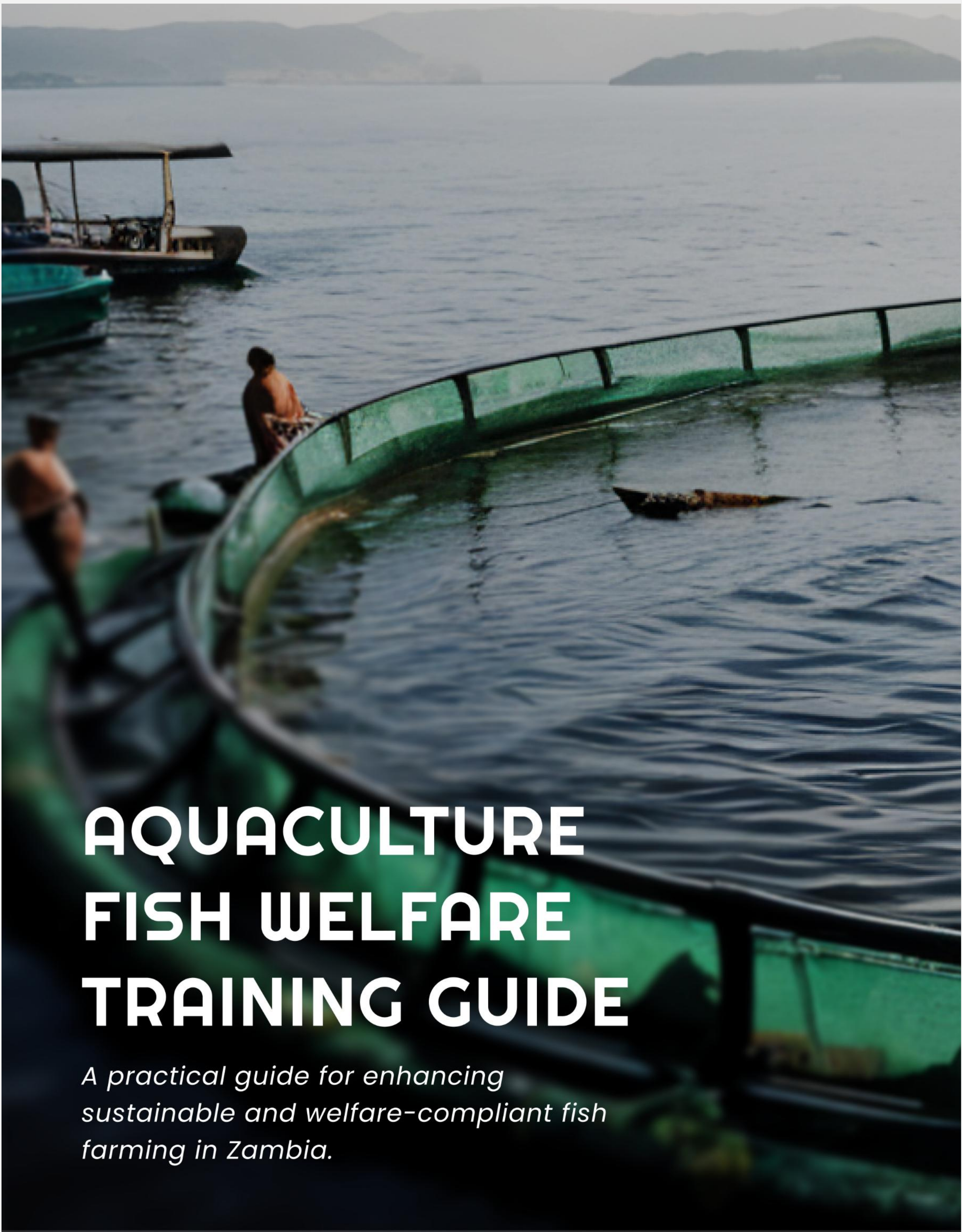

# AQUACULTURE FISH WELFARE TRAINING GUIDE

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

OHDI
ONE HEALTH & DEVELOPMENT INITIATIVE

AFIWEL
Africa Fish and Aquaculture Welfare Program

Zambia

## CONTRIBUTION AND ACKNOWLEDGEMENTS

### Writing and development

- Darlington Besa (BSc, MSc) – Africa Fish Welfare (AFIWEL) Fellow, OHDI

### Technical Review and Validation

- Prof. Cyprian Katongo, Department of Biological Sciences, University of Zambia (UNZA), Lusaka
- Dr Mwansa Songe, Senior Lecturer and Researcher, University of Zambia (UNZA), Lusaka
- Mr Evans Mutanuka, Director of Fisheries, Department of Fisheries – Chilanga
- Mr Masuzyo Steinslous Nyirenda, Principal Fisheries Research Officer, Central Fisheries Research Institute (CFRI), Department of Fisheries, Chilanga
- Mr Lumbwe Kalumba, Chief Aquaculture Research Officer, Department of Fisheries – Chilanga
- Mr Mbamwai Mbewe, Assistant Director – Aquaculture, Department of Fisheries – Chilanga
- Dr Chanda Chitala, Veterinary Research Officer, Central Veterinary Research Institute (CVRI), Chilanga
- Ms. Mazuba Mwanachingwala, Senior Advisor, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Zambia
- Dr Kikiope Oluwarore, Executive Director, One Health and Development Initiative and Program Lead, AFIWEL

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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 a growing urgency to embed welfare principles into production systems, policy frameworks, and capacity-building efforts.

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

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

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

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

**With best regards,**
**The AFIWEL Program Team**
One Health and Development Initiative (OHDI)

## ABBREVIATIONS AND ACRONYMS

AAH – Aquatic Animal Health
ALI – Aquatic Life Institute
AMR – Antimicrobial Resistance
AU-IBAR – African Union – Inter-African Bureau for Animal Resources
AWRA – Animal Welfare Research in Africa
CEA – Centre for Effective Altruism
DoF – Department of Fisheries (Zambia)
DVS – Department of Veterinary Services (Zambia)
EA – Effective Altruism
EU – European Union
FAO – Food and Agriculture Organisation
FW – Fish Welfare
FWI – Fish Welfare Initiative
GAWS – Global Animal Welfare Strategy
GRZ – Government of the Republic of Zambia
MDAs – Ministries, Departments, and Agencies
NAQEZ – National Action for Quality Education in Zambia
NARDC – National Aquaculture Research and Development Centre (Zambia)
NFAP – National Fisheries and Aquaculture Policy
NGO – Non-Governmental Organisation
NISIR – National Institute for Scientific and Industrial Research (Zambia)
OHDI – One Health and Development Initiative
Q&A – Questions and Answers
SDGs – Sustainable Development Goals
TWGs – Technical Working Groups
UNZA – University of Zambia
WOAH – World Organisation for Animal Health
WTO – World Trade Organisation
ZEMA – Zambia Environmental Management Agency
ZNFU – Zambia National Farmers Union

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

## Introduction to Fish and Aquaculture

Fish and aquaculture play a pivotal role in global food security, significantly contributing to dietary protein and supporting the livelihoods of millions. Aquaculture refers to the farming of aquatic organisms, including fish, crustaceans, molluscs and aquatic plants, under controlled conditions to enhance production and sustainability (FAO, 2020). This practice complements capture fisheries, which have faced overfishing pressures globally, necessitating the development of sustainable alternatives (World Bank, 2013). This sector also supports employment opportunities along its value chain, from hatchery operations to processing and marketing. In Zambia, fish and aquaculture play a significant role in the national economy, providing a primary source of protein for many communities (DoF, 2023).

## Overview of the Fish and Aquaculture Sector in Zambia

Zambia is a landlocked country endowed with vast water resources, including natural lakes such as Lake Tanganyika, Lake Bangweulu, Lake Mweru-Luapula, and Mweru-Wantipa, as well as man-made reservoirs like Lake Kariba and Itezhi-Tezhi. These water bodies offer substantial potential for both capture fisheries and aquaculture development (Department of Fisheries, 2023). According to the DoF (2023), the fishing and aquaculture sector contributes approximately 1.42% to Zambia's GDP and 42% to the agricultural GDP, and has the potential to deliver both agricultural-led growth and socio-economic transformation, as aspired to in Vision 2030 (MFL, 2023). Capture fisheries are concentrated in Zambia's extensive freshwater systems, including Lakes Kariba, Tanganyika, and Mweru, as well as the Zambezi and Kafue Rivers. However, overfishing and environmental degradation have caused capture fisheries to reach a production plateau, emphasising the need to shift to sustainable aquaculture systems (DoF, 2022).

Zambia's fisheries and aquaculture sector is integral to national food security, providing affordable protein, employment, and economic opportunities. Approximately 50% of Zambia's population relies on fish as their primary source of animal protein (DoF, 2020). The sector comprises capture fisheries and aquaculture, with the latter experiencing significant growth in recent years. Annual aquaculture production in Zambia grew from 20,000 metric tons in 2010 to approximately 76,627 metric tons in 2023, driven by government interventions, private sector investment, and donor support (DoF, 2023; FAO, 2023). In 2024, aquaculture production increased by 16.6 percent from 76,627 metric tons in 2023 to 89,342 metric tons, while capture fisheries production marginally increased by 4.0 percent from 101,825 metric tons in 2023 to 105,869 metric tons in 2024 (DoF, 2024 – Annual Report).

**The sector comprises three main components:**

1. **Capture Fisheries**: This involves the management and harvesting of fish from natural water bodies, contributing the majority of Zambia's fish production. Some of the major species harvested include *Oreochromis macrochir* (Green-headed tilapia), *Oreochromis andersonii* (Three-spotted tilapia), *Oreochromis niloticus* (Nile tilapia), *Limnothrissa miodon* and *Stolothrissa tanganicae* (freshwater sardine), *Lates starpersii* (Perch) and *Clarias gariepinus* (African catfish) (DoF, 2020; Sikawa and Mwale, 2013). Capture fisheries in Zambia further support tourism-oriented sport fishing, where species such as *Hydrocynus vittatus* (Tigerfish) and *Hepsetus cuvieri* (Pike) are targeted.
2. **Aquaculture**: The aquaculture sub-sector has grown steadily over the past decade, driven by increasing demand for fish and government initiatives to promote fish farming. Zambia's aquaculture production focuses primarily on tilapia and African catfish (FAO, 2023; DoF, 2022).
3. **Ornamental Fisheries**: Though relatively small, ornamental fish farming and trade are emerging as a niche market, leveraging the biodiversity of Zambia's water systems (DoF, 2022). Species such as *Tilapia rendalli* (redbreast tilapia) and *Aphyosemion spp.* (killifish) are among those being

utilised for ornamental purposes due to their vibrant colours and adaptability to aquarium conditions.

### Types of Aquaculture Production Systems in Zambia

Zambia's aquaculture industry employs various farming systems tailored to the specific environmental, social, and economic contexts of the country:

#### Pond-Based Systems

Ponds are the most common aquaculture system, particularly among small-scale farmers. These systems rely on natural or artificial water sources and are often integrated with crop and livestock farming (DoF, 2022; Musuka *et al.*, 2018; Hoevenaars and Ng'ambi, 2019).

Pond conformations vary and include:

- **Earthen ponds** – These are the most widespread due to their low construction costs and ease of integration with natural landscapes. They are typically dug directly into the ground and lined with clay-rich soil to retain water.
- **Lined ponds** – These ponds are similar to earthen ponds but are lined with materials such as plastic (HDPE) or concrete to reduce seepage and improve water management. They are increasingly used in areas with porous soils or where water conservation is critical.
- **Concrete ponds** – Less common and more expensive, these are primarily used in urban or peri-urban areas, research stations, and for hatchery or ornamental fish production, where better control of water quality and biosecurity is needed.

Among these, earthen ponds remain the predominant system due to their affordability and suitability for extensive and semi-intensive production systems in rural areas.

- Benefits include low start-up costs and suitability for rural areas with adequate water availability (FAO, 2023). Stocking rates usually range from 3 to 8 fish per square metre.

*Figure 1 Pond-based system using dam liners (Source: WorldFish Centre/NRDC, 2019)*

**Cage and Pen Culture Systems**

Cage farming is practised in large water bodies such as Lake Kariba and involves raising fish in floating enclosures made of netting, allowing for intensive production in limited surface areas (Sikawa and Mwale, 2013). Similarly, pen culture uses fixed enclosures with netting or mesh walls that are anchored to the bottom of the water body and open to the natural substrate, offering a semi-controlled environment for fish rearing.

These systems are predominantly utilised by commercial operators due to their high initial investment costs (DoF, 2022). Commercial cage farmers typically have high stocking densities, ranging from about 100 to 200 fish/m³, to maximise production efficiency.

*Figure 2 An intensive commercial fish farm using fish cages at Lake Kariba in the Siavonga district (Source – Yalelo Zambia Limited)*

**Tank Systems**

Tanks, often constructed from concrete or plastic, are used for intensive fish farming. They provide greater control over water quality and temperature, making them suitable for hatcheries and urban farms (FAO, 2023; Musuka *et al.*, 2018).

*Figure 3 Concrete tank culturing system (Source: Royd Mukonda - Mukasa Agro Fish Farm)*

**Integrated Systems**

Integrated aquaculture combines fish farming with other agricultural activities, such as poultry or crop farming, to maximise resource efficiency and reduce waste (DoF, 2022).

**Additional Relevant Information**

Zambia's aquaculture sector faces challenges such as limited access to quality seed and feed, limited access to finances, inadequate infrastructure, and gaps in the dissemination or accessibility of technical expertise – particularly at the smallholder level – despite the presence of trained personnel within the Department of Fisheries. However, ongoing government initiatives and donor-funded programmes aim to address these gaps. Policy frameworks such as the Aquaculture Development Strategy, the National Fisheries and Aquaculture Policy, and the National Blue Economy Strategy provide the foundation for guiding sustainable growth in the sector, while interventions such as increased investment in research and extension services are critical to supporting effective implementation and capacity development (DoF, 2020; FAO, 2023; World Bank, 2022). These policies align with Zambia's Eighth National Development Plan (8NDP) and contribute to the country's commitments to regional and global frameworks such as the African Union's Agenda 2063 and the United Nations Sustainable Development Goals (SDGs), particularly goals related to food security, livelihoods, and sustainable use of aquatic resources.

Zambia's aquaculture growth is underpinned by favourable policies such as Zambia's Vision 2030, the National Policy on Climate Change (NPCC), National Fisheries and Aquaculture Policy and Implementation Plan (2022–2026) (NFAPIP), Ministry of Fisheries and Livestock Strategic Plan (2022–2026) (MFLSP), National Climate Change Response Strategy (NCCRS), Aquatic Animal Health Strategy and Implementation Plan, and the National Aquaculture Trade Development and Action Plan. These policy documents aim to increase fish production, improve fish value chains, and support smallholder aquafarmers (DoF, 2020; GRZ, 2022). Despite all the aforementioned efforts, challenges such as limited access to quality seed and feed, inadequate financing, and weak extension services persist in the industry (FAO, 2023; World Bank, 2022).

**Mode of Delivery of the Module**

To enhance participant engagement and ensure a clear understanding of key concepts, the module will be delivered through a combination of presentations, group discussions, and interactive sessions. One such interactive component is the question-and-answer session outlined below:

**Q&A Session**

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

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

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

**Discussion Questions**

To reinforce learning and stimulate critical thinking, participants will engage with the following discussion questions at the end of the module:

1. What are the key factors influencing the growth of the aquaculture industry in Zambia?

2. How can small-scale fishers be supported to transition from capture fisheries to aquaculture?

3. What role does government policy play in promoting sustainable aquaculture practices in Zambia?

4. Discuss the potential of integrated aquaculture systems to improve livelihoods in rural communities.

## 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. The module also introduces the five freedoms and domains of animal welfare, sharing insights into general animal/fish welfare violations and practices. Lastly, it provides insights into the provisional country-level legal frameworks in Zambia regarding animal welfare.*

### History and trends of animal welfare in Zambia and Africa

Animal welfare, the ethical treatment and care of animals, has evolved significantly in Zambia and across Africa, shaped by a convergence of indigenous traditions, religious values, modern science, policy developments, and global advocacy. While historically rooted in cultural and ecological norms, the concept has gained greater prominence in recent decades, with growing recognition of its role in sustainable development, food security, and ethical stewardship of animals in agriculture, aquaculture, wildlife, and domestic settings.

#### *Early Perspectives and Traditional Practices*

Historically, animal welfare in Zambia and Africa was grounded in indigenous knowledge systems and traditional practices. Communities engaged in livestock and fishing often observed ethical animal care rooted in cultural beliefs, spiritual connections, and ecological balance. While these practices promoted humane treatment, they were informal and lacked codification into formal standards or national policy frameworks.

#### *Emergence of Animal Welfare Awareness (1960s–1990s)*

The post-independence period marked the beginning of formal attention to animal welfare in Africa. International organisations such as the World Organisation for Animal Health (WOAH/OIE) and World Animal Protection (formerly WSPA) began influencing animal welfare practices, primarily focusing on terrestrial animals, particularly livestock. Emphasis was placed on humane slaughter, transport, and disease control.

In Zambia, this period saw initial efforts channelled through veterinary services under the Ministry of Agriculture. However, animal welfare was not yet recognised as a standalone issue, and public awareness remained low.

***Institutional Development and Policy Integration (2000s–2010s)***

The early 21st century marked a shift toward formalising animal welfare within national legislation and agricultural policies. This was largely guided by the adoption of OIE Animal Welfare Standards and increasing support from civil society and professional bodies.

**In Zambia:**

- The Animal Health Act of 2010 included components related to animal welfare, though primarily linked to disease prevention and control.
- The Zambia Veterinary Association and some NGOs began advocating for humane animal husbandry.
- Awareness and policy engagement remained limited in aquaculture and fish welfare.

**Regionally:**

- The African Union Inter-African Bureau for Animal Resources (AU-IBAR) led initiatives to harmonise animal welfare standards across member states.
- The First Africa Animal Welfare Conference, held in Nairobi in 2017, catalysed a broader continental dialogue on animal welfare.

***Recent Trends and Expanding Scope (2015–Present)***

In recent years, there has been a marked expansion in the scope and depth of animal welfare efforts across Africa. Key developments include:

- Mainstreaming of animal welfare into agricultural and aquaculture policies in countries such as Kenya, South Africa, Uganda, and Zambia.
- Recognition of aquatic animals, particularly fish, as sentient beings requiring welfare considerations.
- Active involvement of international NGOs (e.g. World Animal Protection, Compassion in World Farming) and academic networks supporting research and advocacy in animal and fish welfare.

- Capacity building and training initiatives, such as the African Fish Welfare Fellowship (AFIWEL) and the incorporation of welfare topics into veterinary and aquaculture education.
- Adoption of regional frameworks and strategies, including those developed by AU-IBAR and the Pan-African Animal Welfare Alliance (PAAWA).

**In Zambia:**

- The Department of Fisheries (DoF) has begun integrating fish welfare principles into its extension and research activities.
- Initiatives such as the ***Fish Welfare Training Guide for Zambia*** reflect a growing commitment to improving aquatic animal welfare as part of broader sustainable development goals.

This evolution underscores a growing commitment in Zambia and the region to integrate animal welfare into policy, practice, and public consciousness, thereby contributing to food security, ethical production, environmental stewardship, and alignment with global standards and goals (FAO, 2021).

**Overview of Animal Welfare in Zambia and Africa**

In Zambia, animal welfare is a growing priority, supported by a combination of government policy, non-governmental action, and international collaboration. The Departments of Fisheries, Livestock Development and Veterinary Services lead national efforts to integrate welfare considerations into livestock, aquaculture, and wildlife management. These departments are implementing policies that promote humane animal husbandry practices, aligning with international standards such as those set by the World Organisation for Animal Health (WOAH).

A key contributor to animal welfare efforts in Zambia is the Lusaka Animal Welfare Society (LAWS), a non-governmental organisation that has played a critical role in advocating for and promoting the humane treatment of domestic animals. LAWS is actively involved in rescue operations, public education, veterinary outreach, and awareness campaigns. Its grassroots and policy-level work has helped bridge the gap between animal welfare advocacy and public engagement, especially in urban settings.

Across Africa, the relationship between humans and animals is influenced by a mosaic of cultural traditions, socioeconomic factors, and environmental conditions. Countries such as Nigeria, Kenya, South Africa, and Ghana have taken significant steps in formalising animal welfare through policies and programmes that emphasise humane practices in agriculture, aquaculture, and wildlife conservation (FAO, 2021; OIE, 2023). These efforts reflect a broader continental shift toward recognising animal welfare as integral to sustainable development, food systems, and public health.

**Historical Development of Animal Welfare**

***Ancient Civilisations (Prehistoric Times to 600 BCE)***

Early African societies practised sustainable use of animals based on respect for nature. Ancient Egyptian civilisations, for instance, domesticated animals for farming and companionship, with depictions in art showcasing the importance of animal well-being. Traditional practices across Africa often reflected a balance between human needs and ecosystem health, emphasising coexistence (Breyer, 2020).

***Religious Influence (600 BCE–1800 CE)***

Religious teachings profoundly influenced attitudes toward animals. For example, Islamic principles emphasised humane slaughter (halal), while African traditional religions viewed animals as sacred or symbolic of deities. Christianity, introduced during European colonisation, reinforced stewardship over animals, advocating for their care while recognising their utility.

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

The global animal welfare movement originated in Europe during the 19th century, with its early impacts also being felt in Africa through colonial administration. European settlers introduced laws targeting cruelty, primarily to protect livestock and working animals used in agriculture and transport. These laws were limited and often excluded indigenous practices and wildlife conservation efforts.

***Formation of Animal Welfare Societies (19th Century)***

Organisations like the Royal Society for the Prevention of Cruelty to Animals (RSPCA) inspired the formation of similar societies across Africa. South Africa was among the first countries on the continent to establish formal animal welfare organisations, laying the groundwork for broader awareness and advocacy. In Zambia, initiatives focused on livestock and wildlife protection, including the establishment of the Society for the Prevention of Cruelty to Animals (SPCA), which has contributed to promoting the humane treatment and welfare of animals, particularly in urban areas.

***Laboratory Animal Welfare (20th Century)***

The 20th century witnessed an increased use of animals in research, necessitating the development of ethical guidelines for the use of laboratory animals. International frameworks, such as the "3Rs" (Replacement, Reduction, Refinement), influenced African nations to incorporate welfare standards in scientific research. Zambia began aligning with these guidelines as research institutions expanded (OIE, 2023).

***Modern Animal Welfare Movement (Late 20th Century–Present)***

The modern animal welfare movement in Africa is characterised by:

- Increased advocacy from NGOs such as World Animal Protection (WAP) and the Humane Society International (HSI).
- The adoption of policies like the African Union's *Continental Animal Welfare Strategy* (2017).
- A shift toward recognising animal welfare as integral to sustainable development, public health, and food security. Zambia's Aquaculture Development Strategy and National Livestock Development Policy reflect this shift.

**Trends in Animal Welfare**

***Policy and Legislation***

Zambia has legislation, such as the Animal Health Act (2010), and policy documents, including the National Livestock Development Policy (2018), which include provisions for the humane treatment of animals. Other African countries, such as South Africa, have introduced robust legislation, including the Animal Protection Act of 1962, subsequent amendments that address cruelty prevention and welfare standards (FAO, 2021).

***Awareness and Advocacy***

Non-governmental organisations (NGOs) and community-based organisations are driving animal welfare advocacy. For instance, World Animal Protection (WAP) operates in Africa to promote humane practices in farming and wildlife conservation.

***Integration into Development Programmes***

Animal welfare is increasingly recognised as a component of sustainable development. Programmes like Zambia's Aquaculture Development Strategy and the African Union's Livestock Development Strategy integrate welfare into broader objectives, such as poverty reduction and environmental protection.

***Education and Training***

Veterinary schools in Zambia and other African countries are incorporating animal welfare into curricula. Training programmes for farmers emphasise the connection between welfare and productivity, particularly in livestock and aquaculture sectors.

***Wildlife and Conservation***

In regions with rich wildlife, such as Zambia's Luangwa Valley and South Africa's Kruger National Park, conservation programmes now integrate welfare considerations, including ethical tourism practices and humane wildlife management.

***Adoption of International Standards***

Many African nations are aligning their practices with global standards such as those of the WOAH, emphasising the Five Freedoms: freedom from hunger, thirst, discomfort, pain, injury, disease, and fear, as well as the freedom to express normal behaviour.

Despite significant advancements in global animal welfare practices, poor welfare standards persist in many regions, including Zambia and Africa. These challenges are largely attributed to limited awareness among smallholder farmers and local communities, insufficient funding for welfare programmes, weak policy frameworks, and socio-cultural factors, such as traditional or religious practices that often conflict with modern welfare principles (FAO, 2021). The enforcement of existing animal welfare laws and policies remains inadequate, hindering progress. Moreover, climate change poses a growing threat to animal welfare, exacerbating challenges through extreme weather conditions, habitat degradation, and shifts in disease patterns (World Animal Protection, 2023).

On a more positive note, animal welfare is gaining recognition as an essential component of the "One Health" approach, which emphasises the interconnectedness of animal, human, environmental, and ecosystem health. The emerging "One Welfare" concept extends this framework, advocating for interdisciplinary partnerships to simultaneously address animal and human welfare while incorporating environmental considerations (Pinillos *et al.*, 2016). This integrated perspective highlights the importance of collaboration across sectors in overcoming existing challenges, enhancing welfare standards, and promoting sustainable development in the region (Marchant-Forde and Boyle, 2020; FAO, 2021; World Animal Protection, 2023).

## Negative Impacts of Poor Animal Welfare on Sustainable Development

### *Reduced Agricultural Productivity*

Poor animal welfare, including that of livestock and fish, leads to increased stress, susceptibility to disease, and reduced growth and reproductive performance. In livestock, this translates into lower yields of meat, milk, and eggs. Similarly, in aquaculture, stressed or poorly handled fish exhibit slower growth rates, higher mortality rates, and lower feed conversion efficiencies, ultimately undermining both agricultural and aquacultural productivity and threatening overall food security.

### *Increased Poverty and Economic Loss*

Smallholder farmers and communities reliant on livestock face significant economic losses due to decreased productivity, higher veterinary costs, and lower market value of animals in poor welfare conditions. This perpetuates poverty, especially in rural areas.

### *Compromised Public Health*

Poor welfare practices can increase the risk of zoonotic diseases, such as avian influenza, rabies, and brucellosis, posing a direct threat to human health and straining healthcare systems.

***Environmental Degradation***

Inefficient animal farming systems, often associated with poor animal welfare, contribute to deforestation, soil degradation, and water pollution. Unmanaged waste from stressed or sick animals can also harm ecosystems.

***Inefficient Use of Resources***

Poorly managed animal systems waste feed, water, and energy due to inefficiencies caused by poor health or stress in animals, exacerbating resource scarcity.

***Threat to Biodiversity***

Overexploitation of certain species through poor welfare practices, including unsustainable fishing or poaching, disrupts ecosystems and reduces biodiversity, negatively affecting ecological balance.

***Social and Cultural Implications***

In regions where animals play integral cultural, economic, or social roles, poor welfare undermines the benefits derived from animals, including labour, transportation, and companionship. This can lead to social instability in communities heavily reliant on animal resources.

***Ethical Concerns and Loss of Consumer Trust***

The growing awareness of animal welfare among consumers has led to an increased demand for ethically sourced animal products. Poor welfare practices damage the reputation of industries and reduce market access, especially in international trade.

***Stunted Educational and Research Advancements***

A lack of emphasis on animal welfare reduces opportunities for research and innovation in sustainable livestock and aquaculture systems, hindering the development of best practices.

***Impacts on Sustainable Development Goals (SDGs)***

Poor animal welfare directly hampers progress on multiple SDGs, such as:

- **Goal 1:** No Poverty – By reducing income from livestock.
- **Goal 2:** Zero Hunger – By limiting food production.
- **Goal 3:** Good Health and Well-being – Through zoonotic disease outbreaks.

- **Goal 12:** Responsible Consumption and Production – By promoting unsustainable practices.

Addressing these impacts is crucial to ensuring that animal welfare aligns with broader sustainable development objectives, as illustrated in the figure below, which summarises the impacts of poor animal welfare (Oluwarore, 2022).

