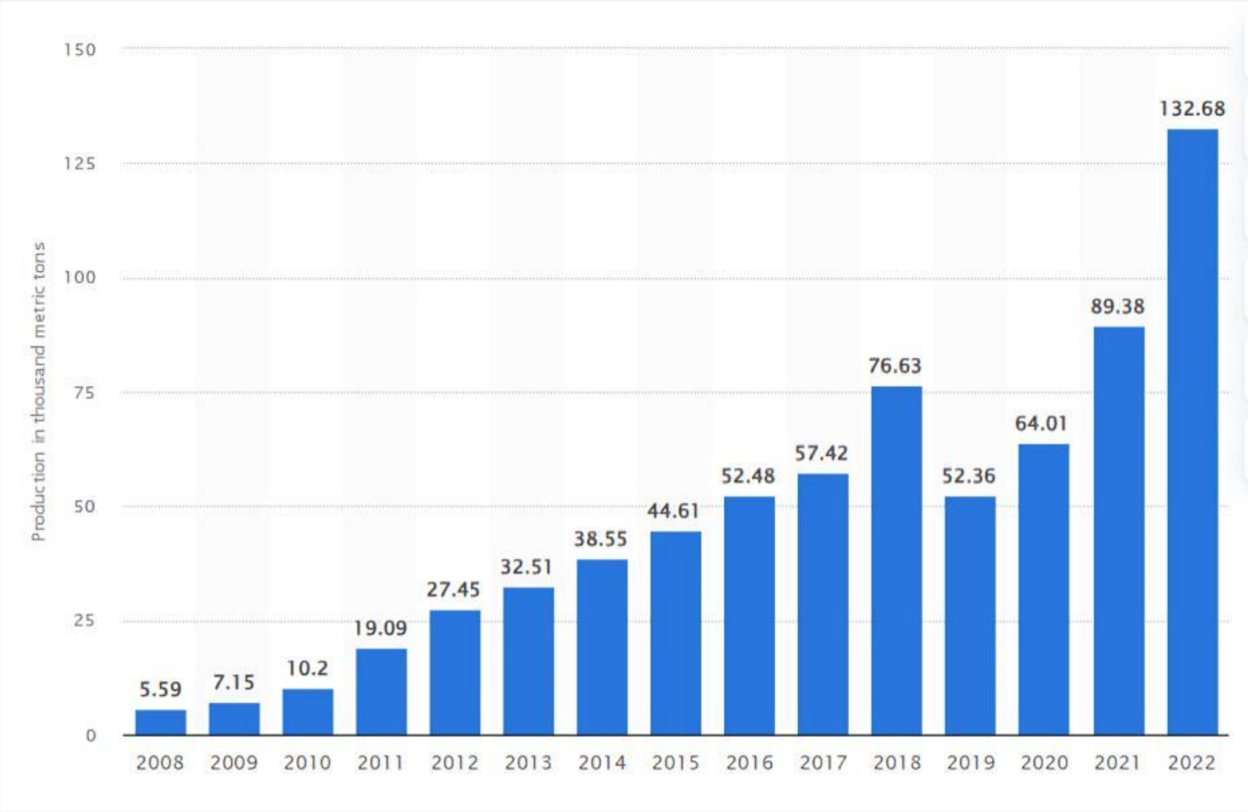

Figure 1 Aquaculture production in Ghana from the year 2008 to 2022 (in 1,000 metric tonnes)

Ghana's aquaculture is predominantly produced in freshwater, with the Nile tilapia (>70%) and the African catfish (~20%) being the main cultured species. Indigenous species, including the African Bonytongue and African Snakehead, are currently subjects of research for future culture initiatives. Although several high-performing commercial projects have lately developed, the sector is still dominated by extremely underperforming non-commercial systems (extensive, small-scale and subsistence), frequently using earthen ponds (GNADP, 2024-2028).

Plates of Fish Species Cultured in Ghana

a) Nile tilapia (*Oreochromis niloticus*)
Photo credit: Isaac Frimpong Arthur

(b) African catfish (*Clarias gariepinus*). Source: https://ffanch.com/product/catfish/

(c) African Bonytongue (Heterotis niloticus).

(d) African snakehead (Parachanna Africana)
Source: https://www.nytimes.com

Plate 1 Figure 2 Fish species cultured in Ghana (a)-(d) (Source: https://www.fishbase.se)

AQUACULTURE FISH PRODUCTION SYSTEMS IN GHANA

Holding facilities mostly used to raise fish in Ghana include earthen ponds, cages, concrete/tarpaulin tanks, Intermediate Bulk Containers (IBC) tanks and dams. These are used in semi-intensive, intensive, extensive, and integrated culture systems of farming and aquaponics. These systems are differentiated based on the stocking density of the culture organisms, the level of inputs and the degree of management. These are explained in more detail below.

Extensive culture system (Culture-based fisheries)

Extensive systems use low stocking densities. Fish depend solely on natural foods with little to no supplemental feeding. It is the system with the least investment and management in Ghana. This system is mostly used for freshwater staple food fish species by small-scale farmers. This system is mostly found in the Northern, Northeast, Upper West, and Upper East regions of Ghana. They are carried out in large irrigation sites, reservoirs, dams, homestead ponds or water enclosures close to rivers and streams. Yield is poor, and survival is low. Labour and investment costs are the lowest with this system.

Figure 2 An extensive aquaculture system (GRID & NEA) is being harvested in Northern Ghana (source: https://grid-nea.org/2009/09/fish-farming-a-first-in-Northern-Ghana/)

Semi-intensive culture system

With the Semi-Intensive System, care is taken to develop natural food by fertilisation with supplemental feed. Yield and survival are moderate compared to the Intensive culture system of production. This is the most practised system in Ghana and involves earthen ponds and tanks with relatively higher stocking density compared to the Extensive culture system of production. Most farmers practice this system in waterlogged areas or wetlands where water naturally fills the dug-out pond after construction. If the topography of an area prevents the installation of a well-designed outlet, ponds can suffer from ammonia poisoning due to limited water exchange. These ponds may also be vulnerable to flooding.

Figure 3 An Earthen Fishpond, an example of a Semi-Intensive aquaculture system with supplemental feed. Theophilus Ezrane Fish Farm, New Nzulezo, Jomoro –Photo credit: Isaac Frimpong Arthur

Intensive culture system

Under this system, fish are fed on entirely formulated feed. Water quality is actively maintained through regular water changes, the use of aeration, and the installation of biofilters. Compared to the other culture systems, intensive farming is a well-managed form of fish farming in Ghana, where meticulous attempts are made to achieve maximum production. This system may involve tanks, cages, ponds and more recently, Recirculatory Aquaculture Systems (RAS) and Biofloc with very high stocking densities. An intensive system is usually expensive for farmers to set up. It is also often the system with the most welfare issues due to its intensive factory farm settings. In Ghana, an intensive culture system is mostly practised at the Ghana National Aquaculture Training Centre and Commercial Farms, as well as some large-scale commercial farms and a few private small-scale farms. Survival rate is very high, leading to high yield.

Figure 4 Circular tanks (Greenhouse RAS system with paddle-wheel aerator and biofilter), an example of an Intensive aquaculture system. National Aquaculture Training Centre, Amrahia, Accra. Source: https://www.agritopgh.com/project/national-aquaculture-centre/

Integrated aquaculture system

An integrated aquaculture system involves the production of fish, crops, and livestock or poultry on a farm. This system is not popular and is now being promoted in Ghana. Examples include poultry-fish farming, rice-fish farming, fish-piggery and aquaponics. Farmers with tarpaulin and concrete tanks who often discharge wastewater by gravity are being taught and encouraged to use them for irrigation. In some cases, farmers manually fetch the water with watering buckets to irrigate crops. The core idea is to utilise the nutrient-rich wastewater generated from fish farming to fertilise and irrigate crops (i.e. fertigation). This creates a closed-loop system, minimising waste and maximising resource utilisation. It is environmentally friendly as it saves water and does not rely on artificial fertilisers.

Plate 2 Photograph of an integrated aquaculture system; Fa Debie Fish Farm, Half Assini, Jomoro-Photograph by Isaac Frimpong Arthur

Aquaponics

Aquaponics is an integrated aquaculture system that combines fish production (or other aquatic organisms) with hydroponics (growing plants in water) in a symbiotic relationship. Fish waste provides nutrients for the plants, and the plants clean the water for the fish. With this system, the basic components of RAS are utilised. However, the plants act as biofilters, purifying water and reintroducing it into the system by assimilating nitrogenous waste products generated by fish and feed. This system reduces disease transmission and the spread of infection and saves water. However, it is capital-intensive and requires professional knowledge.

Plate 3 An example of an Aquaponics set-up (Source: https://www.gothicarchgreenhouses.com/aquaponic-system)

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 you are 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.

QUESTIONS FOR DISCUSSION

- Introduce yourselves. Have you heard about Fish Welfare? What is it?
- Farmers to describe their fish farm (intensive, extensive, semi-intensive, culture system, species of fish, number of fish, location, successes and challenges, etc.). Others (non-farmers) should discuss why they are taking the course and what they seek to benefit?
- Can you share with us the different fish farming systems you know (by practice/ observation/knowledge)?
- What is/are the most common fish farming system(s) practised in your area? Why is this system common?
- Tell us which fish farming system you prefer the most and why. Share your personal experiences (if any) with your preferred fish farming system, including the advantages and disadvantages.
- Have you practised integrated aquaculture before? If yes, share details of the integrated fish farm system, your experience with it, and what you consider as advantages and disadvantages of the system.
- Have you attempted to culture any other fish species apart from tilapia and catfish? If yes, share details of the species and your experience with it.

MODULE 2: INTRODUCTION TO ANIMAL WELFARE

This module provides a basic introduction and overview of animal welfare, including information on the general animal welfare principles and rationale. We also introduce the 5 freedoms and domains of animal welfare and shared insights into general animal/fish welfare violations and practices. Lastly, we provide insights into provisional country-level legal frameworks in Ghana on Animal and Fish Welfare.

OVERVIEW, HISTORY AND TRENDS OF ANIMAL WELFARE

Animal welfare refers to the physical and mental state of an animal, encompassing all aspects of its well-being. It involves ensuring animals are healthy, comfortable, well-nourished, safe and able to express their natural behaviours, while minimising suffering and distress. 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 used to focus primarily on health disposition, improved methods of 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 towards animals, ranging from reverence and protection to exploitation.
- Some ancient civilisations, such as 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 brought increased urbanisation and factory farming practices, leading to 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 animal protection laws.

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 laboratory animal welfare.
- 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, including poor awareness, inadequate resources, flawed policy frameworks, and socio-cultural influences (such as 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 and incorporate the environmental components of welfare (Marchant-Forde and Boyle, 2020).

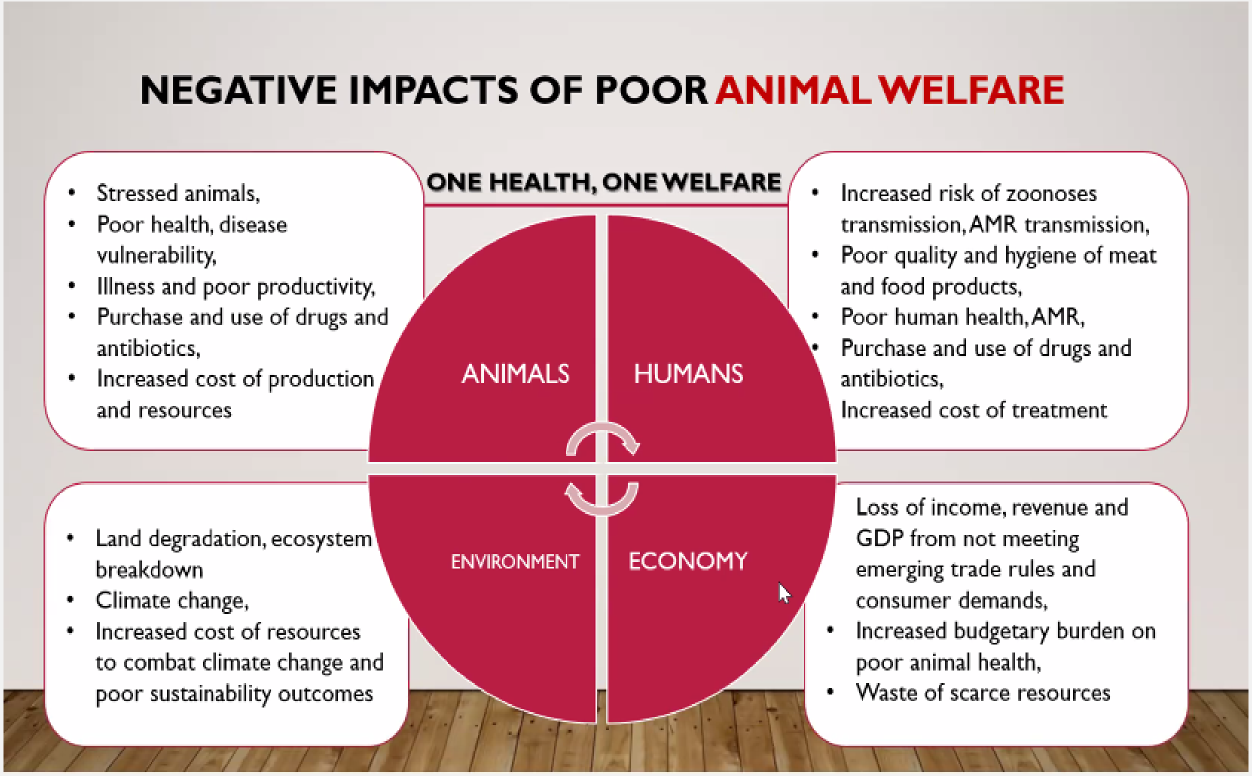

Figure 5 Impacts of poor animal welfare [Extracted from Oluwarore (2022)]

For example, improved animal welfare practices can contribute to a reduction in animal diseases and zoonoses in humans (Madzingira 2017), reduces mortality, improves growth, increases feed efficiency and, all in all, improves 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.

