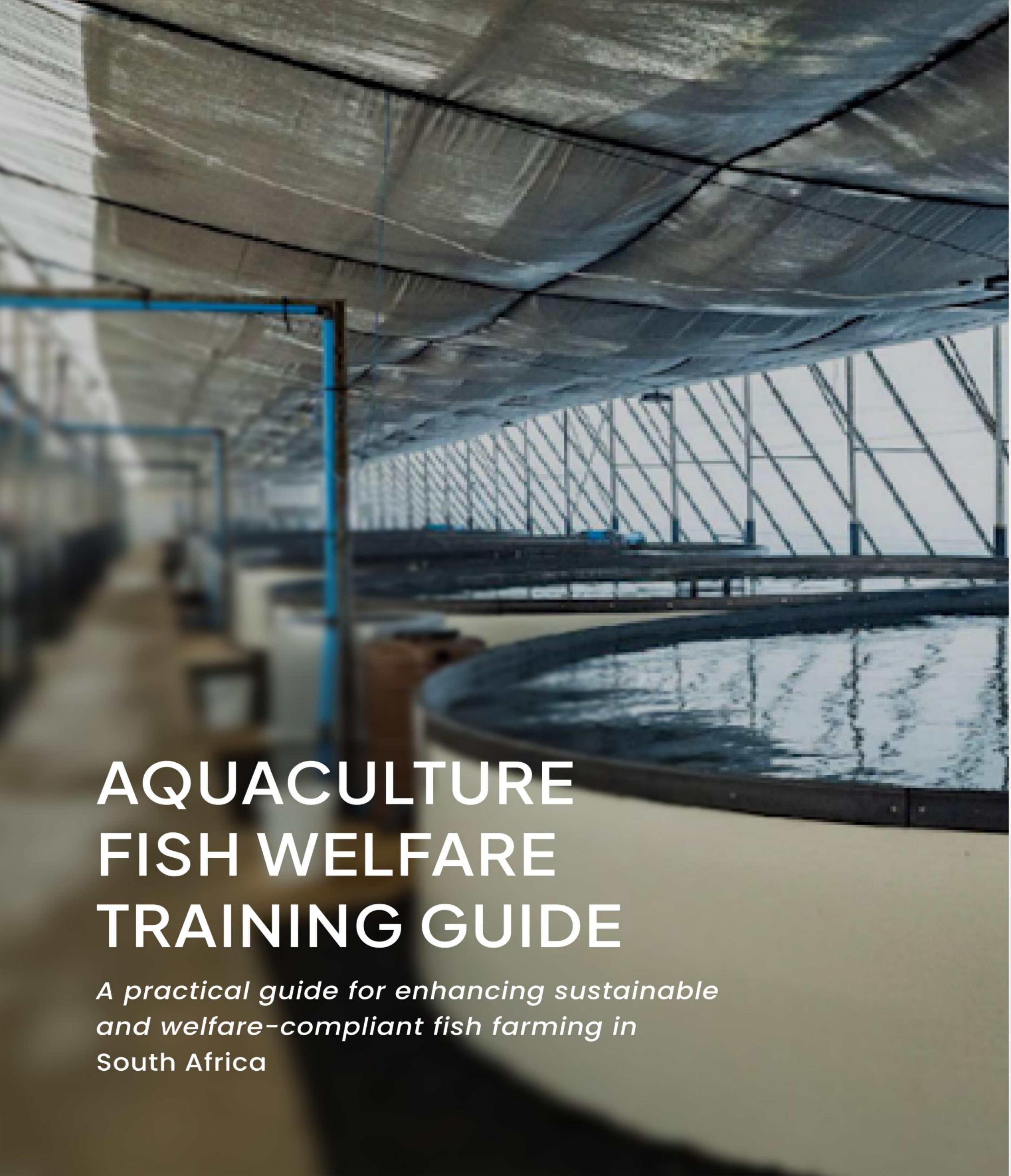

AQUACULTURE FISH WELFARE TRAINING GUIDE

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

OHDI
ONE HEALTH & DEVELOPMENT INITIATIVE

AFIWEL
Africa Fish and Aquaculture Welfare Program

South Africa

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PREFACE

Fish welfare is increasingly recognised as an essential pillar of sustainable and ethical aquaculture. In Africa, where aquaculture plays a vital role in food security, livelihoods, and economic growth, there is a growing urgency to integrate welfare principles into production systems, policy frameworks, and capacity-building efforts.