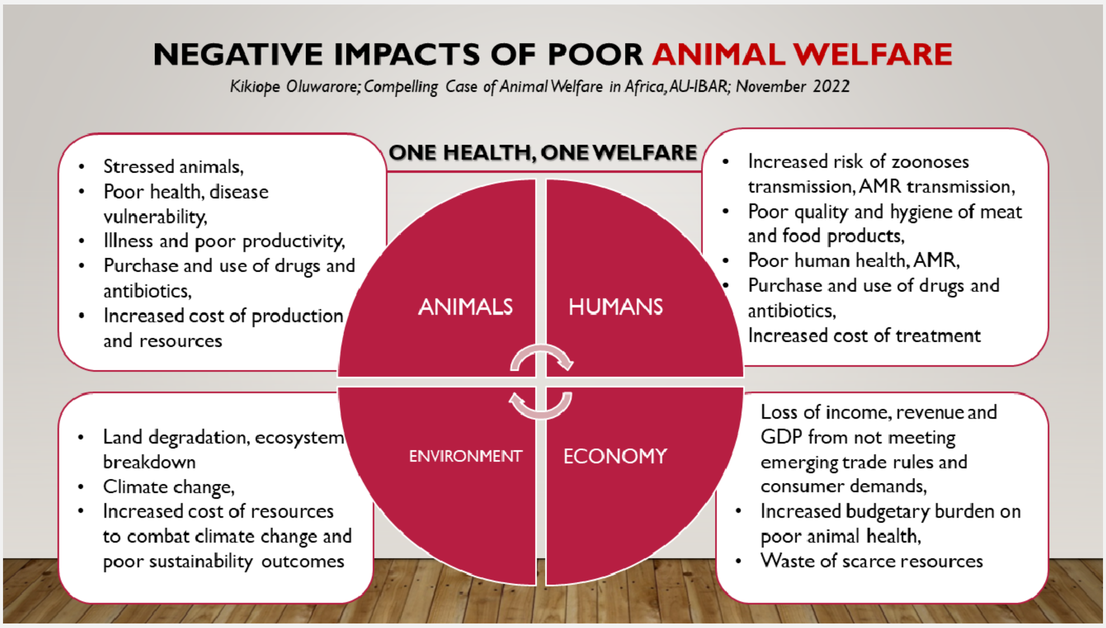


*Figure 4 Oluwarore (2022), Compelling Case of Animal Welfare in Africa, AU-IBAR, Africa Conference for Animal Welfare, November 2022*

Improved animal welfare significantly contributes to reducing animal diseases and zoonoses, benefiting both animals and humans. Proper welfare practices, including appropriate housing, nutrition, and veterinary care, minimise stress and susceptibility to diseases, reducing the risk of transmission of zoonoses such as brucellosis and avian influenza (FAO, 2023). This reduces animal mortality rates and promotes healthier livestock, directly enhancing growth rates, feed efficiency, and overall productivity. These outcomes foster human-animal bonds, which have been shown to positively influence human health and social well-being, particularly in communities that rely on livestock for their livelihoods (Fraser, 2008).

Addressing welfare concerns through improved housing and management practices has profound impacts on production performance. For instance, providing adequate shelter reduces exposure to harsh environmental conditions, improving animal comfort and preventing stress-induced illnesses

(WOAH, 2022). Properly designed facilities that promote natural behaviour and reduce overcrowding enhance feed utilisation, leading to cost reductions and higher-quality outputs such as meat, milk, and eggs. This improves food safety, as animals raised in stress-free environments are less likely to produce contaminated or low-quality products (Grandin, 2015).

Moreover, focusing on animal welfare aligns with sustainable farming practices, ensuring the development of ethical and environmentally sound livestock production systems. Good management practices, including regular health monitoring and humane handling, create a more predictable and stable production environment. This ensures consistent meat quality, addressing consumer concerns and enhancing market access, especially in regions emphasising ethical sourcing. As such, improving animal welfare serves as a cornerstone for advancing food security, public health, and sustainable development goals (FAO, 2023).

### The Five Freedoms of Animal Welfare

The Five Freedoms of Animal Welfare provide a universal framework for ensuring the physical and mental well-being of animals under human care. Developed in 1965 and refined by the UK's Farm Animal Welfare Council (FAWC) in 1979, these principles emphasise the prevention of suffering and the promotion of good health and behaviour in animals (FAWC, 1979; Webster, 2001). The principles provide globally validated basic guidelines and indicators used to determine the welfare status of animals, including fish. These guidelines have been adopted 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). Below is a detailed description of each of the freedoms.

#### *Freedom from Hunger and Thirst*

This freedom ensures that animals have access to adequate, nutritious food and clean drinking water at all times. Proper nutrition and hydration are essential for maintaining an animal's health, energy levels, and resistance to diseases. Failure to provide this can lead to malnutrition, dehydration, and related health issues. Adequate feeding and watering systems should also prevent competition or injury among animals (Appleby *et al.*, 2018).

***Freedom from Discomfort***

Animals must be provided with an appropriate environment that includes shelter from adverse weather and a comfortable resting area. The environment should be free from extreme temperatures, excessive humidity, and physical hazards. Proper bedding, ventilation, and lighting contribute to minimising physical and thermal discomfort, enhancing the animal's overall welfare and productivity (Fraser *et al.*, 1997).

***Freedom from Pain, Injury, or Disease***

This freedom highlights the importance of preventive healthcare, prompt diagnosis, and treatment of illnesses or injuries. It ensures animals are protected from unnecessary suffering through proper management practices, vaccinations, and veterinary care. Effective measures such as biosecurity and regular health monitoring can reduce disease prevalence and improve animal welfare (Webster, 2001; FAO, 2012).

***Freedom to Express Normal Behaviour***

Animals should be provided with sufficient space, appropriate facilities, and the opportunity to interact with their own kind. This freedom acknowledges the importance of natural behaviours, such as grazing, nesting, or social interaction, for the mental and emotional well-being of animals. For example, allowing chickens to perch or pigs to root contributes to their psychological health, preventing frustration and abnormal behaviours like aggression (Broom, 2010).

***Freedom from Fear and Distress***

This freedom emphasises the need for an environment that minimises psychological stress and ensures animals are handled calmly and humanely. Stress can negatively affect animals' immune systems, growth, and reproduction. Practices such as proper handling, reducing noise, and avoiding overcrowding help minimise fear and distress, promoting both mental well-being and productivity (Grandin, 2015).

### Significance of the Five Freedoms

The Five Freedoms serve as guiding principles for animal welfare policies, legislation, and practices worldwide. They apply across diverse sectors, including farming, research, zoos, and companion animal management, reflecting a commitment to humane treatment and ethical responsibility. And while all the freedoms have distinct roles, they all feed into and impact each other in several ways. An example of this is "freedom from hunger and thirst", which contributes to the satisfaction of the other four freedoms (Oluwarore *et al.*, 2023).

### The Five Domains of Animal Welfare

Although the "Five Freedoms of Animal Welfare" provide a strong basis for assessing animal welfare standards in animals, a more updated framework called the "Five Domains of Animal Welfare has since been established. The "*Five Domains of Animal Welfare*" were developed as an extension of the Five Freedoms to provide a more nuanced framework for assessing and addressing animal welfare. Initially introduced by Professor David Mellor and his colleagues in the 1990s, this model emphasises the physical and mental states of animals by evaluating their interaction with the environment and their overall well-being (Mellor and Reid, 1994). The five domains include nutrition, environment, health, behaviour, and mental state. These domains are described as a science-based best practice framework for assessing animal welfare and quality of life (Oluwarore *et al.*, 2023). Below is a detailed description of these domains:

#### *Nutrition*

The nutrition domain focuses on ensuring animals have access to an appropriate quantity and quality of food and water to meet their physiological needs. Proper nutrition supports growth, reproduction, immune function, and overall health. Nutritional deficiencies or excesses can lead to stress, poor health, and reduced productivity (Mellor *et al.*, 2020).

***Environment***

This domain emphasises the importance of providing an appropriate environment that offers shelter, adequate space, and suitable conditions, such as temperature and ventilation. A well-maintained environment protects animals from discomfort and promotes natural behaviours, reducing stress and improving their overall welfare (Beausoleil and Mellor, 2015).

***Health***

The health domain focuses on preventing and managing injuries, diseases, and other physical ailments. It also includes considerations for pain relief and access to veterinary care. Maintaining good health not only prevents suffering but also ensures animals can live productive and fulfilling lives (Mellor and Beausoleil, 2015).

***Behaviour***

The behavioural domain evaluates whether animals can express species-specific behaviours and interact positively with their environment and peers. Restrictions on natural behaviours, such as foraging, grooming, or social interaction, can lead to frustration and stress. Providing enrichment and appropriate social settings can improve mental well-being (Mellor *et al.*, 2020).

***Mental State***

This domain synthesises the inputs from the first four domains to assess the animal's overall mental state. By considering factors such as stress, fear, pleasure, or contentment, this domain evaluates the animal's emotional experiences. Ensuring a positive mental state is key to achieving comprehensive welfare (Mellor, 2016).

**Importance of the Five Domains**

The Five Domains model offers a more comprehensive approach to animal welfare than the Five Freedoms, as it integrates both physical and mental aspects of well-being. It has been widely adopted in various contexts, including farm animal management, laboratory research, and wildlife conservation, as a framework for humane treatment and ethical decision-making.

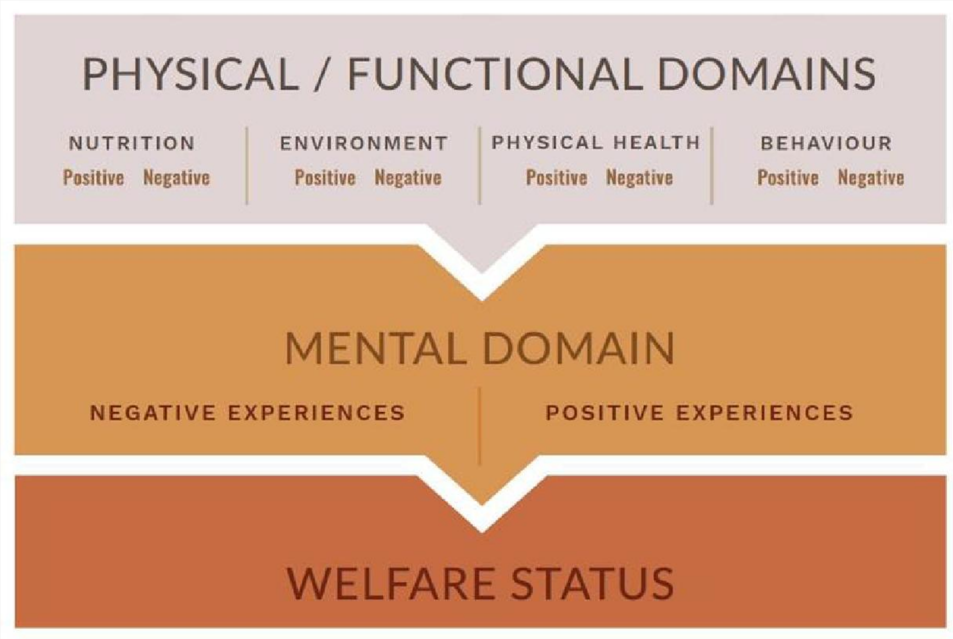


*Figure 5 Domains of Welfare (Source: Zoo Aquarium Australia)*

In order to obtain a "good life", an animal must have the opportunity to have positive experiences, including satisfaction and satiation. To achieve this, those responsible for the care of animals need to provide them with environments that not only allow them to express their behaviour but also encourage them to do so (RSPCA, n.d.). Thus, the five domains provide a means of evaluating the welfare of an individual or groups of animals in a particular situation, with a strong focus on the mental well-being and positive experiences (Oluwarore *et al.*, 2023).

**Comparison and Integration of the Five Freedoms and Five Domains of Animal Welfare**

The "Five Freedoms" and "Five Domains" are complementary frameworks that guide the assessment and promotion of animal welfare. While the Five Freedoms provide foundational ethical principles, the Five Domains expand on these principles to offer a more detailed and nuanced understanding of welfare, particularly in terms of physical and mental well-being (see Tables 1 and 2).

**Comparison of the Five Freedoms and Five Domains**

Table 1 describes an overall comparison of the five freedoms and five domains:

*Table 1 First overall comparison of the five freedoms and five domains*

| Aspect | Five Freedoms | Five Domains |
|---|---|---|
| **Origin** | Developed in 1965 by the Brambell Committee and refined by the Farm Animal Welfare Council (FAWC). | Developed by David Mellor and colleagues in the 1990s as an advancement of the Five Freedoms framework. |
| **Focus** | Ethical principles outlining basic needs and rights for animals. | Scientific and operational model emphasising mental states and multidimensional welfare factors. |
| **Scope** | Primarily addresses physical conditions and basic negative welfare aspects. | Includes both negative and positive welfare states, considering animals' mental and emotional experiences. |
| **Application** | Provides comprehensive guidelines applicable to all species and settings. | Provides a detailed assessment framework for practical application in diverse contexts. |
| **Mental Well-being** | Implied, but not explicitly addressed. | Explicitly incorporates mental states into welfare assessment. |

Table 2 describes in detail the special focus of these five freedoms and five domains comparatively:

*Table 2 Detailed comparison of the special focus of the five freedoms and five domains*

| Aspect | Five Freedoms Focus | Five Domains Focus |
|---|---|---|
| **From Hunger and Thirst → Nutrition** | Ensures animals have access to sufficient food and water to avoid hunger and dehydration (FAWC, 1979). | Addresses the quality, quantity, and timing of food and water availability, considering species-specific dietary needs and feeding behaviours (Mellor, 2016). |
| **From Discomfort → Environment** | Focuses on providing adequate shelter and a comfortable resting area to prevent physical discomfort (FAWC, 1979). | Evaluates environmental conditions, such as temperature, humidity, ventilation, and space, to ensure they meet the animal's physical and behavioural needs (Mellor *et al.*, 2020). |
| **From Pain, Injury, and Disease → Health** | Prevents and treats pain, injury, and disease to ensure animals remain physically healthy (FAWC, 1979). | Includes prevention strategies, early diagnosis, treatment, pain management, and promotion of long-term health and well-being (Mellor, 2016). |
| **To Express Normal Behaviour →** | Ensures animals can perform species-specific behaviours, including | Examines environmental and social factors that enable animals to express natural behaviours, focusing on both |

| | | |
|---|---|---|
| **Behavioural Interactions** | social interactions and exercise (FAWC, 1979). | individual and group dynamics (Mellor *et al.*, 2020). |
| **From Fear and Distress → Mental State/Positive Experiences** | Aims to minimise fear and distress to prevent suffering and promote a sense of safety (FAWC, 1979). | Explores animals' emotional states, incorporating both the reduction of negative experiences and the promotion of positive welfare outcomes, such as comfort and contentment (Mellor, 2016). |

### Key Insights

- The **Five Freedoms** provide ethical guidelines to ensure basic needs are met and suffering is avoided.
- The **Five Domains** enhance this framework by incorporating scientific and operational considerations, focusing on both the alleviation of negative states and the promotion of positive welfare experiences.

### Integration of the Five Freedoms and Five Domains

The Five Freedoms serve as the ethical foundation upon which the Five Domains build a more detailed and actionable framework. Each freedom aligns with and is expanded by the domains:

#### *Freedom from Hunger and Thirst → Nutrition Domain*

The Five Domains expand this freedom by addressing the quality, quantity, and timing of food and water availability, as well as the animal's ability to access these resources without stress or competition (Mellor, 2016).

#### *Freedom from Discomfort → Environment Domain*

While the Five Freedoms focus on providing shelter, the Five Domains delve deeper into environmental conditions, such as space, temperature, ventilation, and enrichment, ensuring the environment meets species-specific needs (Beausoleil and Mellor, 2015).

#### *Freedom from Pain, Injury, and Disease → Health Domain*

The Five Domains extend this freedom to include preventative measures, prompt treatment, and pain management, promoting long-term health and well-being (Mellor *et al.*, 2020).

***Freedom to Express Normal Behaviour → Behaviour Domain***

The Five Domains emphasise creating environments and social settings that allow animals to engage in natural behaviours, enhancing both physical and mental well-being (Mellor, 2017).

***Freedom from Fear and Distress → Mental State Domain***

This freedom is fully integrated into the Five Domains, which focus on understanding and addressing animals' emotional states, including stress, anxiety, contentment, and pleasure (Mellor and Beausoleil, 2015).

**Advantages of Integrating the Frameworks**

- **Comprehensive Assessment**: Integration ensures a holistic view of welfare, combining ethical guidelines (Freedoms) with detailed operational tools (Domains).
- **Improved Animal Welfare**: By addressing physical needs and mental well-being, the frameworks collectively promote positive welfare states, leading to better animal health, productivity, and quality of life.
- **Practical Application**: The detailed metrics provided by the Five Domains make it easier to implement the Five Freedoms in diverse settings, such as farms, zoos, and laboratories.

**Key Animal and Fish Welfare Violations**

Violations in animal and fish welfare occur when practices fail to meet established standards for ensuring the health, comfort, and mental well-being of animals. The following are key welfare violations across species, including fish:

***Animal Welfare Violations***

a) **Inadequate Nutrition**
   - o Animals are deprived of sufficient or appropriate food and water, leading to malnutrition, dehydration, or starvation (FAWC, 1979).

b) **Poor Housing Conditions**
   - o Animals are confined to overcrowded, poorly ventilated, or unhygienic spaces, which causes discomfort, stress, and increases their susceptibility to disease (Mellor *et al.*, 2020).

c) **Lack of Veterinary Care**

- Failure to prevent, diagnose, and treat diseases and injuries, leading to prolonged pain and suffering (OIE, 2022).

d) **Inability to Express Natural Behaviours**
   - Confinement or management practices restrict animals from engaging in normal behaviours, such as grazing, socialising, or nest-building, resulting in frustration or abnormal behaviours (FAWC, 1979).

e) **Cruel Handling and Transport**
   - Mishandling during capture, restraint, or transportation causes physical injuries, stress, or death (Grandin, 2019).

f) **Painful Procedures Without Anaesthesia**
   - Procedures such as tail docking, castration, or dehorning are often performed without adequate pain relief, resulting in severe distress (AVMA, 2020).

g) **Neglect and Abuse**
   - Animals are subjected to neglect, physical abuse, or psychological trauma, violating ethical and welfare standards (OIE, 2022).

***Fish Welfare Violations***

1. **Overcrowding in Aquaculture**
   - High stocking densities cause stress, aggression, and increased disease transmission (Conte, 2004).
2. **Poor Water Quality**
   - Inadequate oxygen levels, high ammonia concentrations, or inappropriate temperatures compromise fish health and well-being (Ashley, 2007).
3. **Rough Handling**
   - Fish are subjected to unnecessary injuries or stress during capture, sorting, or transport (Huntingford *et al.*, 2006).
4. **Lack of Enrichment**
   - Failing to provide an environment that supports species-specific behaviours, such as hiding or schooling, leads to stress and reduced welfare (Sneddon *et al.*, 2016).
5. **Painful Slaughter Practices**
   - Insufficient stunning or inhumane killing methods cause unnecessary pain and prolonged suffering during slaughter (Ashley, 2007). Additionally, handling animals – especially fish and livestock – without appropriate sedation or Anaesthesia before slaughter can lead to extreme distress and further compromise animal welfare.

6. **Disease and Parasite Management**
    - Lack of proactive disease monitoring or treatment results in avoidable suffering and mortality (Conte, 2004).

**Legal Framework for Animal and Fish Welfare in Zambia**

Zambia does not have a stand-alone fish welfare act or policy document. Instead, the country relies on a combination of constitutional mandates, legislative acts, and strategic policies to ensure the humane treatment of both terrestrial animals and aquatic species. These instruments collectively promote ethical practices, sustainable resource management, and adherence to international standards across the agriculture, fisheries, and aquaculture sectors.

***Constitution of Zambia (Amendment) Act, 2016***

This constitutional amendment emphasises the importance of sustainable development and environmental protection. Its broad directives support animal and fish welfare indirectly by advocating for the responsible use and conservation of natural resources.

***Prevention of Cruelty to Animals Act, Chapter 245***

This Act establishes a legal framework to combat cruelty by criminalising acts of torture, neglect, or abuse. It sets standards for the humane treatment of animals by regulating transportation, handling, and slaughter practices, ensuring that unnecessary suffering is avoided.

***Fisheries Act No. 22 of 2011***

Focused on the sustainable management of the fishing industry, this Act governs fishing practices to prevent overexploitation of fish stocks. Although it does not explicitly address "fish welfare," its provisions imply welfare concerns by mandating responsible fishing practices and sustainable resource management. The very words “fish welfare” are not mentioned in the Fisheries Act of 2011, but only implied.

***Animal Health Act No. 27 of 2010***

This legislation is dedicated to disease prevention and control, which indirectly supports fish welfare, ensuring that livestock remain healthy and free from diseases. By promoting animal health, it indirectly contributes to overall welfare and aligns with international standards, such as those set by the World Organisation for Animal Health (WOAH).

***Wildlife Act No. 14 of 2015***

Designed to protect wildlife, including aquatic species, in designated protected areas, this Act regulates activities such as hunting and fishing. It aims to prevent unnecessary suffering and ensure that wildlife is treated humanely.

***Environmental Management Act No. 12 of 2011***

This law is integral to environmental sustainability. It promotes biodiversity conservation and pollution control, both of which are crucial for sustaining the ecosystems that support healthy populations of animals and fish.

***National Policy on Climate Change (NPCC)***

The NPCC addresses the impacts of climate change on agriculture and aquaculture. It outlines adaptive strategies to mitigate environmental stressors, thereby safeguarding the welfare of both terrestrial and aquatic species in the face of changing climatic conditions.

***Eighth National Development Plan (8NDP)***

The 8NDP integrates animal and fish welfare into Zambia's broader socio-economic development framework. Its key features include:

- **Sustainable Resource Management:** Encouraging modern agricultural practices that protect animal habitats.
- **Livestock and Aquaculture Development:** Setting targets to improve productivity while upholding ethical treatment standards.
- **Infrastructure and Capacity Building:** Investing in research, training, and facilities to support humane handling, disease control, and welfare practices. This plan ensures that development initiatives are aligned with welfare considerations, fostering both economic growth and responsible animal management.

***National Fisheries and Aquaculture Policy***

The National Fisheries and Aquaculture Policy provide a strategic framework for transforming Zambia's fisheries and aquaculture subsector to promote sustainable development, improve livelihoods, and ensure environmental stewardship.

The overall objective of the policy is to transform the fisheries and aquaculture subsector, thereby promoting sustainable development of fisheries and aquaculture.

To achieve this, the policy outlines the following specific objectives:

- To promote sustainable fish production and productivity;
- To strengthen fisheries and aquaculture extension service delivery;
- To strengthen research and development (R&D) in fisheries and aquaculture;
- To enhance market linkages for fish and fish products;
- To improve and maintain aquatic animal health;
- To prevent and mitigate environmental degradation; and
- To mainstream crosscutting issues in fisheries and aquaculture.

In line with these objectives, the policy embeds animal welfare considerations through the following key measures:

- **Humane Handling and Processing:** Promoting ethical practices in the capture, handling, transport, and processing of fish to minimise stress and suffering.
- **Stocking Density and Water Quality Management:** Establishing and enforcing guidelines to ensure optimal rearing conditions that support fish health and reduce mortality.
- **Research and Innovation:** Supporting scientific research aimed at improving aquaculture practices, fish welfare standards, and environmental sustainability.
- **Capacity Building and Infrastructure:** Investing in training, extension services, and modern infrastructure to enable compliance with best practices in welfare and biosecurity.

Through these actions, the policy positions fish welfare as an integral component of Zambia's strategy for achieving a productive, ethical, and sustainable fisheries and aquaculture sector.

**Alignment with International Standards**

Zambia aligns its animal welfare practices with international standards to ensure humane treatment of animals across various sectors, including livestock, aquaculture, and wildlife. The country subscribes to guidelines established by the **World Organisation for Animal Health (WOAH/OIE)**, which serve as a global reference for animal health and welfare, particularly regarding transport, slaughter, and husbandry practices.

In addition to WOAH/OIE, Zambia also benefits from partnerships and guidance provided by other international organisations that promote animal welfare, such as:

- **The International Fund for Animal Welfare (IFAW):** Advocates for the protection of animals and supports global campaigns to reduce cruelty, promote wildlife conservation, and improve animal welfare policies.
- **World Animal Protection (WAP):** Actively works in Africa to promote humane treatment of farm and aquatic animals, disaster preparedness for animals, and ethical food systems.
- **Compassion in World Farming (CIWF):** Encourages responsible farming practices and promotes fish welfare in aquaculture operations.
- **Food and Agriculture Organisation of the United Nations (FAO):** Provides technical support, policy guidance, and capacity building in animal welfare, particularly in developing countries.
- **African Union – Inter-African Bureau for Animal Resources (AU-IBAR):** Leads continental efforts to harmonise animal welfare standards across member states, including the development of regional strategies and capacity building.

By aligning with these international organisations and adopting their guidelines, **Zambia strengthens its commitment to advancing animal and fish welfare** in line with globally accepted best practices, enhancing both ethical standards and market competitiveness.

Zambia's legal framework for animal and fish welfare is a comprehensive, multi-layered system. Although there is no dedicated fish welfare act, the combination of constitutional provisions, specialised laws, strategic development plans such as the 8NDP, and targeted policies, including the National Fisheries and Aquaculture Policy, ensures that both terrestrial and aquatic species are managed sustainably and humanely.

**Gaps and Challenges**

1. **Enforcement Issues:** Weak enforcement of existing animal welfare laws in Zambia is largely attributed to the absence of clear regulations or guidelines for implementation, rather than a complete lack of trained personnel. While some capacity exists within government departments, enforcement is further constrained by limited financial and logistical resources, affecting consistent monitoring and compliance efforts.
2. **Public Awareness:** Limited understanding of animal and fish welfare laws among communities.
3. **Policy Integration:** Need for more robust integration of welfare considerations into broader agricultural and fisheries policies.

**Future Outlook**

Animal welfare in Zambia and Africa is poised for significant advancement as governments, NGOs, and the private sector collaborate to integrate welfare into agriculture, aquaculture, conservation, and public health initiatives. The adoption of new technologies, increased funding, and continued advocacy will be critical to addressing existing challenges and fostering a culture of humane animal treatment.

**Q&A Session**

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

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

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

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

**Discussions Points**

1. Take a moment to think about the concept of animal welfare. Had you heard of "animal welfare" before this training? Did you previously consider it a key factor in the management and productivity of animals? In what ways, if any, have you thought about animal welfare in your day-to-day activities? How do you think improved animal welfare practices can contribute to higher production outcomes or better food quality? Can you share an example where good animal welfare practices also led to improved human well-being or environmental sustainability?
2. Discuss general animal welfare practices and violations in Zambia. Which of the animal welfare violations listed are common in Zambia?
3. What can be done to address and prevent poor animal welfare practices in Zambia?
4. Discuss your thoughts and feedback on the animal welfare legal framework in Zambia. Is this enough? Are there gaps? Recommendations?
5. What can be done to push for the establishment and implementation of the Animal Welfare Law (including fish welfare) in Zambia? How can you support this?

## MODULE 3: INTRODUCTION TO FISH WELFARE

*This module provides an overview of farmed fish welfare, the 5 Pillars of Welfare in aquaculture, and the corresponding benefits of fish welfare practices.*

### What Is Fish Welfare?

Fish welfare refers to the well-being of fish in their natural habitats, aquaculture systems, or captivity. It encompasses the physical, mental, and behavioural needs of fish, ensuring they are free from unnecessary suffering and capable of expressing natural behaviours. Welfare is not only a moral and ethical consideration but also a critical factor influencing fish health, growth, reproduction, and overall productivity in aquaculture systems (Farm Animal Welfare Council, 2009; Ashley, 2007; Huntingford *et al.*, 2006). Fish welfare involves practices that reduce stress, prevent disease, and provide an environment conducive to healthy living. This includes adequate nutrition, proper water quality, appropriate stocking densities, and effective disease management. Proper fish welfare also aligns with the concept of "One Welfare," which connects animal well-being with human health and environmental sustainability (FAO, 2021).

### The Five Pillars of Animal Welfare in Aquaculture

To guide understanding of Fish Welfare, the Aquatic Life Institute has established specific indicators tailored to the welfare of fish and other aquatic animals. These indicators are referred to as the "five welfare pillars of fish" and include environmental enrichment, feed composition, space requirements and stocking density, water quality, and stunning and slaughter (Oluwarore *et al*, 2023). Also watch this 3-minute video, ***An Introduction to Aquatic Animal Welfare***, for more information.

The five pillars of animal welfare in aquaculture provide a comprehensive framework to ensure the well-being of farmed fish. These pillars are adapted from broader animal welfare principles and tailored to address the unique needs of aquatic species in aquaculture systems. They encompass good feeding, good housing (environment), good health, appropriate behaviour, and positive mental experiences (Huntingford *et al.*, 2006; FAO, 2022).

By focusing on these key aspects, aquaculture systems can promote ethical practices, improve fish health and productivity, and align with global standards for sustainability and humane treatment (Brown *et al.*, 2018). These principles not only support the physical and mental well-being of fish but also contribute to the economic and environmental sustainability of the aquaculture industry. The five pillars serve as a guide for ensuring that fish are raised in conditions that foster health, growth, and natural behaviour, while minimising stress and suffering (Ashley, 2007).

Adopting these pillars is crucial for meeting consumer demand for ethical and sustainable aquaculture practices and supporting the global shift toward a "One Welfare" approach that integrates animal welfare, human well-being, and environmental health (FAO, 2022; Mellor, 2016).

Below is a detailed explanation of the five pillars of fish welfare:

**1. Good Feeding**

Feeding is a central component of fish welfare and production success. Proper nutrition affects growth, immune function, reproductive performance, and stress levels in fish. Inadequate or inappropriate feeding can lead to malnutrition, competition, aggression, and increased mortality.

- Fish should be provided with adequate, high-quality, and species-appropriate feed that meets their nutritional requirements at various life stages.
- Feeding strategies should minimise competition and stress among fish by ensuring even distribution and accessibility.
- Efficient feeding practices also help reduce feed waste, minimising environmental pollution and improving economic sustainability.

**2. Good Housing (Environment)**

The aquatic environment in which fish are raised has a significant impact on their health and welfare. Housing refers not only to the physical infrastructure but also to the management of water quality and habitat features that allow fish to thrive.

- Aquaculture systems must maintain optimal water quality parameters, such as oxygen levels, temperature, pH, and ammonia concentrations, within acceptable ranges for the specific species.
- Appropriate stocking densities should be observed to prevent overcrowding, competition, and associated stress.
- Providing environmental enrichment, like hiding places, plants, or suitable substrates, helps mimic natural habitats and supports normal behaviours.