THE FIVE FREEDOMS OF ANIMAL WELFARE

In the quest for improved animal welfare, a significant advancement is the development of the "Five Freedoms of Animal Welfare". 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, typical behaviour, freedom from discomfort, freedom from fright and despair, as well as 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 provided in timely, consistent, balanced and nutritious rations devoid of contaminants and free of disease-causing organisms.
2. **Freedom from discomfort** – meaning the provision of a comfortable environment that involves a healthy and good quality water ecosystem, and 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 environment, noise, or fearful situations).

3. **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 anti-microbial stewardship.
4. **Freedom to express normal and 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, vocalizing, 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 its natural instincts and behaviours.
5. **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 note that while all Freedoms have their distinct roles, they logically feed into and impact each other in various ways. For example, an animal's "freedom from hunger and thirst" contributes to the satisfaction of the other four freedoms.

THE FIVE DOMAINS OF ANIMAL WELFARE

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 (Figure 2.2). The five domains include *Nutrition, Environment, Health, Behaviour, and Mental Domains* (Mellor, 2017). 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 in many organisations.

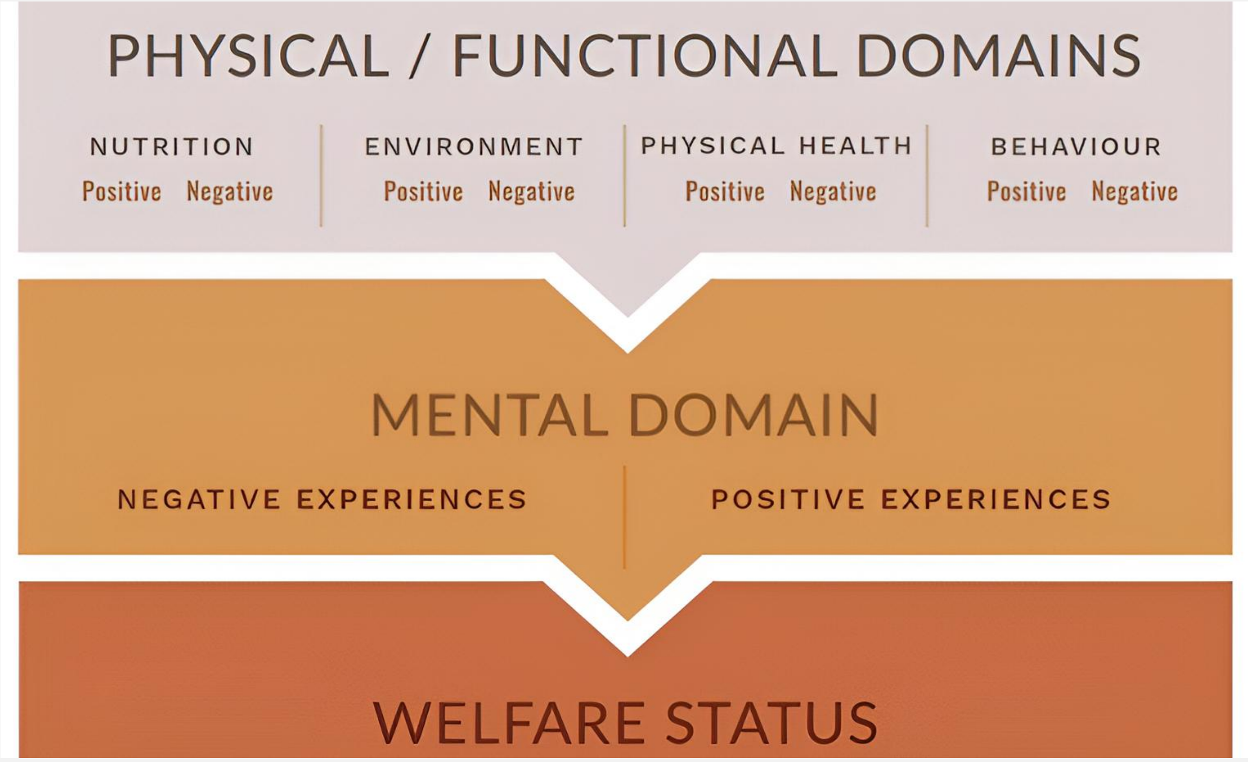

Figure 6 The Five Domains of Welfare (Source: Zoo Aquarium, Australia)

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 encourage animals to express behaviours that are rewarding. Thus, the five domains offer 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 of animal welfare

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 to drive the prevention of negative welfare in animals, they also apply the five domains for animal welfare assessment to progress beyond preventing poor animal welfare to include actively promoting positive animal welfare.

Table 1 Comparing the five freedoms and the five domains of animal welfare (Source – RSPCA)

Five Freedoms of Animal Welfare	Five Domains of Animal Welfare
1. Freedom from hunger and thirst	1. Nutrition
2. Freedom from discomfort	2. Environment
3. Freedom from pain, injury and disease	3. Health
4. Freedom to express normal behaviour interactions	4. Behavioural
5. Freedom from fear and distress	5. Mental state/experiences

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 Ghana), 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, which 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).
- Anti-microbial 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 GHANA

Ghana lacks comprehensive legislation specifically addressing animal welfare concerns, such as transportation, slaughter methods, and the use of animals in research. The legal framework for animal and fish welfare in Ghana is evolving.

Chapter 9, Section 303 of the Criminal Code of Ghana, Amendment (2003) Act 646 [an amendment of the Criminal Offences Act of 1960 (Act 29)], prohibits 'unnecessary cruelty' to animals and establishes penalties for individuals who engage in activities that harm animals unnecessarily. It also includes exceptions for animals being slaughtered or set for slaughter for food. Other legislation includes:

- **Diseases of Animals Act, 1961 (Act 83)**: This act primarily focuses on preventing and controlling the spread of infectious and contagious diseases among animals in Ghana.
- **Veterinary Surgeons Law, 1992 (PNDC L305 C).** This act governs the practice of veterinary medicine in Ghana. It establishes the Veterinary Council of Ghana and outlines the scope of veterinary practice, prohibiting unauthorised individuals from practising veterinary medicine.
- **Biosafety Act, 2011 (Act 831):** This act provides a framework for the safe handling, use and transportation of genetically modified organisms (GMOs) and other potentially hazardous biological materials.
- **Ghana Livestock Development Policy and Strategy (GLDPS) 2016:** While this is not a legal instrument, it outlines the government's approach to animal welfare, emphasising responsible animal husbandry practices.

Legal Frameworks on Fish Welfare in Ghana

Currently, Ghana lacks a dedicated law specifically addressing fish welfare. However, certain aspects of fish welfare are addressed within:

- **Fisheries Regulations, 1979:** This legislation recognises that the importation of live fish has implications for aquaculture. It defines proper fishing methods, regulates and stipulates the requirements for importing live fish into Ghana, as well as the seaworthiness of boats.
- **Fisheries Act, 2002 (Act 625):** This act focuses on sustainable fishing practices, including regulations on fishing gear and methods to minimise bycatch.

- **Fisheries and Aquaculture Regulations, 2010 (L.I.1968):** This regulation requires obtaining a permit before commencing any aquaculture activity. It provides guidelines for responsible aquaculture practices, outlines circumstances under which aquaculture permits can be revoked, and regulates the importation of fish species into the country.
- **Fisheries (Amendment) Regulations (L.I. 2217 of 2015):** This further strengthens licensing and international cooperation in controlling illegal and unreported fishing.
- **Ghana Aquatic Animal Health Policy (GAAHP) 2017:** This policy focuses on five key areas within farmed and wild fisheries to achieve its broad objectives: enhanced biosecurity, improved emergency response capabilities, strengthened surveillance and diagnostic systems, responsible pharmaceutical use, and improved education in aquatic animal health management. It also references principles such as the humane treatment of aquatic animals, focusing on welfare as part of broader health management (Section 2.1.4). Areas for improvement in Fish Welfare include:
    - **Explicit fish welfare guidelines**: The policy could benefit from a dedicated section on fish welfare to ensure humane treatment beyond disease management.
    - **Handling and stocking practices**: There should be clearer guidelines on stocking densities specific to species and growing systems, and handling to minimise stress and physical injury to fish.
    - **Water quality and enrichment**: Emphasising the importance of optimal water quality and environmental enrichment could improve welfare.

Q&A SESSION

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- 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.

QUESTIONS FOR DISCUSSION

- 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 give an example where you know implementing animal welfare practices also improved human wellbeing and environmental health?
- Discuss general animal welfare practices and violations in Ghana. Which of the animal welfare violations listed are common in Ghana?
- What should be done to address and prevent poor animal welfare practices in Ghana? Discuss your thoughts and feedback on the animal welfare legal framework in Ghana. Is this enough? Are there gaps? Recommendations?
- What should be done to push for the establishment and implementation of the Animal Welfare Law (including fish welfare) in Ghana? How can you support this?

MODULE 3: INTRODUCTION TO FISH WELFARE

This module provides an overview of farmed fish welfare, the five pillars of welfare in aquaculture, and the corresponding benefits of fish welfare practices.

WHAT IS FISH WELFARE?

Fish welfare refers to the physical and mental well-being of fish, encompassing their health, comfort and quality of life. It involves ensuring that fish are treated with respect and care, and that their needs are met to minimise stress, suffering and discomfort.

A fish (farmed or wild) is in a state of good welfare if it is in good health with all its biological systems working appropriately; can lead a natural life and meet its "behavioural needs" in the environment; is free of negative experiences (such as pain, fear, hunger, thirst, distress); has access to positive experiences (such as social companionship, other positive experiences: relational contentment, environmental compatibility, happy co-existence and conducive environment); and can adapt to its environment.

THE FIVE PILLARS OF ANIMAL WELFARE IN AQUACULTURE

To guide understanding of fish welfare, the Aquatic Life Institute has established specific indicators that are tailored to the welfare of fish and aquatic animals. They are referred to as the '5 Welfare Pillars of Fish', and they include:

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

[***Watch 3-minute video for further insights at https://www.youtube.com/watch?v=SQTThURP9v8***]

BENEFITS OF IMPROVED AQUACULTURE FISH WELFARE

1. Improved fish health: When fish are treated humanely, especially within the context of the five freedoms and domains of animal welfare, they stand a higher chance of being able to live healthy and optimally productive lives. This rationale is supported by Madzingira (2018), stating that "*Evidence that an animal has a good state of welfare includes having low levels of disease, displaying innate behaviour, normal reproduction and living longer. Therefore, poor animal welfare can manifest as high mortality rates, poor reproduction, increased incidence of disease, body damage, behaviour anomalies, heavy internal parasite load and severe malnutrition*" – all of which are evidence of poor health and invariably lead to poor productivity. The combination of pathogen presence and stressed fish leads to disease and parasite outbreaks, and there is evidence that most disease outbreaks relate to or stem from poor welfare (Aslesen *et al*., 2009; McClure *et al*., 2005). On farms, disease can induce financial hardship, food shortages and even industry failure for the farmer (Arthur and Subasinghe, 2002). Additionally, diseases and parasites often spread to wild populations, where they can endanger entire ecosystems (Naylor and Burke, 2005).

2) Improved quality of life: The concept of animal welfare is embedded in the provision of optimal environments for animals where they are free to express their natural behaviours without restriction, fear, or pain. In recent years, the evidence and scientific knowledge of the mental complexity of animals has become increasingly proven and generally accepted. It is stated that poor animal welfare negatively affects the animal's sentience and mental state, and impacts their ability to express their natural behaviours, leading to a poor quality of life (Nicks and Vandenheede, 2014). This poor quality of life stems from the psychological stress and suffering they experience, which may then further undermine their immune system and hence their physical health (Nicks and Vandenheede, 2014). Therefore, the establishment of these welfare-enhanced environments and living conditions improves the quality of life for animals as living, sentient beings.

3) Meeting emerging trade and consumer demands: As the world continues to evolve, people are increasingly caring about animal welfare, where their products originate from, and what kind of industry their purchase promotes (Conte, 2014; Lai *et al.*, 2018; Buller *et al*., 2018). Poor welfare systems for fish and other animal products are now being rejected by members of the public, government institutions and consumers. Animal welfare standards are being entrenched as part of several measures used in determining an acceptable, sustainable animal health and management system (Broom, 2008), and guide trade standards.