The Africa Fish and Aquaculture Welfare (AFIWEL) Program, implemented by the One Health and Development Initiative (OHDI), was established to address this need. AFIWEL is a pan-African initiative promoting ethical, welfare-driven, safe, and sustainable aquatic production systems. A central feature of the program is the AFIWEL Fellowship, which engages fisheries and aquaculture professionals across the continent in training, community building, and field implementation. Through this fellowship, AFIWEL equips professionals to advance fish welfare practices within education, stakeholder engagement, and policy advocacy.

This Fish Welfare Training Guide is one of several produced by AFIWEL Fellows. Developed specifically for the aquaculture realities of South Africa, it offers practical, evidence-based knowledge and tools for fish farmers, aquaculture workers, extension officers, animal health professionals, and institutions along the aquaculture value chain.

The guide combines global best practices, scientific insights, and local expertise to ensure that recommendations are technically sound and contextually relevant. It covers core aspects of fish welfare, including water quality, stocking densities, feeding, handling, transportation, health management, and humane slaughter, all anchored in the principles of freedom from pain, distress, discomfort, and suffering.

We invite you to use this guide as a resource for developing responsible aquaculture systems that prioritise animal welfare, enhance livelihoods, and foster long-term environmental sustainability.

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

LIST OF ACRONYMS

Acronym	Full Form
AAA	Aquatic Animal Alliance
ADZ	Aquaculture Development Zone
AfCFTA	African Continental Free Trade Area
ALI	Aquatic Life Institute
APA	Animal Protection Act
ASPCA	American Society for the Prevention of Cruelty to Animals
BA	Basic Assessment
BAP	Best Aquaculture Practices
CIWF	Compassion in World Farming
DFFE	Department of Forestry, Fisheries, and the Environment
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organisation
FWI	Fish Welfare Initiative
HBR	Hybrid Biofloc–Recirculating Aquaculture System
HSUS	Humane Society of the United States
IFAD	International Fund for Agricultural Development
ISO	International Organisation for Standardisation
MLRA	Marine Living Resources Act
NGO	Non-Governmental Organisation
NSPCA	National Council of SPCAs
OWI	Operational Welfare Indicator
RAS	Recirculating Aquaculture Systems
RSPCA	Royal Society for the Prevention of Cruelty to Animals
S&EIR	Scoping and Environmental Impact Reporting
SABS	South African Bureau of Standards
SDG	Sustainable Development Goal
SOFIA	State of World Fisheries and Aquaculture
WOAH	World Organisation for Animal Health (formerly OIE)

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MODULE 1: OVERVIEW OF AQUACULTURE IN SOUTH AFRICA

This module introduces the concept of aquaculture by providing a clear definition, explaining its importance, and exploring the various aquaculture systems used in South Africa, with a focus on their characteristics, benefits, and limitations.

INTRODUCTION TO AQUACULTURE

Aquaculture is the production of aquatic organisms, including fish, shellfish, crustaceans, and aquatic plants, in controlled freshwater, brackish water, or marine environments. Its importance includes improving household nutrition, conserving aquatic biodiversity, and enhancing income and employment opportunities. The Aquaculture processes include breeding, seed production, stock management during the culture period, harvesting, and post-harvesting.