**3. Good Health**

Good health is a foundation of fish welfare and production. Maintaining healthy fish populations requires proactive and ongoing disease prevention strategies, rather than relying solely on reactive treatments.

- Health management should involve regular monitoring for signs of disease, implementation of vaccination programmes (where applicable), and robust biosecurity measures to prevent the introduction and spread of pathogens.
- Injuries caused by poor handling, overcrowding, or equipment should be minimised through the use of humane practices.
- Chronic stress should be avoided as it compromises the immune system, making fish more susceptible to disease and reducing growth and survival rates.

**4. Appropriate Behaviour**

Behavioural welfare refers to the ability of fish to express natural, species-specific behaviours. Inadequate environments or poor management can suppress these behaviours, leading to stress, aggression, and abnormal activity.

- Fish should be able to exhibit behaviours such as shoaling, foraging, swimming, and exploring, which are vital indicators of well-being.

- Environmental enrichment—such as structural complexity, variable lighting, or controlled flow—can stimulate natural behaviours and reduce boredom or frustration.
- it is essential to consider behavioural needs at different life stages, from larvae to adults, to ensure welfare across the fish's lifespan.

**5. Positive Mental Experiences**

The emotional and mental state of fish is often underappreciated but is increasingly recognised as a key component of welfare. Scientific evidence indicates that fish are sentient beings capable of experiencing pain, fear, and possibly positive emotions.

- Conditions should be designed to promote mental comfort by reducing exposure to stressors such as poor water quality, handling, or social aggression.
- Providing safe and predictable environments enhances a sense of security and supports positive experiences.
- Ensuring low stress and high welfare can lead to improved feeding behaviour, enhanced immune function, and overall increased productivity.

**Benefits of Improved Aquaculture Fish Welfare**

Improving fish welfare in aquaculture systems yields significant advantages across ecological, economic, and ethical domains. These benefits are critical for enhancing fish health, ensuring sustainable production, and meeting the expectations of consumers and regulatory frameworks. Below is a detailed exploration of these benefits.

***Enhanced Fish Health and Reduced Disease Incidence***

When fish (or any other animals) are treated humanely, especially in the context of the five freedoms and domains of animal welfare, they stand a higher chance of being able to live a healthy and optimally productive life (Oluwarore et al, 2023). Improved welfare practices significantly bolster fish health by mitigating stress and preventing the onset of diseases. 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, diseases can cause financial hardships, food shortages, and even industry failure for the farmer (Arthur and Subasinghe, 2002). It has also been reported that diseases and parasites from aquaculture frequently spread to wild populations, ultimately endangering the entire ecosystem (Naylor and Burke, 2005). Key welfare measures, such as maintaining optimal water quality, stocking density, and biosecurity protocols, reduce the spread of pathogens and enhance immune responses (Ellis *et al.*, 2012). When fish are raised in clean, well-managed environments, their resistance to bacterial, viral, and parasitic infections is significantly increased, resulting in lower mortality rates and reduced production losses (Ashley, 2007).

Moreover, reducing disease outbreaks through welfare improvements minimises the need for antibiotics and other chemical treatments. This not only lowers production costs but also reduces the risks associated with antimicrobial resistance, a growing global concern. Preventing diseases through proactive welfare measures aligns with the principles of sustainable aquaculture and contributes to the production of safer, healthier fish products for consumers (FAO, 2022).

***Improved Growth and Feeding Efficiency***

Stress directly affects fish metabolism, which in turn impacts their growth and feed conversion efficiency (Conte, 2004). Welfare improvements, such as providing balanced nutrition and minimising handling stress, optimise metabolic efficiency, allowing fish to grow faster and convert feed more effectively. Efficient feed utilisation not only reduces costs for farmers but also lessens the environmental impact by minimising nutrient waste in water systems (Huntingford *et al.*, 2006).

In addition, the adoption of welfare-oriented practices ensures fish maintain their natural behaviours, such as feeding and swimming, under conditions that promote growth. For example, maintaining appropriate stocking densities ensures fish have adequate space to thrive, further enhancing their growth rates and overall health (Brown *et al.*, 2018). These practices ultimately lead to higher yields and profitability for aquaculture operations.

***Improved Quality of Life***

The concept of animal welfare emphasises creating optimal environments that allow animals to thrive and exhibit their natural behaviours without fear, pain, or unnecessary restrictions. Scientific advancements have increasingly confirmed the mental complexity and sentience of animals, emphasising their capacity to experience a wide range of emotions. Poor welfare conditions, such as inadequate housing, stressful handling, or lack of stimulation, severely compromise animals' mental states, inhibiting their ability to engage in natural behaviours and diminishing their overall quality of life (Nicks and Vandenheede, 2014).

A poor quality of life often stems from prolonged psychological stress and suffering, which can further weaken the immune system, leaving animals vulnerable to illness and reduced physical health. This underscores the interplay between mental well-being and physiological health in ensuring holistic welfare. Welfare-enhanced environments, which prioritise comfort, freedom, and stimulation, not only improve the mental state of animals but also support better immune function and resilience to diseases (Nicks and Vandenheede, 2014; Broom, 2016).

Furthermore, enabling animals to express natural behaviours, such as foraging, exploring, or socialising, contributes significantly to their psychological well-being. For instance, providing enrichment materials in aquaculture systems or housing designs that align with species-specific needs can reduce stress and improve the quality of life for animals in farming systems (FAWC, 2009). Thus, promoting improved welfare standards ensures that animals, as sentient beings, are not merely productive but also lead lives with dignity and well-being.

***Better Product Quality and Meeting Emerging Trade and Consumer Demands***

The quality of aquaculture products is closely linked to the welfare of the fish during rearing, handling, and harvesting. Stressful environments and poor handling practices negatively impact the physical and biochemical properties of fish, resulting in undesirable traits such as pale muscle colour, poor texture, and reduced shelf life (Ashley, 2007). By contrast, welfare-friendly practices, including humane handling, appropriate stocking densities, and stress-free harvesting, improve meat quality by preserving muscle firmness and minimising the biochemical changes induced by stress-related cortisol release. These practices are especially crucial for accessing high-value markets, where premium product quality is a priority (Brown *et al.*, 2018). Improved welfare practices also enhance food safety by reducing the risk of contamination from diseases or improper handling. Consumers increasingly prefer fish products that are ethically produced, with adherence to welfare standards fostering trust and loyalty. This, in turn, bolsters the marketability of aquaculture products both domestically and internationally (FAO, 2022).

As consumer awareness grows, there is an increasing demand for sustainably produced animal products that align with ethical and welfare considerations. Modern consumers, government institutions, and regulatory bodies reject products from systems with poor welfare standards (Conte, 2014; Lai *et al.*, 2018; Buller *et al.*, 2018). For example, the European Union has established minimum welfare standards, including guidelines for the humane handling and slaughter of farmed fish. It is actively revising its legislation to prioritise animal welfare further (Buller *et al.*, 2018). Welfare standards are now integrated into trade policies and certification schemes, ensuring that fish and other animal products meet the expectations of global markets (Broom, 2008).

For farmers and producers, embracing higher welfare standards is not only about meeting consumer demands but also about maintaining competitiveness in an increasingly dynamic market. Welfare-certified products have higher acceptability in export trade and demonstrate a commitment to sustainability, quality, and compliance with evolving policies. As consumers gain access to more options, including alternative protein sources, producers must prioritise high-quality, welfare-oriented products to remain viable. The integration of welfare standards into aquaculture systems supports growth, enhances product quality, and facilitates access to lucrative markets, while promoting sustainability and ethical production practices.

***Environmental Benefits, Improved Productivity, and Sustainable Livelihoods***

Enhancing fish welfare in aquaculture plays a vital role in promoting environmental sustainability, improving productivity, and supporting sustainable livelihoods. Welfare-oriented systems often emphasise optimal resource utilisation, such as better feed management, which minimises feed wastage and reduces nutrient pollution in aquatic environments (Huntingford *et al.*, 2006). Additionally, by reducing stress and disease prevalence, these systems lessen the need for chemical treatments, such as antibiotics and pesticides, which can accumulate in water bodies and negatively impact biodiversity. These practices contribute to global environmental conservation efforts and align with the United Nations' Sustainable Development Goals (SDGs) by balancing seafood production with ecosystem health and sustainability (Ellis *et al.*, 2012).

From an economic and operational perspective, adopting higher welfare standards fosters improved productivity and greater efficiency in aquaculture systems. Research indicates that welfare-focused practices lead to less aggression among fish, reduced fin damage, improved growth rates, and enhanced feed conversion ratios (Stewart *et al.*, 2012; Schneider *et al.*, 2012). For example, the use of aerators to maintain optimal water quality has been shown to increase fish survival rates by approximately 43%, boosting production and profitability for farmers (Qayyum *et al.*, 2005). Furthermore, humane transport and handling practices reduce stress and mortality rates, while welfare-conscious slaughter methods not only ensure ethical treatment but also enhance product quality (FAO, 2008; Holmyard, 2017).

The economic advantages of improved welfare extend beyond operational efficiency. Consumers increasingly prefer welfare-friendly aquaculture products and are willing to pay a premium for ethically produced options (Lai *et al.*, 2018; BENEFISH, 2010). This growing demand presents opportunities for farmers to increase revenue while adhering to sustainable practices. By integrating welfare principles into their operations, farmers can achieve higher productivity, produce better-quality products, and enhance their marketability, thereby ensuring the long-term viability of their livelihoods.

Ultimately, prioritising fish welfare benefits not only the animals and ecosystems but also supports economic resilience and sustainable development in the aquaculture sector.

***Food Quality and Safety, Economic Gains, and Ethical Considerations***

Enhancing fish welfare not only ensures humane treatment but also has profound implications for food quality and safety. Fish cultivated and processed in adherence to welfare standards are generally healthier, tastier, and of superior quality, as stress before and during slaughter negatively affects the biochemical properties of the meat (Poli, 2009). Poor welfare practices, including prolonged stress, increase the likelihood of bacterial contamination and other health risks such as viruses, biotoxins, and parasites in fish products (EFSA, 2008; EFSA, 2009). Conversely, minimising stress during cultivation and slaughter, such as through effective stunning methods, preserves fillet quality and inhibits bacterial growth post-slaughter, ensuring safer and higher-quality products. These improvements are essential for meeting consumer expectations and ensuring food safety in aquaculture.

From an economic perspective, adopting better welfare practices yields significant financial benefits for aquaculture operators. Reduced mortality and healthier fish result in higher productivity and lower operational costs, directly increasing profitability. Moreover, farmers who adopt welfare-focused practices often gain access to premium markets through certification schemes that emphasise animal welfare, enabling them to sell their products at higher prices (FAO, 2022). These market advantages incentivise the integration of welfare principles into aquaculture operations, supporting economic resilience in the sector.

Ethically, prioritising fish welfare aligns with societal expectations and evolving regulatory standards. As public awareness of animal welfare grows, addressing these concerns enhances the reputation of the aquaculture industry and ensures compliance with international guidelines, reducing the risk of trade restrictions and penalties (Mellor, 2016). By fostering humane treatment, aquaculture contributes to a socially responsible and sustainable food system that benefits producers, consumers, and ecosystems alike. The integration of welfare principles thus bridges ethical considerations, economic sustainability, and food quality, ensuring a holistic approach to aquaculture management.

***Sustaining a Healthy Ecosystem and Environment***

Improved fish welfare plays a crucial role in maintaining healthy ecosystems and minimising environmental degradation. One major benefit is the reduction of harmful wastewater generated during aquaculture operations, which, if left untreated, can have a severe impact on aquatic ecosystems. Wastewater rich in organic matter and nutrients significantly contributes to eutrophication, resulting in algal blooms, oxygen depletion, and ocean dead zones that disrupt biodiversity and ecosystem balance (Global Aquaculture Alliance, 2019). Additionally, untreated aquaculture waste often contains antimicrobials, which, when introduced into the environment, can affect human health and foster antimicrobial resistance (Adams, 2019).

Welfare-oriented practices mitigate these issues through several mechanisms. The use of effective feeding systems reduces waste by improving feed conversion ratios (FCRs) and limiting uneaten feed particles in the water column. Proper feeding strategies also reduce competition and aggression among fish, fostering a stable and less stressful environment (Gan *et al.*, 2013). Additionally, maintaining appropriate stocking densities minimises overcrowding, further enhancing feeding efficiency, reducing injuries, and limiting behavioural issues like cannibalism (Santos *et al.*, 2010). Less stress also supports stronger immune systems in fish, reducing their susceptibility to disease and, consequently, the need for antimicrobial use (McClure *et al.*, 2005).

Another critical aspect of fish welfare in sustaining ecosystems is preventing the escape of farmed fish. Escapes of non-native or genetically distinct fish can lead to competition for food, disrupt local food webs, and outcompete native fish populations, resulting in ecological imbalances (Global Aquaculture Alliance, 2019). By prioritising robust containment systems and welfare measures, aquaculture facilities reduce the risk of escapes, protecting the integrity of natural ecosystems. Incorporating fish welfare into aquaculture practices aligns with broader goals of environmental sustainability. It reduces the ecological footprint of aquaculture by controlling waste output, conserving biodiversity, and supporting the long-term health of aquatic ecosystems. This sustainable approach ensures that aquaculture can continue to meet global food demands while preserving the environment for future generations.

***Contribution to Sustainable Development***

Fish welfare is an integral aspect of sustainable development, aligning closely with the attainment of the United Nations' Sustainable Development Goals (SDGs). Adopted in 2015, the SDGs serve as a global framework to end poverty, protect the planet, and promote peace and prosperity for all by 2030 (UNDP, 2023). These 17 goals are interconnected, emphasising the need for balance across social, economic, and environmental dimensions of development. By implementing fish welfare practices, aquaculture contributes to several key SDGs, fostering ethical, economic, and environmental sustainability.

***Goal 1: No Poverty***

Aquaculture and fisheries provide livelihoods for approximately 250 million people globally, creating employment and economic opportunities, particularly in developing regions. Improving fish welfare enhances productivity and reduces losses, establishing a more sustainable and profitable income base for farmers and fishers, thereby reducing poverty in vulnerable communities (Aquatic Life Institute, 2023).

***Goal 2: Zero Hunger***

Aquaculture is a vital source of nutrition, supplying high-quality protein and essential nutrients to millions worldwide. Welfare improvements increase the health and survival of farmed fish, ensuring a stable and efficient food source for populations, particularly in regions heavily reliant on fish as a primary protein source (FAO, 2022).

***Goal 3: Good Health and Well-Being***

Fish welfare has a positive impact on food safety and public health. Lower stress levels and reduced disease incidences in farmed fish minimise the risk of contamination, zoonotic infections, and the overuse of antimicrobials. This ensures the production of safer and higher-quality fish products, supporting food security and public health in communities that rely on fisheries for their nutrition (Aquatic Life Institute, 2023).

***Goal 6: Clean Water and Sanitation***

Poor fish welfare contributes to water pollution through the accumulation of uneaten feed and antimicrobial residues. By improving feeding practices and reducing the reliance on medication, welfare-focused systems minimise nutrient runoff and antimicrobial diffusion into aquatic ecosystems, promoting cleaner water resources and protecting biodiversity (Gan *et al.*, 2013).

***Goal 12: Responsible Consumption and Production***

Higher welfare standards in aquaculture promote ethical and sustainable farming practices. These improvements reduce waste, enhance feed efficiency, and align production systems with responsible consumption and environmental conservation goals, ensuring that aquaculture meets ethical and ecological benchmarks (UNDP, 2023).

***Goal 14: Life Below Water***

Enhanced fish welfare reduces overfishing pressures by increasing the efficiency of farmed fish production. It also mitigates disease and parasite transmission between farmed and wild fish populations, preserving marine biodiversity and preventing harmful ecological events such as algal blooms caused by nutrient pollution from aquaculture systems (Global Aquaculture Alliance, 2019).

***Goal 17: Partnerships for the Goals***

Advancing fish welfare requires collaboration among diverse stakeholders, including researchers, policymakers, industry leaders, and advocacy groups.

These partnerships foster knowledge sharing and promote sustainability, food security, economic stability, and ethical aquaculture practices on both local and international scales (UNDP, 2023).

***The right thing for fish***

Aquaculture is the fastest-growing food sector globally, currently producing over 50% of the seafood consumed worldwide (Ritchie and Roser, 2021). With an estimated 73 to 180 billion fish being reared in aquaculture systems at any given time, the sector is poised to expand further, likely becoming the primary source of both freshwater and marine fish for human consumption in the future (Fishcount, 2019; FAO, 2022). However, this growth comes with significant welfare concerns. Many farmed fish endure chronic stress due to overcrowding, inadequate water quality, diseases, improper handling, and the inability to express natural behaviours (Animal Charity Evaluators, 2020; Fish Welfare Initiative, 2019). These welfare issues result in high mortality rates and prolonged suffering, which is unacceptable, given the mounting evidence that fish are sentient beings capable of experiencing pain and distress, much like terrestrial animals (Braithwaite, 2010; Brown, 2014; Riberolles, 2020; Babb, 2020).

Despite the lack of universal legal requirements for fish welfare, there is a moral obligation to ensure humane treatment of these animals. Providing farmed fish with a life worth living includes implementing rearing practices that prioritise their well-being, such as maintaining optimal water quality, reducing crowding, and addressing disease prevention. Additionally, transport and slaughter methods should be designed to minimise suffering, aligning with ethical standards and public expectations (Ashley, 2007). Improving fish welfare is not only an ethical choice but also a practical one. Humane practices contribute to healthier fish, reduced mortality, and higher product quality, benefitting both producers and consumers. As the aquaculture industry continues to grow, adopting welfare-oriented practices will be essential for creating a sustainable, ethical, and responsible food system.

## Introduction to Fish Welfare Practices in the Zambian Aquaculture Industry

The aquaculture industry in Zambia has experienced significant growth in recent years, making a substantial contribution to the nation's food security, employment, and economic development. With abundant water resources such as rivers, lakes, and reservoirs, Zambia is well-positioned for aquaculture expansion. Key fish species cultivated in the country include Nile tilapia (*Oreochromis niloticus*), three-spot tilapia (*Oreochromis andersonii*), African catfish (*Clarias gariepinus*), and greenhead tilapia (*Oreochromis macrochir*) (Nsonga *et al.*, 2019). These species are chosen for their adaptability to local conditions and their market demand.

Fish welfare practices encompass measures designed to ensure the health, well-being, and ethical treatment of farmed fish throughout their lifecycle. These practices are essential in Zambia's aquaculture systems, which are evolving from small-scale operations to more intensive, commercial-scale systems. Welfare issues such as poor water quality, overcrowding, inadequate feeding regimes, and disease outbreaks can negatively impact productivity and sustainability. For instance, Nile tilapia, a dominant species in Zambian aquaculture, is particularly sensitive to stressors like poor water quality and overcrowding, which can lead to disease and reduced growth rates (Chikafumbwa *et al.*, 2020).

## Key Fish Welfare Practices

### *Water Quality Management*

Maintaining optimal water quality is a cornerstone of fish welfare in Zambia. Essential parameters like dissolved oxygen, temperature, and pH must be regularly monitored and maintained within suitable ranges for species like African catfish and Nile tilapia. For instance, dissolved oxygen levels below 4 mg/L can cause stress and reduce growth rates in tilapia (FAO, 2022). Water management accessories such as aerators and filtration systems can be utilised to improve water quality, particularly in high-density production systems.

***Stocking Density***
Appropriate stocking densities are crucial to minimise stress, aggression, and competition among fish. Overcrowding not only reduces growth performance but also increases the risk of disease transmission. Maintaining stocking densities of around 25–30 $kg/m^3$ is recommended for Nile tilapia in pond culture systems (Nsonga *et al.*, 2019).

***Feeding Practices***
Feeding regimes should be carefully designed to meet the nutritional requirements of the farmed fish species while minimising waste. In Zambia, the use of formulated feeds is increasing, with a focus on improving Feed Conversion Ratios (FCRs) for species like African catfish. Proper feeding schedules can reduce aggression and ensure even growth across the stock.

***Disease Prevention and Management***
Fish diseases, such as bacterial infections and epizootic ulcerative syndrome, are common challenges in Zambian aquaculture (Chibunda *et al.*, 2021). Implementing biosecurity measures, routine health monitoring, and vaccination programmes can significantly reduce disease prevalence. For instance, African catfish benefit from regular health checks to detect and mitigate early signs of bacterial infections.

***Humane Handling and Transport***
Proper handling techniques during harvesting, transportation, and slaughter are critical to minimising stress and physical injuries. For example, using stress-reducing methods such as sedation during transportation can improve fish survival rates and maintain product quality.

**Benefits of Fish Welfare Practices**

By integrating welfare practices, Zambian aquaculture can achieve higher productivity, improved fish health, and reduced mortality rates. Welfare-focused approaches align with global sustainability goals, enhance market competitiveness, and meet the growing demand of consumers for ethically produced aquatic food. Moreover, adopting welfare practices ensures that fish can express species-specific behaviours, thereby reducing chronic stress and enhancing overall farm performance. As Zambia continues to develop its aquaculture industry, prioritising fish welfare will not only improve production outcomes but also support environmental conservation and the livelihoods of farmers. Such practices position Zambia as a leader in sustainable aquaculture in sub-Saharan Africa.

**Q&A Session**

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

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

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

**Discussion Points and Interactive Activities**

To reinforce learning and encourage practical reflection, participants will engage in both group discussion and interactive exercises based on the following questions:

1. What new knowledge have you gained from this lecture on fish welfare today?

   Reflect on any concepts, practices, or perspectives that were new or particularly impactful.
2. Drawing from your own fish farm (or experience working with fish farmers), how do you plan to adapt and apply the "Five Pillars of Animal Welfare in Aquaculture"?

   Share specific examples of how you might change current practices to improve fish health, behaviour, or environmental conditions.
3. Of all the benefits discussed, which top three do you hope to realise by implementing fish welfare practices? Why?

   Consider benefits such as increased productivity, better fish quality, reduced mortality, or improved market access.

**Interactive Learning Activities**

To enrich discussion and help trainees relate theory to practice, the following activities will be incorporated:

- **Scenario-Based Case Studies:** Trainees will work through illustrated real-life scenarios (e.g. overcrowded pond, poor water quality, stressful handling) and identify welfare issues using the Five Pillars framework.
- **Multimedia Aids (Videos/Cartoons/Diagrams):** Short video clips or animated sketches will be shown to highlight both good and poor welfare practices in aquaculture systems. Trainees will be asked to critique and suggest improvements.
- **Role-Plays or Skits:** Small groups will perform short skits simulating real-world situations, such as handling during harvest or managing a disease outbreak — focusing on decision-making that upholds fish welfare. Each performance will be followed by a brief group reflection.

These methods aim to create an engaging and memorable learning experience while helping participants internalise key welfare concepts and prepare for practical application on their farms or in advisory roles.

# MODULE 4: AQUACULTURE PRODUCTION 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.*

**Planning and Considerations for Establishing a Sustainable Fish Farm in Zambia**

Establishing a fish farm in Zambia requires comprehensive planning and strategic decision-making to ensure the welfare, health, and productivity of fish stocks. Proper planning enhances efficiency, minimises operational risks, and ensures optimal returns on investment (FAO, 2020). To achieve this, fish farmers must develop structured operational standards and protocols, including a business plan, emergency response plan, biosecurity strategy, stocking density guidelines, and best management practices (BMPs). These frameworks help standardise farm operations, ensuring that all personnel, including farm managers, veterinarians, and workers, follow best practices to maintain optimal fish health and welfare (Boyd and Tucker, 2012). See Figure 6 for a sample layout of a fish farm.

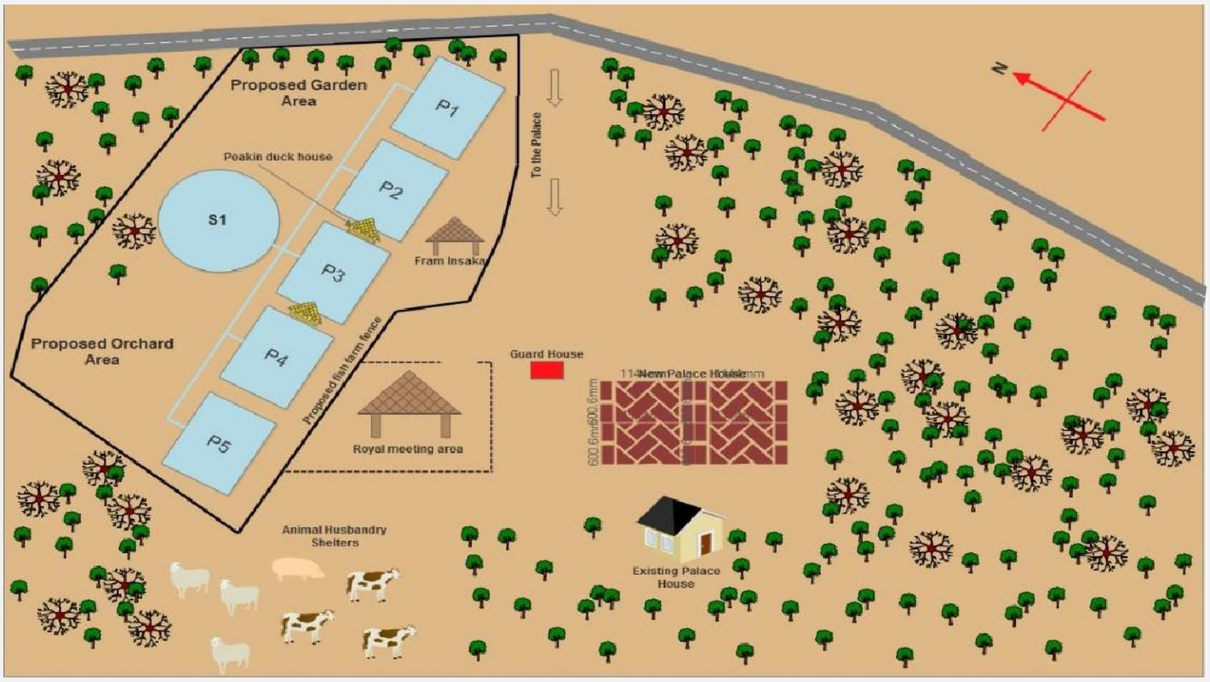


*Figure 6 Sample fish plan in Chisamba district (Source: Namushi, 2018)*

A critical aspect of planning is choosing the right environment for fish farming. The choice of site, rearing system, and stocking density significantly impacts the welfare, health and growth of the fish, influencing overall farm success. These factors are elaborated below.

## Site Selection

### ***Location and Structure of Growing Facilities***

Selecting an appropriate site is fundamental to the success and sustainability of a fish farm. Farms should be strategically located away from industrial zones, commercial farmlands, flood-prone areas, and sources of pollution such as chemical effluents, agricultural runoff, and sewage discharge (Mwango *et al.*, 2019). Contaminants from these sources degrade water quality, leading to fish stress, disease outbreaks, altered behaviour, and increased mortality, ultimately reducing productivity (Beveridge *et al.*, 2020). Additionally, exposure to pollutants can corrode farm infrastructure, increase maintenance costs and pose operational risks.

Proximity to essential services and inputs is equally important. Farms should be located within reasonable distances from markets, hatcheries, feed suppliers, and veterinary services. Longer distances, especially between hatcheries and grow-out farms, can put undue stress on fingerlings during transportation, increasing susceptibility to disease and compromising survival rates. Efficient logistics not only reduce transport stress and post-transport mortality but also lower operational costs and improve access to quality inputs and timely market delivery.

### ***Environmental and Climatic Considerations***

Climate variability, including extreme weather events, temperature fluctuations, and seasonal variations, must be taken into account when selecting a site (Njaya, 2021). In Zambia, particularly in northern and eastern regions, cold weather during certain months may slow down fish metabolism, reducing feeding efficiency and growth rates. Conversely, in hotter regions, such as the Zambezi floodplain and Luangwa Valley, excessively high temperatures may cause thermal stress, leading to higher mortality rates. Fish farmers should therefore implement climate adaptation strategies, such as shading for ponds, aeration or regulating water depth, to mitigate temperature extremes (FAO, 2020).

### *Infrastructure and Regulatory Compliance*

Fish farms must adhere to government regulations on environmental sustainability. Conducting an Environmental Assessment (EA) is mandatory to ensure that the farm's establishment and operations do not negatively impact local ecosystems. An Environmental Project Brief (EPB) is a requirement for a fish farm producing less than 100 metric tonnes of fish, while the one producing above 100 metric tonnes needs an Environmental Impact Assessment (EIA) (Ministry of Fisheries and Livestock, Zambia, 2021). Additionally, hydrological studies should be conducted to assess water availability, quality, and flow dynamics before construction begins. Ensuring compliance with national aquaculture regulations minimises environmental risks and promotes sustainable fish farming practices (Mwango *et al.*, 2019).

### Other Key Considerations for Site Selection

- Accessibility to the farm for logistics and transportation.
- Reliable water supply with adequate quality parameters.
- Proximity to veterinary services and aquaculture extension support.
- Topography that supports efficient water drainage and system design.
- Acceptance of the project by neighbouring communities and local authorities.

### Rearing Systems

The selection of a fish rearing system depends on factors such as the species farmed, farm size, production goals, and available resources (FAO, 2020). In Zambia, common fish culture systems include earthen ponds, concrete tanks, recirculating aquaculture systems (RAS), raceways, cages, and hapas. Each system has unique advantages and operational challenges (Beveridge *et al.*, 2020).