Consumers, institutions (such as the WTO and WOAH), and government policies are now demanding food items from farms and companies that are welfare-certified. For example, global markets such as the European Union have introduced minimum standards for welfare and humane treatment (Buller *et al*., 2018). Additionally, with animal welfare gaining attention in political agendas, the EU is currently reviewing its animal welfare legislation, including stunning and slaughter for farmed fish. Therefore, the integration of welfare (alongside animal health and food safety standards) in the marketing and trade of animal products has driven a change in the actions and behaviours of farmers and associated companies to implement and improve fish welfare standards and obtain certification. This has become a concern in export trade, where there are higher chances of the acceptability of fish and fish products that are welfare-certified. With more products than ever, consumers can now choose between animal protein and a range of new alternatives. Therefore, the only way farmers can remain viable in this increasingly competitive and dynamic market is by offering high-quality, welfare-oriented, and certified healthy products or choosing an alternative means of sustainable livelihood. Exporting to these countries requires welfare to be a core part of production, and introducing higher welfare standards demonstrates that companies are responding to consumer demands and evolving government policies. It also demonstrates a commitment to growth and product quality.

4) Improved productivity and sustainable livelihoods: Increased welfare can improve productivity and potentially profit, and it is an element that mitigates adverse impacts on the environment, climate and sustainable livelihoods. There is evidence that higher welfare standards in production settings and improved efficiency are closely correlated, often reflecting good fish health, productivity, and a return on investment for farmers. Some of this is detailed by the Fish Welfare Initiative (FWI), which discusses the following evidence:

- Some studies show that farmers who integrate welfare on their farms witness less aggression, reduced fin damage, improved growth rates and improved feed conversion ratios (Stewart *et al*., 2012; Schneider *et al*., 2012).
- One study found that the introduction of aerators to enhance water quality increased survival rates by roughly 43%, led to increased fish production, and boosted farm profits (Qayyum *et al*., 2005).
- Appropriate transport and handling further reduce stress and mortality rates (FAO, 2008).
- Keeping suffering and stress associated with slaughter to a minimum is reported to ensure not only animal welfare but also high product quality (Holmyard, 2017).
- Welfare-oriented products are also appreciated by customers who are willing to pay extra for welfare-friendly options (Lai *et al*., 2018; BENEFISH, 2010). By improving welfare, farmers not only increase their efficiency but can also sell their products for a premium price, thereby increasing their revenue.

5) Food quality and safety: Also, as detailed by FWI, fish raised and slaughtered with adherence to welfare and health guidelines may be tastier and healthier to eat, and it guarantees high product quality (Poli, 2009). Stress before and during slaughter not only affects them but also leads to reduced quality. Fish products can contain bacteria, viruses, biotoxins, and parasites, all of which occur more frequently under poor welfare situations or practices, and prolonged stress can increase bacterial growth post-slaughter (EFSA, 2008; EFSA, 2009). On the other hand, reducing stress during cultivation and slaughter safeguards fish welfare and increases fillet quality. For example, effective stunning methods reduce harmful postmortem processes. As a result, high fish welfare ensures humane treatment, which in turn improves food quality and safety.

6) Sustains a healthy ecosystem and environment: As detailed by FWI, improved fish welfare reduces harmful wastewater generation, which, when untreated, can degrade the environment and disrupt ecosystems (Adams, 2019). Such wastewater significantly contributes to eutrophication, causing algal blooms and ocean dead zones (Global Aquaculture Alliance, 2019). Aquaculture waste also often contains anti-microbials, leading to health problems if ingested by humans. Therefore, improved fish welfare can reduce harmful wastewater generation through the following ways:

- By using appropriate feeding systems, which reduce aggression, improve feed conversion ratios (FCRs) and leave less feed suspended in the water (Gan *et al*., 2013).
- By using appropriate stocking densities and reducing crowding, which further enhances feeding efficiency, reduces aggression, the frequency of wounds, and cannibalism, and leads to better feed conversion ratios (Santos *et al*., 2010).
- Less stressed fish exhibit better immune functions (McClure et al., 2005), thereby decreasing the need for antimicrobials. Consequently, fewer anti-microbials end up in the surrounding environment.
- Animal welfare provisions can prevent escapes from the farms into the local ecosystems. The escape of non-native fish from aquaculture farms can lead to competition for food and the potential displacement of native fish, resulting in deleterious consequences for wild fish populations and the local environment.

7) Contribution to sustainable development: As adapted from FWI, fish welfare is also an integral part of sustainable development, and it contributes to the achievement of the Sustainable Development Goals (SDGs). This is also echoed by a 2023 report from the Aquatic Life Institute on the Benefits of Aquatic Animal Welfare for Sustainable Development Goals. SDGs, also known as the Global Goals, were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet and ensure that by 2030, all people enjoy peace and prosperity (UNDP, 2023). The 17 SDGs are integrated; they recognise that action in one area will affect outcomes in others, and that development must balance social, economic and environmental sustainability (UNDP, 2023).

Fish welfare implementation contributes to the following Sustainable Development Goals (SDGs):

- **Goal 1 - No Poverty:** Aquaculture and fisheries currently provide livelihoods for 250 million people worldwide and employment for millions more. By improving fish welfare, farmers enhance fish health and, consequently, create a more ethical and profitable foundation for their income.
- **Goal 2 - Zero Hunger:** Aquaculture significantly contributes to both global nutrition and basic income. This is particularly important in developing countries, most of whom still rely heavily on it as a source of protein and livelihoods.
- **Goal 3 - Good health and well-being:** Fish is currently the primary protein source for millions of people, especially in developing countries. Higher welfare decreases the risk of contamination and zoonotic infections during production and processing. Generally, fish that are less stressed have fewer disease incidences and a lower need for the use of anti-microbials — all of which ultimately ensure food safety. Higher animal welfare in fisheries can also support food security for coastal communities that rely on small-scale fishing as a primary source of nutrition.
- **Goal 6 - Clean water and sanitation:** Aquaculture wastewater can contain toxic residue from fish feed and anti-microbials. Increasing fish welfare improves feed uptake, resulting in less feed being discharged into the wastewater. Higher welfare standards also decrease disease susceptibility and reduce the need for anti-microbials that diffuse into the wastewater.
- **Goal 12 - Responsible consumption and production:** Higher welfare on fish farms reduces our ecological footprint and waste production by

improving the way we farm fish, and it also ensures that we are abiding by ethical and responsible standards.

- **Goal 14 - Life below water:** More efficient production reduces the burden of overfishing, conserves aquatic animals and allows aquatic systems to maintain their natural balance. Reduced waste generation (e.g. ammonia) from mariculture farms prevents events that threaten aquatic life, such as harmful algae blooms. Additionally, higher fish welfare decreases disease and parasite transmission between wild and farmed fish.
- **Goal 17 - Partnerships for the goals:** Work on fish welfare involves local and international stakeholders from various sectors, including academia, research, policy advocacy and industry. By working to improve fish welfare, we can collaborate and promote sustainability, economic stability, food safety and security, as well as more humane treatment of farmed animals.

8) The right thing for fish: As adapted from FWI, aquaculture is the fastest-growing food sector worldwide, and already today, over 50% of seafood comes from farm cultures (Ritchie and Roser, 2021). On these farms, between 73 and 180 billion fish are reared at any given time (Fishcount, 2019). In the future, aquaculture is likely to expand significantly and produce the majority of the seafood consumed. Nevertheless, most fish reared in aquaculture continue to suffer greatly. Welfare issues include diseases, crowding, improper handling, poor water quality, and the inability to display natural behaviour (e.g. Animal Charity Evaluators, 2020; Fish Welfare Initiative, 2019).

Consequently, in most aquaculture farms, fish are exposed to constant stress and mortality rates are high (Ashley, 2007). This suffering is unacceptable because fish are sentient beings capable of feeling pain, just like terrestrially farmed animals (e.g. Brown, 2014; Braithwaite, 2010; Riberolles, 2020; Babb, 2020). Even when there is no legal requirement, we have a moral obligation to provide them with a life worth living. To this end, humane rearing, appropriate transport, and slaughter methods that minimise suffering are essential.

INTRODUCTION TO FISH WELFARE PRACTICES

In most fish farm systems, whether extensive or intensive, fish are captured, confined and may not be able to live as they do in their natural habitats. However, intervention or adaptations can be made to their environment and management practices that would provide a positive environment where they can express their species-specific behavioural needs and preferences. Also, welfare standards should prevent the most harmful practices and not infringe on the health and well-being of fish. This would usually include implementing the appropriate pond designs (shape and size); making appropriate choice of fish species farmed (whether Catfish, Tilapia, African Bonytongue), stocking density (number of fish per space area), feeding regime (unlike in the wild where fish can grow normally feeding on natural nutrients); water quality managements, and disease prevention, treatment, control and management. This will be discussed in full in subsequent modules.

Additionally, to measurably improve welfare, aquatic animal welfare standards should be tailored to specific species, life stages, and holding environments. It is important to note that, currently, only a few species of fish are cultivated in Ghana, and these include:

- Nile Tilapia *(Oreochromis niloticus)* [most farmed, >70%]
- African Catfish *(Clarias gariepinus)* [~20%]
- African Bonytongue *(Heterotis niloticus)*
- African snakehead *(Parachanna Africana)*
- Giant Tiger Shrimp *(Penaeus monodon)*

Though there are species-specific considerations and contexts to cater for, general welfare practices can be implemented across fish species. From the inception of fish production systems to growing, production, handling, slaughter and processing, fish welfare practices should be implemented. Details on specific fish welfare practices for different stages of aquaculture production and management are discussed in subsequent modules.

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 you are 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.

QUESTIONS FOR DISCUSSION

- What new knowledge have you gained from this lecture on fish welfare today?
- Drawing experience from your own fish farm (or working with fish farmers), discuss how you plan to adapt and utilise your knowledge of the "Five Pillars of Animal Welfare in Aquaculture."
- Among all the benefits listed, what are the top three benefits that you look forward to attain when you implement fish welfare and why?

MODULE 4: GROWING SYSTEMS AND FISH WELFARE

This module provides guidance on selecting and evaluating suitable sites for fish farms, offers detailed information on various growing systems and their respective welfare concerns, and explains best practices for stocking density.

Before you start a fish farm, you must plan properly and consider various factors that will affect the health and welfare of your fish, all of which will have a considerable impact on their productivity and on your investment returns. It is generally recommended that you first establish certain strategic planning and operational standards and protocols for your fish farm. These may include a business plan, emergency plan, biosecurity plan, stocking density protocol, and other practices that can be well adopted by anyone working on the farm. You should also have a list of required materials/tools to prevent or tackle specific situations, as well as human resources to hire, and clearly establish job functions for staff members, such as farm managers and veterinarians.

Among these planning arrays, a major process to undertake is making a good decision about the environment in which your fish will be housed and grown. This mainly impacts the health, welfare, and productivity of your fish. Key factors to consider include site selection, rearing systems, and stocking density, which are explained below.

SITE SELECTION

Planning where your fish will be housed must start with the siting (location) of your fish farm. Where will it be situated? What are the environmental conditions, and how will they potentially affect them? These and more have been categorised below, and they include the following:

Location and structure of holding facilities: Ideally, farms should be located away from industrial areas, commercial arable farms, areas prone to flooding, high tidal waters, strong currents, or noise. The precautions are to prevent the runoff of pollutants, such as industrial waste, effluents, fertilisers, and agricultural/sewage waste, into the pond water, as these reduce water quality. Poor water quality will cause stress, disease and suffering to the fish, which may result in morbidity and mortality. Flooding and strong currents may cause damage and breakdown to the culture facilities or total loss if washed away. In addition, extreme weather events observed because of climate change should also be factored into decision-making regarding the structural integrity of the proposed farm. Furthermore, noise pollution can startle the fish unnecessarily, leading to stress and negatively affecting both male and female brooders and their breeding processes.

Environmental Impact Assessment (EIA): This assessment must be conducted as part of the site selection process to ensure minimal adverse impacts**.** Initial cleaning and sanitation of the environment (ideally) should be carried out before siting the system. Safeguards for extreme low and high temperatures must be provided, or production cycles can be tailored to favourable weather conditions to avoid unnecessary stress factors to the fish. When the temperature is too low, the fish will become sluggish in movement, stop feeding, and may eventually die. Extreme hot temperatures (as may be experienced in the northern regions of Ghana or during the dry harmattan seasons) will also lead to massive mortalities.

Construction of culture facilities or growing systems: This should follow the stipulated standards to avoid damage to facilities and environmental problems. All construction permits must be obtained, and the hydrology of the area must be studied and approved before any construction work proceeds.

Other factors to consider in selecting an optimal fish farm site include:

- Accessibility to the farm
- Constant and ample availability of water
- Good water quality
- Access to medications and veterinary services
- Appropriate layout and topography of the fish farm
- Acceptability of the project by the neighbouring communities
- Proximity to market

- Vegetation and soil type of the site.

REARING SYSTEMS

A rearing system (sometimes referred to as holding/growing or culture system) for fish farms is a facility which contains, grows, or holds fish for later harvest, processing, sale, or to release for conservation purposes. Fish growing or culture facilities commonly used in Ghana include earthen ponds, concrete/tarpaulin/plastic tanks, cage systems, hapas, dams and dugouts. Also, in all growing systems, the intended specific purpose should be considered, whether hatchery, nursery, grow-out, brood stock bank, holding or transfer tanks, as these might come with varying welfare and management needs and practices.

General considerations for improved welfare in a fish culture system:

- A key welfare practice is that while fish remain in captivity, they are allowed to grow in an environment that is as similar to their natural habitat as possible. This enhances their ability to express their natural behaviour and gives them a comfortable environment to reside in. Therefore, providing environmental enrichment of the rearing space will simulate the natural environment of these aquatic animals and improve their welfare.
- The rearing systems should be constructed in a way that prevents damage to skin, fins and other parts of their body, etc.
- The rearing system should allow an easy, effective removal of faecal content, avoiding disturbance of the fish as much as possible.
- The rearing system should be able to protect the fish from predators and prevent the escape of farmed fish.
- The rearing system should prevent noise such as the ones from pumps, construction noise and other machines, as this can be a disturbing factor to farmed fish.
- The rearing system should ensure appropriate illumination of the tanks.