Figure 1 Source: Status of the aquaculture sector; aquaculture year book, DFFE, 2023

The 2024 edition of the FAO's State of World Fisheries and Aquaculture (SOFIA) report marks a historic milestone: for the first time ever, aquaculture has surpassed capture fisheries in the production of aquatic animals. In 2022, global aquaculture production reached a record 130.9 million tonnes, with 94.4 million tonnes comprising aquatic animals, accounting for 51% of the total aquatic animal production, compared to 92.3 million tonnes from capture fisheries. This shift signals a structural transformation in global aquatic food systems, with farming now the dominant source of aquatic animal products. Overall, total fisheries and aquaculture production hit a record 223.2 million tonnes, highlighting the sector's growing role in global food systems.

Despite this progress, aquaculture remains geographically concentrated, with ten countries, led by China, Indonesia, India, Vietnam, and Bangladesh, accounting for nearly 90% of production. Asia dominates the overall production of aquatic animals, accounting for 70%, while Africa lags behind with only 7%. The FAO stresses that many low-income nations, particularly in Africa, have vast untapped potential. Achieving more equitable growth will require targeted policies, responsible investment, capacity building, and the transfer of technologies to regions where the benefits of aquaculture are most needed.

The report also underscores aquaculture's critical role in addressing food insecurity and malnutrition. In 2021, 89% of aquatic animal production was used for direct human consumption. Global per capita consumption of aquatic foods has more than doubled since 1961, increasing from 9.1 kg to 20.7 kg in 2022, which supplies 15% of the world's animal proteins and essential nutrients to billions. However, the FAO warns that per capita consumption in Africa may decline due to population growth outpacing supply, posing serious risks for regions that heavily rely on fish for nutrition.

The SOFIA report categorises South Africa as part of the wider Southern and Eastern Africa sub-region, yet it still highlights the country as the continent's most diversified and policy-active aquaculture producer. In terms of ecosystems and production footprint, marine cold-temperate coastlines, primarily along the Western and Eastern Cape, support intensive land-based and sea-cage farming of high-value species, such as abalone (Haliotis midae), dusky kob, and pilot projects on Atlantic salmon. Warm temperate estuaries and near-shore zones host mussel and Pacific oyster farming, while integrated seaweed–shellfish polyculture systems are emerging in the newly established Algoa Bay Aquaculture Development Zone (ADZ). Inland ecosystems also contribute to the sector, with high-altitude regions in Mpumalanga and KwaZulu-Natal supporting trout aquaculture and lowland pond systems producing tilapia and catfish. Although inland aquaculture volumes remain below 2,000 tonnes per year, they play a critical role in local food security.

Regarding culture species and production volumes for 2022, South Africa produced approximately 1,650 tonnes of abalone, maintaining its position as the fifth-largest producer of farmed abalone globally. Mussels and oysters had a combined output of around 6,800 tonnes, with Saldanha Bay being the major site for mussels and Knysna and Walvis Bay leading oyster production. Trout farming contributed approximately 2,100 tonnes (including both rainbow and brown trout), while warm-water finfish, such as tilapia, catfish, and dusky kob, accounted for less than 1,500 tonnes. However, production is growing due to the increasing adoption of recirculating aquaculture systems (RAS) and Biofloc technology.

Despite its potential, the sector faces several challenges, including high input costs (especially for feed, energy, and biosecurity), complex and overlapping permitting processes between national and provincial authorities, limited freshwater availability in drought-prone areas, and skills shortages in specialised areas such as genetics, fish health, and hatchery management. Market access is another constraint, with South African producers facing long distances to major Asian markets and stiff competition from lower-cost producers. Another critical issue is the theft of fish and machinery at fish farms, which has led to the closure of numerous enterprises in recent years, as highlighted by Madibana et al. (2020).