### Common Rearing Systems in Zambia

According to the Aquaculture Survey Report (2023), fish farmers in Zambia utilise a variety of rearing systems based on the availability of resources, scale of production, and location. The most common systems are ranked below from the most to least prevalent:

1. **Earthen Ponds** – These are the most widely used systems across the country due to low operational costs, simplicity in construction, and their ability to mimic natural fish habitats. They dominate small to medium-scale aquaculture enterprises.
2. **Cages and Pens** – Commonly used in natural water bodies such as Lake Kariba, Lake Mweru, and Lake Bangweulu, especially among large-scale and commercial operators. These systems enable high stocking densities and provide access to open-water environments.
3. **Mobile Fishponds** – These include fibreglass, polyethylene, and tarpaulin-lined tanks. They are gaining popularity among small-scale and emerging urban farmers for their portability and ease of setup, particularly in peri-urban and space-constrained settings.
4. **Concrete Tanks and Raceway (Flow-through) Systems** – These are typically used in hatcheries and specialised operations where water quality and temperature control are critical. However, they remain relatively less common due to higher construction and maintenance costs.
5. **Recirculating Aquaculture Systems (RAS)** – These are advanced, high-tech systems designed to reuse water efficiently while ensuring strict biosecurity. While RAS offers high productivity and environmental control, it is still rarely used in Zambia due to high capital and technical requirements.

**Key Welfare Considerations for Rearing Systems**

- Providing a naturalistic environment that allows fish to exhibit their normal behaviours, reducing stress and promoting growth.
- Designing culture systems to minimise physical injuries (damage to fins, scales, or body surfaces).
- Ensuring efficient waste management to remove faecal matter and excess feed while minimising water disturbances.
- Protecting fish from predators such as birds, snakes, and predatory fish species.
- Minimising noise and external disturbances, which can cause stress and affect fish reproduction and growth.

- Implementing biosecurity protocols to prevent the introduction and spread of diseases.
- Establishing emergency response plans for climate-related disasters, disease outbreaks, or infrastructure failures.
- Ensuring proper staff training and continuous professional development on the best fish welfare and management practices.

**Common Growing Facilities and Welfare Considerations in Zambian Aquaculture**

Zambia's aquaculture industry utilises several fish-growing systems, each with unique welfare considerations. Understanding these systems is essential for ensuring optimal fish health, growth, and productivity while maintaining high welfare standards.

***Earthen Ponds***

Earthen ponds are artificial water bodies designed to simulate natural aquatic environments for fish farming (Marywil, 2022). In Zambia, these ponds are commonly used due to their cost-effectiveness and ability to support various fish species, including Nile tilapia (*Oreochromis niloticus*), the Longfin tilapia or the Green head tilapia (*O. macrochir*), Three-spotted tilapia (*O. andersonii*), Red-breasted tilapia (*Coptodon rendalli*) and African catfish (*Clarias gariepinus*).

*Figure 7 Dug-out earthen ponds used for breeding fish at Fiyongoli Aquaculture Research Station in Mansa (Source: Darlington Besa)*

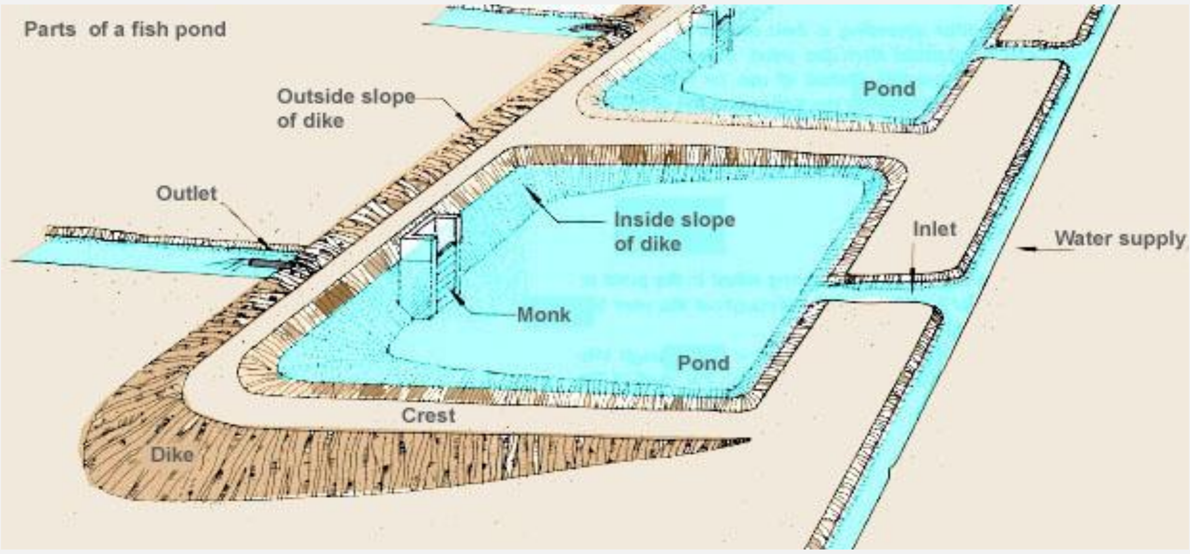


*Figure 8 Features of an earthen fish pond (Source - FAO)*

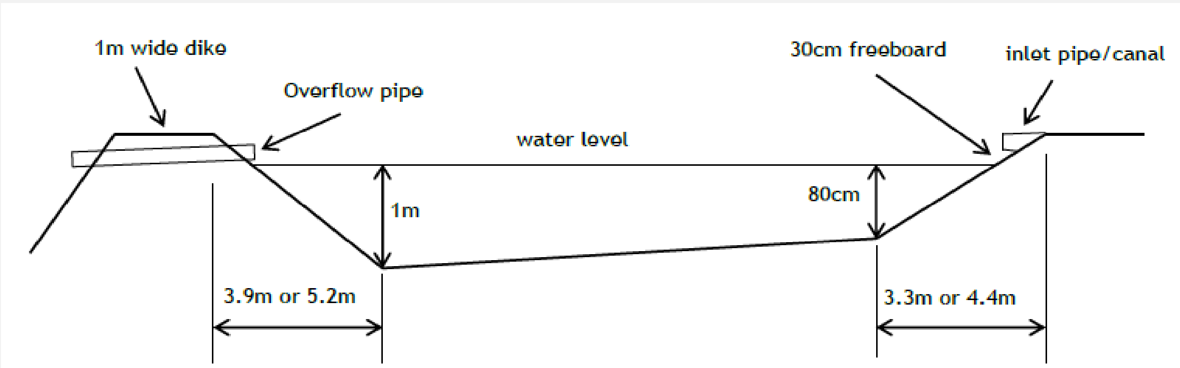


*Figure 9 Cross-section of a fish pond (Source: Peacecorps, 2014)*

**Key Welfare Considerations**

- **Site selection** should prioritise clay or loamy soil with a clay content of over 65% to prevent seepage. The optimal soil pH range for maintaining water quality is between 6.5 and 8.5 (FAO, 2023). Potential sites with sandy soils should be avoided due to their porous nature, which may cause percolation or high seepage of water, potentially leading to the infiltration of wastewater from the surrounding area into the fish ponds.

  Sites with sandy soils can lead to excessive water seepage and wastewater infiltration, resulting in unstable water levels and fluctuating water quality parameters, such as temperature, pH, and dissolved oxygen (FAO, 2022). These changes induce stress and weaken fish immune systems, increasing susceptibility to diseases (Huntingford *et al.*, 2006). Additionally, wastewater may introduce pollutants and excess nutrients that promote eutrophication and harmful algal blooms, ultimately compromising fish growth, survival, and overall welfare (Global Aquaculture Alliance, 2019).
- **Water sources** should be free from contaminants such as iron, which can impair fish gill function, causing stress and stunted growth (Kareem *et al.*, 2023).
- **Predators** such as birds, snakes, and rodents must be controlled through proper screening and habitat management.
- **Flood control** measures must be implemented to prevent fish loss and minimise environmental disruptions.

**Common Welfare Issues**

- Handling stress during sorting and harvesting, as fish are often removed from water for extended periods.
- Cannibalism and predation, particularly in polyculture systems, where aggressive species may dominate.
- Disease outbreaks due to poor water quality and the accumulation of organic waste.
- Soil enrichment techniques must be carefully managed to prevent unintended chemical imbalances or pathogen introduction.

**Concrete Tanks**

Concrete tanks in Zambia are typically constructed using concrete blocks or reinforced slabs, with a blend of sand, cement, and gravel to minimise cracks and leakages. These tanks, which facilitate controlled water flow through drains, are designed to allow water reuse for purposes such as crop irrigation or safe discharge into natural water bodies (FAO, 2022). To maintain water quality, tanks must be equipped with effective drainage and overflow systems. They should also be properly cured, often with a salt treatment, to prevent chemical leaching from the cement, which can lower pH levels and create an acidic environment detrimental to fish health. In the Zambian context, these tanks are generally built-in various sizes and shapes, with a minimum recommended size of 2m x 3m and a depth between 1.2m and 1.5m to ensure adequate cooling and support fish behavioural needs, while factors such as production targets, duration of production cycles, sanitation protocols, and fish swimming patterns determine the optimal design (Nsonga *et al.*, 2019). (See Figures 10 and 11 below)

*Figure 10 Concrete tanks constructed to culture fish at Chilanga Aquaculture Research Station in Chilanga district (Source: Chad Kancheya)*

*Figure 11 Concrete tanks installed with a dam liner to improve water retention at Chilanga Aquaculture Research Station in Chilanga district (Source: Chad Kancheya)*

**Key Welfare Considerations**

- Proper curing of tanks with salt or other treatments is necessary to neutralise the alkalinity of cement residues (Oke and Goosen, 2019). Sometimes, dam liners are also installed to further prevent cement residues from contaminating the water once the tanks are filled.
- Water depth should be at least 1.2 to 1.5 metres to regulate temperature fluctuations and reduce thermal stress.
- Tanks must have functional drainage and aeration systems to maintain water quality.

**Common Welfare Issues**

- Rapid temperature fluctuations, particularly in poorly shaded tanks, can cause stress in fish and lead to mortality.
- Water pollution caused by the buildup of organic waste requires frequent water exchange and proper filtration.
- Structural failures, such as cracks or leaks, leading to reduced water retention and potential fish escapes.

**Mobile Fishpond Systems**

Mobile fishpond systems in Zambia offer flexibility, allowing for easy relocation or permanent installation according to operational requirements. These systems are constructed from materials such as fibreglass, wood (often lined with carpet or linoleum), polyethylene, or plastic. They are designed with various inflow and outlet mechanisms to suit different production setups (FAO, 2022). In the Zambian climate, it is essential that mobile fishponds be installed under shade or protective covers to reduce the impact of direct sunlight and high temperatures. For instance, circular fibreglass tanks are commonly used due to their durability and ease of cleaning, and many are equipped with aerators or sprinklers at the inlet to maintain optimal oxygen levels. However, alternative systems, such as wooden tanks, while cost-effective, tend to be more vulnerable to wood rot, which can lead to leakage, water loss, and deterioration of water quality (Nsonga *et al.*, 2019). (See Figure 12 below)

*Figure 12 Figure 12 Plastic tanks or ponds set up to rear fish (Source: IBAN Aquafish and Consultancy Limited)*


*Figure 13 Circular PVC fish tank set up (Source: IBAN Aquafish Solutions and Consultancy Limited)*

**Key Welfare Considerations**

- Placement under shade to reduce temperature fluctuations.
- Regular cleaning, especially in fibreglass tanks, is necessary to prevent excessive algae build-up.
- Proper installation of aerators or sprinklers is essential to ensure an adequate oxygen supply.

**Common Welfare Issues**

- Algae overgrowth can compromise water quality.
- High risk of accidental contamination from feed spillage and organic waste.
- Susceptibility to temperature variations, particularly in uncovered or poorly insulated tanks.

**Recirculating Aquaculture Systems (RAS)**

Recirculatory Aquaculture Systems (RAS) are advanced, automated setups designed to recycle and treat water, thereby providing a controlled environment that supports high stocking densities and optimal fish growth (Gullian-Klanian and Arámburu-Adame, 2013). In these systems, water is continuously recirculated through a series of fish tanks, sedimentation tanks, and chemical and biological filters that efficiently remove particulate matter, ammonia, and nitrite, while aeration systems, often equipped with ozone generators, help maintain proper dissolved oxygen levels and buffer the pH.

The success of RAS relies on maintaining impeccable water quality, which is achieved through stringent cleaning of intake water, optimised sludge removal, and comprehensive water treatment protocols. These measures not only minimise the need for water replacement in situations of limited water supply but also allow farmers to achieve high biomass stocking intensity. However, the effective management of RAS requires skilled and well-trained personnel who can monitor and adjust system parameters to ensure a stable and healthy environment for fish, making these systems increasingly popular in commercial fish farming in Zambia.

*Figure 14 Tilapia fish hatchery utilising a Recirculatory Aquaculture System (RAS) at the National Aquaculture Research Development Centre (NARDC) (Source: Chad Kancheya)*

*Figure 15 Hatching facility using the RAS system in Solwezi district (Source: Chad Kancheya)*

**Key Welfare Considerations in Recirculating Aquaculture Systems (RAS)**

- Efficient aeration and filtration are crucial for maintaining optimal water quality and ensuring a stable environment for fish.
- Skilled management is critical for operating biological and mechanical filtration systems, as any malfunction can quickly compromise fish welfare.
- Regular monitoring of key water parameters, such as ammonia, nitrite, and pH levels, is required to prevent water toxicity, stress, and potential fish mortality.

- While RAS is designed to offer high biosecurity and controlled conditions, welfare issues are generally minimal when systems are properly managed. However, lapses in monitoring or technical failures can result in rapid deterioration of water quality, emphasising the need for continuous oversight.

**Cages and Pens**

Cage and pen culture involves enclosing fish in net structures within natural water bodies and is increasingly adopted in Zambia, particularly in lakes such as Kariba and Bangweulu (FAO, 2022). In this system, a cage is a net enclosure suspended in the water, anchored to the natural bed and kept buoyant by floats, while a pen is a shallow enclosure that typically rests on the bottom of the water body. Both systems must be constructed to avoid obstructing navigation because regular movements to accommodate waterway use can induce stress in the fish, negatively affecting their feeding behaviour and overall health. Ideally, cages are installed in deeper waters (greater than 4 metres), and pens are used in shallower areas (1–2 metres). The materials used must be durable enough to withstand severe weather conditions, prevent debris ingress, and allow excess feed to escape without polluting the water, while also supporting the natural dietary needs of the fish when stocking densities are high (FAO, 2022).

*Figure 16 A floating fish cage (Source: Yalelo Zambia Ltd)*

**Key Welfare Considerations**

- Durable net materials to prevent fish escapes and predation.

- Strategic placement to avoid conflicts with navigation routes and upstream activities.
- Adequate feed management to prevent nutrient pollution of natural water bodies.

**Common Welfare Issues**

- Exposure to environmental hazards such as water pollution and predation.
- Potential spread of diseases due to proximity to wild fish populations.
- Maintenance challenges, including net fouling and wear.

**Stocking Density and Its Impact on Welfare**

Stocking density, expressed as the biomass of fish (kg) per cubic metre of water, is a critical factor in aquaculture that directly influences fish welfare by affecting water quality, growth, stress levels, and social interactions (FAO, 2022). Optimal stocking density depends on various factors, including the fish species, life stage, rearing system, water flow, and prevailing environmental conditions. When water quality is high, farms can support greater biomass, but if quality deteriorates, lower stocking densities are required to avoid stress and the risk of mortality (Huntingford *et al.*, 2006).

High stocking densities may lead to deteriorated water quality, increased competition, and aggressive interactions, all of which elevate stress levels and compromise immune function, ultimately reducing growth rates and survival. Conversely, excessively low stocking densities can disrupt natural social structures, leading to abnormal behaviour and underutilisation of the production system (Conte, 2004). Therefore, determining the appropriate stocking density is not only essential for maximising production but also for ensuring that fish experience minimal stress and maintain a good quality of life, in line with established welfare standards (FAO, 2022).

**How to Measure Stocking Density**

Determining the stocking density of a fish production system requires accurate measurement of the water volume in the culture system, along with a count of the fish and their individual weights. Stocking density is typically expressed as the biomass (in kilograms) of fish per unit volume (in cubic meters or litres) of water. Using biomass rather than mere numbers is preferred because it better reflects the fish's growth stage and the actual space occupied by them (FAO, 2022).

*For example, if a pond has a total water volume of 10,000 litres, but only 6,000 litres are usable for fish culture, and it is stocked with 1,500 fish each weighing 400 g, the total biomass would be calculated as 1,500 × 400 g = 600,000 g (or 600 kg). The stocking density is then determined by dividing the biomass by the effective water volume, yielding 600 kg / 6,000 L = 0.1 kg per litre (or 100 g per litre) (Huntingford et al., 2006).*

Alternatively, this can be expressed as a numerical density; however, using biomass provides a clearer picture since 10 fish weighing 500 g each will occupy more space than 10 fish weighing 100 g each. Consequently, before establishing a fish farm in Zambia, it is essential to determine the optimal stocking density based on scientific research and guidelines specific to the species being cultured. Additionally, the natural feeding habits and behaviours of the species must be considered in stocking calculations to maximise productivity and ensure high welfare standards (Conte, 2004).

**Recommended Stocking Densities**

Optimal stocking densities for tilapia and other fish species have been extensively studied, with research providing clear guidelines to ensure both high productivity and good fish welfare. Overstocking can lead to poor water quality, increased stress, and lower growth rates, while understocking may result in reduced production efficiency and productivity. Different production systems and species require specific stocking densities for optimal performance. For instance, research suggests that *Clarias gariepinus* (African catfish) can be stocked at 250 fish/m² in intensive earthen ponds, whereas extensive systems should limit stocking densities to about 7 fish/m² (Kareem *et al.*, 2023; Oke and Goosen, 2019). *Oreochromis niloticus* (Nile tilapia) perform well in cages at 120 fish/m³, while in intensive tanks, densities of 40–80 fish/m³ are recommended depending on aeration levels (Nouman *et al.*, 2021; FAO, 2022). Similarly, *Cyprinus carpio* (common carp) thrives at a stocking density of

25 fish/m² in cages (Ahmed *et al.*, 2002). For larval catfish, an initial stocking density of 100 per m² is advised, reducing to 35–40 fingerlings per m² after five weeks to optimise growth and welfare (FAO, 2022).

For tilapia, stocking densities vary depending on the production system. In earthen ponds, 3–6 fish/m² is recommended for semi-intensive culture, while in intensive tank systems, 40–80 fish/m³ may be maintained with proper aeration (El-Sayed, 2006). These stocking densities are crucial for balancing fish health, growth, and production efficiency in Zambian aquaculture.

Below is a summary table of the recommended stocking densities:

*Table 3 Stocking densities for various culture species under different production systems*

| Species | System | Recommended Stocking Density | Reference |
|---|---|---|---|
| *Clarias gariepinus* (African catfish) | Intensive Earthen Ponds | 250 fish/m² | Kareem *et al.* (2023) |
| | Extensive Earthen Ponds | 7 fish/m² | Oke & Goosen (2019) |
| *Oreochromis niloticus* (Nile tilapia) | Cages | 120 fish/m³ | Nouman *et al.* (2021) |
| | Semi-Intensive Ponds | 3–6 fish/m² | FAO (2022) |
| | Intensive Tanks | 40–80 fish/m³ | El-Sayed (2006) |
| *Oreochromis andersonii* (Three-spotted tilapia) | Breeding ponds | 4 fish/m² | DoF Reports (2019) |
| | Nursery ponds | 300 fish/m² | DoF Reports (2019) |
| | Grow-out ponds (mono-sex) | 5-10 fish/m² | DoF Reports (2019) |
| *Oreochromis macrochir* (Green-headed tilapia) | Extensive pond culture | Estimated 5-10 fish/m² (similar to *O. andersonii*) | DoF Reports (2019) |
| *Coptodon rendalli* (Red-breasted tilapia) | Extensive pond culture | 5-10 fish/m² | DoF Reports (2019) |
| *Cyprinus carpio* (Common carp) | Cage Culture | 25 fish/m² | Ahmed *et al.* (2002) |
| | Semi-intensive pond culture | 2-5 fish/m² | FAO (2022) |
| | Intensive earthen ponds | 10-15 fish/m² | FAO (2022) |
| Larval *Clarias* | General (Growing System) | 100 fish/m² initially; 35–40 fingerlings/m² after 5 weeks | FAO (2022) |

**Implications of not adhering to recommended stocking densities**

According to the State of World Fisheries and Aquaculture (FAO, 2024), failing to adhere to recommended fish stocking densities can have several negative implications for fish production and productivity. These implications include and may not be limited to the following:

- **Reduced Growth Rates** – Overcrowding leads to increased competition for food and oxygen, resulting in slower growth rates of fish.
- **Increased Disease Incidence** – High stocking densities increase stress, making fish more susceptible to diseases and parasites.
- **Poor Water Quality** – Overstocking leads to excessive waste accumulation, depleting oxygen levels and increasing ammonia concentrations, which can be toxic to fish.
- **Higher Mortality Rates** – Stress, poor water quality, and disease outbreaks contribute to higher mortality in densely stocked systems.
- **Uneven Size Distribution** – Aggressive behaviour and competition can lead to some fish growing faster while others remain stunted.
- **Reduced Feed Efficiency** – Overcrowding increases stress, which negatively impacts feed conversion efficiency, leading to higher production costs.
- **Environmental Degradation** – Excess fish waste and uneaten feed can lead to eutrophication and degradation of surrounding aquatic ecosystems.
- **Lower Market Value** – Poor growth and health conditions may reduce the quality of harvested fish, making them less desirable in the market.

**Q&A Session**

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

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

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

**Discussion Points**

1. Describe the type of fish farming system you are using and the challenges you are currently facing.
2. Did you conduct a site assessment before choosing your system? Share your findings and reasons for selecting your current setup.
3. Based on the new knowledge, how do you plan to enhance your growing system and farm site to promote better fish welfare?
4. What is your current stocking density, and how do you manage it?
5. Did you determine the appropriate stocking density before starting? How did you decide on the optimal number of fish?
6. What stocking density-related issues have you faced, and how do you plan to improve your practices for better efficiency, fish welfare and health?
7. How can you enhance fish welfare under varying culture and production systems?

# MODULE 5: WATER QUALITY AND FISH WELFARE

*This module explores the impact of water quality on fish welfare and how to effectively monitor this crucial factor to ensure the health and well-being of fish.*

## Introduction to Water Quality and Fish Welfare

Water quality is one of the most critical factors influencing fish health, growth, and overall welfare in aquaculture systems. Since fish live in direct contact with their aquatic environment, any changes in water quality parameters can have significant effects on their physiological functions, stress levels, and susceptibility to diseases (Boyd, 2018). Maintaining optimal water quality is essential for ensuring high survival rates, efficient feed conversion, and sustainable fish farming operations (FAO, 2020). Fish species have specific requirements for water quality, which must be maintained within optimal ranges to support healthy development. Key parameters include temperature, dissolved oxygen, pH, ammonia, nitrite, nitrate, hydrogen sulphide, and salinity. These factors influence metabolic processes, immune function, and overall behaviour (Wedemeyer, 1996). For instance, low oxygen levels can lead to hypoxia, stress, and mortality, while high concentrations of ammonia and nitrite are toxic to fish and can impair gill function (Tucker and Hargreaves, 2018).

Water flow and exchange rates are also crucial in maintaining quality. In stagnant or poorly circulated water, metabolic wastes accumulate, leading to deteriorating conditions that can affect fish health and welfare (Colt, 2006). Proper water movement ensures an adequate supply of oxygen while preventing the buildup of harmful substances, such as hydrogen sulphide, which is highly toxic even at low concentrations (Boyd and Tucker, 2014). Modern aquaculture systems utilise advanced monitoring and filtration technologies to maintain optimal water quality. Recirculating aquaculture systems (RAS) and flow-through systems help maintain stable water conditions through mechanical filtration, biofiltration, and aeration (Martins *et al.*, 2010). However, equipment failure in intensive systems can lead to rapid declines in water quality, making real-time monitoring and alarm systems essential for preventing catastrophic losses (Bregnballe, 2015).

To optimise fish welfare, aquaculture farmers must implement best management practices (BMPs) that involve routine monitoring, adequate aeration, proper stocking densities, and effective waste management strategies. Ensuring stable water quality conditions not only enhances fish welfare but also improves production efficiency and sustainability in aquaculture (FAO, 2022).

**Considerations for Optimal Fish Health and Welfare**

***Water Quality as a Fundamental Requirement***

Fish live in constant contact with water, making the quality of that water the most critical factor for their health and overall welfare. Optimal water quality supports physiological processes, reduces stress, and enhances growth, whereas poor water quality or sudden changes in key parameters can cause both acute and chronic health issues (Wedemeyer, 1996; FAO, 2022). Fish are particularly sensitive to pollutants and chemical contaminants, and even low concentrations of toxins can compromise their immune systems, leading to increased disease susceptibility (Huntingford *et al.*, 2006).

***Source of Water and Its Characteristics***

For any aquaculture system, the water source should be as natural as possible, matching the optimal quality required for the target fish species. This means the water must be free from harmful chemicals, pollutants, and pathogenic organisms. Using water that closely mimics the fish's natural habitat not only minimises stress but also promotes normal behaviour and better overall health (Boyd, 2018).

***Water Budget, Storage, and Supply***

Maintaining an adequate water budget is essential for consistent fish health. This involves regularly calculating, monitoring, and replenishing the water supply. Inadequate water supply or acute shortages can lead to decreased oxygen levels and increased pollutant concentration, both of which can induce stress and trigger disease outbreaks in fish (FAO, 2022). Ensuring that the system has sufficient water storage and that it is managed properly helps maintain stable water quality parameters, supporting robust fish growth.

***Regular Water Monitoring and Analysis***

Continuous monitoring of water quality is crucial for promptly detecting any deviations from optimal conditions. Daily measurements of key physical parameters, such as temperature, pH, dissolved oxygen, salinity, ammonia, nitrite, hydrogen sulfide, alkalinity, hardness, turbidity, and suspended solids, are essential. Regular monitoring also includes checking for organic chemical contaminants (e.g. veterinary drugs, antibiotics, hydrocarbons) and biochemical hazards, such as toxins, as well as biological contaminants like bacteria and viruses (Tucker and Hargreaves, 2018). Maintaining comprehensive records of these measurements can help identify trends and implement corrective actions promptly.

***Water Flow and Exchange***

The design of water flow within a rearing system is a critical factor. Adequate water circulation ensures that oxygen is evenly distributed and that metabolic wastes – such as faeces and uneaten feed – are effectively removed from the system. Inadequate circulation can create "dead zones" with low oxygen levels and high concentrations of harmful compounds, thereby compromising fish welfare (Colt, 2006). Automated systems equipped with alarms and sensors are increasingly used in modern aquaculture to monitor water flow and quality, providing timely alerts if parameters fall outside the desired range.

**Implications for Fish Welfare**

Poor water quality directly affects fish welfare by inducing stress, impairing growth and increasing the risk of disease outbreaks. Chronic exposure to suboptimal conditions can weaken the immune system, resulting in higher mortality rates, reduced production efficiency, and ultimately lower economic returns. In contrast, maintaining high water quality through careful management of water sources, supply, and regular monitoring promotes robust fish health and welfare, supports natural behaviour and improves overall production performance (FAO, 2022; Huntingford *et al.*, 2006).

**Life Stage and Species-Specific Considerations**

Water quality requirements differ markedly among fish species and even across the different stages of their life cycles. These differences are critical because the physiological tolerances and nutritional needs of juveniles and adults vary, making it essential to tailor water quality parameters for each species to promote optimal growth, health and welfare.

For instance, studies have shown that farmed catfish (e.g. *Clarias gariepinus*) thrive in water temperatures ranging from 26°C to 32°C (Kashimuddin *et al.*, 2021). In addition, catfish require dissolved oxygen (DO) levels between approximately 2.91 and 4.85 mg/L (Boyd and Hanson, 2010) and a pH range of 6.5–8.5 (Fathurrahman *et al.*, 2020). Ammonia concentrations should be maintained around 0.34 mg/L to avoid toxicity (Edward *et al.*, 2010), while nitrite levels should be kept low — around 1.19 mg/L as a fraction of the LC50-96h (de Lima *et al.*, 2011). Other parameters, such as alkalinity (approximately 4.56 mg/L; Baldisserotto and Rossato, 2007), water hardness (25–50 mg $CaCO_3$/L; Copatti *et al.*, 2011), and turbidity (ideally below 88 NTU; Jayadi, 2022), also play crucial roles in ensuring the welfare of catfish.

Tilapia species, such as *Oreochromis niloticus*, have slightly different requirements. Optimal temperatures for tilapia range from 20.2°C to 31.7°C (Leonard and Skov, 2022) with DO levels ideally maintained between 5 and 7 mg/L (Abd El Hack *et al.*, 2022). The pH should fall within the range of 6 to 8.5 (El-Sherif *et al.*, 2009), while ammonia levels should be lower — around 0.14 mg/L (Benli *et al.*, 2011). Nitrite concentrations are generally recommended to be minimal (0–7 mg/L, according to various reports). Tilapia require alkalinity levels between 1.6 and 9.3 mg/L (Colt and Kroeger, 2013), along with higher water hardness (approximately 401.33–634.00 mg/L; Choudhary and Sharma, 2018).