- The rearing system should minimise external disturbances such as external visitors.
- They should have proper protocols for disease prevention, disinfection and cleaning, site biosecurity, control of disturbance, etc.
- They should have emergency plans in case of adverse climate events, fires, floods and other potential catastrophic events.
- Farmers should ensure that their staff members are regularly trained and kept informed on updated protocols and best practices established for their fish farms.

Common Growing Facilities and Welfare Considerations

Some common holding facilities and their welfare considerations and issues are discussed in detail below.

Earthen Ponds

A fish pond is a dug-out in the form of a basin with specific dimensions and features (inlet, outlet, overflow, dike, etc.) for holding water for the purpose of rearing fish (FC AFJ Manual, 2022). It is constructed manually or mechanically in a carefully selected site with enough clay soil for high water retention.

Plate 4 Photograph of dug-out earthen ponds used for housing fish in their clusters, Assiko Fish Farm-New Edobo, Jomoro

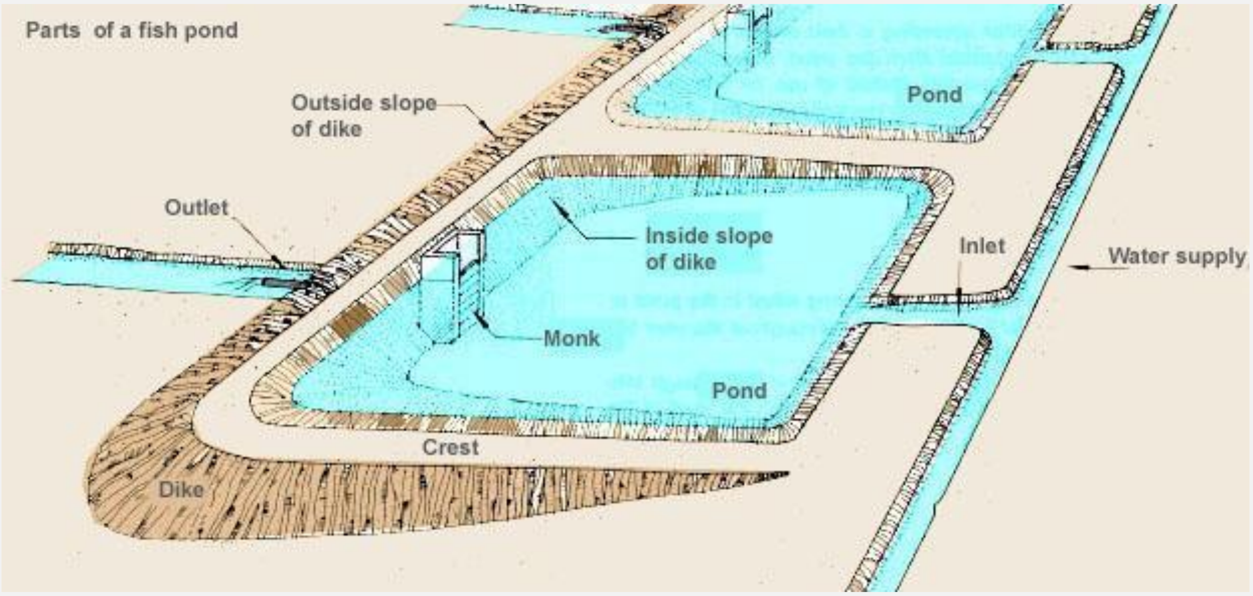

Figure 7 Schematic representation of earthen ponds (Source – FAO)

To use an earthen pond, the following welfare considerations, protocols and activities must be undertaken:

- Proper soil and water analysis must be carried out to determine the suitability of the location, vegetation and topography.
- Locations with clay or loam-based soil containing more than 65% clay and a pH between 6.5 and 8.5 are preferable. Sites with sandy soil should be avoided due to their porous nature, which can cause water percolation or seepage, as well as the infiltration of wastewater from the surrounding area into the ponds. Soil with heavy metal deposits must also be avoided.
- The pond must be structured in such a way that it will not cause flooding or obstruct water drainage flow patterns in flood plains or wetlands, or cause erosion.
- Low-lying ponds should be screened with appropriate non-toxic material to prevent fish loss during flooding as well as entry of wild fish and other predators.
- There must be an adequate and continuous supply of good-quality water, especially in areas prone to drought.
- Water sources must be free from iron as this affects fish gills and oxygen intake, causing stress, poor reproductive ability and stunting.

- Measures to cope with predators (snakes, rodents and birds) should be in place, and this may include the use of screens, scare-crows and keeping the environment clean.

Common welfare issues with fish grown in earthen ponds

- Sorting the fish along the growing cycle will be difficult. The standard practices of sorting and cropping fish often result in them being taken out of water for a considerable length of time, which can cause stress. While some fishes can stay out of water longer than others (e.g. catfish compared to tilapia), it should not be encouraged.
- The throwing of fish into ponds is also a grave issue of animal welfare as it temporarily disorientates them before they regain their balance.
- Cannibalism and predation are often common within the earthen pond environment, especially in polyculture. Generally, growing carnivorous fish with other fish species with the intent of using these others to feed and grow the former is a grave and unapproved rearing method.
- Earthen ponds are highly vulnerable to environmental pollution and other hazards. There is a high probability of lower sanitation, which increases the risk of disease transmission from humans to the fish and vice versa.
- Some farmers try to manipulate soil quality and provide enrichment in ponds. However, caution must be exercised to prevent wrong application and overdosing. This will negatively impact water quality (growing environment) and fish welfare. There have been reported cases of fish skin bleaching and mass mortality in growing ponds during soil enrichment, and accidental introduction of pathogens through the application of organic fertilisers. Such pollutants also have one health implication that may impact both aquatic and land animals, including humans.

Concrete Tanks

Concrete ponds are often made from concrete blocks or reinforced slabs. A mixture of sand, cement and gravel is used to prevent cracks and leakages. Therefore, water flows in and out of the pond through drains. The water may be treated for use in crop farming and vegetable production or may be released into natural water bodies. Concrete tanks must be well designed with a complete drainage and overflow system. Additionally, the tank must be cured (treated with salt) before use to prevent water pollution from chemicals in the cement, as this can lower the pH and make the water acidic. They can vary in size and shape. Ideally, the tanks should not be smaller than 2m x 3m, and a depth of 1.2m-1.5m is desirable to cool the water. The shape could be rectangular, square, or circular, and is determined by several factors, such as expected production, length of the production period, sanitation regime, and fish behavioural swimming pattern.

Plate 5 Photograph of concrete tanks constructed to house fish. Akannimos Fish Farm, Half Assini – Photograph by Isaac Frimpong Arthur

Plate 6 Concrete tanks built in an enclosed housing space to house fish; Source – Everlush.ng

Common welfare issues with fish grown in concrete tanks

- High fluctuation of temperature (temperature shock) may happen if adequate volume and consistent availability of good-quality water are not guaranteed. This situation would incredibly stress the fish and often lead to mortality if not addressed on time.
- This system is easily prone to built-in water pollution and fish mortality if daily good management practices are not strictly adhered to.
- Faulty inlet, outlet and drainage system or leakages may lead to massive fish mortality borne out of issues such as lower water levels, temperature fluctuation, oxygen depletion, etc.

Mobile and other Fishpond Systems

Mobile fishponds can be easily moved around or placed in a stationary position, depending on the need. They may be made up of fibreglass, wood lined with carpet or linoleum (fish vat), UV-resistant PVC or polyethene and plastic tanks**.** These systems are also designed with inlets and outlets with a variety of designs and levels of sophistication. They may be installed outdoors or indoors, depending on the objectives of the operations. Yet, in the event of an excessive rise in temperature (beyond 30°C), some form of shade must be provided. Some use aerators to ensure an adequate oxygen concentration, or have installed sprinklers (showers) at the inlet. Other mobile pond systems are not as durable. For example, wooden frames are particularly prone to wood rot, which may lead to the collapse of the tank, water loss and pollution. Non-resistant/non-coated metal frames may corrode, especially in coastal areas, leading to the collapse of the tank as fish gain weight. Improperly handled sharp objects around tarpaulin/polythene/PVC tanks may pierce them, causing leakage and loss of water.

Plate 7 Photograph of plastic tank pond set-up to rear fish (Source – Everlush.ng)

Plate 8 Photograph of tarpaulin fishpond set-up at Amazing Youth Fish Farm - New Ankasa -Jomoro

Plate 9 Photograph of tarpaulin pond set-up to house fish with tarpaulin material placed in a dug-out earthen space; Source – Everlush.ng

Common welfare issues with fish grown in mobile fishpond systems

- Increased risk of algae excess buildup on the rearing system's wall, which may affect water quality.

- Possibility of an accidental introduction of food items and waste, which will cause pollution and reduce water quality.
- High risk of water temperature fluctuations that may stress fish.

Recirculatory Aquaculture System (RAS)

A water recirculating system is an automated system that aerates fish-growing water, efficiently removes particulate matter, provides biological filtration to remove ammonia and nitrite, and buffers the pH. It consists of fish tanks, sedimentation tanks, chemical and biological filter systems, aeration systems (ozone generator), and pathogen control systems. Water is recirculated to minimise water replacement, maintain optimal water quality conditions, and compensate for an insufficient water supply. The key to this system is water quality. Farmers achieve high biomass stocking intensity by maintaining good water quality, and that requires skill and education. High emphasis needs to be placed on the cleaning of intake water, ensuring good water flow inside the tank, optimised sludge removal, and thorough water treatment within the RAS.

Plate 10 Photograph of Small-scale Backyard RAS Fish Pond set-up; (Source –Hydroponics Nigeria)

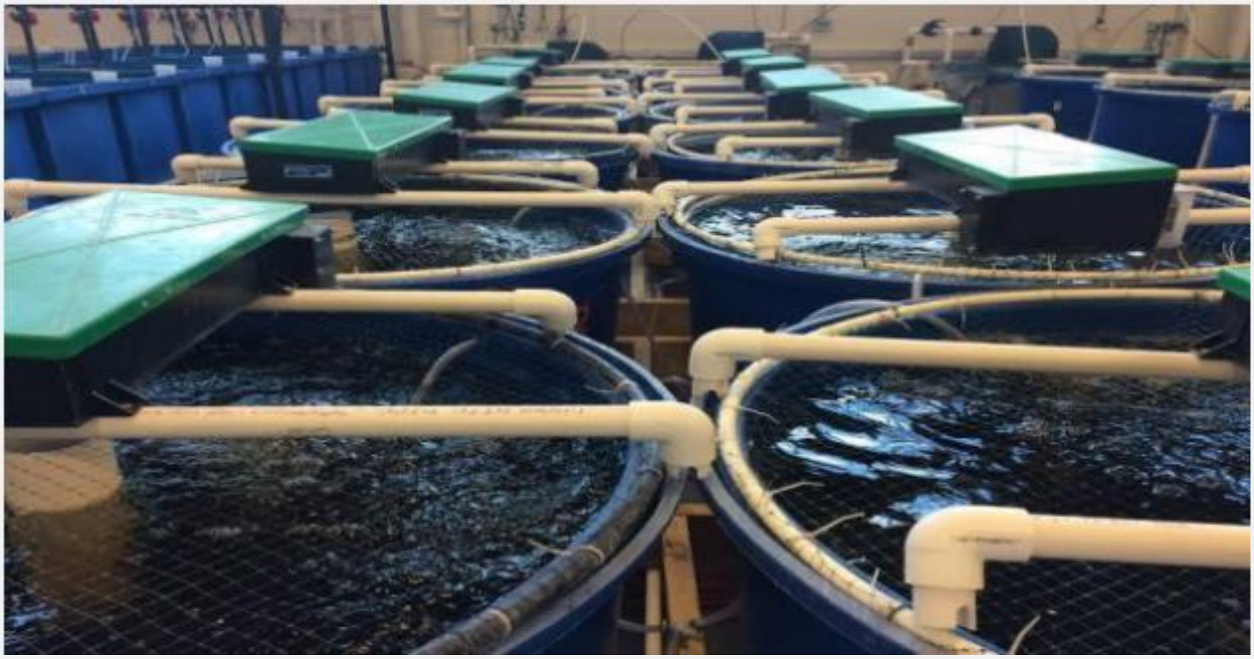

Plate 11 Photograph of RAS Fishpond set-up; (Source – Africaninfoblog)

Issues of fish welfare with the water recirculatory system

- It is a highly intensive system that is not often welfare-friendly. It consists of high stocking density, which restricts fish movement and behaviour and causes stress.
- The capital-intensive maintenance of the system may not be sustainable, and any slight disruption may create immense stress on the fish.
- Sourcing and availability of high-quality feed required may be difficult.
- Disruption to continuous electric power supply will lead to ammonia build-up in the system and fish blood, leading to stress, pain and in extreme cases, death.
- System breakdown will create stress on the fish and may lead to high mortalities.
- Its complex nature requires skilled personnel to manage it.