Nonetheless, the sector is presented with several opportunities: the government's Operation Phakisa initiative has prioritised aquaculture, unlocking blended financing and streamlined licensing processes; Aquaculture Development Zones in Saldanha, Algoa Bay, and Richards Bay offer pre-cleared farming sites with shared infrastructure; and technological innovations like RAS and seawater well boats are improving water efficiency and biosecurity. Furthermore, partnerships with local universities (such as Rhodes and Stellenbosch) and international bodies like the FAO are strengthening training and capacity-building initiatives. South Africa's reputation for producing premium abalone, mussels, and certified organic trout gives it a competitive advantage in high-value markets, while the African Continental Free Trade Area (AfCFTA) opens new regional market opportunities.

The South African aquaculture industry is composed of 204 farms (marine and freshwater) producing (DFFE, 2024). However, the total number of aquaculture farms has declined over time, with 229 farms recorded in 2018, 225 in 2019, 201 in 2020, and 195 in 2021. The 2022 DFFE, South Africa Aquaculture Yearbook, indicate a total production of approximately 7,000 tonnes. This output encompasses various marine and freshwater species, with abalone, mussels, oysters, and trout being the primary contributors. The Western Cape Province dominates the sector, accounting for over 80% of the national production, followed by the Eastern Cape at around 12.75%.

Biosecurity is crucial for sustainable aquaculture in South Africa, especially in preventing the spread of disease and maintaining access to international markets. Although the impact of diseases and parasites on production is not fully understood, significant investments are being made to prove freedom from WOAH-listed diseases. WOAH defines biosecurity as a set of management and physical measures aimed at reducing the risk of introducing, establishing, and spreading diseases, infections, or infestations within, to, or from animal populations. This includes measures such as controlled access, disinfection, quarantine, and compartmentalisation to prevent pathogen transmission between farms, regions, or countries. WOAH defines disease as any clinical or non-clinical signs of infection or exposure to an agent that causes abnormality or impairment of an animal's normal functions. As the sector is expected to grow rapidly, implementing strong biosecurity systems is increasingly important.

FISH PRODUCTION SYSTEMS IN SOUTH AFRICA

South Africa's aquaculture is dominated by marine and freshwater species. The sector utilises a combination of land-based systems (ponds, tanks, and recirculating aquaculture systems) and sea-based installations (cages, rafts, and long-lines). Key marine commodities remain abalone (*Haliotis midae*), dusky kob (*Argyrosomus japonicus*), Mediterranean blue mussel (*Mytilus galloprovincialis*), farmed alongside the indigenous black mussel (*Choromytilus meridionalis*), and Pacific oyster (*Crassostrea gigas*). Freshwater aquaculture in South Africa includes a vast array of mainly alien species, ranging from Tilapia (*Oreochromis mossambicus* and *Oreochromis niloticus*), Sharptooth catfish (*Clarias gariepinus*), Rainbow trout (*Oncorhynchus mykiss*), Brown trout (*Salmo trutta*), Ornamental koi and Carp (*Cyprinus carpio*), and Marron (*Cherax tenuimanus*) (i.e. freshwater crayfish), forming the bulk of commercial production.

In fresh water, the dominant species by volume is rainbow trout (*Oncorhynchus mykiss*), followed by African sharptooth catfish (*Clarias gariepinus*). Tilapia, principally Mozambique (*Oreochromis mossambicus*) and the Marron crayfish (*Cherax cainii*) remain experimental, while common carp (*Cyprinus carpio*) and its koi variety (*C. carpio var. koi*) are farmed mainly for ornamental markets alongside aquarium species such as guppies (*Poecilia reticulata*), swordtails (*Xiphophorus hellerii*), and goldfish (*Carassius auratus*). (DFFE Aquaculture Yearbook 2023; Babatunde et al. 2021). Abalone continues to dominate South Africa's aquaculture industry, contributing approximately 909 million Rands, or 90% of the total industry value in 2022. This is followed by oysters at 6%, with tilapia and Pacific salmon each accounting for 1%.