Carp, such as *Cyprinus carpio*, typically require warmer water, with optimal temperatures reported between 28°C and 34°C (Veluchamy *et al.*, 2022). They can tolerate a wider range of dissolved oxygen levels from as low as 0.5 mg/L to as high as 20 mg/L (Homoki *et al.*, 2021) and prefer a pH range of 7 to 8 (Heydarnejad, 2012). For carp, ammonia levels around 0.24 ± 0.06 mg/L are optimal (Heydarnejad, 2012), while nitrite should be maintained at about 0.18 ± 0.02 mg/L (Heydarnejad, 2012). Nitrate levels are ideally kept below 80 ppm to prevent long-term toxicity (Sacramento Koi). Carp require an alkalinity of around 7.8 ± 0.9 mg/L (Heydarnejad, 2012). Water hardness for carp is optimal at 300–500 mg/L $CaCO_3$ (Rach *et al.*, 2010) with turbidity levels maintained between 25 and 100 mg/L (FAO, 2022).

These parameters are not static; they must be closely monitored and adjusted based on the specific life stage of the fish. For instance, larval and juvenile stages are more sensitive to fluctuations in water quality than adult fish. Thus, more stringent monitoring and tighter control of parameters are essential during early developmental stages to reduce stress and mortality, thereby enhancing overall fish welfare and ensuring robust growth performance.

Below is a summary table of water quality parameters for commonly cultured fish species in aquaculture, tailored for catfish, tilapia, and carp, along with the relevant citations:

*Table 4 Recommended water quality parameters for commonly cultured fish species*

| Parameter | Catfish | Tilapia | Carp |
|---|---|---|---|
| **Temperature** | 26°C – 32°C (Kashimuddin *et al.*, 2021) | 20.2°C – 31.7°C (Leonard & Skov, 2022) | 28°C – 34°C (Veluchamy *et al.*, 2022) |
| **Dissolved Oxygen (DO)** | 2.91 – 4.85 mg/L (Boyd & Hanson, 2010) | 5 – 7 mg/L (Abd El Hack *et al.*, 2022) | 0.5 – 20 mg/L (Homoki *et al.*, 2021) |
| **pH** | 6.5 – 8.5 (Fathurrahman *et al.*, 2020) | 6 – 8.5 (El-Sherif *et al.*, 2009) | 7 – 8.0 (Heydarnejad, 2012) |
| **Ammonia** | 0.34 mg/L (Edward *et al.*, 2010) | 0.14 mg/L (Benli *et al.*, 2011) | 0.24 ± 0.06 mg/L (Heydarnejad, 2012) |
| **Nitrite** | 1.19 mg/L (2% of LC50-96h) (de Lima *et al.*, 2011) | 0 – 7 mg/L (Amazon Web Services) * | 0.18 ± 0.02 mg/L (Heydarnejad, 2012) |
| **Nitrate** | 400 ppm (Agricultural Marketing Resource Centre) | 5 – 500 ppm (Sallenave, 2016) | Below 80 ppm (Sacramento Koi) * |
| **Alkalinity** | 4.56 mg/L (Baldisserotto & Rossato, 2007) | 1.6 – 9.3 mg/L (Colt & Kroeger, 2013) | 7.8 ± 0.9 mg/L (Heydarnejad, 2012) |

| | | | |
|---|---|---|---|
| **Water Hardness** | 25 – 50 mg $CaCO_3$/L (Copatti *et al.*, 2011) | 401.33 – 634.00 mg/L (Choudhary & Sharma, 2018) | 300 – 500 mg/L $CaCO_3$ (Rach *et al.*, 2010) |
| **Turbidity** | Below 88 NTU (Jayadi, 2022) | 200 mg/L (Ardjosoediro & Ramnarine, 2002) | 25 – 100 mg/L (FAO, 2022) |

**Note**: The nitrite and nitrate values for tilapia and carp have been referenced from general sources and may vary according to specific regional studies.

**Welfare and Water Quality for Tilapia and Catfish**

Tilapia, particularly *Oreochromis niloticus*, *Oreochromis andersonii* and *Oreochromis macrochir*, are among the most extensively cultured species in Zambia due to their adaptability and market demand (Nsonga *et al.*, 2019). However, maintaining high water quality is critical for their welfare and optimal growth. Tilapias are sensitive to fluctuations in water quality parameters, such as temperature, dissolved oxygen (DO), pH, and concentrations of nitrogenous compounds (Leonard and Skov, 2022; Abd El-Hack *et al.*, 2022). Poor water quality – characterised by low DO, high ammonia and nitrite levels and unsuitable pH – can induce stress, suppress immune responses and lead to increased disease susceptibility (Huntingford *et al.*, 2006). For instance, tilapia thrive when DO levels are maintained between 5 and 7 mg/L and pH values are kept between 6 and 8.5. Therefore, continuous monitoring of water parameters through automated systems or routine manual testing is essential to ensure a stable and optimal environment. Additionally, water flow is crucial in tilapia culture as it promotes the exchange of water, dilutes waste products, and maintains consistent water quality, ultimately supporting healthy growth and reducing mortality rates (FAO, 2022).

Catfish, such as *Clarias gariepinus*, are renowned for their hardiness and ability to tolerate a wider range of environmental conditions compared to many other cultured species. This robustness is partly due to the presence of accessory breathing organs – often referred to as “false lungs” – that enable them to extract oxygen from air when dissolved oxygen levels in water drop (Kashimuddin *et al.*, 2021). Despite this resilience, catfish welfare remains highly dependent on water quality. When removed from water or exposed to deteriorating water conditions, catfish experience significant stress, which can lead to impaired immune function, reduced growth and higher mortality rates (Boyd and Hanson, 2010; Wedemeyer, 1996). Therefore, even though catfish are considered hardy, their capacity for aerial respiration should not be used as an excuse to overlook proper welfare practices. In intensive production systems in Zambia, maintaining optimal water quality; including careful regulation of temperature (26°C – 32°C), DO (approximately 2.91 – 4.85 mg/L), pH (6.5 – 8.5), and low levels of ammonia and nitrite is critical for ensuring that catfish remain healthy and productive (Fathurrahman *et al.*, 2020; Edward *et al.*, 2010).

**Integrated Considerations for the Zambian Aquaculture Industry**

In Zambia's dynamic aquaculture sector, both tilapia and catfish are cultivated under varying environmental conditions, making water quality management a cornerstone of successful production. While tilapia may require stricter water quality control due to their sensitivity to sub-optimal conditions, catfish, despite their adaptive capabilities, still depend on a well-managed water environment to minimise stress and ensure robust growth. The implementation of regular water monitoring, proper aeration, effective waste removal and controlled feeding regimes can significantly improve fish welfare in both species, leading to better health, higher productivity and increased profitability for farmers (FAO, 2022; Nsonga *et al.*, 2019).

**How to Measure and Correct Water Quality Parameters**

***Measuring Water Quality***

In Zambian aquaculture, maintaining optimal water quality is essential for fish health and welfare. Farmers can measure water quality using portable test kits, electronic meters, or by sending water samples to accredited laboratories for comprehensive analysis. It is crucial to follow the manufacturer's instructions for the water quality-testing devices to obtain accurate measurements. Key parameters to monitor include temperature, dissolved oxygen (DO), pH, ammonia, nitrite, nitrate, total dissolved solids (TDS), salinity, alkalinity, hardness, and turbidity. Regular monitoring, ideally at least once a day, enables farmers to track changes over time and establish a historical record, allowing for the early detection of potential issues (FAO, 2022; Boyd, 2018).

**Corrective Measures for out-of-Range Parameters**

When water quality parameters deviate from optimal ranges, immediate corrective actions are necessary to prevent stress and health issues among the fish. Specific measures include:

- **Temperature:** Water temperature that is too high or too low can negatively affect fish metabolism, immune response, and growth. Adjusting the temperature to suit the optimal range for specific species is, therefore, essential. For instance, tilapia typically require temperatures between 20.2°C and 31.7°C, while catfish perform best between 26°C and 32°C (Leonard and Skov, 2022; Kashimuddin *et al.*, 2021).

  To regulate temperature effectively:
    - **Heaters or chillers** can be used in controlled systems to maintain desired thermal conditions.
    - **Greenhouses** constructed over pond systems help retain heat during cooler periods and buffer temperature fluctuations, especially in high-altitude or temperate areas.
    - **Aerators** help maintain a uniform temperature distribution throughout the water column and mitigate temperature stratification in deeper ponds or tanks.
- **pH:** Maintaining stable pH levels is vital for fish health, as extreme pH values can cause stress, impair physiological functions, and increase susceptibility to disease. The optimal pH range varies by species but generally falls between 6.5 and 8.5 for most freshwater fish. To raise pH, aquaculturists can use natural buffers such as sodium bicarbonate (baking soda). To lower the pH, phosphoric acid is commonly applied in controlled quantities. Additionally, natural materials like ground and sterilised crustacean or mollusc shells are often used to gradually moderate and stabilise pH levels (Fathurrahman *et al.*, 2020). Closely related to pH are alkalinity and water hardness, which help buffer the water against rapid changes in pH. Maintaining proper levels of alkalinity and hardness supports overall water chemistry stability. This can be achieved by using crushed coral, alkaline buffers, or calcium-based supplements (Colt and Kroeger, 2013). Together, consistent monitoring and management of pH, alkalinity and hardness

ensure a stable aquatic environment conducive to optimal fish welfare and productivity.

- **Ammonia, Nitrite, and Nitrate:** Elevated levels of these nitrogenous compounds can be diluted through partial water changes. Additionally, robust biological filtration systems help convert toxic ammonia and nitrite into less harmful nitrate, thereby maintaining water quality (Huntingford *et al.*, 2006).
- **Dissolved Oxygen:** Low DO levels are detrimental to fish health. Increasing aeration through the use of air stones, diffusers, or enhancing water circulation ensures sufficient oxygen levels. This is especially important in high-density systems where oxygen demand is greater (Boyd, 2018).
- **Total Dissolved Solids and Salinity:** Excessive TDS or salinity may require regular water changes or the use of purified water (e.g. via reverse osmosis units) to maintain appropriate mineral concentrations.
- **Turbidity:** High turbidity reflects the presence of suspended solids such as uneaten feed, fish waste, silt and organic matter, which can reduce light penetration and stress fish by impairing respiration and gill function. Turbidity can be managed through mechanical filtration, settling tanks, and by addressing the root causes of sediment or organic buildup (Jayadi, 2022). In addition, elevated turbidity may promote algal blooms, particularly blue-green algae (cyanobacteria), which can produce toxins harmful to fish, humans and other aquatic organisms. These blooms can deplete dissolved oxygen levels during die-offs, increase pH and impair water quality. Preventing nutrient overloads, especially nitrogen and phosphorus from feed and runoff, is critical in reducing the risk of harmful algal blooms.

Implementing these corrective measures gradually is key to avoiding sudden changes that might stress the fish. Continuous monitoring coupled with timely adjustments helps maintain a stable environment that supports optimal fish health and productivity. In cases where persistent issues occur, consulting with an experienced aquaculturist, aquatic biologist, or aquatic veterinarian is recommended to tailor solutions to the specific needs of the farm.

**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.

**Discussion Points**

1. What has been your experience with both optimal and poor water quality, and how has it impacted fish health and productivity on your farm?
2. What methods or tools do you currently use to monitor water quality, and how effective are they?
3. What corrective measures have you been using to moderate acidity/alkalinity, temperature, turbidity, etc.? Would you please share/demonstrate how you have been doing it?
4. What would you attribute the observed deviations in pH, temperature, and turbidity at your farm (or among your farmers)?
5. Which specific water quality issues (e.g. low dissolved oxygen, pH imbalances, high ammonia) have you encountered, and what effects have they had on fish welfare?
6. Based on what you have learned so far, what strategies do you plan to implement to correct any water quality issues?
7. Which water quality parameters do you consider most critical for maintaining fish health, and why?
8. How can you improve your water quality monitoring practices to ensure timely and effective corrective actions?

## 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 in Zambian Aquaculture

Feeding is a critical aspect of aquaculture management, directly influencing fish growth, health and welfare, as well as overall productivity. In Zambia, where aquaculture is becoming an increasingly vital source of food security and income, adhering to best practices in feeding is essential. Below are detailed guidelines tailored to the Zambian context:

***1. Optimal Feeding Times and Quantities***

- **Feeding Frequency and Timing**: Fish should be fed at optimal times, typically early morning and late afternoon, to align with their natural feeding rhythms. Maintaining consistent feeding schedules supports efficient digestion and reduces stress. Avoid prolonged starvation periods (exceeding 72 hours), as this can weaken immune responses, reduce growth and increase disease susceptibility (FAO, 2020).
- **Feed Quantities and Growth Stages**: The amount and frequency of feeding should be adjusted according to the species, age and developmental stage of the fish. For instance, fry and fingerlings for tilapia and catfish require smaller, more frequent feedings throughout the day due to higher metabolic rates, while adult fish may thrive on fewer, larger meals (see Tables 5 and 6 below).
- **Avoiding Overfeeding and Underfeeding**: It is essential to provide just enough feed to meet the fish's nutritional requirements without waste. Overfeeding can deteriorate water quality due to excess feed and faecal matter, while underfeeding can lead to poor growth, stress and reduced productivity (Nguyen *et al.*, 2021).

*Table 5 Feeding Chart for Tilapia*

| Life Stage | Age/Size Range | Feed Type | Feed Size (mm) | Feed Quantity (% body weight/day) | Feeding Frequency (per day) |
|---|---|---|---|---|---|
| **Fry** | 0–4 weeks/ <0.5 g | Powdered starter feed | 0.2–0.4 mm | 10–15% | 4–6 times |
| **Fingerlings** | 4–8 weeks/ 0.5–10 g | Crumble or micro pellets | 0.5–1.0 mm | 5–8% | 3–4 times |
| **Juveniles** | 8–12 weeks/ 10–50 g | Grower pellets | 1.0–2.0 mm | 3–5% | 2–3 times |
| **Sub-Adults** | 12–16 weeks/ 50–150 g | Grower/finisher pellets | 2.0–3.0 mm | 2–3% | 2 times |
| **Adults/Breeders** | >150 g | Maintenance/breeder feed | 3.0–4.0 mm | 1.5–2% | 1–2 times |

*Table 6 Feeding Chart for African Catfish (Clarias gariepinus)*

| Life Stage | Age/Size Range | Feed Type | Feed Size (mm) | Feed Quantity (% body weight/day) | Feeding Frequency (per day) |
|---|---|---|---|---|---|
| **Fry** | 0–3 weeks/ <0.5 g | Powdered or mash feed | 0.2–0.4 mm | 12–18% | 5–6 times |
| **Fingerlings** | 3–6 weeks/ 0.5–15 g | Crumble or mini pellets | 0.5–1.2 mm | 6–10% | 3–4 times |
| **Juveniles** | 6–10 weeks/ 15–100 g | Grower pellets | 1.5–2.5 mm | 3–5% | 2–3 times |
| **Sub-Adults** | 10–14 weeks/ 100–300 g | Finisher pellets | 2.5–4.0 mm | 2–3% | 2 times |
| **Adults/Breeders** | >300 g | Maintenance/breeder pellets | 4.0 mm+ | 1.5–2% | 1–2 times |

***2. Feed Form and Accessibility***

- **Feed Presentation and Pellet Size**: Feed should be provided in appropriate forms and sizes based on the developmental stage of the fish. Common feed types in aquaculture include starter crumbles (for fry and small fingerlings), grower pellets (for juveniles) and finisher pellets (for sub-adults and adults). Pellet size should correspond to the mouth gape of the fish; smaller pellets are ideal for juveniles, while larger pellets suit adult fish (FAO, 2020).

- **Feed Buoyancy**: Consider the feeding habits of the species when choosing between floating and sinking feeds. Surface feeders like tilapia benefit from floating feeds that allow for easy monitoring of consumption and reduce waste. Bottom dwellers such as catfish may prefer sinking pellets, which align with their natural feeding behaviour.
- **Feed Distribution**: To ensure equitable access to feed, distribute it evenly across the pond or tank. Avoid localised feeding that can allow dominant or larger fish to outcompete others. Grading fish by size is a useful management strategy to reduce competition and promote uniform growth across the population (Nguyen *et al.*, 2021).

***3. Feed Location and Environmental Enrichment***

- **Varying Feed Locations:** Periodically change the feeding locations within the enclosure to simulate natural foraging behaviour and reduce stress. This practice also prevents overcrowding at specific feeding points, which can lead to aggression and injury (FAO, 2020).
- **Mental Stimulation:** Varying feeding locations and methods can provide mental stimulation, improve fish welfare and mimic their natural environment (Nguyen *et al.*, 2021).

***4. Co-Production Systems***

- **Integrated Farming:** Where feasible, implement integrated farming systems where fish and their feed are co-produced. For example, integrating aquaculture with agriculture can provide a sustainable source of feed, such as duckweed or other aquatic plants, reducing reliance on external feed sources (FAO, 2020).

**Composition and Quality of Feed Ingredients**

***1. Nutritional Balance***

- **Protein Content:** For most farmed fish species in Zambia, such as tilapia and catfish, the feed should contain 30-45% protein, depending on the species and growth stage. High-quality protein sources, such as fishmeal or plant-based proteins, should be used to ensure digestibility and optimal growth (FAO, 2020).
- **Carbohydrates, Fats, and Minerals:** The feed should also contain balanced amounts of carbohydrates, fats and essential minerals. Avoid feeds treated

with growth hormones, as they can have adverse effects on fish health and pose a risk to consumer safety (Nguyen *et al.*, 2021).

***2. Feed Form and Digestibility***

- **Pelleted Floating Feed:** Floating pellets are preferred as they allow farmers to observe feeding behaviour and adjust quantities accordingly. The feed should be highly digestible, with an ideal feed conversion ratio (FCR) of 1:1.5 to 1:2 for species like catfish (FAO, 2020).
- **Pellet Size Adjustment:** As fish grow, the pellet size should be increased to match their mouth size, ensuring efficient feeding and reducing waste (Nguyen *et al.*, 2021).

***3. Contaminant-Free Ingredients***

- **Quality Control:** All feed ingredients must be free from contaminants, such as heavy metals, pesticides and pathogens. Regular testing of feed ingredients should be conducted to ensure safety and quality (FAO, 2020).
- **Taste and Smell:** The feed should have a good taste and smell to encourage consumption. Poor-quality feed with an unpleasant odour or taste can lead to reduced feed intake and poor growth (Nguyen *et al.*, 2021).

**Fish Welfare Considerations**

***1. Minimising the Use of Animal-Based Feed***

- **Alternative Feed Sources:** To promote fish welfare and sustainability, minimise the use of animal-based feed ingredients, such as wild-caught fish or insects. Instead, opt for plant-based or alternative protein sources that have high feed efficiency ratios and maintain good nutrition (FAO, 2020).
- **Herbivorous Species:** Where possible, shift from carnivorous species to herbivorous or omnivorous species, such as tilapia, which require less animal protein in their diet (Nguyen *et al.*, 2021).

***2. Ethical Considerations***

- **Avoiding Unethical Practices:** The use of chicken offal or maggots as feed is discouraged due to the risk of pathogen transmission and other ethical concerns. If such practices are employed, the feed must be treated to eliminate potential pathogens (FAO, 2020).

- **Regulatory Advocacy:** Advocate for country-level and regional regulations to ban unethical feeding practices and promote the use of sustainable and safe feed alternatives (Nguyen *et al.*, 2021).

***3. Feeding Rates and Monitoring***

- **Daily Feeding Rates:** The recommended daily feeding rate is 2-5% of the fish's body weight. However, feeding to satiation is often practised, especially in catfish farming, to prevent cannibalism and predation (FAO, 2020).
- **Monitoring Factors:** Regularly monitor factors that affect feed consumption, such as water temperature, pH, dissolved oxygen levels and fish health. Keep detailed records to evaluate feeding practices and make necessary adjustments (Nguyen *et al.*, 2021).

***4. Feed Storage***

- **Proper Storage:** Store feed in a cool, dry place, away from direct sunlight, moisture, and pests. Proper storage prevents mould growth, contamination, and degradation of feed quality (FAO, 2020).
- **Rodent and Pest Control:** Ensure that feed storage areas are secure and free from rodents, insects, and birds, which can contaminate the feed and spread diseases (Nguyen *et al.*, 2021).

**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.

**Discussion Points**

1. Reflect on your previous experience with both high-quality and poor-quality fish feed. How do you determine whether feed is beneficial or detrimental to fish welfare in your Zambian farm?
2. Based on your experience in Zambia, what challenges have you faced when sourcing fish feed, and how have these experiences influenced your current practices?
3. What strategies or improvements do you plan to implement on your farm to ensure that feeding practices fully support optimal fish welfare and growth?
4. What local alternatives exist in Zambia to replace unethical feeding practices, such as the use of small animals, hormone-treated feeds, chicken offal, maggots or certain insects? How might these alternatives enhance fish welfare?
5. How can innovative approaches, such as alternative feed formulations, co-production of feed resources, or improved delivery systems, be applied in your operation to meet optimal welfare standards while maintaining productivity?

# MODULE 7 – FISH WELFARE DURING HANDLING AND TRANSPORTATION

*This module provides general welfare considerations and guidelines in handling and transportation of fish.*

**Handling and Fish Welfare**

In Zambia's aquaculture sub-sector, routine handling of fish is a necessary component of production, encompassing activities such as vaccination, grading, tagging and ultimately, slaughter. Additionally, fish are frequently moved between rearing units or transferred between farms for marketing and processing. However, the capture and handling of fish can elicit significant stress responses, as fish are highly sensitive to being removed from their aquatic environment (Humane Slaughter Association, 2005; Huntingford *et al.*, 2006). In Zambia, where aquaculture operations often contend with variable ambient temperatures, extra care must be taken during handling procedures to minimise stress and injury.

Research and industry guidelines recommend that the duration of handling, specifically, the time fish are out of water, should be minimised to no longer than 15 seconds unless fish are properly anaesthetised. This is because even brief periods out of water can trigger a maximal emergency stress response, leading to physiological disturbances that compromise fish welfare (Humane Slaughter Association, 2005). Moreover, the sensitivity of fish to handling is particularly pronounced at extreme temperatures. In Zambia, where seasonal temperature fluctuations can be significant, handling should be avoided during periods of high or near-freezing temperatures, as both conditions exacerbate stress responses and increase the risk of injury.

*Figure 17 Handling in preparation for fish broodstock transportation (Source: Chad Kancheya)*

Poor handling techniques can cause physical injuries, including damage to the eyes, fins and muscle tissues, and may result in scale loss. Furthermore, rough handling damages the fish's protective mucous coating, which is critical for defending against pathogens, thereby increasing the fish's susceptibility to diseases (Huntingford *et al.*, 2006). To mitigate these risks, all handling equipment must be maintained in excellent hygienic condition and ideally designed with smooth, non-abrasive surfaces. Implementing less stressful capture and transfer methods, such as using gentle nets, hand gloves, reducing handling time and employing proper anaesthetic techniques, when necessary, will improve fish welfare outcomes in Zambian aquaculture operations.

**Transportation and Fish Welfare**

In Zambian aquaculture, transporting live fish involves several stages, including capture, handling, loading, conveyance, and unloading, all of which can induce significant stress responses in fish. Elevated cortisol levels, a primary indicator of stress, are commonly observed during these processes. For instance, a study on channel catfish (*Ictalurus punctatus*) demonstrated that cortisol levels peaked immediately after a 3.5-hour transport and gradually returned to baseline within 72 to 168 hours post-transport, indicating a recovery period of up to seven days (Li *et al.*, 2018). These findings underscore the importance of implementing stress-mitigation strategies during fish transport. Such strategies may include minimising handling time, maintaining optimal water quality parameters (like temperature, dissolved oxygen, and pH), and allowing adequate recovery periods post-transport to ensure fish welfare and reduce mortality rates. Research from Fish Count (2019) also indicates that fish exhibit stress physiology comparable to that of mammals and birds, with stressful stimuli leading to metabolic, hormonal, and behavioural alterations that compromise immune function and osmoregulation.

*Figure 18 Insulated holding and transportation tanks for fish*

In the Zambian context, improper transportation practices can exacerbate these stress responses. Common methods, such as using makeshift containers or improvised nets, can cause physical damage, including abrasions, scale loss, and injuries to fins and muscles. Poorly designed pumping systems may cause fish to be dropped onto hard surfaces, further increasing the risk of injury (Huntingford *et al.*, 2006). Moreover, overcrowding, inadequate water quality, limited oxygen, and the build-up of carbon dioxide and ammonia during transit all contribute to significant welfare challenges. These factors are particularly critical when fish are loaded into transport containers, which is often the most stressful part of the process.

*Figure 19 Photo credit - IBAN Aquafish Solutions and Consultancy Limited*

To mitigate these risks, ideal transport systems in Zambia should include specially designated vehicles equipped with insulated holding tanks and monitoring devices that maintain optimal water quality throughout the journey. For shorter journeys, fish seeds can be transported in gassed polyethene bags within Styrofoam boxes to reduce movement shocks, with receiving tanks pre-prepared with high-quality, oxygenated water to serve as temporary holding facilities. It is crucial that water parameters remain stable during transport, and any changes, especially abrupt shifts in temperature, are minimised, as they can cause further stress. Although anaesthesia or sedation may reduce stress, these methods are not currently approved for use in farmed fish. As a result, welfare advocates recommend limiting live fish transportation to the shortest duration possible and following established guidelines from the World Organisation for Animal Health (WOAH, 2020).

**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.

**Discussion Points**

1. What are the main stressors observed during fish capture and handling on your farm, and how do these affect fish welfare and productivity?
2. How do you ensure that the duration fish are removed from water is minimised, and what techniques have you found most effective to limit handling time?
3. How do seasonal temperature variations in Zambia impact fish stress during handling and transport, and what measures do you take to mitigate these effects?

4. What methods do you currently use to maintain optimal water quality during fish transportation, and how do you monitor key parameters such as dissolved oxygen and pH?
5. How effective is your current handling equipment (e.g. nets, pumps, containers) in reducing physical injuries, and what improvements would you recommend?
6. In your experience, how does the duration and condition of transportation affect fish recovery and overall welfare and what strategies can reduce these negative impacts?
7. What role do you think advanced monitoring systems and insulated transport vehicles could play in improving water quality and reducing stress during fish transport?
8. How are international welfare guidelines, such as those from the World Organisation for Animal Health (WOAH, 2020), integrated into your handling and transportation practices, and what challenges have you faced in meeting these standards?

## MODULE 8: SLAUGHTERING AND FISH WELFARE

*This module provides a comprehensive overview of humane fish slaughter, explaining its rationale and benefits for both welfare and product quality. It outlines the essential pre-slaughter welfare considerations in Zambian aquaculture and details common slaughter methods and processes used in Zambia, concluding with general guidance for implementing humane slaughter techniques to uphold ethical standards.*

### Overview of Human Fish Slaughter

Fish are a vital source of protein in Zambia, with millions of fish harvested annually to meet local and export market demands. Ensuring humane slaughter is essential to prevent unnecessary pain and suffering, maintain product quality, and comply with international welfare standards. Globally, at least 124 billion fish are reared and slaughtered annually (Mood *et al.*, 2023), highlighting the enormous scale of this industry and the pressing need for ethical practices.

Humane fish slaughter typically involves stunning, a process that renders fish immediately unconscious and insensible to pain until death occurs (Holmyard, 2017; European Union Regulations, 2009). In Zambia, the adoption of methods such as electrical stunning is critical because it enables rapid, effective and minimally invasive slaughter, thereby reducing injuries and stress. However, inhumane practices, such as prolonged live transport and excessive handling, can lead to high stress levels, physical injuries, and poor meat quality. Such practices are not only ethically problematic but also hinder access to export markets that require strict adherence to animal welfare standards (Fish Count, 2019).

To address these challenges, the World Organisation for Animal Health (WOAH) has issued guidelines for fish welfare during stunning and slaughter, which Zambia is encouraged to adapt for local use (WOAH, 2020). It is imperative that fish slaughter in Zambia is carried out by technically trained personnel who can operate slaughter equipment effectively, recognise when fish are adequately stunned, and re-stun if necessary. Regular training, upskilling, and meticulous record-keeping are essential to ensure that the evolving technologies and methods in fish slaughter are used to achieve a seamless and painless process. By adopting these humane slaughter practices, Zambia can improve fish welfare, enhance product quality, and secure its position in both domestic and international markets.

**Benefits of Humane Slaughter of Fish in Zambia**

Implementing humane slaughter methods in Zambian aquaculture offers significant benefits for fish welfare, product quality, and overall economic value. Firstly, humane slaughter techniques, which typically involve effective stunning to render fish unconscious before killing, improve meat quality by reducing stress-induced physiological damage. This results in firmer, more translucent fillets with brighter colouration, a delayed onset of rigor mortis, and a lower incidence of gaping, bruising, and scale loss compared to conventional, less humane methods (Holmyard, 2017; Humane Slaughter Association, 2019). Improved meat quality also extends shelf life and reduces spoilage, which is critical for maintaining the market value of fish products both locally and in export markets (Fish Count, 2019).

Furthermore, reducing stress at slaughter not only enhances the physical quality of the fish but also positively impacts eating quality and taste, resulting in higher consumer satisfaction. In an industry where ethical concerns are increasingly influencing purchasing decisions, adopting humane slaughter practices adds ethical value to the product. Consumers, particularly in both domestic and international markets, are often willing to pay a premium for fish that have been processed with minimal suffering, which in turn can improve the economic returns for Zambian fish farmers (Fish Count, 2019). Additionally, aligning with humane slaughter standards facilitates compliance with local and global food safety and processing regulations, thereby enhancing the marketability of Zambian aquaculture products (Holmyard, 2017).