Cages and Pens

A cage is a net enclosure usually suspended in a water body, anchored on the natural waterbed, kept buoyant by floats, and used for farmed fish. A pen is a shallow water enclosure for the rearing of fish in an open water body, and often sits on the floor of the water body. These should be constructed not to obstruct navigation on water, as the regular movement of the cages and pens to allow passage to other users of the water bodies will cause extreme stress to the fish, which may affect the rate of feeding and their health. The cage and pen should not be constructed on waterways that are used for navigation. Cages can be installed in deeper waters (>4m), whereas pens should be in shallow waters (1-2m). Additionally, the materials used must be durable enough to withstand severe weather conditions and prevent the inflow of debris, while allowing for the free flow of water out of the system and excess feed that would otherwise pollute it. Often, farmed fish rely on natural live foods within their environment, augmented with artificial feed, particularly when stocking densities are high, which is a common practice in such systems.

Plate 12 Photograph of fish cage set-up; (Source – Everlush.ng)

Issues of Fish Welfare with Cages and Pens

- The system is vulnerable to environmental pollution from the surrounding water body. Also, other environmental hazards and predators will stress the fish.
- Use of poor-quality material may create tears and openings for other unintended stray fish species, predators or aquatic animals' access to the cages and pens, and these could hurt farmed fish, introduce extraneous pathogens and diseases to farmed fish, and vice versa.
- Conflicts in the use of waterways and upstream activities could lead to disruption of maintenance activities and disturbances to the fish in cages and pens.

STOCKING DENSITY

Stocking density (kg fish/m^3) describes the number of fish per unit of water in the rearing system. Optimal stocking densities are based on several factors, such as the type of fish species, life stages, growing systems, and water flow rates, and can also depend on environmental conditions. It is also one of the main characteristics that determines whether a fish farm is extensive, semi-intensive or intensive. It can have a significant impact on fish welfare, as it influences water quality, growth, stress status, and social interactions, such as aggression among the fish. For example, if you manage to maintain high water quality, you can increase the biomass or stocking density. However, if you don't maintain high water quality, you will need to lower stocking density; otherwise, this will lead to stress, and in extreme cases, death of fish.

For species like rainbow trout, other salmonids, tilapia and catfish, successful rearing is generally possible at densities in which all fish of the rearing unit form a community. Such fish species thrive best in groups and may develop dominant and aggressive behaviour if there are too high or too low stocking densities, or if there is only one gender. Because of this, deciding on stocking densities on a fish farm is not a simple discussion to have, even though farmers usually prefer higher stocking densities as they assume this would automatically increase their production capacity. However, based on research and experience, stocking density should be carefully considered and always supported by research and welfare guidelines.

How to measure stocking density

To find the current stocking density of an already stocked growing system, one needs to have the following preliminary information:

1) The volume of water in the growing system,
2) The volume of the growing system, and
3) The number and weight of the fish stocked. To calculate stocking density, the simple formula is:

$$\frac{Total\ number\ or\ weight/biomass\ of\ fish\ stocked}{Volume\ of\ water\ in\ the\ growing\ system}$$ = either Biomass/volume or number/ volume.

Using biomass is preferable because it captures the current growth state of the fish better than mere numbers. For instance, 10 fish weighing 500g each will occupy more space than 10 fish weighing 100g each; thus, using numbers without regard for the growth stage can be misleading.

So, with this formula, it is assumed that a pond carrying 6,000 litres of water with 1,500 fish weighing 400g each,

Total biomass= 400g x 1500 = 600,000g (600kg)

Stocking density will be = $\frac{600,000}{6000}$ =100g of fish per litre of water.

Therefore, the stocking density of that growing system will be 100g of fish per litre (going by weight/biomass of fish) of water or ¼ fish per litre (going by number of fish). Before embarking on fish farming, the stocking density for the desired species (established by research and guidance) must be known and strictly adhered to. Furthermore, the feeding habits and natural behaviours of the species in question must be known and factored into the stocking density computations, as this will enhance productivity and welfare.

Recommended Stocking Densities

Information on optimal stocking density for different fish species is not novel, as the optimum stocking densities for the commonly cultured fish species in Ghana (tilapia and catfish) have been established by the Fisheries Commission. Generally, the following stocking densities can be followed according to the 2022 training manual for government's flagship Aquaculture for Food and Jobs (AFJ)

- Tilapia (*Oreochromis niloticus*) mixed sex = 2 – 3 fingerlings/m^2
- Catfish (*Clarias gariepinus*) only = 4 – 8 fingerlings/m^2
- All-male tilapia = 5 fingerlings/m^2

However, it is very important and a good welfare practice to follow species-specific and growing system-specific recommendations for optimum stocking densities. For instance, Asaase (2013) recommends the stocking density of *Oreochromis niloticus* as 50-150 fish/m^3 for cages on the Volta Lake.

As mentioned earlier, every system has a carrying capacity, and different fish species have their specific optimal stocking densities. Therefore, fish farms should not be overstocked, as this has a negative impact on the health and welfare of the fish. For example, the optimal stocking density of larval catfish is 100 per square metre. After 5 weeks, 35–40 fingerlings per square metre can be harvested, each weighing 2–3 grams. Increasing this stocking density does not increase the production, and while lower stocking densities will result in fewer fingerlings per square metre, the harvested fingerlings will be bigger in size.

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 you are 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.

QUESTIONS FOR DISCUSSION

- 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? Please share your findings and explain why you chose your current system.
- Based on what has been learned 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 learned 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

This module discusses the impact of water quality on fish welfare and how to monitor this important factor to ensure the health and welfare of fish.

INTRODUCTION TO WATER QUALITY

Fish are in intimate contact with water. Thus, water quality is arguably one of the most critical factors for fish welfare and needs to be closely monitored. Poor water quality or rapid changes in its parameters can lead to both acute and chronic health and welfare problems for fish. Each species has its specific requirements for water quality. Under all circumstances, it must be kept at optimal levels. Water quality parameters include temperature, conductivity, pH, oxygen concentration, and nitrogenous compounds such as ammonia, nitrite, and nitrate concentrations, as well as hydrogen sulphide and others. Additionally, the water flow rate is a crucial determinant of its quality, as it provides a fresh oxygen supply and dilutes and disperses metabolic waste. At a high flow rate, certain rearing systems may tolerate much higher stocking densities than at a low flow rate.

Flow speed and direction within a tank should be arranged in a way that all water is exchanged regularly to avoid "dead" unexchanged zones, thus preventing areas with low oxygen content and/or increasing ammonia and/or hydrogen sulphide concentration due to unwanted sedimentation of faeces and uneaten feed. Modern fish farming often relies on technical equipment to maintain optimal water quality. Malfunctions of such equipment may rapidly cause serious deteriorations in water quality, especially in intensive production systems. Hence, monitoring and alarm systems are necessary to detect and report rapid changes, allowing for responsive actions to address them.

CONSIDERATIONS FOR OPTIMAL FISH HEALTH AND WELFARE

Water quality is one of the most important factors contributing to fish health, and their entire existence is dependent on the water environment they live in. This makes fish very sensitive to pollution and poor water quality issues. On the other hand, they will flourish and remain in good health in an optimal water environment that suits them. To ensure good water quality for optimal fish health and welfare, the following must be taken into consideration:

- **Source of water and type**: The Source of water for any growing system should be natural water or as close as possible in quality and consistency to what is determined as optimum for the fish species. It should also be free from chemicals, pollutants, and infectious organisms.
- **Water budget and storage**: This needs to be calculated, monitored and replenished regularly. Adequate provisions should be made prior to any production activity. As much as possible, an acute shortage of water must be avoided because it may lead to water pollution and a decrease in oxygen concentration. This will immediately induce stress, affect fish welfare and health and in extreme cases, cause death.
- **Water monitoring and analysis:** This should be carried out regularly for key water parameters and indicators to determine water quality before usage. This must be done continuously, at least once daily, and at consistent intervals. It is also important to have a record for keeping track of all the historical measurements. The water quality parameters to be monitored include:
    - **Physical parameters** – temperature, pH, dissolved oxygen, salinity, ammonia, nitrite, hydrogen sulphide, alkalinity, hardness, turbidity and suspended solids.
    - **Organic chemical contaminants** – veterinary drugs, antibiotics, hydrocarbon-based chemicals and other pollutants.
    - **Biochemical hazards** – toxins
    - **Biological contaminants –** pathogens such as bacteria and viruses.

Life Stage and Species-Specific Considerations

Water quality requirements vary for different species of fish and even for the different stages of their life cycles. The following table presents general water quality.

Table 2 Water quality parameters for catfish and tilapia

Parameters	**Catfish**	**Tilapia**	**African Bony tongue**
Temperature	26 °C-32 °C (Kashimuddin *et al*., 2021)	20.2°C – 31.7°C (Leonard and Skov, 2022)	24.5°C-26.7°C (Ofori-Darkwah *et al.,* 2023)
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)	4.7-5.0 mg/L (Ofori-Darkwah et al., 2023)
PH	6,5- 8,5 (Fathurrahman *et al*., 2020)	6-8.5 (El-sherif *et al*., 2009)	6.0-7.45 (Ofori-Darkwah *et al*., 2023)
Ammonia	0.34 mg/L (Edward *et al*., 2010)	0.14mg/l (Benli *et al*., 2011)	<0.01 mg/L (Ofori-Darkwah *et al.,* 2023)
Nitrite	1.19 mg. L-1 (2% of LC50-96h) (de Limal *et al*., 2011)	0-7 mg/L (Amazon Web Services)	
Nitrate	400 ppm nitrate (Agricultural Marketing Resource Centre)	5-500 ppm (Sallenave, 2016)	
Alkalinity	4.56 mg/L (Baldisserotto and Rossato, 2007)	1.6 to 9.3 mg/L (Colt and Kroeger, 2013)	
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)	
Turbidity	Below 88 (Jayadi, 2022)	200 mg/L (Ardjosoediro and Ramnarine, 2002)	

Catfish Welfare and Water Quality

Catfish is the second most produced farm fish species in Ghana. Most small-scale farmers opt for this species because it can often withstand greater environmental fluctuations. This is due to the presence of their false lungs (arborescents), which help them to breathe in air, unlike most other fish species that depend solely on their gills. Catfish are said to be hardy, but if they are out of water, they undergo high stress, which negatively impacts their welfare. Therefore, their hardiness should not be an excuse to ignore welfare practices, and they must be kept in optimal water quality conditions.

How to Measure and Correct Water Quality Parameters

Measuring water quality is essential for maintaining a healthy aquatic environment. Farmers can use various testing kits, electronic meters, or send samples to a water quality laboratory for more comprehensive analysis. For the use of test kits and meters, follow the instructions provided on the kit for accurate measurements.

Solutions for Out-of-Range Parameters

When any of the water quality parameters fall outside the desired range, farmers must take immediate action to correct the issue. On a general note, after removing the agent causing the water parameter imbalance, partial/full water replacement with water of desirable parameters can salvage most parameters; this needs to be done in a way that minimises stress/shock to the fish. In addition, here are some parameter-specific measures to correct out-of-range water quality parameters:

- **Temperature**: If the temperature is too high or too low, consider using a heater or a chiller to adjust the water temperature to the desired range for the specific species you are caring for.
- **pH**: To adjust pH, use pH buffers or pH adjusters. For example, adding sodium bicarbonate (baking soda) can raise pH, while adding phosphoric acid can lower it. Improvised pH buffers, such as ground crustacean and mollusc shells, can also be applied to moderate the pH.

- **Ammonia, Nitrite, Nitrate**: High levels of ammonia and nitrite can be toxic to aquatic organisms. Perform partial water changes to dilute these compounds. Beneficial bacteria in biological filtration systems can also help convert ammonia and nitrite to less harmful nitrate. Regularly monitor these parameters and ensure proper filtration.
- **Dissolved Oxygen**: Low oxygen levels can lead to stress and health issues for fish. Increase aeration and water movement to improve dissolved oxygen levels. Address sources of oxygen depletion, such as excessive organic matter decomposition or overstocking, to prevent further damage.
- **Total Dissolved Solids and Salinity**: High TDS or salinity can indicate excessive mineral content. Regular water changes can help reduce TDS, and for saltwater systems, use purified water or a reverse osmosis unit to maintain appropriate salinity levels.
- **Alkalinity and Hardness**: Maintain stable alkalinity and hardness levels to prevent pH fluctuations. You can use alkaline buffers to adjust alkalinity, and crushed coral or calcium supplements can increase hardness.
- **Turbidity**: Turbid water can be a sign of sediment or organic matter. Address the source of the turbidity and use mechanical filtration to clear the water.

To reiterate, it is beneficial to always refer to species-specific water quality guidelines and adjust water parameters gradually to avoid stressing the aquatic organisms. Regular monitoring of water quality is crucial to prevent issues before they escalate. If you encounter persistent problems or are unsure about the appropriate solutions, consult with an experienced veterinarian, aquaculturist, or aquatic biologist for personalised guidance.

Q&A SESSION

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- 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.

QUESTIONS FOR DISCUSSION

- Discuss your previous knowledge and experience with good and bad water quality.
- Have you been monitoring water quality? If yes, how?
- 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 practices?
- How can you better measure water quality on your farm? What parameters are most important to you?

MODULE 6: FEEDING AND FISH WELFARE

This module provides general welfare considerations and guidelines for feeding fish, including best practices, feed composition, and feed quality.