Freshwater aquaculture production is most concentrated in Limpopo Province, followed by Gauteng, Mpumalanga, KwaZulu-Natal, and the Western Cape. According to the 2023 Aquaculture Yearbook by the Department of Forestry, Fisheries, and Environment, aquaculture is practised across all nine provinces of South Africa. Freshwater production dominates in the inland provinces, while marine production is more prevalent in the four coastal provinces. In 2022, a total of 204 operational farms were recorded, comprising 163 freshwater fish farms and 41 marine fish farms. The number of active fish farms has increased by nine, up from 195 farms in 2021 (DFFE, 2023). In South Africa, freshwater farms utilise Recirculating Aquaculture Systems (RAS), ponds, aquaponics and earthen ponds to culture several species. Marine farms utilise rafts, longlines, ponds, cages and Integrated Multi-Trophic Aquaculture Systems (IMTAs). The culture systems utilised are further explained below:

Recirculating Aquaculture Systems (RAS)

Recirculating aquaculture systems (RAS) are closed-loop, tank-based setups that enable fish to be grown at high densities under controlled environmental conditions. Water moves from the fish tanks through a treatment process and is then returned to the tank, hence the term "recirculating aquaculture systems," allowing the facility to reuse 90–99% of its water and significantly reduce waste, chemical use, and escapes (Aich et *al.* 2020). By conserving water, enhancing biosecurity, and boosting output, RAS can multiply fish production while relying on limited

Figure 2 RAS System (Source-Status of the aquaculture sector; aquaculture year book, DFFE, 023)

resources. Because water exchange is minimal, indoor RAS employ biofiltration to maintain both ionised and unionised ammonia at safe levels (Ebeling and Timmons, 2010). Successful operation depends on effective filtration, skilled management, proper feeding, and reliable equipment and power. In South Africa, most catfish farmers are small-scale producers who utilise RAS and pond systems across Mpumalanga, Limpopo, KwaZulu-Natal, Gauteng, North West, and the Eastern Cape.

Pond Culture System

Pond culture is one of the most practised methods of raising fish in earthen or lined ponds, which are naturally or artificially supplied with water. This method is particularly suited for freshwater species such as tilapia and catfish due to their adaptability to varying environmental conditions (Noble *et al.,* 2020). Earthen ponds are less expensive to construct and maintain compared to advanced systems. Ponds can utilise natural food sources, such as phytoplankton and zooplankton, thereby reducing reliance on commercial feeds (Moyo and Rapatsa, 2021). However, poor management can lead to degradation of water quality and eutrophication of surrounding ecosystems.

Aquaponics

Aquaponics integrates aquaculture and hydroponics into a symbiotic system where fish waste supplies nutrients for plant growth, and the plants, in turn, purify the water for the fish (Palm *et al.,* 2019). This innovative, productive, and sustainable system holds significant potential for addressing challenges in agriculture, such as drought, soil pollution, and the impacts of climate change.

Figure 3 Aquaponics in South Africa (Source: Borgen Project, 2018)

Tilapia is the most commonly farmed fish in South African aquaponics systems, accounting for 82% of production, while leafy vegetables dominate plant cultivation, comprising 75% of crops grown (Mchunu *et al.,* 2018). However, many current practitioners have limited knowledge of aquaponics production techniques. To fully harness the potential of aquaponics, efforts should focus on raising awareness about its benefits and providing technical training to operators. This would not only increase the number of aquaponics operations but also boost food production, contributing to food security and agricultural innovation.

Cage Culture

Cage culture is an aquaculture system in which fish are raised in floating net pens that allow free water exchange. The cages confine the fish while the surrounding water removes waste and supplies fresh, oxygenated water. This method is used to rear various finfish and shellfish species in freshwater, brackish, and marine environments (Soltan, 2016; Devi *et al.,* 2017). This system is efficient in utilising water resources, cost-effective, and scalable, making it suitable for both small-scale and commercial production in appropriate locations (Schmittou, 2024). However, it comes with risks, such as theft and degradation of water quality due to the accumulation of waste, like uneaten food and fish excrement, which can lead to eutrophication and impact surrounding ecosystems. Additionally, cage culture is vulnerable to diseases and predation by wild animals, which can result in significant losses if not managed effectively. In South Africa, cage culture is mainly practised in marine and freshwater environments, farming species such as tilapia, trout, and, more recently, marine finfish like yellowtail and dusky kob. However, the practice is largely confined to the Gansbaai and Saldanha Bay areas in the Western Cape due to the region's high-energy coastline, which limits its widespread adoption (Babatunde *et al.*, 2021).