**Pre-Slaughter Welfare Considerations in Zambian Aquaculture**

In the Zambian aquaculture industry, ensuring optimal fish welfare during the pre-slaughter phase is crucial for reducing stress, preventing injuries, and improving overall product quality. Best practices in this phase focus on three key areas: purging, crowding, and dewatering.

***Purging (Fasting)***

Purging, also known as fasting, involves withholding feed from fish for 24 to 48 hours prior to slaughter to allow their digestive tracts to clear completely. This process minimises the risk of gut contamination during processing and enhances the hygiene and quality of the final product (Humane Slaughter Association, 2005; FAO, 2022). In Zambia, the duration of purging may need to be adjusted based on water temperature – warmer conditions may require a shorter fasting period to achieve gut clearance, whereas cooler conditions might extend the time required.

***Crowding***

Crowding is the practice of gradually reducing water volume or increasing fish density immediately before slaughter. This step is used to consolidate fish for handling, but if not managed properly, it can quickly lower oxygen levels and degrade water quality, leading to significant stress and injuries. In Zambian farms, crowding should be implemented gradually, with careful monitoring by a dedicated welfare officer who can detect issues and intervene promptly. Ideally, fish should not be crowded for more than two hours. Utilising natural behaviours, such as guiding fish towards a shaded inlet where they can swim against the current, can further help reduce stress during this process (Humane Slaughter Association, 2005; Huntingford *et al.*, 2006).

***Dewatering***

Dewatering refers to the phase where fish are removed from the water, typically just before stunning and slaughter. Because fish are highly sensitive to air exposure, this step must be executed swiftly and gently to minimise stress. In Zambia, dewatering should be carried out as close to the stunning point as possible. Employing methods such as aquatic anaesthetics to sedate fish, using well-designed pumps to transfer them, or utilising soft nets can help ensure that the process is both efficient and humane. The aim is to minimise the time fish spend out of water and reduce the likelihood of physical injuries during transport to the stunner (Humane Slaughter Association, 2005; FAO, 2022).

By strictly adhering to these pre-slaughter welfare practices – purging, crowding and dewatering – Zambian fish farms can significantly reduce stress, enhance fish welfare, and improve the quality of fish products. Such practices not only meet ethical and regulatory standards but also increase the marketability of fish, supporting both domestic and export opportunities.

**Common Fish Slaughter Methods**

In Zambia's aquaculture sector, where fish production is expanding rapidly to meet both domestic and export demands, ensuring humane slaughter is critical for both ethical and commercial reasons. Humane slaughter practices not only reduce the suffering of millions of fish but also contribute to improved meat quality and market acceptance. The following sections outline the various slaughter methods currently in use, their inherent challenges, and potential adaptations for the Zambian context, with a focus on minimising pain and stress.

**Air Asphyxiation**

Air asphyxiation is the oldest method of fish slaughter, wherein fish are removed from the water and left to die from oxygen deprivation. This method is widely regarded as inhumane because it can take well over an hour for fish to die, during which they may suffer prolonged distress. In Zambia, species such as the Nile tilapia (*Oreochromis niloticus*) and the African sharptooth catfish (*Clarias gariepinus*), which are commonly found in local aquaculture, are known to be relatively resistant to hypoxia. Their ability to breathe atmospheric air can further delay death, thus increasing their suffering (FAO, 2022). Moreover, the rate of oxygen depletion is highly dependent on ambient temperature and fish activity; for instance, studies have shown that rainbow trout lose consciousness faster at higher temperatures compared to lower ones (Robb *et al.*, 2000). Consequently, this method not only leads to unnecessary pain but also adversely affects meat quality and shelf life due to stress-induced biochemical changes in the muscle tissues (Holmyard, 2017).

**Head Strike and Stunning (Manual Percussion)**

Manual percussion, or head striking, involves removing fish from the water and delivering a sharp, forceful blow to the head to induce immediate unconsciousness. Ideally, the strike should be applied just above the eyes to ensure effective disruption of brain function. However, the success of this method is highly dependent on the operator's skill and the force applied. Inconsistent strikes may leave fish partially conscious, leading to prolonged suffering and increased likelihood of physical injuries, such as skull fractures, bruising, and scale loss (Humane Slaughter Association, 2005). In Zambia, where traditional practices are still common, inadequate training in these techniques can compromise fish welfare and ultimately reduce product quality. Additionally, manual percussion may not be practical in large-scale harvesting operations due to the time and labour required to stun each fish individually.

**Spiking**

Spiking is a traditional method that involves inserting a sharp instrument directly into the fish's head to destroy the brain. This method requires precise anatomical knowledge and significant expertise, particularly for smaller fish whose brains are more difficult to locate. Inaccurate spiking results in insufficient destruction of neural tissue, leading to prolonged stress responses and negative impacts on meat quality (Holmyard, 2017). Given these challenges, spiking is less favoured in modern operations, and its application should be limited to contexts where operators are adequately trained and where fish size permits precise targeting.

**Live Chilling**

Live chilling involves rapidly reducing the temperature of the fish, typically by placing them in ice or chilled water to slow their metabolism and delay spoilage. While chilling can effectively delay the onset of rigor mortis and improve carcass quality by reducing enzymatic and microbial degradation, it does not induce immediate unconsciousness. In Zambia, some fish farmers use crude methods, such as pouring ice directly onto the fish, which may lead to systemic shock and prolonged distress. The challenge lies in balancing the benefits of delayed spoilage with the ethical imperative of minimising suffering, suggesting that chilling should ideally be combined with an effective pre-stunning method (Poli *et al.*, 2005).

**Exsanguination (Bleeding to Death)**

Exsanguination entails inducing rapid bleeding by cutting or severing major blood vessels – such as gills, the caudal artery, or even decapitating the fish. This method is sometimes used because it can prevent undesirable red colouration and bloody odours in the meat, thus enhancing its marketability. However, if exsanguination is performed without prior stunning, fish may remain conscious for several minutes, experiencing significant pain and stress. In Zambia, where export standards are increasingly stringent, ensuring that fish are rendered unconscious before bleeding is crucial to meet both ethical and quality requirements (FAO, 2022).

**Use of Anaesthesia**

Chemical anaesthesia can render fish unconscious before slaughter, reducing stress and facilitating a more humane process. However, its application in Zambia is limited by several factors: the high cost of approved anaesthetic agents, regulatory concerns regarding residue levels, and variable responses among species. For example, African sharp-tooth catfish have shown resistance to certain anaesthetics, such as Aqui-S, often resulting in paralysis without complete loss of consciousness (Babb, 2020).

An alternative, more accessible option increasingly explored in small-scale settings is the use of clove oil or clove powder, which has shown promising results as a low-cost, plant-based anaesthetic. Clove oil, in particular, is effective in inducing sedation and anaesthesia in several species when used at appropriate dosages, although efficacy may vary with water temperature, species, and concentration. Despite its potential, standardised guidelines and training on safe and effective use are still needed. Thus, while anaesthesia offers opportunities to improve fish welfare, its practical implementation in Zambia requires further research, regulation, and capacity building.

**Carbon Dioxide ($CO_2$) Narcosis**

$CO_2$ narcosis involves saturating water with carbon dioxide to induce narcosis in fish. Although this method can eventually lead to unconsciousness, fish may exhibit vigorous, stress-induced behaviours such as thrashing and colliding with the container, resulting in bruising and physical injuries. Additionally, the resulting acidification of the water can exacerbate distress. Some countries have experimented with nitrous oxide as an alternative, given its milder effects on fish behaviour, but overall, $CO_2$ narcosis remains a contentious method due to its inconsistent efficacy and ethical concerns (Robb and Roth, 2003).

**Electrical Stunning**

Electrical stunning is increasingly regarded as one of the most humane methods for fish slaughter. This technique involves applying a controlled electrical current to the fish, inducing immediate and reversible unconsciousness (electronarcosis) if the parameters are correctly managed. For electrical stunning to be effective, the current intensity, duration, and application point (ideally near the head) must be precisely controlled, while water conductivity and temperature are closely monitored. In Zambia, adoption of electrical stunning is limited by the cost of equipment and the variability of power supply in rural areas; however, recent advances in portable, battery-operated systems offer promising alternatives for achieving humane stunning (Lines and Spence, 2019; WOAH, 2020).

Transitioning to humane fish slaughter methods in Zambia is crucial for reducing fish suffering, enhancing meat quality, and improving the overall marketability of aquaculture products. Although traditional methods, such as air asphyxiation and manual percussion, are still in use, modern techniques, like electrical stunning and pre-slaughter anaesthesia, can significantly improve welfare outcomes when properly implemented. Embracing these practices, coupled with regular training and strict adherence to international guidelines (e.g. WOAH and FAO standards), will enable Zambia to meet both ethical standards and the demands of international export markets.

**Overview of Slaughter Processes in Zambia**

In Zambia, the commercial processing of live fish, particularly species such as Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*), often follows methods that are similar to those observed in other parts of Africa. Common practices include the manual striking of the head with a heavy instrument, followed by gill-cutting to induce bleeding. However, these methods do not induce an immediate loss of consciousness. Studies have shown that African catfish, for example, can remain conscious for over 10 minutes after a single gill is cut, with some fish taking even longer to lose consciousness and succumb (Holmyard, 2017; FAO, 2022).

Before the gill-cutting process, fish in Zambia often endure additional stressors, including prolonged removal from water, crowding in holding containers such as bowls and baskets, and rough handling by farm workers. These preliminary handling conditions exacerbate the distress experienced by the fish. Moreover, if only one gill is cut rather than both, the bleed-out process is slowed, further extending the period of suffering (Humane Slaughter Association, 2005).

Efforts are ongoing in Zambia to modernise these processes and adopt more humane slaughter techniques. Nonetheless, traditional methods remain prevalent, particularly in small- to medium-scale operations, thereby highlighting the need for improved training and the implementation of standardised, welfare-friendly slaughter protocols in the Zambian aquaculture sector.

**General Guidance for Humane Slaughter Methods for Fish**

Humane fish slaughter methods are designed to cause immediate loss of consciousness or instant death, thereby minimising pain and distress. Whether through manual or automated processes, effective humane slaughter typically requires that fish be stunned immediately before slaughter and remain in water until just before the stunning process. The primary goal is to render the fish insensible to pain until death occurs (Humane Slaughter Association, 2005; FAO, 2022).

Several techniques are commonly employed to achieve humane slaughter, including:

- **Percussive and Electrical Stunning:** Automated devices or manual percussion (using a club) are used to deliver a forceful, accurate blow that disrupts brain function and induces immediate unconsciousness. Electrical stunning, when properly calibrated in terms of current, duration, and application point, offers a rapid and effective method for immobilising fish with minimal physical trauma (Lines and Spence, 2019; WOAH, 2020).
- **Spiking the Brain:** This method involves inserting a sharp spike into the fish's head to destroy the brain and induce instant unconsciousness. Although

effective for larger fish, it requires significant precision and skill, making it less practical in settings lacking specialised training. For this reason, manual percussive stunning is generally preferred over spiking in many operations (Holmyard, 2017).

- **Combined Techniques:** Some methods incorporate spiking along with food-grade fish sedatives to improve the effectiveness of the stun. However, these require careful control of dosage and timing, and their use is regulated in some countries (Poli *et al.*, 2005).

For optimal humane slaughter, the following operational guidelines should be implemented:

1. **Minimise Stress Duration:** Develop a well-organised operating cycle that minimises the duration and intensity of stress during the pre-slaughter process.
2. **Effective Stunning:** Ensure that fish are rendered immediately unconscious before any further processing occurs.
3. **Trained Personnel:** Only trained staff should carry out stunning and slaughter procedures. They must be able to recognise signs of re-consciousness and be prepared to administer additional stunning if necessary.
4. **Equipment Standards:** Where possible, use manual pneumatic guns rather than completely manual methods. Pneumatic systems, which have been adapted for use with various species, offer improved consistency and reduce the risk of human error (Humane Slaughter Association, 2005).

In summary, humane slaughter practices for fish are critical for maintaining product quality and ethical standards. With the availability of both manual and automated technologies, farmers in Zambia are encouraged to adopt methods that ensure rapid, effective stunning and minimise suffering. By adhering to established guidelines and continually training staff, the Zambian aquaculture industry can enhance fish welfare and meet both local and international market requirements.

**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.

**Discussion Points**

1. Do you currently slaughter your fish? If so, what specific method(s) do you use (e.g. air asphyxiation, manual percussion, electrical stunning, etc.)?
2. What are the perceived advantages and disadvantages of your current method in terms of fish welfare?
3. Reflect on any challenges or mistakes you have encountered with fish slaughter on your farm. Which method(s) contributed to these issues, and what were the outcomes (e.g., prolonged stress, injury, and poor meat quality)?
4. Based on your learning so far, how do you plan to modify or enhance your current slaughter practices to better align with humane welfare standards?
5. What specific changes (e.g., adopting electrical stunning or better handling protocols) do you believe would reduce stress and pain during slaughter?
6. What local innovations or traditional practices exist in Zambia that could be adapted or improved to meet optimal welfare standards during fish slaughter?
7. How can technology or modified equipment be integrated into your operations to improve the overall humaneness and efficiency of the slaughter process?

8. How well are your staff trained in humane slaughter techniques, and what additional training or upskilling might be needed?
9. What role do you think ongoing monitoring and record-keeping should play in improving your slaughter practices?

## MODULE 9: ENVIRONMENTAL ENRICHMENT AND FISH WELFARE

*This module aims to equip participants with the knowledge to define environmental enrichment within the context of Zambian aquaculture and explain its critical role in promoting fish welfare by reducing stress and abnormal behaviours. By the end of this module, learners will be able to identify and describe the various categories of enrichment, including physical, social, sensory, and occupational methods, and will be able to evaluate their current farm environments to develop and implement practical strategies for effective environmental enrichment that encourages the expression of natural, species-specific behaviours and ultimately leads to improved fish health and production.*

### What is Environmental Enrichment?

Environmental Enrichment (EE) refers to the process of enhancing an animal's living conditions in order to promote the expression of natural, species-specific behaviours, stimulate mental activity, and improve overall well-being. In the context of fish aquaculture, EE involves modifying rearing environments to mimic natural habitats, thereby encouraging natural behaviours such as exploration, hiding, and swimming against water flow. This may include the addition of structural elements like rocks, plants, or artificial shelters; modifications in water flow patterns; varied lighting conditions and colours; and even the introduction of auditory stimuli or diverse food types that reflect the fish's natural diet (Leone and Estévez, 2008; Näslund and Johnsson, 2014).

Implementing environmental enrichment in captive settings, such as aquaculture farms and public aquariums, has been shown to reduce stress, enhance growth and improve overall health. The challenge in applying EE in fish culture lies in determining the appropriate type and amount of enrichment that aligns with the sensory abilities and biological needs of each fish species. For example, while some species may benefit from hidden shelters to reduce stress, others might thrive when provided with structures that encourage active swimming against a current, mimicking natural riverine conditions (Zhang *et al.*, 2020a). Researchers and practitioners utilise tools such as Operational Welfare Indicators (OWIs) and Precision Fish Farming (PFF) techniques to assess and tailor enrichment strategies to the specific needs of the species being reared (Arechavala-Lopez *et al.*, 2021).

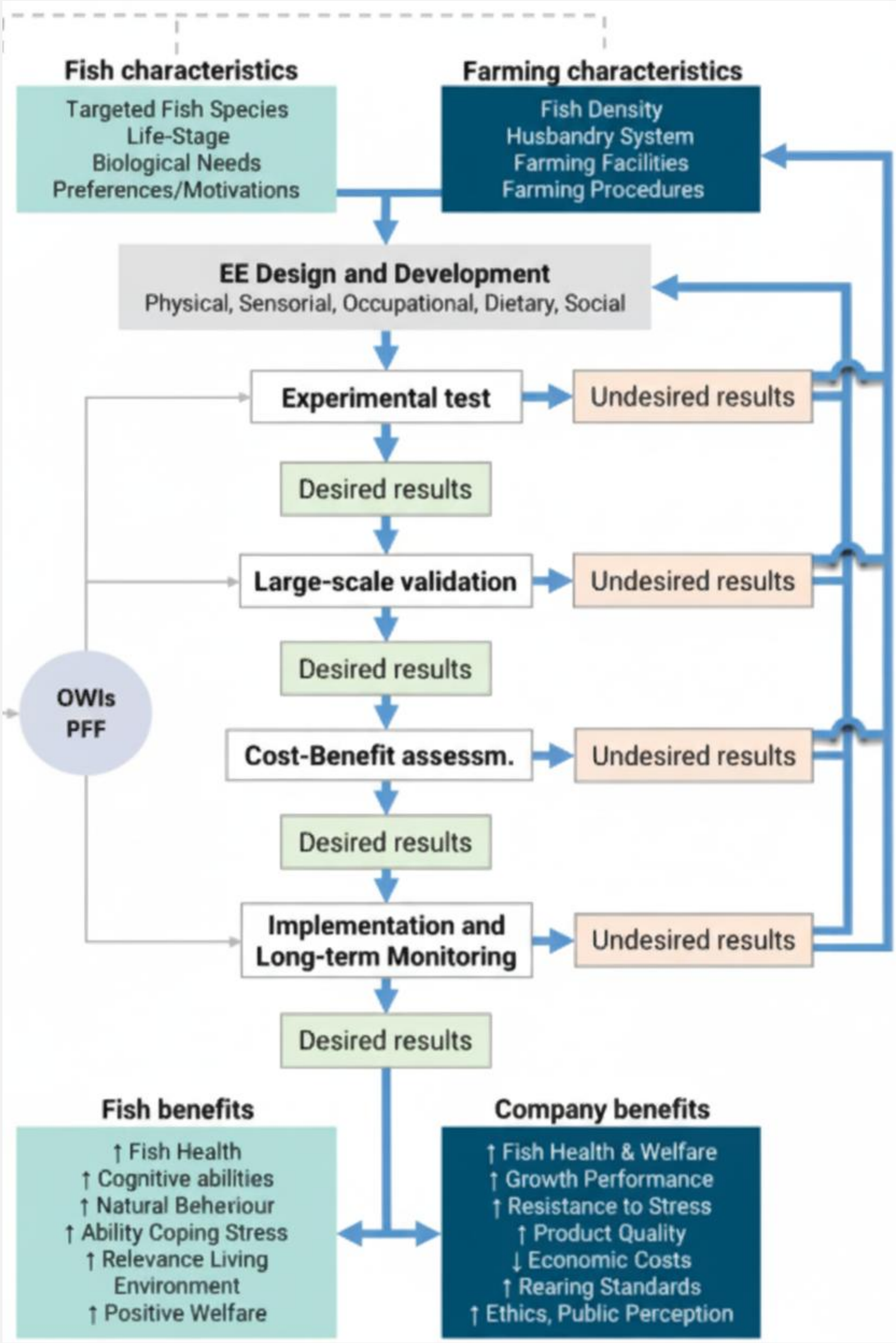


*Figure 20 Schematic for the decision-making process in Environmental Enrichment; OWIs: Operational Welfare Indicators; PFF: Precision Fish Farming; (Source: Arechavala-Lopez et al., 2021)*

**Types of Environmental Enrichment**

Environmental enrichment (EE) in aquaculture is the process of enhancing a fish's living environment to encourage natural behaviours, provide mental stimulation, and improve overall welfare. As outlined by Näslund and Johnsson (2014), enrichment strategies can be integrated across several domains, each addressing different aspects of a fish's needs. In Zambia's aquaculture industry, these strategies are crucial for improving fish health and productivity while reducing stress.

***Social Enrichment***

This involves creating conditions that foster appropriate interactions among fish. For social species, providing ample opportunities for group formation can reduce stress, whereas for more aggressive or cannibalistic species, ensuring adequate spacing and controlled interactions is essential. This balance helps maintain a harmonious environment and minimises stress-induced injuries (Näslund and Johnsson, 2014).

***Occupational Enrichment***

Occupational enrichment aims to stimulate both the physical and psychological activities of fish. This can be achieved by incorporating interactive feeding systems, varied swimming areas, and opportunities for play or exploration that mimic natural behaviours. Such stimulation promotes cognitive function and overall well-being, reducing the monotony of captive conditions (Näslund and Johnsson, 2014).

***Physical/Structural Enrichment***

This form of enrichment involves modifying the rearing environment to add complexity and provide shelter. Examples include the addition of substrates like silt or sand to facilitate natural burrowing behaviour, and the installation of structures that mimic natural habitats (e.g. rocks, artificial vegetation). These modifications enable fish to express their natural behaviours, thereby reducing stress and improving welfare (Näslund and Johnsson, 2014).

***Sensory Enrichment***

Sensory enrichment focuses on stimulating the fish's senses through controlled variations in light, sound, odour, tactile inputs and even taste. Arechavala-Lopez *et al.* (2019) note that providing a variety of sensory stimuli can enhance a fish's cognitive abilities and create an environment that more closely resembles their natural habitat. This may involve adjusting lighting conditions, varying water flow, or introducing natural soundscapes.

***Dietary Enrichment***

Dietary enrichment involves providing a varied, nutritionally balanced diet that meets the specific nutritional needs of the fish. This can involve varying the types of feed, incorporating natural ingredients, and adjusting feeding frequency and methods to simulate natural foraging behaviours. A well-formulated diet not only supports growth and health but also contributes to overall welfare by reducing stress associated with inadequate nutrition (Näslund and Johnsson, 2014).

Integrating these various forms of environmental enrichment into aquaculture systems in Zambia can lead to enhanced fish welfare, improved growth performance, and increased survival rates. By tailoring enrichment strategies to the specific biology and natural behaviour of the fish species, farmers can create more stimulating and less stressful rearing environments, which ultimately support sustainable aquaculture practices.

**Benefits of Environmental Enrichment**

Environmental enrichment (EE) has been widely recognised as a key strategy for enhancing fish welfare in aquaculture systems by promoting natural behaviours, reducing stress, and improving overall health. In practice, EE involves modifying the rearing environment to mimic natural habitats better, thereby providing fish with the opportunity to express species-specific behaviours and increasing their spatial use. For instance, the inclusion of structural elements such as artificial vegetation, substrates, or shelters has been shown to reduce aggression, minimise fin damage, and promote social cohesion among fish (Rosburg *et al.*, 2019; Huysman *et al.*, 2019).

In addition to behavioural benefits, environmental enrichment positively impacts various physiological parameters. Studies indicate that EE can reduce stress responses and energy expenditure, lower the incidence of injuries, and decrease susceptibility to diseases by providing continuous sensory and motor stimulation (Arechavala-Lopez *et al.*, 2019; Zhang *et al.*, 2020b). By offering a more complex environment, fish are better able to cope with acute stressors, and their overall welfare is improved, as evidenced by enhanced growth rates and more robust immune function (Oliveira *et al.*, 2022; Arechavala-Lopez *et al.*, 2021).

Moreover, EE has been linked to improved post-stocking survival and foraging efficiency, ultimately contributing to higher production yields and better economic returns. For example, the addition of physical structures in the rearing environment has been associated with reduced intraspecies aggression and lower incidences of fin erosion, particularly in juvenile fish such as seabream (Zhang *et al.*, 2021). This holistic approach not only supports the well-being of the fish but also aligns with sustainable aquaculture practices by integrating ecosystem and biodiversity management with locally adapted strategies (Schweiz *et al.*, 2015; Aubin *et al.*, 2017).

## Species Recommendations for Environmental Enrichment

### *Catfish*

Environmental enrichment (EE) is essential for optimising the welfare and growth performance of farmed fish, and its application must be tailored to the life stage and species-specific needs. For African sharp-tooth catfish (*Clarias gariepinus*), several enrichment strategies are recommended for both juvenile and adult stages.

Here is the adapted environmental enrichment table for African sharp-tooth catfish (*Clarias gariepinus*) in the Zambian aquaculture context. The recommendations take into account local farming conditions, environmental constraints, and best aquaculture practices in Zambia.

*Table 7 Environmental Enrichment Recommendations for African Sharp-Tooth Catfish in Zambia*

| Enrichment Category | Juvenile | Adult |
|---|---|---|
| **Enclosure Colouration** | Black or dark-coloured tanks to reduce stress and promote higher survival rates (FishEthoBase, 2021; Zulu *et al.*, 2022). | Not enough research in Zambia; farmers should consider natural conditions, such as earthen ponds or dark tank linings. |
| **Substrate Provision** | Provide vegetation or mud banks to mimic natural conditions and promote burrowing behaviour (Musuka and Musonda, 2020). | Use a combination of mud, shale, sand and aquatic plants to provide a natural substrate for |

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| | | bottom-dwelling behaviour (FishEthoBase, 2021). |
| **Lighting** | Light intensity ≤15 lux for fry and juveniles to minimise stress. A photoperiod of 9-15 hours is ideal (FishEthoBase, 2021). | Blue light (0.002-1.4 μmoles/m²/s) helps reduce aggression. Natural or simulated daylight cycles should be maintained (FishEthoBase, 2021). |
| **Water Augmentation** | Shallow tanks (0.1 m² x 0.03 m depth) improve fry growth. Water exchange and aeration should be well maintained (Phiri *et al.*, 2023). | Depth should be at least 2-4 m, ideally up to 10 m, with variations in water inlet velocity and direction to optimise oxygenation and waste removal (Musuka and Musonda, 2020). |
| **Structures** | Bamboo poles or floating structures encourage periphyton growth, providing additional nutrition (Zulu *et al.*, 2022). | High-density aquatic plants in coupled aquaponic systems can reduce injuries and aggression (Phiri *et al.*, 2023). |
| **Shelter** | Artificial shelters (e.g. PVC pipes, ceramic tiles) help reduce juvenile cannibalism (Hecht and Appelbaum, 1988; Hossain *et al.*, 1998). | Provide mud banks or artificial shelters (such as black plastic shade cloth or wooden panels) while monitoring aggressive territorial behaviours (FishEthoBase, 2021). |
| **Feeding System** | Juveniles fed by hand were more active in the morning, while self-fed fish were more active in the afternoon. Night feeding improves growth and lowers the feed conversion ratio (Boerrigter *et al.*, 2016). | Install automated belt feeders for night feeding. Ensure high-quality, protein-rich feeds suited for *Clarias gariepinus* in Zambian aquaculture (Musuka and Musonda, 2020). |

***Tilapia fish***

Environmental enrichment strategies for Nile tilapia have been studied to enhance fish welfare, behaviour and growth in captivity. Structural enrichment, such as the use of plant-fibre ropes, aquatic vegetation, and artificial shelters, has been shown to improve cognition, exploratory behaviour, and stress resistance in tilapia (Torrezani *et al.*, 2013). Research also suggests that enriched environments reduce aggression and promote stable hierarchical structures (Arechavala-Lopez *et al.*, 2020). In Zambia, these strategies can be adapted for local aquaculture systems, particularly in pond and cage culture.