GENERAL BEST PRACTICES FOR FEEDING

Feeding is a crucial part of the fish life cycle and a constant activity in fish farm management. However, to ensure optimal fish welfare and health, the following general best practices must be implemented:

- 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 providing too much 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 homogeneous group and to avoid competition for the smaller fish.
- Also, provide feed formulations in appropriate amounts that are available to all fishes in the farm.
- Ideally, vary the locations periodically where feed is administered within the enclosure, to provide mental stimulation for fish, simulate their natural environment and avoid overcrowding in feed locations.
- Where possible, farmers can implement systems where animals and their feed are co-produced.

COMPOSITION AND QUALITY OF FEED INGREDIENTS

All ingredients used for fish feed must be of high quality, devoid of any form of contaminants, and should have good taste and smell. Feed must be nutritionally balanced in terms of the protein content, carbohydrate, fat and oil, and mineral contents. Hormones, especially growth hormones-treated feeds, should NOT be fed to fish. For catfish, recommendations for high quality feed consists of about 40-45% protein and it must be highly digestible with an ideal feed conversion ratio of 1:2. Also, fish feed should preferably be in pelleted floating form, and it is vital to match the size of the pellet to the fish mouth – indicating that pellet sizes should keep increasing following fish growth.

Table 3 Protein requirement and feed size required for different sizes of tilapia (source: AFJ Manual, 2022)

Fish Size	Crude Protein (%)	Life stage	Feed Size
< 20 g	40 – 45	Fry and larvae (0.01 – < 1 g)	Powdered feed
20 – 100 g	38 – 40	Fingerlings (1 – 5 g)	0.5-2 mm
100 – 250 g	33 – 35	Juveniles (5 – 50 g)	2-3 mm
250 – 450 g	32 – 30	Adults (> 50 g)	3-6 mm
> 450 g	28 – 30		

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. Wild-caught fish and animal species that are smaller in size and have a larger individual-to-weight ratio, such as insects and krill, should not be used as feed. To this end, producers, where possible, must move towards the use of alternative feed products which have the following characteristics:

- Have higher feed efficiency ratios that also maintain good nutrition and health.
- 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 undergo further treatment to destroy potential pathogens before being fed to fish. Apart from being visually unethical for consumption by the fish and the end-consumers (humans and other animals), it has 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 will be promoted.

Feeding rates: The recommended daily rate for fish feeding is 2-5% of fish body weight. In reality, especially in catfish farming, the fish must be fed to satiation, with the last feeding schedule preferably done at 10 p.m. This practice will limit the risk of cannibalism and predation in most fish farms in Ghana, as there are hardly any farms with automatic feeders that can ensure continuous feeding until the next day. Factors affecting food consumption rates include fish health, water temperature, pH, oxygen content, feed quality in terms of taste, size, and palatability, as well as the method of feeding. These factors should be monitored at regular intervals, and a log should be kept, allowing for evaluations and taking corrective measures if needed.

Feed storage: Feeds must be stored appropriately to prevent exposure to moisture, heat from direct sunlight, mould, and other contaminants, which may lead to degradation of their ingredients and impact their overall quality and composition. They must also be stored appropriately to avoid contact with rodents, insects, birds and other animals or parasites.

Q&A SESSION

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- 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.

QUESTIONS FOR DISCUSSION

- 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:

  a) Use of smaller animals for fish feed,

  b) Use of hormones,

  c) Use of chicken offal and maggots, and

  d) 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

This module provides welfare considerations and guidelines for handling and transporting fish.

HANDLING AND FISH WELFARE

The capture and handling of fish on a farm is unavoidable due to the need to carry out various procedures (e.g. vaccination, grading, tagging and slaughter) throughout the production cycle. It is also needed to move fish between facilities, and these include transferring them within the rearing system, transporting them between farms for marketing and slaughter.

Welfare Considerations in Fish Handling

Fish are very sensitive to handling, and the removal of fish from water elicits a maximal emergency stress response. Therefore, animal welfare groups and organisations advise that handling should be kept to an absolute minimum, and the removal of fish from water should only be carried out when absolutely necessary, for no longer than 15 seconds, unless the fish is anaesthetised (Humane Slaughter Association, 2004). Building on this, it is important for the aquaculture industry to continually develop less stressful ways of carrying out on-farm procedures that would involve fish capture, handling and transportation.

Fish sensitivity to handling is particularly dependent on temperature. At high temperatures, they are usually more sensitive, and handling should be avoided. The same applies to very low temperatures, and below zero, where fish should not be handled at all. Poor handling may cause injuries to eyes, fins and muscles, as well as scale loss. It also damages the skin’s protective mucous coating, which serves as the primary line of defence against pathogens, thus increasing the vulnerability of fish to disease. Furthermore, all equipment used for handling must be in a good hygienic condition and, if possible, have a plain surface structure to avoid fish injury.

TRANSPORTATION AND FISH WELFARE

Transporting live fish is a multi-step operation that involves preliminary capture and preparation of the animals, as well as the setup of transport facilities, harvesting of the fish, loading, and conveyance, including maintaining water quality, and unloading at the delivery location. These procedures can induce significant stress responses from which the fish will take a long time to recover. For example, salmon smolts take more than 48 hours for their cortisol levels to return to pre-transport levels (Iversen et al., 1998).

Additionally, according to Fish Count (2019), it is reported that fish exhibit a stress physiology that is directly comparable to that of mammals and birds. Stressful stimuli in this manner have been shown to produce a wide variety of effects on transported fish, such as metabolic, hormonal, and behavioural alterations. They further report that immunosuppressive effects and osmoregulatory problems can activate latent disease organisms and are the major cause of death when fish are handled and transported. Furthermore, for some species, the initial loading of fish into the container is the most stressful component of transport.

Welfare considerations in fish transportation

Methods and equipment used: 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. 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 popular method for transporting tilapia seed in Ghana is by using oxygen-gassed polyethylene bags partly filled with water, often placed within a sack. Catfish, on the other hand, are typically transported in repurposed plastic containers, such as the Nigerian 50L black gallons or the 25L Frytol gallons. These containers are frequently transported on buses or in vehicles that emit 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. However, these methods are completely unacceptable and totally against the principles of fish welfare. The process is extremely stressful for fish and may negatively affect their survival rates.

Ideal transport systems should include the following:

- Transported in specially designated vehicles with insulated holding tanks, monitoring apparatus and for very short journeys.

Figure 8 Insulated holding tanks

- 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.

Plate 13 Photograph of tilapia fingerlings packaged for transportation, Photo Credit: POMEGRID AQUA, Takoradi (Hatchery)

Conditions during transport: Fish transportation exposes fish to a range of stressful stimuli and poor conditions, including overcrowding, inadequate water quality, limited oxygen and accumulation of carbon dioxide and ammonia. Stress can occur at different stages of transport, such as during:

- Pre-transport treatment (e.g. draining of ponds, pre-transport starvation to clear the gut).
- Loading (e.g. netting the fish); and
- The journey (e.g. inadequately maintained water quality leading to low oxygen levels and build-up of CO_2 and excretory products).

These can cause irreparable damage to the fish and even death. Whilst stress can be reduced by using anaesthesia or sedation, these are not licensed or acceptable for use in farmed fish. For these reasons, welfare advocates remain opposed to transporting live fish over long distances, instead recommending that transport be kept to an absolute minimum.

Additionally, the changes in temperature to which fish are exposed during transport are highlighted as a significant welfare concern (Fish Count, 2019).

Lowering the temperature at which fish are transported may increase the stocking density that they can tolerate, as lower temperatures slow their metabolism (reducing oxygen requirements). However, abrupt temperature changes are stressful. On a final note, the WOAH has published general welfare guidelines for fish transportation, which are very useful for fish farmers, researchers and other stakeholders.

Q&A SESSION

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- 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.

QUESTIONS FOR DISCUSSION

- 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, please 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? Please mention all transportation methods used.
- As a fish farmer, have you received training on transportation OWIs? If so, please 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

This module discusses common slaughter methods and provides pre-slaughter welfare considerations, as well as the benefits of humane slaughter of fish and general guidance for humane slaughter methods for fish.

OVERVIEW OF HUMANE FISH SLAUGHTER

Fish slaughter is the process of killing fish, typically after they have been harvested from their growing system. At least 124 billion fish are reared and slaughtered each year for human consumption (Mood *et al*., 2023). In line with animal welfare standards, slaughter should be humane and cause no unnecessary pain or suffering to the fish. Humane fish slaughter often involves stunning, which means an intentionally induced process that renders fish immediately unconscious and insensible to pain, a condition that must persist until they are dead (Holmyard, 2017; European Union Regulations, 2009). It provides benefits to the slaughter process of fish by making fish easy to handle and causing less injuries to the flesh. Although various systems have recently been developed to achieve humane stunning and slaughter, inhumane fish slaughter remains predominant, especially in Ghana, in both commercial and non-commercial fish farms, markets, and private homes. Also, many catfish farmed in Ghana are sold live before slaughter, and they often suffer prolonged transport without food and sometimes water, while contending with asphyxia, temperature shock, excessive handling and ineffective stunning. Millions of farmed fish are subjected to significant pain and suffering, which is a major impediment to the export of certified fish products to countries such as the United States and Europe.

WOAH's Aquatic Animal Health Code has provided guidelines for fish welfare, including stunning and slaughter, and all member states are expected to adapt these guidelines for their own slaughter practices. In response, more humane slaughter methods are emerging, demonstrating progress from unacceptable, inhumane practices. While these newer methods are still evolving, they represent a significant advancement in the field. Electrical stunning, in particular, is widely accepted due to its rapid process and has been shown to have minimal physical and biological impact on fish.

Furthermore, it is highly recommended that stunning and slaughter of fish must be conducted by staff who have the technical capacity, training and knowledge to utilise slaughter equipment, can recognise when effective stunning has taken place, and know how and when to re-stun, if necessary. They should receive periodic retraining, upskilling, and evaluation of their stunning and slaughter methods, and keep records of these activities on the farm. This is especially important because fish slaughter equipment and methods are still evolving as fish welfare and industry professionals continue to make efforts to ensure a seamless and painless slaughter process.

BENEFITS OF HUMANE SLAUGHTER OF FISH

Carrying out humane slaughter of fish offers several benefits for the fish, farmers and consumers. The following points outline these advantages:

- Humane slaughter methods improve meat quality and reduce the risk of spoilage (Fish Count, 2019). It minimises defects like soft flesh, gaping, bruising and scale loss, and improves shelf life when compared to the traditional, less humane slaughter methods (Holmyard, 2017). For example, fish slaughtered with more humane methods often have firmer, translucent fillets with brighter colours, and the onset and severity of rigor mortis are delayed when compared to conventional, less humane slaughter methods (Humane Slaughter Association, 2019).
- Humane slaughter methods reduce stress and are more likely to improve eating quality and taste for the consumer (Fish Count, 2019).
- Adhering to humane slaughter procedures enhances the ethical value of the fish product, which can potentially add economic value. Consumers driven by ethical concerns usually show preference, and are willing to pay extra, for humanely produced and slaughtered fish (Fish Count, 2019).
- Humane slaughter practices improve compliance with existing local and global food processing and safety standards, which ultimately improve the market value of the product.

PRE-SLAUGHTER WELFARE CONSIDERATIONS

The Humane Slaughter Association provides recommendations for pre-slaughter welfare considerations, which are detailed as follows:

Purging: Purging (also known as fasting) is the act of withdrawing feed from farmed fish prior to slaughter, allowing 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. The higher the water temperature, the less time is required.

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 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 this person, who is solely responsible for the welfare of the fish, can recognise problems and know what action to take to resolve them. Where possible, a crowd pen should be set up so that fish can swim against the tide towards the inlet pipe and preferably into a shaded area. Taking advantage of the natural behaviour of the fish in this way will encourage movement with minimal stress.

Dewatering: This is the phase from crowding to the stunning/slaughter point, during which 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 amount 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.

COMMON FISH SLAUGHTER METHODS

Air Asphyxiation: This is the oldest method of fish slaughter, where fish are removed from the water and allowed to die through asphyxiation. It is considered inhumane because it can take the fish over an hour to die. Nile tilapia and African sharptooth catfish fall within the category of fish that are quite resistant to hypoxia and take a long time to die. This is especially true for African catfish because they can breathe atmospheric air to some extent, which means they take even longer to die.

Additionally, the rate at which oxygen is depleted is dependent on ambient temperature and the rate of fish activity. For example, at 20 °C, rainbow trout experience brain death in about 2.6 minutes and cease moving in 11.5 minutes. At 14 °C, the same processes require 3 and 28 minutes, respectively. Since the body temperatures of fish vary according to ambient temperature, reducing the temperature of their bodies typically prolongs the time to anoxia and, therefore, the time to insensibility, lengthening the period of distress. Also, fish that evolved from low-oxygen environments take longer to die, while at higher temperatures, fish lose consciousness more quickly. Another major drawback of the asphyxiation method is that it diminishes meat quality and shelf life.

Head strike and stunning: Also known as manual percussion, this is one of the traditional methods for stunning and slaughtering fish. 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.

Percussive stunning is a recommended stunning method that involves a forceful and accurate blow to the head with a blunt instrument. The force required will depend on the size of the fish. The blow should be aimed just above the eyes to impact the brain. The effectiveness of the stun should be checked, and another blow applied if the fish is not unconscious. The main disadvantages are the unethically violent nature of the method and the often stressful handling of the fish before the slaughter or stunning process. In this case, fish undergo pain and rigour, thereby affecting their flesh and taste even after the processing. Also, there are high failure rates in some fish (such as catfish), and they may remain conscious or retain body movement and sensibilities despite such head strikes.