Integrated Multi-Trophic Aquaculture Systems (IMTA)

Integrated Multi-Trophic Aquaculture (IMTA) is a sustainable system that combines species from different trophic levels, repurposing waste from one species as resources for others, such as shellfish or aquatic plants (Nissar *et al.*, 2023). This approach promotes ecological sustainability by recycling nutrients, minimising waste discharge, and reducing aquaculture's environmental impact. Studies highlight the economic and ecological benefits of IMTA, with species like oysters and mussels thriving when integrated with fish such as salmon (Lander *et al.*, 2013; Dong *et al.*, 2018). However, IMTA systems require careful management to balance the needs of different species, making them complex but promising for sustainable aquaculture.

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 afiwelprogram@onehealthdev.org or contact@animalwelfarecourses.com
- Share your questions on the Discussion Forum on the online training platform for Fish Welfare at www.animalwelfarecourses.com

DISCUSSION

- Introduce yourselves. Farmers to describe their fish farm; culture system, species of fish, number of fish, location, successes, and challenges, etc.) Others (non-farmers) should discuss why they are taking the course and what benefits they hope to gain.
- What is/are the most common fish farming system(s) practised in your area? Why is this system common?
- Tell us which fish farming system you prefer the most and why. Share your personal experiences (if any) with your preferred fish farming system, including the advantages and disadvantages.
- Have you practised integrated aquaculture before? If yes, share details of the integrated fish farm system, your experience with it, and what you consider as advantages and disadvantages of the system.
- What strategies can be implemented to mitigate the high energy requirements of recirculating aquaculture systems (RAS) to make them more cost-effective and environmentally sustainable, especially in regions with limited access to renewable energy sources?

MODULE 2: INTRODUCTION TO ANIMAL WELFARE

This module provides a foundational introduction to animal welfare, outlining core principles and the rationale for their importance. It introduces the Five Freedoms and the Five Domains of animal welfare, while highlighting common animal and fish welfare challenges and poor practices. The module also offers an overview of provisional country-level legal frameworks on animal welfare in South Africa, providing context for how welfare principles are being recognised and applied nationally.

OVERVIEW AND HISTORY OF ANIMAL WELFARE

Although once a marginalised discipline, the field of animal welfare has grown significantly over the past three decades, driven by a growing recognition of the link between animal sentience and well-being. Initially, animal welfare focused primarily on physical health, early disease detection, and basic animal management (Pinillos *et al.,* 2015). However, the field has since expanded to encompass a deeper understanding of animals' social behaviour, cognitive abilities, and capacity to experience pain and suffering. Farm animal welfare, in particular, has become a pressing concern for both society and the food production industry. To accurately assess farming practices and prevent poor welfare conditions, it is essential to consider not only the behavioural needs of animals but also their cognitive capacities (Nawroth *et al.,* 2019).

The following section outlines key chronological milestones in the evolution of animal welfare (Animal Rights Movement, 2023):

1. **Ancient Civilisations (Prehistoric times - 600 BCE):** Early human societies had varying attitudes toward animals, ranging from reverence and protection to exploitation. Some ancient civilisations, like the ancient Egyptians and

Greeks, held certain animals in high regard and established laws to protect them.