## Nile tilapia (*Oreochromis niloticus*)

*Table 8 Environmental Enrichment Recommendations for Nile Tilapia in Zambia*

| Enrichment Category | Juvenile | Adult |
|---|---|---|
| **Enclosure Colouration** | No specific studies for Zambia. However, tilapia have shown preferences for green and blue tank colours (Maia and Volpato, 2016). Farmers may experiment with blue or green tank linings for better adaptation. | No specific studies for Zambia. Earthen ponds with natural colouration remain the most suitable. Dark-coloured nets may be used in cage culture. |
| **Substrate Provision** | Small river pebbles, aquatic vegetation, or plastic kelp models can provide enrichment, but they must be monitored to prevent territorial aggression (FishEthoBase, 2021). | Males prefer sandy substrates for nest building. Farmers using artificial tanks should provide sand and mud to promote natural behaviours (FishEthoBase, 2021). Bamboo poles have been found to increase growth rates in earthen ponds (Zulu *et al.*, 2022). |
| **Lighting** | Increased light intensity (280-1390 lux) reduces aggressive interactions among juvenile males. A natural photoperiod of 9-15 hours is ideal. Farmers should ensure access to natural light or simulate daylight cycles (FishEthoBase, 2021). | Blue light reduces stress by preventing cortisol release (Volpato and Barreto, 2001). Farmers should avoid excessive artificial lighting (>1400 lux), as it may increase aggression. |
| **Water Augmentation** | Depth should be at least 2-4 m in ponds, with proper aeration to improve water quality. In tanks, varying water flow rates can provide additional enrichment (Phiri *et al.*, 2023). | In cages, tilapia should have access to depths of at least 2-6 m. Cage positioning should allow fish to choose their preferred swimming depth depending on environmental conditions and life stage (Musuka and Musonda, 2020). |
| **Structures** | Enrichment structures can increase resource value, leading to more intense territorial fights. Use artificial water hyacinths or floating vegetation to promote natural behaviour and reduce aggression (FishEthoBase, 2021; Neto and Giaquinto, 2020). | Tilapia kept in enriched environments (e.g. submerged branches, artificial shelters) exhibit lower aggression and better welfare (Arechavala-Lopez *et al.*, 2020). Farmers can introduce artificial reefs or submerged logs in ponds and cages. |
| **Shelter** | Juveniles benefit from hiding spaces to reduce predation and aggressive encounters. Providing | Adult tilapias prefer submerged structures such as tree roots, aquatic plants, or artificial reefs. In cage |

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| | artificial shelters, such as PVC pipes or submerged vegetation, can help reduce stress (Hecht and Appelbaum, 1988; Hossain *et al.*, 1998). | culture, installing shelter structures can improve survival rates (FishEthoBase, 2021). |
| **Feeding System** | Self-feeders can reduce food competition and stress among juveniles. Farmers should provide sufficient feed 4-8 days after hatching (FishEthoBase, 2021). | Tryptophan-supplemented feeds have been found to reduce aggressive confrontations. Farmers should consider incorporating tryptophan-rich ingredients in formulated feeds (Neto and Giaquinto, 2020). Sand, mud, and bamboo poles can promote natural foraging behaviours in pond systems (Zulu *et al.*, 2022). |

## Longfin tilapia (*O. macrochir*) and three-spotted tilapia (*O. andersonii*)

*Table 9 Environmental Enrichment Recommendations for Three-Spotted Tilapia (O. andersonii) and Longfin Tilapia (O. macrochir) in Zambia*

| Enrichment Category | Juvenile | Adult |
|---|---|---|
| **Enclosure Colouration** | No specific studies are available for Zambia, but dark-coloured tanks (e.g. green or blue) may enhance growth and reduce stress (Maia and Volpato, 2016). Farmers can experiment with different colours in hatchery systems. | In pond systems, earthen colouration is ideal. In tanks and cages, black or green netting may provide a better environment for adaptation and reduce stress. |
| **Substrate Provision** | Providing aquatic vegetation, pebbles, or artificial substrates (e.g. bamboo poles) can improve juvenile growth but must be monitored to prevent excessive aggression (FishEthoBase, 2021). | Males of both species exhibit territorial nesting behaviour. Providing sandy or muddy substrates supports natural breeding behaviour. In cages and tanks, artificial gravel beds or shallow nesting areas can be used (Musuka and Musonda, 2020). |
| **Lighting** | Light intensity between 200-800 lux helps reduce aggression and improve welfare. Natural photoperiod (9-15 hours) should be maintained (FishEthoBase, 2021). | Blue light has been reported to reduce stress and improve social interactions (Volpato and Barreto, 2001). Farmers should avoid excessively bright artificial lighting (>1400 lux) in tanks and indoor systems. |

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| **Water Augmentation** | Depth should be at least 2-4 m in ponds, and proper aeration should be maintained in tanks to ensure high oxygen levels (Zulu *et al.*, 2022). | In cages, fish should have access to depths of at least 2-6 m. Three-spotted tilapia prefers structured environments, while longfin tilapia benefits from slightly deeper, well-oxygenated waters (Phiri *et al.*, 2023). |
| **Structures** | Juveniles benefit from submerged artificial structures (e.g. plastic kelp, water hyacinth mats) to reduce stress and predation risk (Arechavala-Lopez *et al.*, 2020). | Adult *O. andersonii* and *O. macrochir* thrive in structured environments with submerged vegetation, roots, and artificial shelters. Floating platforms may be used in cages to mimic natural habitat (Neto and Giaquinto, 2020). |
| **Shelter** | Providing artificial shelters such as PVC pipes or mesh structures can help reduce aggression and promote social stability among juveniles (Hecht and Appelbaum, 1988; Hossain *et al.*, 1998). | Submerged vegetation, tree roots, and artificial reefs are recommended in ponds and cages. Black nylon nets may also provide shaded refuge areas (FishEthoBase, 2021). |
| **Feeding System** | Self-feeders can reduce food competition and stress in hatcheries. Feed must be provided within 4-8 days post-hatching (FishEthoBase, 2021). | Tryptophan-supplemented feeds have been shown to reduce aggression in tilapia species. In pond systems, incorporating organic materials such as rice bran or algae mats may improve natural foraging behaviour (Zulu *et al.*, 2022). |

## Carp fish

*Table 10 Environmental Enrichment Recommendations for Carp Fish (Cyprinus carpio) in Zambia*

| Enrichment Category | Juvenile | Adult |
|---|---|---|
| **Enclosure Colouration** | Avoid red and black tanks; use lighter, natural colours to reduce stress (FishEthoBase, 2021) | Use natural or earthen colouration; in cages, consider using dark or green netting for better adaptation (FishEthoBase, 2021) |
| **Substrate Provision** | Provide sand, mud, gravel, and submerged vegetation to simulate a natural bottom; this encourages natural foraging (FishEthoBase, 2021) | Provide sand, mud, gravel, and submerged vegetation; supports natural breeding and foraging behaviours (FishEthoBase, 2021) |

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|---|---|---|
| **Lighting** | Maintain a natural photoperiod of 7-17 hours; use controlled lighting (~200 lux) to reduce aggression (FishEthoBase, 2021) | Provide access to natural or simulated daylight with a resting period in the dark; avoid excessive brightness (>1400 lux) (FishEthoBase, 2021) |
| **Water Augmentation** | Ensure tank or pond depth is at least 1.5 m, ideally 2-4 m, with proper aeration to support high oxygen levels (FishEthoBase, 2021) | In cages or larger ponds, provide depth of 2-5 m or more; allow fish to choose swimming depth based on life stage (FishEthoBase, 2021) |
| **Structures** | Incorporate submerged structures (e.g. artificial kelp, bamboo poles) to reduce aggression and promote natural behaviour (Hecht and Appelbaum, 1988; Hossain *et al.*, 1998) | Use partial covers or artificial reefs that mimic natural habitats, ensuring not to restrict daily activity rhythms (FishEthoBase, 2021) |
| **Shelter** | Provide artificial shelters such as PVC pipes or mesh structures to reduce cannibalism and aggression (FishEthoBase, 2021) | Use natural vegetation, submerged branches, or artificial shelters to provide protection and reduce stress (FishEthoBase, 2021) |
| **Feeding System** | Implement self-feeders to minimise competition; provide feed 4-7 days post-hatching; enrich feed with 4% fructo-oligosaccharides to improve stress tolerance (FishEthoBase, 2021) | Optimise feeding intervals to ensure continuous but non-disruptive feed supply; install self-feeders and ensure uniform access to food (FishEthoBase, 2021) |

In Zambia, environmental enrichment represents a powerful strategy for enhancing fish welfare by creating rearing environments that promote species-specific behaviours, provide mental stimulation, and improve overall health. By mimicking natural habitats through the integration of appropriate substrates, structural complexity and controlled lighting and water conditions, local aquaculture systems can reduce stress and encourage natural behaviour among fish, leading to improved growth performance and product quality (Zulu *et al.*, 2022; FishEthoBase, 2021). Emphasising environmental enrichment not only contributes to the ethical treatment of fish but also supports the sustainability of Zambia's rapidly expanding aquaculture industry. Continued research and collaboration among local scientists, aquaculturists, and conservationists will be critical in refining and adapting enrichment strategies that meet the unique needs of fish farms in Zambia and across Africa while aligning with international welfare standards (Oluwarore *et al.*, 2023; FAO, 2022).

**Q&A Session**

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

If 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.

**Discussion Points**

1. Have you encountered the concept of "Environmental Enrichment" in fish farming before? Share any experiences you or someone you know has had with implementing enrichment strategies.
2. Based on what you currently know, what changes would you consider making to improve the environmental enrichment on your fish farm to ensure it meets high welfare standards?
3. How can local innovations and traditional knowledge be integrated into your enrichment practices to create a more natural and stimulating environment for your fish?

# MODULE 10: FISH HEALTH AND WELFARE

*This module is designed to enable participants to fully comprehend the interrelationship between fish health and welfare in aquaculture, focusing on the critical role of proactive health management and biosecurity in disease prevention. Upon completion, learners will be able to recognise and diagnose the behavioural and physical signs of healthy versus sick fish, identify common diseases, and effectively develop and implement a comprehensive, site-specific Fish Health Management System that minimises the risk of disease outbreaks and ensures high welfare standards on the farm.*

**Fish Health and Welfare in Zambian Aquaculture**

In the context of Zambian aquaculture, fish health and welfare are critical components of sustainable production. Fish welfare is broadly defined as the overall state of the animal, which reflects the quality of care it receives, ranging from husbandry and nutrition to humane handling and its ability to cope with the environmental conditions in which it is reared (Animal Welfare Institute, 2018). In contrast, fish health refers primarily to the absence of disease and the normal functioning of physiological processes, ensuring that fish exhibit typical behaviour and vitality (Ducrot *et al.*, 2011). Although these concepts are distinct, they are closely intertwined: a healthy fish is more likely to exhibit good welfare, being comfortable, well-nourished, and free from pain, fear, or distress.

In Zambia, ensuring both fish health and welfare requires an integrated approach. Good fish welfare in aquaculture involves not only disease prevention and effective treatment but also the provision of appropriate shelter, nutrition, and gentle handling practices that minimise stress. For instance, when fish are reared under optimal conditions that mimic their natural environment, they tend to be more resilient, display natural behaviours, and ultimately contribute to better production outcomes. While fish health focuses on managing diseases and sub-optimal physiological conditions, welfare extends to recognising the sentience and emotional complexity of fish, acknowledging their capacity to experience stress and pleasure, adapt to captivity, and express natural behaviours without undue restriction (Nicks and Vandenheede, 2014).

Thus, in Zambia's aquaculture sub-sector, improving fish welfare is as important as maintaining robust health. This means adopting practices that prevent disease, ensure high-quality nutrition, and promote humane handling and slaughter procedures. By integrating these welfare principles into daily farm management, producers can enhance fish growth, improve product quality, and support the overall sustainability of aquaculture operations in Zambia.

**Biosecurity for Fish Health and Welfare in Zambia**

In Zambia's aquaculture industry, biosecurity is a critical set of practices designed to prevent the introduction, establishment, and spread of pathogens within fish farms and beyond. This comprehensive approach involves implementing systematic protocols that minimise the risk of infectious diseases entering or leaving a facility, thereby protecting not only the cultured fish but also the surrounding aquatic ecosystems. Effective bio-security measures reduce stress in fish, which in turn enhances their immune responses and overall welfare (Yanong and Erlacher-Reid, 2012).

The primary objectives of biosecurity, as outlined by Yanong and Erlacher-Reid (2012), include:

- **Effective Stock Management:** Acquiring and maintaining healthy fish stocks through rigorous husbandry practices to optimise health and immunity.
- **Pathogen Management:** Preventing, reducing, or eliminating the presence of pathogens through regular monitoring, sanitation, and appropriate quarantine measures.
- **Human Management:** Educating, training, and regulating the movement of farm staff and visitors to minimise the risk of pathogen transmission.

In the Zambian context, the likelihood of a pathogen infiltrating a fish farm and causing disease depends on numerous factors, including the stringency of the biosecurity measures in place, the species being reared, their immune status, life stage, and overall welfare. Environmental conditions, such as water quality and chemistry, also play a pivotal role, as do the biological characteristics of pathogens, including their life cycle and ability to survive on inanimate objects (fomites). Strong bio-security practices, which involve measures such as hygiene, segregation and waste management, can significantly reduce the risk of pathogen introduction and spread. On the other hand, weak or poorly implemented biosecurity measures can lead to outbreaks and increased disease transmission. The effectiveness of bio-security measures hinges on the skill, understanding, and compliance of farm workers with established protocols (Yanong and Erlacher-Reid, 2012).

Potential sources of contamination in Zambian fish farms include:

- **Fomites (Inanimate Objects):** Nets, buckets, siphons, footwear, clothing, vehicles, and containers that can harbour pathogens if not properly disinfected.
- **Vectors (Living Creatures):** New livestock introductions, wild or domestic animals (such as predatory birds and pets), and human visitors, all of which can act as carriers for disease.
- **Direct Contact:** Pathogen transmission can occur through interactions between healthy fish and diseased or dead fish, as well as through exposure to contaminated feed or water. This includes water from on-site sources, reused water, or during transportation, where fish may come into direct or indirect contact with infected individuals or contaminated holding containers (Sahu *et al.*, 2020).

**Benefits of Biosecurity on Fish Farms in Zambia**

Biosecurity is a vital set of practices designed to prevent the introduction, establishment, and spread of pathogens in fish farms, thereby protecting fish health and welfare. As noted by Aarattuthodiyil and Wise (2017), biosecurity is one of the most cost-effective and efficient means of disease control available. In Zambia, where aquaculture is growing to meet local and export demands, robust biosecurity measures are essential for several reasons:

- **Reduction of Disease Transmission:** Implementing systematic biosecurity protocols helps minimise the spread of infectious diseases within a single farm and between different farms. This containment is crucial for preventing outbreaks that can devastate fish stocks, particularly in intensive systems such as recirculating aquaculture systems (FAO, 2022).

- **Promotion of Aquatic Animal Health:** By maintaining a pathogen-free environment and reducing stress levels, biosecurity supports optimal fish health. Healthy fish are better able to grow, reproduce and perform naturally, which contributes directly to improved welfare and productivity (Sahu *et al.*, 2020).
- **Prevention of New Disease Outbreaks:** Proactive biosecurity measures help prevent the introduction of new diseases into fish farms. This is particularly important in Zambia, where many aquaculture operations are expanding, and the risk of pathogen transmission can be high if proper protocols are not followed.
- **Protection of Human Health:** Effective biosecurity reduces the risk of zoonotic disease transmission and ensures food safety by preventing the spread of pathogens from fish to humans, thereby safeguarding public health and enhancing market confidence (Sahu *et al.*, 2020).
- **Reduction of Stress and Improved Welfare:** By minimising exposure to pathogens and reducing the likelihood of disease outbreaks, biosecurity measures also lower stress levels among fish. This stress reduction not only improves fish welfare but also enhances growth performance and overall production efficiency.
- **Economic and Market Benefits:** The absence of a robust biosecurity plan can lead to catastrophic losses due to disease outbreaks, resulting in high treatment costs, decreased product quality, and damaged market reputation. Conversely, farms that can demonstrate comprehensive biosecurity protocols are more competitive in international trade markets, as they meet the stringent standards required for export (Aarattuthodiyil and Wise, 2017).

**Common Biosecurity Measures and Practices in Zambian Aquaculture**

According to Bera *et al.* (2018) and Ernst *et al.* (2017), effective biosecurity in aquaculture involves a systematic set of practices aimed at preventing the introduction, establishment, and spread of pathogens. In the Zambian context, these measures are essential for protecting fish health, ensuring sustainable production, and safeguarding both the farm environment and public health. The key biosecurity measures include:

- **Water Source Management:** Ensure that land-based fish farms have access to a clean, pathogen-free water source at all times. This is particularly critical in Zambia, where water quality can be variable, and treatment processes must be implemented to prevent the introduction of contaminants. A barrier, such as wire mesh, needs to be placed in a case where the source of water is a natural water body. This will prevent the mixing of fish from the wild with fish in a fish farm.
- **Control of Fish Movement:** Limit the transfer of fish between farms or within different sections of a single farm, especially when the incoming stock is of inferior health. This helps to reduce the risk of disease transmission across facilities. It is essential to use designated holding or quarantine ponds for all new arrivals before integrating them with the existing stock. This allows for observation, health screening, and treatment, if necessary, thus preventing the introduction of pathogens into healthy populations.
- **Access Restriction:** Implement physical barriers such as gates and fences, and install clear signage to control and monitor the movement of visitors and staff, as well as restrict access of other animals, thereby minimising the risk of external contamination.
- **Sanitary Protocols:** Establish and enforce strict sanitary measures, including the definition of designated sanitary zones, regular cleaning and disinfection protocols for all individuals entering the facility, and the mandatory use of protective clothing, foot dips, and proper hand hygiene practices.
- **Equipment and Material Control:** Restrict the movement of tools, equipment, and other culture organisms into the farm. All equipment, vessels, and vehicles entering the site should undergo disinfection and inspection to prevent the introduction of pathogens.
- **Stock Health Maintenance:** Maintain fish stock health by minimising stress and ensuring optimal water quality. Implement quarantine procedures during stock movement to further reduce the risk of disease spread.

- **Pest and Vector Management:** Control the risk of pest and disease transmission by managing potential vectors such as predatory birds, rodents, and other animals. This includes implementing effective pest control strategies to minimise the presence of wildlife and scavengers on the farm.
- **Waste Management:** Treat wastewater and solid waste appropriately before disposal to prevent environmental contamination. Implement a regular schedule for waste treatment to maintain a clean and safe environment.
- **Record-Keeping and Training:** Keep detailed records of staff training, visitor logs, equipment disinfection, and regular biosecurity inspections. Continuous monitoring, surveillance, and audits of biosecurity measures are critical to ensuring compliance and identifying areas for improvement.
- **Biosecurity Management Plan:** Develop and implement a comprehensive biosecurity management plan that outlines all protocols, assigns responsibilities, and establishes contingency plans in case of a disease outbreak.

**Fish Diseases and Their Impacts in Zambian Aquaculture**

Fish disease outbreaks pose a significant challenge to sustainable aquaculture in Zambia, often resulting in substantial economic losses due to increased mortality, reduced growth rates, and diminished productivity, all of which increase production costs. FAO (2020) identifies disease outbreaks as a major obstacle to sustainable aquaculture worldwide, a challenge that is particularly acute in Zambia, where many operations are small-scale and resource-constrained.

Key barriers to effective disease prevention and control in Zambian fish farms include limited training in aquaculture disease management, inadequate access to effective pharmaceuticals, high costs of quality feed and treatments, and insufficient financial support for implementing biosecurity measures (Mukaila *et al.*, 2023). These factors underscore the need for comprehensive capacity building and improved biosecurity protocols to reduce disease incidence and enhance overall farm performance.

Infectious diseases in aquaculture are often caused by viruses, bacteria, parasites, fungi or protozoa, and can spread through direct contact, contaminated water, feed, or equipment (Cascarano *et al.*, 2021). In Zambia, pathogen transmission is further exacerbated by additional factors such as the movement of infected stocks, poor water quality, and suboptimal biosecurity practices. These conditions create an enabling environment for disease outbreaks, undermining fish health and farm productivity. The adverse effects of these diseases extend beyond aquaculture production, undermining sustainable development goals by reducing income, leading to job losses, and compromising food security and nutrition in vulnerable communities (World Bank, 2014). Moreover, in many rural settings, disease outbreaks frequently go undetected, untreated, and unrecorded, placing an excessive burden on communities already striving to overcome poverty.

**Common Bacterial Diseases in Zambian Aquaculture**

Bacterial infections pose a significant challenge in aquaculture, affecting both fish health and farm productivity. These infections can lead to elevated mortality rates, reduced growth performance, and increased costs associated with treatment and management. In Zambia, where aquaculture is expanding rapidly, bacterial disease outbreaks are particularly concerning due to the intensive production systems, limited diagnostic capabilities, and varying biosecurity standards. The most prevalent bacterial diseases observed include (See Table 11):

- **Streptococcosis**: Caused by *Streptococcus iniae* and *S. agalactiae*, this disease is often seen in tilapia. Affected fish exhibit erratic swimming, corneal opacity, exophthalmia (pop-eye) and darkening of the skin. It is commonly associated with elevated water temperatures and high stocking densities, which exacerbate stress and immune suppression.
- **Lactococcosis**: Attributed to *Lactococcus garvieae*, this condition mirrors many signs of streptococcosis, including lethargy, skin haemorrhages and neurological symptoms such as spinning. It often affects fish in warmer waters and under suboptimal environmental conditions.
- **Aeromoniasis (including Red Pest)**: Infections by *Aeromonas hydrophila* and related species can manifest in various forms, including skin ulcers,

haemorrhagic lesions, abdominal swelling (dropsy), and fin and tail rot. Red Pest, frequently linked to this group, is characterised by blood streaks along fins and body surfaces and is prevalent in systems with poor water quality and crowding.

- **Vibriosis**: Caused by *Vibrio anguillarum* and other species, vibriosis presents with skin lesions, haemorrhaging and in severe cases, ulceration and necrosis. Though more common in brackish environments, cases have been reported in freshwater systems during periods of high stress or temperature fluctuations.
- **Francisellosis**: A systemic disease caused by *Francisella noatunensis* subsp. *orientalis*, affecting tilapia. Infected fish may appear emaciated, with granulomatous lesions in internal organs. It is a chronic disease that often goes unnoticed until advanced stages.
- **Columnaris Disease**: Triggered by *Flavobacterium columnare*, this infection results in lesions with a yellowish-white appearance, usually on the gills, fins, and mouth. It progresses rapidly in warm, stagnant waters with high organic loads.
- **Edwardsiellosis**: Caused by *Edwardsiella tarda* and *E. ictaluri*, this disease affects both catfish and tilapia. Symptoms include abscesses, organ swelling, and ulceration. It can also cause internal granulomas and systemic infections, leading to high mortality.

*Table 11 Tabular presentation of bacterial diseases, common signs, and susceptible fish species*

| Disease Name | Causative Agent | Common Signs/Symptoms | Susceptible Fish Species | Classic Presentation |
|---|---|---|---|---|
| **Streptococcosis** | *Streptococcus iniae*, *S. agalactiae* | Exophthalmia (pop-eye), erratic swimming, lethargy, skin haemorrhages, swollen abdomen | Tilapia, Catfish | Pop-eye, spiralling motion |
| **Lactococcosis** | *Lactococcus garvieae* | Haemorrhages on skin and fins, exophthalmia, erratic swimming | Tilapia, Trout | Skin lesions with internal haemorrhaging |
| **Aeromoniasis** | *Aeromonas hydrophila*, *A. sobria* | Haemorrhagic septicemia, ulcers, swollen abdomen, red fins | Tilapia, Catfish, Carp | Open ulcers, reddened base of fins |

| | | | | |
|---|---|---|---|---|
| **Vibriosis** | *Vibrio anguillarum*, *V. vulnificus* | Dark colouration, haemorrhages on the body, fin erosion, ulcers, lethargy | Tilapia, Marine and estuarine species | Red patches on the body, body ulcerations |
| **Francisellosis** | *Francisella noatunensis subsp. orientalis* | Granulomatous lesions in internal organs, emaciation, and splenomegaly | Tilapia | Nodules in the kidney/spleen, chronic weight loss |
| **Columnaris disease** | *Flavobacterium columnare* | Lesions on fins, gills, and skin; necrotic gill tissue; white or yellow mucus patches | Tilapia, Catfish, Carp | Cotton-wool-like patches on the body and fins |
| **Edwardsiellosis** | *Edwardsiella tarda*, *E. ictaluri* | Skin ulcers, haemorrhagic septicemia, ascites, erratic swimming | Catfish, Tilapia | Reddened skin, swollen belly, spiralling motion |

A combination of poor water quality, overcrowding, inadequate nutrition, and insufficient biosecurity often predisposes fish to these infections. Early detection, proper sanitation, vaccination (where available), and appropriate antibiotic use (guided by sensitivity testing) are essential for managing bacterial diseases in aquaculture systems.

**Common Fungal Diseases in Zambian Aquaculture**

Fungal diseases, including true fungi and fungal-like pathogens, present significant health challenges in Zambia's aquaculture systems, especially under conditions of poor water quality, overcrowding, and inadequate biosecurity. These infections often follow stress events, physical injuries, or the concurrent presence of parasitic and bacterial infections. The most common fungal diseases of concern include (see Table 12):

- **Saprolegniasis**: Caused by water moulds of the genus *Saprolegnia*, this disease is one of the most frequently reported fungal infections in aquaculture. It manifests as cotton-like, white to grey filamentous growths on the skin, fins, and gills of fish, especially in stressed or injured individuals. In Zambia, Saprolegniasis often emerges following handling injuries, spawning, or poor environmental conditions, and can lead to secondary infections and high mortalities if left unmanaged.

- **Branchiomycosis**: Also known as "gill rot," this condition is caused by *Branchiomyces sanguinis* and *Branchiomyces demigrans*. It leads to severe necrosis and destruction of gill tissues, impairing respiration and often resulting in rapid mortality. Affected fish exhibit respiratory distress, lethargy, and darkened colouration. The disease is commonly associated with stagnant water conditions, organic pollution, and elevated temperatures, which are not uncommon in some intensive pond systems in Zambia.
- **Epizootic Ulcerative Syndrome (EUS)**: A severe fungal-like disease caused by the oomycete *Aphanomyces invadans*, EUS is characterised by deep, necrotic skin ulcers and granulomatous lesions in internal organs. It affects a wide range of freshwater fish species, particularly under stressful environmental conditions. Though not yet widely reported in Zambia, its potential presence is of concern due to the increased movement of live fish and climate variability.

These fungal diseases can have a severe impact on fish health and farm profitability. Management strategies include improving water quality, reducing stocking densities, minimising handling stress, and applying antifungal treatments where appropriate. Early detection and robust biosecurity measures remain critical to limiting the spread and recurrence of these infections.

*Table 12 Tabular presentation of fungal diseases, common signs, and susceptible fish species*

| Disease Name | Causative Agent | Common Signs/Symptoms | Susceptible Fish Species | Classic Presentation |
|---|---|---|---|---|
| **Saprolegniasis** | *Saprolegnia* spp. (especially *S. parasitica*) | Cotton wool-like fungal growths on skin, fins, eggs; skin ulceration; lethargy | Eggs, Fry, Juveniles, Adults (Tilapia, Catfish) | White/grey fluffy patches on external surfaces |
| **Branchiomycosis** | *Branchiomyces sanguinis*, *B. demigrans* | Gasping, gill necrosis, darkened gill areas, respiratory distress | Catfish, Tilapia, Carp | Rotten or discoloured gills with patchy lesions |
| **Epizootic Ulcerative Syndrome (EUS)** | *Aphanomyces invadans* | Deep ulcers on body, haemorrhagic lesions, and | Tilapia, Snakeheads, Clarias spp. | Deep spreading ulcers with red, inflamed margins |

| | | | | |
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| | | granulomas in internal organs | | |

**Common Parasitic Diseases in Zambian Aquaculture**

Parasitic diseases are among the most prevalent and economically significant health challenges in Zambia's aquaculture sector. These infections impair fish welfare, reduce growth performance, and increase susceptibility to secondary infections. Understanding their signs, causes, and control strategies is essential for sustainable production (See Table 13).

- **Ichthyophthiriasis (White Spot Disease)**: Caused by the protozoan *Ichthyophthirius multifiliis*, this highly contagious disease is characterised by white cysts on the skin, fins, and gills, often resembling grains of salt. Infected fish exhibit abnormal swimming, flashing (rubbing against surfaces), respiratory distress, and reduced feeding. White spot disease is particularly problematic in high-density aquaculture systems, where stress and poor water quality promote outbreaks.
- **Gyrodactylosis**: This disease results from infestation by *Gyrodactylus* spp., a group of viviparous monogenean parasites that attach to the skin and fins of their host. Infected fish typically show signs of lethargy, fin erosion, flashing and localised skin damage. Gyrodactylosis is commonly reported in hatcheries and grow-out systems in Zambia and can rapidly spread under crowded and poorly managed conditions.
- **Clinostomum Infections (Yellow Grub Disease)**: These are caused by metacercariae of *Clinostomum* spp., which encyst in the muscle and under the skin, appearing as yellow or white nodules. Although not typically fatal, the condition causes severe marketability issues due to the fish's unsightly appearance. These parasites complete their life cycle via aquatic snails and piscivorous birds, making environmental management a critical control measure.
- **Nematode Infections**: Nematodes, such as *Camallanus* spp. and *Contracaecum* spp., affect the gastrointestinal tract, liver, or swim bladder. Signs include emaciation, visible worms protruding from the anus, and poor feed conversion. In Zambia, nematode infestations are more common in

poorly managed earthen ponds and in systems where wild fish serve as intermediate or reservoir hosts for the parasites.

- **Cichlidogyrus Infections**: Caused by *Cichlidogyrus* spp., these monogenean gill parasites are prevalent in cichlids such as tilapia. Infected fish show signs of respiratory stress, excessive mucus secretion, and gill tissue damage, which impair oxygen uptake. These parasites are commonly found in intensive systems characterised by high stocking densities and low water exchange rates.
- **Dactylogyrus Infections**: These are also monogenean parasites, commonly referred to as gill flukes. *Dactylogyrus* spp. affect mainly carp and related species, and their presence is associated with gill congestion, clamped fins, and erratic swimming. They can lead to secondary bacterial infections if left untreated.
- **Diplostomiasis (Eye Fluke Disease)**: This disease is caused by the metacercariae of *Diplostomum* spp., which invade the eye lens and cause cataracts or blindness. Infected fish become disoriented and more susceptible to predation. Diplostomiasis poses a risk in earthen pond systems that support populations of snails and birds, acting as intermediate and definitive hosts, respectively.

*Table 13 Tabular presentation of parasitic diseases, common signs, and susceptible fish species*

| Disease Name | Causative Agent | Common Signs/Symptoms | Susceptible Fish Species | Classic Presentation |
|---|---|---|---|---|
| **Ichthyophthiriasis (Ich)** | *Ichthyophthirius multifiliis* (protozoan parasite) | White cysts/spots on skin, fins, and gills, flashing, respiratory distress | Tilapia, catfish, carp, and other freshwater fish | White pinhead-sized spots ("white spot disease") on skin/gills |
| **Gyrodactylosis** | *Gyrodactylus* spp. (monogenean ectoparasite) | Skin irritation, flashing, frayed fins, lethargy | Tilapia, catfish, ornamental fish | Microscopic worm-like parasites on skin and fins |
| **Dactylogyrosis** | *Dactylogyrus* spp. (monogenean gill flukes) | Gasping, excess gill mucus, inflamed or pale gills, reduced feeding | Tilapia, catfish, carp | Heavy gill parasite load visible under the microscope |

| | | | | |
|---|---|---|---|---|
| **Clinostomum Infection** | *Clinostomum* spp. (digenean trematode; "yellow grub") | Yellow cysts under the skin, in muscles or gills; reduced market value | Tilapia, catfish, wild fish | Visible yellow metacercariae under skin or muscle tissue |
| **Nematodiasis** | *Camallanus*, *Capillaria*, *Contracaecum* spp. | Bloating, anaemia, poor growth, and the presence of worms in the intestines or body cavity | Tilapia, catfish, and many freshwater species | Thread-like worms are visible in the intestines or abdominal cavity |
| **Lernaeosis** | *Lernaea* spp. (anchor worm – copepod parasite) | Red sores, inflammation, ulcers, and fish rubbing on surfaces | Tilapia, carp, goldfish | Worm-like body protruding from skin, often with haemorrhage |
| **Argulosis** | *Argulus* spp. (fish lice – crustacean ectoparasite) | Skin irritation, haemorrhagic spots, flashing, reduced feeding | Tilapia, catfish, carp | Flat, disc-shaped parasites attached to skin or gills |
| **Trichodiniasis** | *Trichodina* spp. (protozoan ectoparasite) | Mucus excess, skin opacity, flashing, poor growth | Tilapia, ornamental fish, carp | Circular ciliates on skin/gills under the microscope |
| **Hexamitiasis (Spironucleosis)** | *Hexamita/Spironucleus* spp. (intestinal flagellates) | Weight loss, abdominal swelling, pale faeces, spiralled movement | Tilapia, cichlids | Internal protozoa, best identified via microscopy |

Effective management of these parasitic diseases in Zambia hinges on integrated fish health strategies. These include improving water quality, applying targeted treatments, practising good pond hygiene, controlling snail populations, and limiting interactions with wild hosts. Regular parasitological monitoring and proactive health management help ensure high productivity and fish welfare in both smallholder and commercial aquaculture systems.