Spiking: Another crude traditional method is spiking, which involves inserting a sharp spike (such as an ice pick or a sharpened screwdriver) directly into the brain of the fish through the head. 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 undergo stress, and some undesirable meat quality changes 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.

Live chilling: Live chilling is considered by the aquaculture industry since it has the advantage of sustained carcass quality, as reducing muscle temperature close to 0 °C helps delay enzymatic and microbial spoilage processes. 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. Also, the method immobilises the fish so they can be more easily handled. 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.

In Ghana, farmers may use basic, crude methods by pouring ice blocks directly on the fish, but this leads to a slow and painful death, causing systemic shock to the fish.

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

Use of anaesthesia: 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 humans and animals would consume. 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 dosage and on 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 makes fish paralysed. 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 varying regulations regarding the use of pre-slaughter chemical anaesthesia for fish intended 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.

Carbon dioxide narcosis: This slaughter method involves dissolving carbon dioxide in the water prior to 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.

Electrical stunning: Stunning by use of electricity is known as *electronarcosis*, whereas killing by electricity is known as *electrocution*. Electrical shock using either alternating or direct current has received substantial interest in recent years. Electric stunning is reversible, as normal brain function is disrupted for a short period only. Hence, electronarcosis must be immediately followed by bleeding. Electrocution destroys brain function and, therefore, renders the animal unconscious while stopping the breathing reflex from functioning.

For electrical stunning to be effective, proper current and stun duration must be maintained. Also, water factors such as conductivity and temperature must be properly managed. This method has gained substantial support due to concerns for the ethical treatment of animals and their immobilisation (used in other slaughter methods), which requires mechanical or hand processing. It also prevents stress and struggling prior to slaughter, which helps to maintain quality.

A potential risk of electrical stunning methods is inflicting pre-stun electrical shocks (which are electrical shocks that fish will consciously endure without losing consciousness). Pre-stun shocks can happen for the following reasons:

1) The electrical parameters are not adequate.
2) The way the electrical shock is applied is not adequate, because:
   a) The current is applied to a part of the fish's body far away from its brain, e.g. its tail.
   b) The current loses its strength because of the resistance of fish bodies if it is applied in such a way that it has to go through the bodies of some fish before reaching other fish.

c) When performed in water, the electrical parameters are not suited to the water conductivity.

d) When performed in water, the way the current is applied makes it so that the resulting electric field is not homogeneous.

Although electrical stunning is among the most humane available methods, not all electrical stunning methods are good. Acceptable electrical stunning methods include:

- In-water pipeline electrical stunning
- Head-to-body dry/semi-dry electrical stunning
- In-water batch electrical stunning

Unacceptable electrical stunning methods include:

- Batch electrical stunning in an electrical tank without any water
- Prod electrical stunning with or without any water

Recent advances in electrical equipment design have made substantial improvements in preventing or minimising undesirable physical and biological effects in treated fish. However, the use of electronarcosis and electrocution remains a challenge in many developing nations due to the expensive setup and inconsistent electricity supply in many of these countries.

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; and using a pneumatic accurate gun, which can deliver the required velocity for effective stunning. Generally, the WOAH Aquatic Animal Health Code particularly considers air asphyxiation, ice bath, CO_2 narcosis and exsanguination without stunning as inhumane. Overall, research continues in the search for the most humane slaughter methods for farmed fish, and fundamental technical issues still need to be resolved for some species.

OVERVIEW OF SLAUGHTER PROCESSES IN GHANA

In Ghana, various methods are used for commercial fish processing, depending on factors such as the intended use, travel distance to market, and quantity being processed. Large quantities of tilapia purchased at the farm gate after dewatering are immediately packed live in layers of ice blocks within large, sack-lined baskets. Some large-scale buyers and processors also use refrigerated vans (cold vans), which similarly result in live chilling and death. For shorter distances and smaller quantities, buyers may either gut live tilapia shortly after dewatering, once the fish becomes immobile, or are transported dead through asphyxiation. These methods are not ideal, as they prolong the period of consciousness and do not effectively minimise the fish's ability to experience discomfort.

Commercial processing of live catfish often involves hitting the head with a strong club and bleeding the fish to death by cutting one of the gills. This does not cause immediate loss of consciousness, and the pain and distress are likely to last several minutes. African catfish have been shown to remain conscious for more than 10 minutes after cutting, while some fish take even longer for loss of consciousness and death. It is important to note that prior to gill cutting, the fish may have experienced removal from water for some time, crowding in bowls and baskets, and rough handling by the handler. Note also that cutting only one of the gills, and not both, will result in a slower bleed-out and a slower death, prolonging the distress further.

GENERAL GUIDANCE FOR HUMANE SLAUGHTER METHODS FOR FISH

Generally, humane methods of fish slaughter are ones that cause an instant death or render fish instantly insensible to pain until dead. This can be possible for both manual and automated processes, and it often requires fish to be stunned (rendered instantaneously insensible) before being slaughtered. The fish should also remain in water until immediately prior to the stunning process. Generally humane methods of fish slaughter include:

- Percussive and electrical stunning machines
- Percussive stunning with a club

- Spiking the brain
- Spiking combined with food-grade fish sedatives (licensed for use in some countries).

To achieve optimal humane slaughter, these methods can be combined as stunning and slaughter. They must also be properly designed for the target species and effectively carried out. Certain systems must be put in place, and these include:

1) A well-organised operating cycle that can reduce to an absolute minimum the duration and intensity of stress;
2) Incorporation of fish stunning to induce unconsciousness of the fish; and
3) The need for well-trained personnel who can recognise signs of regained consciousness in the fish species after stunning.

Additional general considerations for humane slaughter are detailed below:

- It is important to note that, when possible, it is better to use manual pneumatic guns rather than fully manual methods. While pneumatic guns have been developed for salmonids, other pneumatic guns originally designed for small mammals or poultry can also be used.
- Manual percussive stunning requires less precision to be effective than brain spiking. Therefore, unless operators have specific skills to implement brain spiking correctly, percussive stunning is preferable if you must choose between the two.

In conclusion, for most commercially important fish species, technologies are now available that allow humane slaughter. It is the responsibility of farmers to apply or adapt manual or automated technologies for fish stunning and slaughter to avoid distress and pain for the fish during the procedures.

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 you are 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.

QUESTIONS FOR DISCUSSION

- 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

WHAT IS ENVIRONMENTAL ENRICHMENT?

Environmental Enrichment (EE) involves enhancing an animal's living environment to reduce stress, promote species-specific natural 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 to the surroundings of the animal, such as buildings made of 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). The challenge is determining the type and quantity of environmental enrichment that fish prefer, and this can be aided by understanding their sensory abilities. To get started, we must ensure that each potentially enriching material is pertinent to the biology and preferences of the species. For instance, some fish may prefer hiding, while others may prefer swimming against the flow of the water (Zhang *et al*., 2020a).

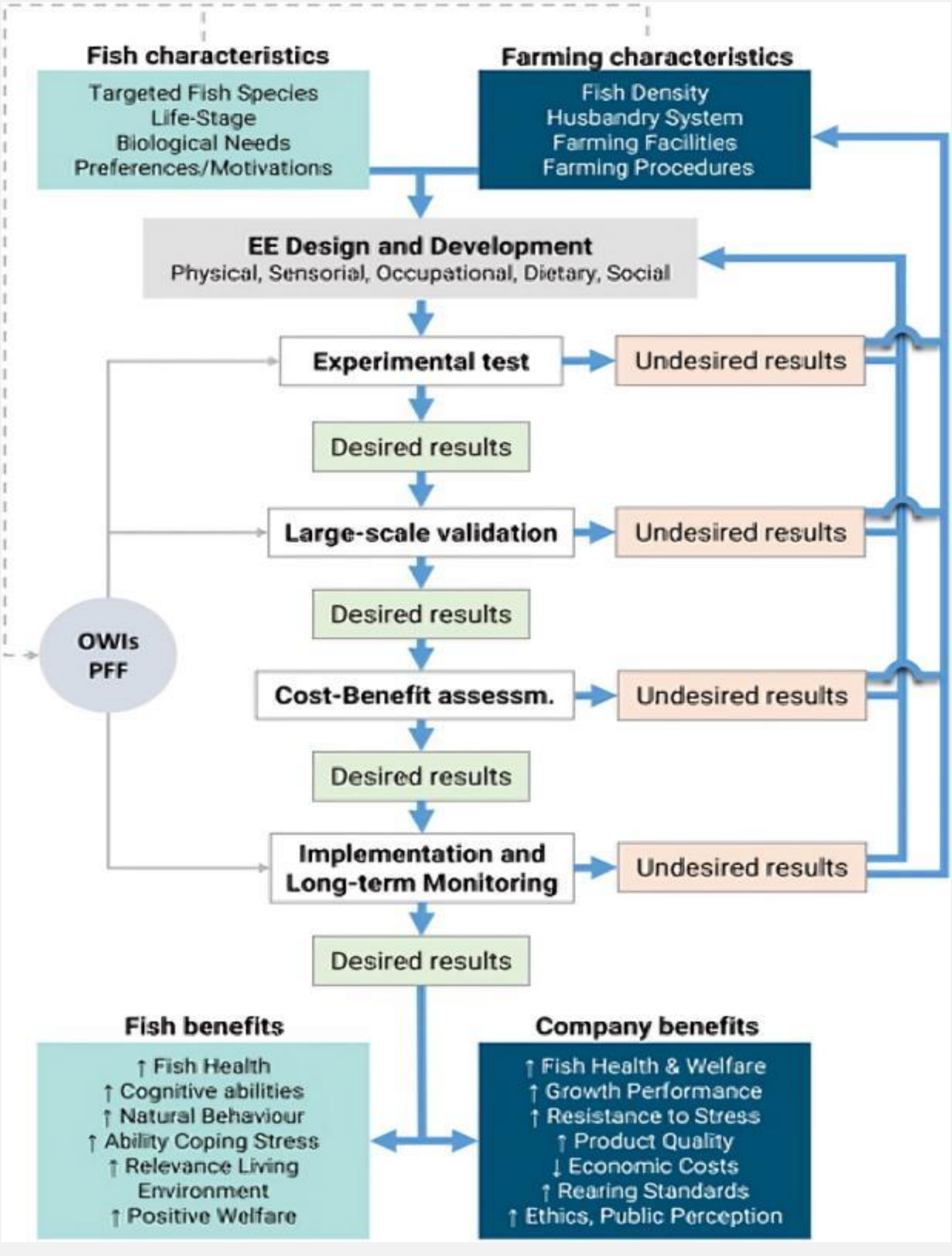

Figure 9 Schematic for the decision-making process in Environmental Enrichment; OWIs: Operational Welfare Indicators; PFF: Precision Fish Farming; (Source: Arechavala-Lopez et al., 2021)

TYPES OF ENVIRONMENTAL ENRICHMENT

Näslund and Johnsson (2014) outlined commonly recognised spheres of enrichment that can be incorporated into farm enclosures for aquatic animals. Producers should strive to achieve enrichment inclusion in each of these areas where possible.

- **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 mutually aggressive or cannibalistic species.
- **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.
- **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 incubation substrates to the floor, which allows animals to burrow.
- **Sensory enrichment** – It aims at stimulating the fish's senses through the use of different stimuli such as light, sound or odour (Arechavala-Lopez *et al*., 2019), which is a diversity of visual, auditory, olfactory, tactile and taste stimuli.
- **Dietary 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, the feeding frequency, and/or the delivery system.

These different types of environmental enrichment can have positive effects on fish physiology, health and survival, ultimately improving their welfare.

BENEFITS OF ENVIRONMENTAL ENRICHMENT

Environmental enrichment (EE) has been shown to have several benefits for fish welfare if applied correctly. These are explained as follows:

- 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 sensorial and motor stimulation to help meet their behavioural, physiological, morphological, and psychological needs, while reducing stress and the frequency of abnormal behaviours (Arechavala-Lopez *et al*., 2021).
- It also increases spatial use of the tank and enhances growth rate in fish (Zhang et al., 2020a).
- 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. These include:
    - ❖ Adding structural environmental enrichment to rearing environments has proven positive in reducing aggression, interactions with net pens and fin erosion in juvenile seabream (Zhang *et al*., 2021).

- Intraspecies aggression in fish can be reduced with increased levels of physical enrichment (Zhang *et al*., 2020b).
- Occupational enrichment, such as providing opportunities for fish to engage in natural behaviours, can help fish cope with acute stressors (Arechavala-Lopez *et al*., 2019).

Overall, 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 aqua-ecosystem and biodiversity management, as well as the use and application of local and traditional knowledge (Schweiz *et al*., 2015; 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 1 below.

Table 4 Environmental Enrichment Recommendation for Catfish Species

African 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 preference in fry and for lower stress in juveniles, provide ≤15 lux. For	For lower aggression under light intensities of 0.002-1.4 μmoles/m2/s, provide blue light.

	juveniles, 24- hour photoperiod is stressful, stress decreases and growth increases with decreasing photoperiod. Natural photoperiod is 9-15 hours. (FishEthoBase).	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 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 2-4 m, 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 monitored.	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).
Feeding System	Ensure that you provide sufficient feed from approximately 4-8 days after hatching. Self-	Tryptophan-supplemented food was found to reduce confrontations (Neto

	feeders could prevent stressful food competition (FishEthoBase).	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 food. (FishEthoBase)

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 shown the reduction of aggression and increased 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 2 below.