2. **Religious Influence (600 BCE - 1800 CE):** Religious texts, such as the Old Testament in Judaism and Hindu scriptures, promoted compassion and respect for animals. Philosophers like Pythagoras and later Saint Francis of Assisi advocated for the ethical treatment of animals.
3. **Animal Welfare Movement (1800s):** The Industrial Revolution brought increased urbanisation and factory farming practices, leading to concerns about animal welfare. Influential figures such as Richard Martin and William Wilberforce in Britain campaigned for the welfare of working animals and passed laws against animal cruelty.
4. **Formation of Animal Welfare Societies (19th century):** Animal welfare societies, such as the Royal Society for the Prevention of Cruelty to Animals (RSPCA), founded in 1824, emerged to promote animal welfare and enforce animal protection laws.
5. **Laboratory Animal Welfare (20th century):** Concerns grew regarding the use of animals in scientific experiments, leading to the establishment of regulations and guidelines for laboratory animal welfare. Organisations like the American Society for the Prevention of Cruelty to Animals (ASPCA) and the Humane Society of the United States (HSUS) expanded their work to address animal experimentation.
6. **Modern Animal Welfare Movement (Late 20th century - Present):** Animal welfare concerns expanded to various areas, including factory farming, animal entertainment, and wildlife conservation. Animal welfare legislation and regulations are being enacted globally, focusing on issues such as animal transportation, humane slaughter, and the use of animals in entertainment. Non-Governmental Organisations (NGOs) and grassroots movements are playing a significant role in advocating for animal welfare and raising awareness about animal cruelty.

However, despite these remarkable improvements in best practices globally, poor animal welfare practices persist and remain a significant challenge. This apparent neglect has been attributed to several reasons, including poor awareness, inadequate resources, flawed policy frameworks, and socio-cultural influences (such as traditional or religious biases), among other constraints.

On a more positive note, animal welfare is also receiving increasing recognition as an important contribution to an interconnected myriad of animal, human, environmental and ecosystem health (One Health), and sustainable development outcomes. This has led to the development of the ongoing '*One Welfare*' concept, which encourages interdisciplinary partnerships to improve animal and human welfare simultaneously, incorporating the environmental components of welfare (Marchant-Forde and Boyle, 2020).