**Common Protozoan Diseases in Zambian Aquaculture**

Protozoan diseases are a significant health concern in Zambian aquaculture, particularly in systems where high stocking densities, poor water quality, and inadequate biosecurity practices persist. These microscopic parasites can affect various tissues, including the skin, gills, intestines, and internal organs, resulting in reduced growth, increased mortality, and substantial economic losses.

- **Ichthyophthiriasis (White Spot Disease)**: Caused by *Ichthyophthirius multifiliis*, this is one of the most prevalent protozoan infections in Zambian fish farms. It presents as small, white, salt-like cysts on the skin, fins and gills. Affected fish may show signs of flashing, respiratory distress, anorexia, and lethargy. The disease spreads rapidly under stress and in poor water conditions, especially in tilapia and other warm-water species.
- **Trichodiniasis**: Caused by *Trichodina* spp., this protozoan parasite is commonly found on the gills and skin, forming a saucer-shaped attachment. Infected fish display signs of gill irritation, increased mucus production, and flashing. Trichodiniasis often occurs in systems with poor hygiene and excessive organic loading, such as understocked or overcrowded ponds.
- **Hexamitiasis**: This internal protozoan disease is caused by *Hexamita* spp., which inhabit the intestines of fish. Affected individuals typically show signs of anorexia, weight loss, and poor feed conversion. In Zambia, this disease has been reported especially in intensive hatchery operations where water quality control is inadequate.
- **Chilodonelliasis**: *Chilodonella* spp. are ciliated protozoans that infest the skin and gills, particularly of weakened or stressed fish. Symptoms include respiratory difficulty, abnormal swimming, and increased mucus production. The disease is common in colder temperatures and poorly managed systems, especially during seasonal transitions.
- **Myxosporidiosis**: Caused by parasites in the order *Myxosporea*, including *Myxobolus* spp. and *Henneguya* spp., this disease leads to the development of nodular cysts in the gills, muscles, and internal organs. Affected fish may appear bloated or deformed and eventually succumb to organ failure. Myxosporidiosis is frequently found in earthen pond systems where long-term sediment buildup and the presence of annelid worms (intermediate hosts) are common.

- **Coccidiosis**: *Eimeria* spp. and related coccidian protozoa infect the intestinal tract of fish, causing internal haemorrhaging, poor digestion and general weakness. Although not invariably fatal, coccidiosis has a negative impact on growth and survival, particularly in juvenile fish.
- **Piscinoodinium (Velvet Disease)**: Caused by *Piscinoodinium pillulare*, this parasitic dinoflagellate creates a dusty, yellowish appearance on the fish's body and gills. It causes severe respiratory distress and is highly infectious in recirculating and high-density systems.

*Table 14 Tabular presentation of protozoan diseases, common signs and susceptible fish species*

| Disease Name | Causative Agent | Common Signs/Symptoms | Susceptible Fish Species | Classic Presentation |
|---|---|---|---|---|
| **Ichthyophthiriasis (Ich)** | *Ichthyophthirius multifiliis* | White cysts/spots on body and fins, flashing, laboured breathing, anorexia | Tilapia, catfish, carp | White "salt-like" spots; gill and skin irritation |
| **Trichodiniasis** | *Trichodina* spp. | Skin mucus excess, flashing, skin darkening, poor growth | Tilapia, carp, ornamental fish | Circular protozoa on gills and skin are seen under the microscope |
| **Costiasis (Ichthyobodoiasis)** | *Ichthyobodo necator* (formerly *Costia*) | Lethargy, skin cloudiness, increased mucus, and gill irritation | Tilapia, fry and fingerlings | Skin appears greyish/blue; heavy mucus on body and gills |
| **Hexamitiasis** | *Hexamita* spp./ *Spironucleus* spp. | Weight loss, anorexia, pale faeces, spiralling swimming, abdominal distension | Tilapia, ornamental fish | Seen mostly in the intestines, internal protozoa affect nutrition |
| **Epistylis Infection** | *Epistylis* spp. | Grey-white patches on skin, scale loss, haemorrhaging | Catfish, tilapia, and other freshwater | Sessile protozoa on skin, fins, or gills, appearing like fuzz |
| **Chilodonellosis** | *Chilodonella* spp. | Lethargy, gill damage, increased respiration, clamped fins, skin lesions | Tilapia, carp, ornamental fish | Flattened protozoan visible under the microscope on the gills/skin |
| **Ambiphryiasis** | *Ambiphrya* spp. | Excess mucus, skin sloughing, reduced | Tilapia, carp, catfish | Sessile protozoa on |

| | | | | |
|---|---|---|---|---|
| | | feeding, and respiratory distress | | gills are visible via wet mount microscopy |
| **Apiosoma Infection** | *Apiosoma* spp. | Skin lesions, ulcers, haemorrhages, poor condition | Tilapia, catfish, ornamental fish | Ciliate protozoa are found on injured or weakened fish |

Managing protozoan diseases in Zambian aquaculture requires a combination of good husbandry practices, regular health monitoring, improved water quality management, and biosecurity protocols. Early detection through routine microscopic screening and prompt treatment can significantly reduce mortality and economic losses.

**Viral Diseases in Fish in Zambia**

Although no viral diseases have been officially confirmed in Zambia's aquaculture sector, several viral pathogens pose a potential threat due to their global emergence and devastating effects, particularly in tilapia, the country's most widely farmed species. As fish farming intensifies, proactive disease surveillance and stringent biosecurity are essential to prevent viral incursions.

- **Tilapia Lake Virus (TiLV):** TiLV is a highly contagious virus affecting Nile tilapia (*Oreochromis niloticus*) worldwide. Though not yet detected in Zambia, its presence in neighbouring countries raises significant concern. Infected fish may exhibit skin erosion, eye lesions, abdominal swelling, and lethargy, often resulting in high mortality rates. Classic pathological signs include external haemorrhages, skin ulcers and necrosis of the liver and brain.
- **Infectious Spleen and Kidney Necrosis Virus (ISKNV)**: ISKNV has been linked to major die-offs in tilapia and ornamental fish in Asia and Africa. Infected fish typically present with darkened skin, erratic swimming, and swelling of the spleen and kidneys. Juveniles are particularly vulnerable, with high mortality rates. Though no cases have been recorded in Zambia, the expanding ornamental fish trade and increasing tilapia production make vigilance critical.
- **Tilapia Parvovirus (TiPV):** TiPV is an emerging viral pathogen associated with significant mortalities in fry and fingerlings. Symptoms include anorexia, pale internal organs, stunted growth, and high mortality — especially in

hatcheries. Infected fish may exhibit pale liver and kidney tissues. Although not confirmed in Zambia, poor hatchery management and the use of non-certified broodstock could increase the risk of introduction.

*Table 15 Tabular presentation of viral diseases, common signs, and susceptible fish species*

| Disease Name | Causative Agent | Common Signs/Symptoms | Susceptible Fish Species | Classic Presentation |
|---|---|---|---|---|
| **Tilapia Lake Virus (TiLV)** | *Tilapia Lake Virus* (TiLV, Orthomyxo-like virus) | Skin erosion, eye lesions, abdominal swelling, lethargy, and high mortality | Nile Tilapia (*Oreochromis niloticus*) | External haemorrhages, skin ulcers, liver and brain necrosis |
| **Infectious Spleen and Kidney Necrosis Virus (ISKNV)** | *Megalocytivirus* group (Family: Iridoviridae) | Darkened skin, erratic swimming, spleen and kidney swelling, haemorrhages, and mortality | Tilapia, ornamental fish | Enlarged spleen and kidney, high mortality in juveniles |
| **Tilapia Parvovirus (TiPV)** | *Tilapia parvovirus* (Family: Parvoviridae) | Anorexia, pale organs, high mortality in fry and fingerlings, poor growth | Nile Tilapia | Pale liver and kidney, stunting, severe losses in hatcheries |

While Zambia has not yet reported any of these viral infections, the aquaculture industry must prioritise early detection and prevention. Establishing national diagnostic capacity, enforcing biosecurity protocols, and monitoring regional disease trends will be crucial to protecting fish health and sustaining the sector's growth.

## General Treatment Options for Fish Diseases in Zambian Aquaculture

Effective treatment strategies in aquaculture are critical to maintaining fish health and ensuring sustainable production. In Zambia, treatment protocols must be tailored to address both infectious and non-infectious health issues in fish. These protocols typically involve a combination of chemical treatments, physical interventions, and, when necessary, culling of infected stock.

### *Chemical Treatments*

Chemical treatments are often employed in aquaculture to manage bacterial, protozoan, and fungal diseases. However, in Zambia, the use of these substances is not yet standardised, as formal treatment guidelines are still under development. It is, therefore, crucial for fish farmers and stakeholders to exercise caution and adhere to best practices, international safety standards, and local regulatory guidelines.

- **Salt (Sodium Chloride):** Common salt remains the most frequently used and accessible treatment for external parasites and fungal infections in Zambian aquaculture. Salt baths are relatively safe, cost-effective, and can significantly reduce ectoparasite loads when applied at appropriate concentrations.
- **Antibiotics:** Antibiotics are sometimes used in Zambia to manage bacterial infections, although comprehensive records of specific types in use are limited. Anecdotal evidence suggests the occasional use of broad-spectrum antibiotics such as oxytetracycline and chloramphenicol; however, the latter is prohibited in many countries due to safety concerns. Since antibiotics can disrupt biological filtration and contribute to antimicrobial resistance, their use should be minimised and monitored. Until national treatment guidelines are finalised, the use of antibiotics should be guided by veterinary consultation, water quality monitoring (particularly ammonia and nitrite levels), and environmental safety considerations.
- **Antiprotozoal and Antifungal Agents:** Although substances such as metronidazole, copper sulphate, acriflavine, thiabendazole, and potassium permanganate are globally recognised for treating protozoan and fungal infections, many of these agents are rarely or inconsistently used in Zambia. Furthermore, malachite green is banned due to its carcinogenic properties, and organophosphates, such as trichlorfon, are considered environmentally hazardous and undesirable, particularly in food fish production systems. Their use should be avoided.
- **Supportive Treatments:** Enhancing water quality remains a foundational aspect of disease prevention and treatment in Zambia. Disinfection of tanks, ponds, and equipment, combined with enhanced biosecurity and husbandry practices, is crucial to minimise disease outbreaks and facilitate fish recovery during treatment interventions.

In the absence of approved national treatment guidelines, Zambian fish farmers are encouraged to consult veterinary professionals and follow regional or international best practices for guidance and advice. The development and dissemination of Zambia-specific treatment protocols are urgently needed to ensure responsible chemical use and protect public health and aquatic ecosystems.

***Physical Interventions***

For less severe infestations or localised infections:

- **Manual Removal:** For larger fish with light parasitic infestations, physical removal of parasites (such as lice) using forceps can be effective (Hossain *et al.*, 1998).
- **Culling and Safe Disposal:** In instances where treatment is ineffective, or the disease has progressed extensively, humane culling, slaughter, or destruction of infected fish may be the most appropriate course of action to prevent further losses and reduce the risk of disease spread within and between aquaculture systems. As part of biosecurity protocols, it is essential to ensure that culled or dead fish are disposed of safely and responsibly to avoid contaminating water bodies and spreading pathogens to other fish populations, animals, or humans.

  Recommended safe disposal methods include:

  - Deep burial in a secure location away from water sources, lined with lime or disinfectants to neutralise pathogens.
  - Incineration, where facilities are available, to ensure the complete destruction of infectious agents.
  - Composting in a controlled and contained environment using high-temperature protocols, where appropriate, to degrade biological material safely.
  - Avoid feeding culled fish to animals, as this can perpetuate disease cycles.

  Proper disposal should be carried out using protective equipment, and contaminated tools or surfaces should be thoroughly disinfected afterwards. These measures are crucial to safeguarding fish health, farm productivity, and environmental integrity.

### *Addressing Underlying Conditions*

Often, disease outbreaks are exacerbated by unkempt conditions or overcrowding. In these cases, it is imperative to improve the overall management practices:

- **Optimising Stocking Density and Water Quality:** Adjust stocking densities and improve water quality management to reduce stress, which in turn decreases susceptibility to disease.
- **Biosecurity Measures:** Strengthen biosecurity protocols to prevent the introduction and spread of diseases, ensuring that treatment interventions are more effective and sustainable (Yanong and Erlacher-Reid, 2012).

### Important Considerations

- **Impact on Biological Filtration:** Antibiotic treatments can disrupt the biological filtration in tanks, making regular monitoring of ammonia and nitrite levels essential to maintain water quality (Boyd, 2018).
- **Chemical Safety:** Some treatment chemicals may pose risks to both fish and human health if not used correctly. It is essential to follow proper dosage instructions and wear protective clothing and gloves during handling.
- **Non-Infectious Health Issues:** Aside from infectious diseases, non-infectious issues such as congenital abnormalities, physical injuries, constipation (often due to diet) and poor nutrition also affect fish health. Addressing these issues requires improved feeding regimes and overall farm management (Okhueleigbe, 2021).

### Disease Reporting in Zambian Aquaculture

Accurate disease reporting is fundamental to safeguarding fish welfare and ensuring the sustainability of aquaculture in Zambia. All aquaculture facilities, both public and private, must maintain comprehensive records detailing disease incidents, treatments administered, transport conditions, mortality rates, and the specific causes of mortality. These records serve as critical data sources for monitoring fish health, identifying emerging disease trends, and informing management practices that improve production and welfare standards (FAO, 2022; Yanong and Erlacher-Reid, 2012). As a precautionary measure, any suspected cases of severe disease or unusual mortality should be reported immediately, even if a confirmed diagnosis has not yet been established. Prompt reporting enables swift response and the implementation of effective biosecurity measures, limiting the spread of infectious agents and mitigating economic losses.

In Zambia, official disease-reporting channels are in place, particularly for notifiable diseases of interest to the World Organisation for Animal Health (WOAH). The WOAH Focal Point for Aquatic Animals, located within the Department of Veterinary Services (DVS), is responsible for compiling reports on aquatic diseases. This officer reports to the WOAH Delegate, who is the Director of Veterinary Services, or may designate another officer to submit official reports directly to WOAH. An organogram adapted from the terrestrial animal disease reporting system (used by DVS) can be applied to aquatic systems, clearly outlining reporting responsibilities from the farm level to the national authority and international bodies. This ensures a coordinated and hierarchical flow of information, as well as compliance with both national legislation and international standards.

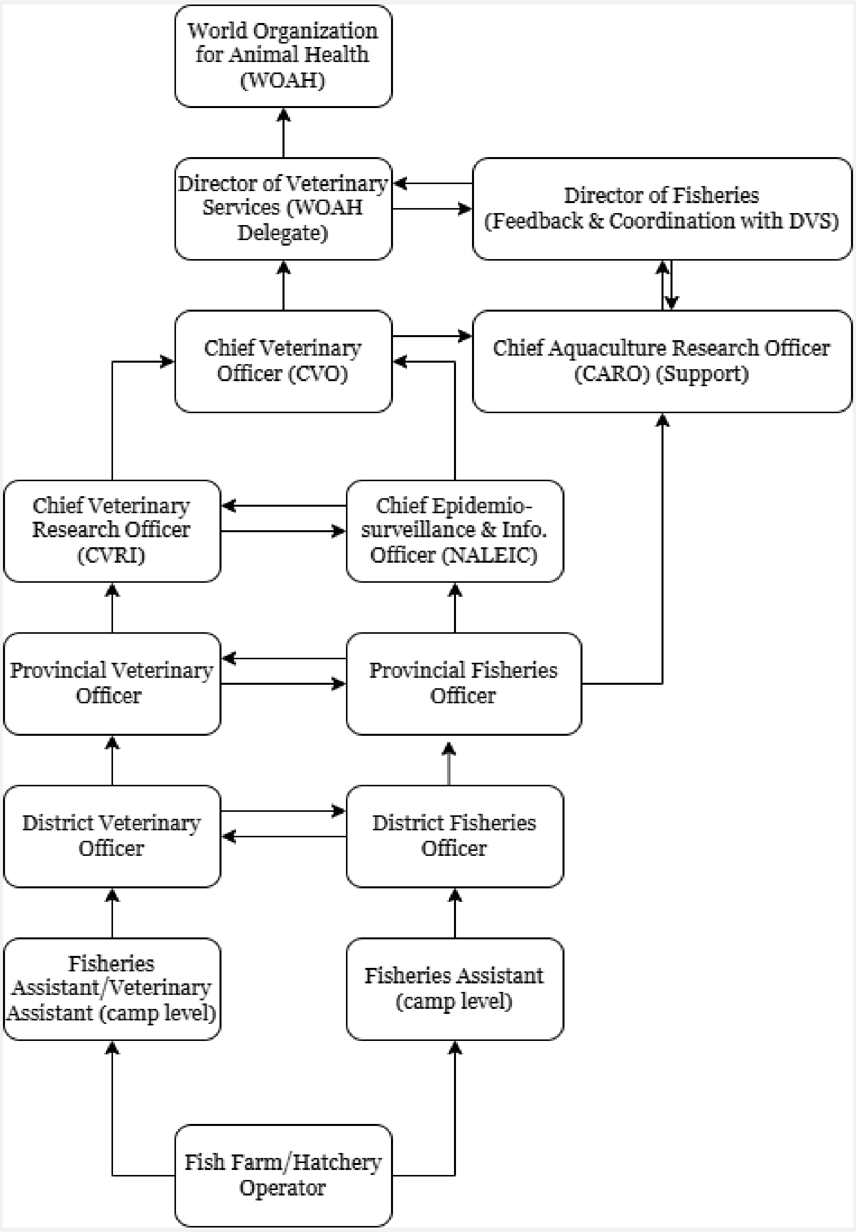


*Figure 21 Organogram illustrating disease reporting flow from the farmer to WOAH*

Robust disease surveillance and reporting systems are essential not only for regulatory compliance but also for early detection, effective containment, and prevention of future outbreaks in the Zambian aquaculture sector.

**Antimicrobial Resistance in Zambian Aquaculture**

Antimicrobial resistance (AMR) is defined as the ability of bacteria, viruses, fungi, and parasites to withstand the inhibitory or lethal effects of antimicrobial agents such as antibiotics, antifungals, antiparasitic drugs and antivirals. In aquaculture, the emergence of AMR poses a serious threat by enabling pathogens to survive and proliferate in the presence of these medications. This results in prolonged treatment durations, increased production costs, persistent disease outbreaks, higher mortality rates in fish and potential risks to public health through the food chain (Towers, 2014; WHO, 2021).

In Zambia, as in many low- and middle-income countries, the misuse and overuse of antimicrobials in aquaculture are key drivers of AMR. Limited awareness of prudent antimicrobial use, inadequate diagnostic capacity, and the lack of locally adapted treatment guidelines often lead to inappropriate or prophylactic antimicrobial use, especially in intensive production systems (Cabello, 2006; Chowdury *et al.*, 2022; Henriksson *et al.*, 2018; Adekanye *et al.*, 2020).

A recent study by Ndashe *et al.* (2022) provides evidence of antibiotic use and emerging resistance patterns in tilapia and catfish farms in Zambia, particularly in peri-urban and commercial aquaculture settings. The study identified tetracycline, oxytetracycline, and sulfonamides as among the commonly used antibiotics. Alarmingly, resistance was observed in *Aeromonas spp.*, *Pseudomonas spp.*, and other bacterial isolates recovered from aquaculture environments, highlighting a growing risk of treatment failure and environmental contamination.

Antibiotics in Zambian fish farms are often administered through medicated feeds, water baths, or direct injection, and improper use can lead to the accumulation of residues in fish tissues and surrounding water bodies. Failure to observe correct withdrawal periods further increases the likelihood that consumers ingest sub-therapeutic antibiotic residues, contributing to the evolution and spread of resistant microorganisms (Heuer *et al.*, 2009; Sapkota *et al.*, 2008).

Moreover, poor animal welfare and weak biosecurity measures, common in smallholder and poorly regulated operations, increase the likelihood of disease outbreaks and further reliance on antimicrobials (Cabello, 2006). Resistant pathogens and residual drugs may spread between aquatic systems and terrestrial environments through effluent discharge, posing wider ecological and public health threats (Goldburg and Naylor, 2005; Naylor and Burke, 2005; Chowdury *et al.*, 2022).

Efforts to combat AMR in Zambian aquaculture must therefore include strengthening regulatory oversight, promoting responsible use of antimicrobials, investing in diagnostic infrastructure, and building capacity for antimicrobial stewardship across the aquaculture value chain.

**Antimicrobial Resistance in Zambian Aquaculture: Spread, Impact and Mitigation Strategies**

Antimicrobial resistance (AMR) poses a significant challenge in aquaculture, as resistant bacteria can transfer from fish to humans through multiple pathways. In Zambia, AMR can be disseminated via:

- **Food Contamination:** Improper antimicrobial stewardship, such as misuse or overuse of antibiotics, leads to contamination of fish and fish products, facilitating the transfer of resistant bacteria to consumers (Towers, 2014).
- **Occupational Exposure:** Farm workers, fish keepers, abattoir personnel, veterinary practitioners and health workers are at risk through direct contact with treated fish and contaminated farm environments (Towers, 2014).
- **Environmental Transfer:** Resistant bacteria, resistance genes, and antibiotic residues can be disseminated into the environment via water discharge and waste, enabling horizontal gene transfer among microbial communities (Towers, 2014; Sarmah *et al.*, 2006).
- **Recreational Activities:** Individuals participating in recreational fishing and swimming in contaminated waters may also be exposed to resistant organisms (Towers, 2014).

The impact of AMR in aquaculture is profound. Antibiotics such as oxytetracycline, amoxicillin, and sulphadiazine-trimethoprim are extensively used to manage fish diseases and boost productivity. However, misuse and overuse lead to treatment failures, elevated production costs, and compromised fish welfare (Chowdury *et al.*, 2022; Schar *et al.*, 2020). Additionally, the widespread use of antimicrobials leads to significant environmental contamination through water distribution systems. This contamination alters the microbiome of aquatic environments, affecting their ecological balance and facilitating the spread of resistance genes (Sarmah *et al.*, 2006; Larsson *et al.*, 2018).

To combat AMR, Zambian aquaculture farmers should adopt an integrated approach that addresses animal, human, and environmental health. Key strategies include:

1. **Prudent Antimicrobial Use**: Implementing responsible antimicrobial usage protocols is essential to preserving the long-term efficacy of antibiotics in aquaculture. This includes strict adherence to veterinary prescriptions, avoiding self-medication, and limiting the prophylactic use of antibiotics, especially in intensive farming systems where disease risks are higher (FAO, 2016; Chowdury *et al.*, 2022). The development and availability of national treatment guidelines, currently underway in Zambia, are expected to significantly enhance antimicrobial stewardship. These guidelines will provide standardised approaches to diagnosis, treatment and withdrawal periods, thereby supporting fish farmers and veterinary professionals in making informed decisions. While their implementation is still in progress, it is hoped that their adoption will lead to more judicious and accountable use of antimicrobials, reducing the risk of resistance development across the aquaculture sector.
2. **Provision of Clean, Disease-Free Environments**: Maintain high water quality and robust biosecurity measures to prevent disease outbreaks, thereby reducing reliance on antimicrobials (FAO, 2022).
3. **Routine Monitoring:** Conduct regular monitoring of antimicrobial resistance during disease outbreaks to inform targeted interventions (Chowdury *et al.*, 2022).
4. **Adoption of Optimal Animal Welfare Practices**: Enhance fish welfare through improved husbandry and stress reduction, which bolsters immune function and decreases disease incidence (Schar *et al.*, 2020).
5. **Removal of Antibiotic Residues:** Employ advanced techniques such as adsorption, filtration, biological methods, sedimentation, and flocculation to eliminate antibiotic residues from water, thereby mitigating environmental impacts (Homem and Santos, 2011).

6. **Vaccination:** Vaccination remains a critical preventive strategy in aquaculture for controlling infectious diseases and reducing the reliance on antibiotics. Administering oral or injectable vaccines helps build immunity in fish populations against common bacterial and viral pathogens, thereby lowering disease incidence and associated losses (Newaj-Fyzul and Austin, 2015). In Zambia, ongoing research on vaccines for bacterial pathogens is being conducted in Lake Kariba, with key contributions from researchers such as Dr Chanda Chitala. These efforts signal progress toward the local development of effective fish vaccines, which, once validated and adopted, could significantly enhance disease prevention strategies across the aquaculture industry. Continued investment in vaccine research, development, and field trials will be essential to establish cost-effective and widely accessible immunisation programmes tailored to Zambian production systems.
7. **Use of Probiotics:** Consider using probiotics as an alternative strategy for preventing and controlling infections. Probiotics have been shown to help manage pathogens such as *Vibrio harveyi* in aquaculture (Chabrillon *et al.*, 2005).
8. **Immunostimulants and Phage Therapy:** Explore the application of immunostimulants, such as β-1,3 glucans, and broad-host-range bacteriophages in the management of infections. Phage therapy has shown promise in controlling bacterial infections where vaccines are unavailable (Ngamkala *et al.*, 2010; Castillo *et al.*, 2012).
9. **Traditional Medicinal Plants**: Investigate the use of locally available medicinal plants and seaweed extracts, such as those from mango, peppermint, turmeric, jasmine and neem, as alternative antimicrobials to treat bacterial infections in fish (Newaj-Fyzul and Austin, 2015).

Combating AMR in Zambian aquaculture requires the coordinated implementation of stringent animal health practices and biosecurity measures, supported by government regulation. By adopting these practices, farmers can reduce losses due to infectious diseases, minimise antimicrobial usage and ultimately curb the development and spread of AMR. Additionally, strict adherence to withdrawal periods established by local regulatory authorities is essential to ensure that antimicrobial residues are not present in fish products at harvest, thereby protecting consumer health (WOAH, 2023).

**Climate Change, Risk and Resilience in Aquaculture**

Climate change presents a growing threat to aquaculture, with direct and indirect implications for fish welfare, productivity and economic viability in Zambia. Rising water temperatures, shifting rainfall patterns, prolonged droughts, and extreme weather events, such as floods and heatwaves, affect water quality, increase fish stress, and amplify the risks of disease outbreaks, poor growth, and mortality.

In Zambia, small- and medium-scale fish farmers are particularly vulnerable due to limited access to climate-resilient infrastructure, adaptive technologies, and early warning systems. As climate-related impacts intensify, integrating resilience-building strategies into aquaculture management becomes essential.

**Key Climate-Related Risks to Fish Welfare**

- **Temperature fluctuations:** Can impair immune responses and growth rates.
- **Drought:** Reduces water availability, concentrating pollutants and pathogens.
- **Flooding:** Facilitates pathogen spread and fish escapes, undermining biosecurity.
- **Extreme rainfall:** Alters Pond salinity and pH, disrupting aquatic balance.

**Climate Resilience Strategies for Zambian Aquaculture**

- **Water management:** Invest in rainwater harvesting, efficient irrigation, and integrated water reuse systems.
- **Infrastructure:** Design climate-smart fishponds with drainage and flood control mechanisms.
- **Stocking strategies:** Optimise stocking densities and species selection to match seasonal water availability.
- **Early warning systems:** Strengthen meteorological services and disseminate timely forecasts to farmers.

- **Capacity building:** Train farmers in climate-resilient practices, risk assessment, and disaster preparedness.
- **Ecosystem-based adaptation:** Promote reforestation and wetland conservation to protect watershed health.

Mainstreaming climate resilience in Zambian aquaculture is not only a sustainability imperative but also a proactive welfare measure that protects both fish and livelihoods in an increasingly uncertain climate.

**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.

**Discussion Points**

1. What biosecurity measures do you have in place to prevent disease introduction and spread on your fish farm?
2. Have you experienced disease outbreaks on your farm? If so, how did you diagnose, treat, and control them?
3. Do you consult qualified professionals for fish health management, or do you rely on alternative diagnostic and treatment methods?
4. How do you currently use antibiotics on your farm, and do you consider it responsible antimicrobial stewardship?
5. Do you keep records of fish health, disease outbreaks and antibiotic usage? If so, how do you use them to improve disease management?

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@afiwelprogram

Africa Fish & Aquaculture Welfare

afiwelprogram@onehealthdev.org