Table 5 Environmental Enrichment Recommendation for Tilapia Fish Species

Nile tilapia (Oreochromis niloticus)		
Enrichment Category	**Juvenile**	**Adult**
Enclosure Coloration	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	Males choose to make their nests in sand substrate when compared to other substrates, such as stones. Individuals presented with an equal

	territories (FishEthoBase). Must be closely monitored.	frequency of total attacks, whether they were kept with or without substrates; however, 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 (Volpato and Barreto, 2001). 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 Augmentation	Depth: Provide at least 2-6m, ideally up to 20 m, 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 20 m, 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 and 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 inside the system (e.g. 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 food. (FishEthoBase)

In conclusion, environmental enrichment is a powerful tool for enhancing fish welfare by providing opportunities for species-specific behaviours, mental stimulation, and improved overall health. Recognising the importance of environmental enrichment in captive settings can contribute to the ethical treatment of fish and the sustainability of aquaculture practices. Regular research and collaboration between scientists, aquaculturists and conservationists will continue to advance our understanding of effective enrichment strategies.

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 you are 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.

QUESTIONS FOR DISCUSSION

- 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

ANIMAL HEALTH AND WELFARE

Animal welfare is defined as the state of the animal, the treatment it receives from animal care and animal husbandry, as well as the humane treatment it receives, and how an animal copes with the conditions in which it lives (Animal Welfare Institute, 2018). Animal Health can also be defined as the absence of disease and the normal functioning of an organism, as well as normal behaviour (Ducrot *et al*., 2011). From the above definitions, it is evident that the concepts of animal 'health' and 'welfare' are distinct yet closely linked. For example, an animal in a good state of welfare is considered healthy, comfortable, well-nourished, safe, able to express its innate behaviour, and is not suffering from unpleasant states such as pain, fear, and distress.

The main difference is that animal health primarily focuses on the occurrence, impact and treatment of diseases, infections and sub-optimal health conditions, while welfare incorporates the sentience and mental complexity of animals which includes their ability to feel emotions, have needs, be conscious and their ability to adapt to domestication without negatively impacting their freedom of expression of natural behaviours (Nicks and Vadenheede, 2014). Although varying in their approaches to well-being, they mutually impact each other and are both integral to the overall optimal well-being and livelihood of animals. Good animal welfare, especially for farmed animals, encompasses disease prevention, appropriate shelter, management, nutrition, humane handling and humane slaughter (Animal Welfare Institute, 2018). Therefore, the idea of welfare remains an important element in addition to traditional animal health concerns (Nicks and Vadenheede, 2014).

BIOSECURITY FOR FISH HEALTH AND WELFARE

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). These practices also reduce stress to the animals, thus 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.

The ease with which a specific pathogen can enter a fish farm, spread from one system to another, and cause disease depends on many factors. These include the fish species, their immune status, their condition (with reference to welfare and well-being) and life stage. It also depends on environmental factors, such as water quality and chemistry, the characteristics of the pathogen, including its biology and life cycle, the presence of potential disease hosts or reservoirs, and its ability to survive on inanimate objects or fomites. Finally, it depends on the workers' skills, understanding, husbandry practices and compliance with bio-security principles and protocols (Yanong and Erlacher-Reid, 2012).

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:

1) Fomite (inanimate objects): which may be nets, buckets, siphons, footwear, clothing, vehicles, hauliers, containers, etc.

2) Vectors (living creatures): which may be new livestock, predatory birds, pets and people.

3) 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

As noted by Aarattuthodiyil and Wise (2017), it can be simply stated that biosecurity offers protection from exposure to diseases, and is the most cost-efficient and effective means of disease control available. Generally, implementing biosecurity measures will contribute to achieving the following goals:

- ❖ Reduce the risk of disease transmission and minimise the spread of the disease within the same farm or from one farm to another.
- ❖ Promote aquatic animal health.
- ❖ Prevent new diseases in ponds.
- ❖ Protect human health (zoonoses, food safety) (Sahu *et al.,* 2020).
- ❖ Reduce stress and improve fish welfare and well-being.

Lack of a biosecurity plan in the face of a disease outbreak could result in fish morbidity/mortality, increased cost of treatment and diagnosis – all of which lead to poor fish welfare, reduced quality and value of products, damaged market reputation and fish facility closure.

The consequences of infectious disease outbreaks can be catastrophic, especially in intensive farming systems like recirculating systems and hatcheries, due to the inherently expensive nature and operational intensity. These intensive aquaculture practices create a higher risk of disease for producers, and it is risky to ignore biosecurity. A single disease outbreak has the potential to put a farmer out of business and leave them in huge financial debt. Therefore, since aquaculture operations will always have to deal with pathogens, it is a sensible approach to adopt biosecurity practices, as disease prevention is better than cure (Aarattuthodiyil and Wise, 2017). Also, with the international nature of trades in today's world, farmers who can demonstrate the establishment and integration of documented biosecurity measures and systems on their farm are more readily accepted in international trade markets (Aarattuthodiyil and Wise, 2017)

Common biosecurity measures and practices

Bera *et al*. (2018) and Ernst *et al*. (2017) share a comprehensive list of good biosecurity measures and practices to be adopted by fish farmers. These include the following:

- 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).

FISH DISEASES AND IMPACTS

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, to reduce the occurrence of disease outbreaks and to increase their farms' economic performance.

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). Fish diseases undermine sustainable development goals, especially in developing nations, by reducing income earnings, leading to job losses, endangering food availability, and posing a threat to nutrition and food security (World Bank, 2014). Because aquaculture in developing nations is typically small-scale and rural, the vast majority of infections remain undetected, untreated, and unreported, placing a significant burden on populations struggling to overcome poverty (Mukaila et al., 2023).

Diseases of fish and other animals may be from infectious organisms such as bacteria, viruses, fungi, parasites and protozoa, or may be from miscellaneous non-infectious origins.

Common bacterial diseases of farmed fish in Ghana include:

- Streptococcosis is caused by *Streptococci spp*. This disease affects tilapia and trout, leading to lethargic movement, erratic swimming, dorsal rigidity, a haemorrhagic anus, damaged internal organs, a distended abdomen, ascitic fluid, a pale liver, and a swollen kidney.
- Mouth Fungus is caused by the bacterium *Flavobacterium columnaris* and is characterised by white cotton-like patches around the mouth and discoloured patches on their bodies, sloughing scales and eroded gill filaments. Columnaris disease is prevalent in warm-water fish, especially during warmer months and when fish are under stress. It may be fatal due to the production of toxins and the inability to eat.
- Red pest is 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 is caused by the bacterium *Mycobacterium piscium* and is characterised by emaciation, hollow belly, and possibly sores. The leading cause is usually overcrowding or high stocking density in unkept conditions.

- Dropsy/Bloat is 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 is 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.
- Edwardsiellosis is an acute to chronic systemic disease in fish characterised by exophthalmia, ascites, hernia and severe lesions of the internal organs.
- Pseudomonas infection is caused by *Pseudomonas* spp, leading to various symptoms, including fin erosion and redness, scale sloughing, skin lesions and darkening, petechial haemorrhage, pale gills, abdominal distension and exophthalmia.
- Ulcer caused by bacteria, *Haemophilus* sp and characterised by loss of appetite and slow body movements.
- *Micrococcus luteus* is an emerging opportunistic pathogen in fish, causing various diseases like skin infections, gill damage, exophthalmia, haemorrhages in muscles and abdominal fluid accumulation. While generally harmless, it can become pathogenic in stressed or immunocompromised fish.

Common fungal diseases of farmed fish in Ghana include:

- Saprolegniasis causes tufts of dirty, cotton-like growth on the skin and can cover large areas of the fish, including fin, skin and gills. It may also cause brownish patches on the skin, damage to fins, including lesions, ulcerations and discoloured body, erosion of skin, fins and reddening around the affected area. These fungal attacks always follow some other health problems like parasitic attacks, injury, or bacterial infection. Eventually, if left untreated, the fungus will continue to eat away at the fish until it finally dies.

Once a fungal disease occurs, it is usually very challenging to manage or cure. Therefore, the most effective approach is always to prevent them from occurring in the first place.

- Gill rot disease, also called Branchiomycosis, is caused by *Branchiomyces demigrans* and *Branchiomyces sanguinis.* It mainly affects the gill area (blotchy gills), leading to impaired exchange of oxygen and osmoregulatory deficiency, leading to respiratory distress.

Common parasitic diseases of fish in Ghana 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.
- 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.
- 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.
- 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. Most leeches live in freshwater, but there are a few species in the marine ecosystem. They are capable of causing anaemia, lethargic movement, pale gills, increased respiration and negative buoyancy. Large leeches may cause ulcers in fish.
- Ichthyophoniasis or Ichthyosporidium disease is a fungal-like disease, but caused by a parasite, *Ichthyosporidium hoferi*. It manifests itself internally, primarily attacking the liver and kidneys, but may spread everywhere else. Symptoms include sluggishness, loss of balance, hollow belly, external cysts and sores.

Common Protozoan diseases of fishes in Ghana

- Ich is a protozoan called *Ichthyophthirius multifiliis,* and it 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.
- Costia is a rare protozoan disease that causes a milky cloudiness of the skin.
- Trichodina disease, also known as Trichodinosis, is a parasitic infection in fish caused by protozoan parasites called *Trichodina spp*. Typical signs of the disease include skin and gill damage, respiratory distress, loss of appetite and loss of scales.
- Hexamita is an intestinal flagellated protozoan that attacks the lower intestine and is characterised by the loss of appetite.
- Neon Tetra disease is caused by the sporozoa *Plistophora hyphessobryconis*. It causes muscle degeneration, leading to abnormal swimming movements.

- Glugea and Henneguya are sporozoans which 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 caused by protozoa, *Myxobolus exiguous* and Bio-disease caused by protozoa *Myxobolus pfcifferi,* with symptoms such as large boils of varying sizes appearing in several parts of the body.

  ● Myxosporidiosis is caused by infection with Myxospora. Cysts appear on the body, internal tissues and organs. Infected fish become weak, and the scales may become perforated and fall off.

Viral diseases of fish in Ghana

- Infectious Spleen and Kidney Necrosis Viruses (ISKNV) are a group of viral agents in the genus Megalocytivirus, family Irodoviridae. ISKNV disease can be pandemic and is capable of killing 50-100% of the infected fish population. The viruses thrive in temperatures ranging from 20 °C to 32 °C. However, 25 °C is more conducive for them. Infection by ISKNV causes epidermal lesions in which petechial haemorrhages and abdominal oedema are prominent features.
- 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.

General treatment options

For many, disease 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, Trichlorfon, potassium permanganate, common salt solution, quinine hydrochloride, quinine sulphate, or quicklime – all in the correct dosage. In other cases, the best thing to do 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:

1) 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.

2) With larger fish and light infestations, parasites such as lice can be picked off with a pair of forceps.

3) Some chemicals used for treatments may pose risks to fish and even human health. Therefore, ensure that they are used in the correct dosages and wear protective clothing and gloves.

Miscellaneous non-infectious health issues may be caused by:

- Congenital abnormalities, which usually occur when professional breeders are trying to acquire certain strains in breeds.
- Physical injuries.
- Constipation, which is mostly caused by diet.
- Poor nutrition (Okhueleigbe, 2021).

Disease reporting

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 document and retain records of diseases, treatments, transportation, mortality rates, and causes of mortality for all animals in their care. They must use these records actively to further improve conditions within their production. As a precaution, you should report any suspected serious disease or unusual mortality, even if you have not identified the infectious disease.

ANTIMICROBIAL RESISTANCE

Antimicrobial resistance (AMR) 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, anti-parasitic 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 (Towers, 2014; 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 a lack of AMR and antimicrobial stewardship awareness and a lack of diagnostic capacity (mostly in low- and middle-income countries (LMICs). This affects proper identification of causative pathogens in diseased animals and antimicrobial prescriptions (Henriksson *et al*., 2018; Adekanye *et al*., 2020). Another contributing factor is the use of antibiotics as prophylactics in disease prevention, especially in intensive factory farm settings of 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).

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 the administration of antibiotics, consumers of such fish will ingest antibiotic residues at suboptimal doses, and this can facilitate AMR development and other health risks (Heuer *et al*., 2009; Sapkota *et al*., 2008). Furthermore, these residues and resistant bacteria can be transferred between the aquatic and terrestrial animals through the environment and waterways (Goldburg and Naylor, 2005; Naylor and Burke, 2005; Chowdury et al, 2022).

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), anti-biotic residues, and
- Recreational activities, including fishing and swimming (Towers, 2014).

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).

Furthermore, antimicrobial misuse in aquaculture results in wide contamination of the environment with antimicrobial residues via water distribution systems (Schar *et al.*, 2020). These residues can affect the environment's microbiome and, consequently, its regulatory and supporting activities in ecosystems (Sarmah *et al*., 2006; Larsson *et al*., 2018). 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.

COMBATING AMR

How can aquaculture farmers contribute to AMR prevention and control while addressing the increasing demand for seafood animals without compromising food safety, environmental health, human health, animal health and welfare?

The FAO action plan on AMR (2016–2020) recommends the 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 are β-1, 3-glucans, which are reportedly effective alternatives against various aquatic diseases like vibriosis, enteric redmouth, aeromonadiasis, pasteurellosis, and Hitra disease (Ngamkala *et al*., 2010).

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 you are 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.

QUESTIONS FOR DISCUSSION

- 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 don't, why? What are the alternative options you employ?
- 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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