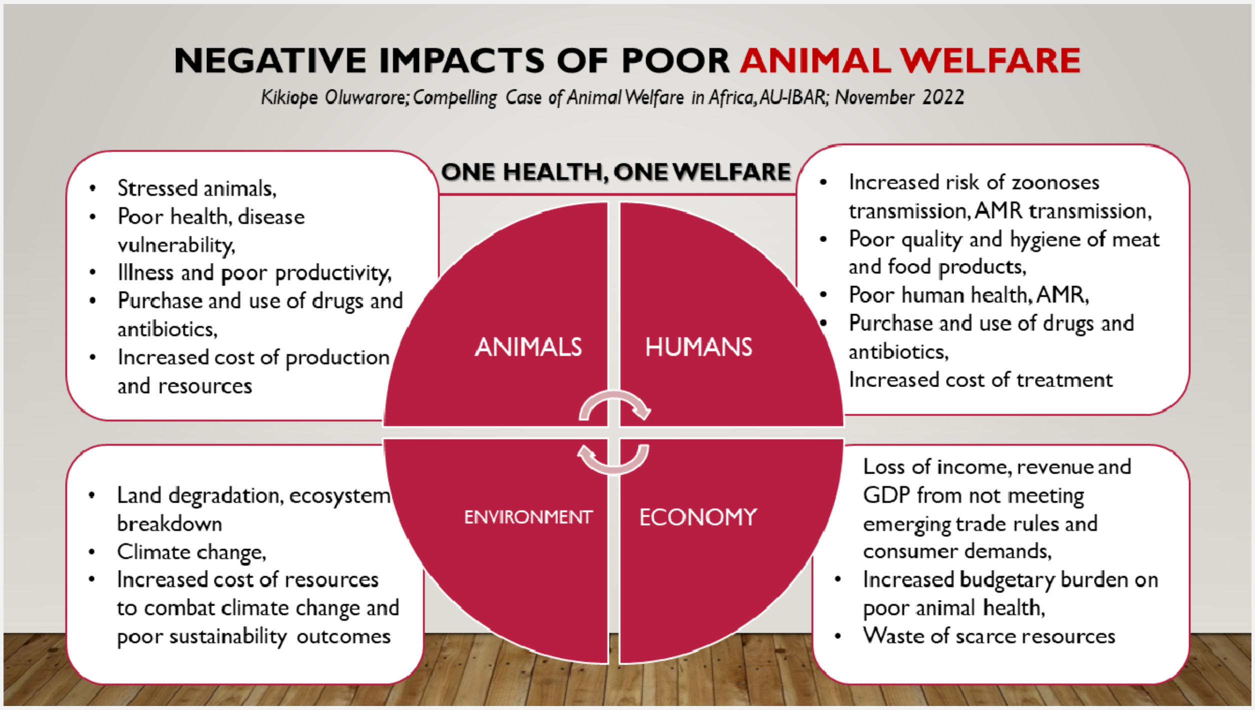

Figure 4 Oluwarore (2022), Compelling Case of Animal Welfare in Africa, AU-IBAR, Africa Conference for Animal Welfare, November (2022)

According to Compassion in World Farming (CIWF, 2020), addressing welfare concerns such as housing and good management practices has positive impacts on animal health, farms' environmental footprint, and economic and social performance. This recognition has stimulated concerted efforts by stakeholders at all levels to improve the welfare of animals, reduce their pain and suffering, and enhance their health and well-being.

UNDERSTANDING ANIMAL WELFARE

The Five Freedoms of Animal Welfare

In the quest for improved animal welfare, a major advancement is the development of the "Five Freedoms of Animal Welfare". This has contributed to the recognition, understanding and establishment of good animal welfare systems and practices. The Five Freedoms of Animals are globally validated basic guidelines and indicators used to determine the welfare status of animals, including fish. It has been touted by several in-country and international animal health and welfare organisations, including the World Organisation for Animal Health (WOAH). The 'Five Freedoms' include: freedom from thirst and hunger, freedom to display natural, typical behaviour, freedom from discomfort, freedom from fright and despair, as well as freedom from disease, pain, and injury (Mellor, 2016).

1. **Freedom from hunger and thirst:** By ready access to fresh water and a diet to maintain health and vigour. This must be specific to the animal.
2. **Freedom from discomfort:** Meaning the provision of a comfortable environment that involves a healthy and good quality water ecosystem, and an existence that is devoid of restrictions, unpleasant perceptions, and harsh environmental conditions.
3. **Freedom from pain, injury, and disease:** Meaning providing adequate care and environmental conditions that are devoid of (but not limited to) any form of infliction of painful or injurious experience, provision of standard fish management practice and biosecurity measures, prompt and quality veterinary care and treatment, and good antimicrobial stewardship.

4. **Freedom to express normal and natural behaviour:** This includes the provision of conditions that are not unduly restrictive in which the fish can move around (including swimming and other fish locomotion, vocalising, feeding, and interacting with other fish) within the considerable limits of a protected and safe environment, duplicating its natural settings or environment as much as possible.
5. **Freedom from fear and distress:** This includes considerate humane treatment of animals in a manner that does not induce fear, anxiety, distress, or other forms of psychological suffering to the animals.

It is essential to note that while all Freedoms have their distinct roles, they logically feed into and impact each other in various ways. For example, an animal's "freedom from hunger and thirst" contributes to the satisfaction of the other four Freedoms (Animal Humane Society, 2025).

The Five Domains of Animal Welfare

Although the Five Freedoms of Animal Welfare provide a strong basis for assessing animal welfare standards, a more updated framework, known as the Five Domains of Animal Welfare, has since been established. The five domains include Nutrition, Environment, Health, Behaviour, and Mental Domains. These domains are described as a science-based best practice framework for assessing animal welfare and quality of life.

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

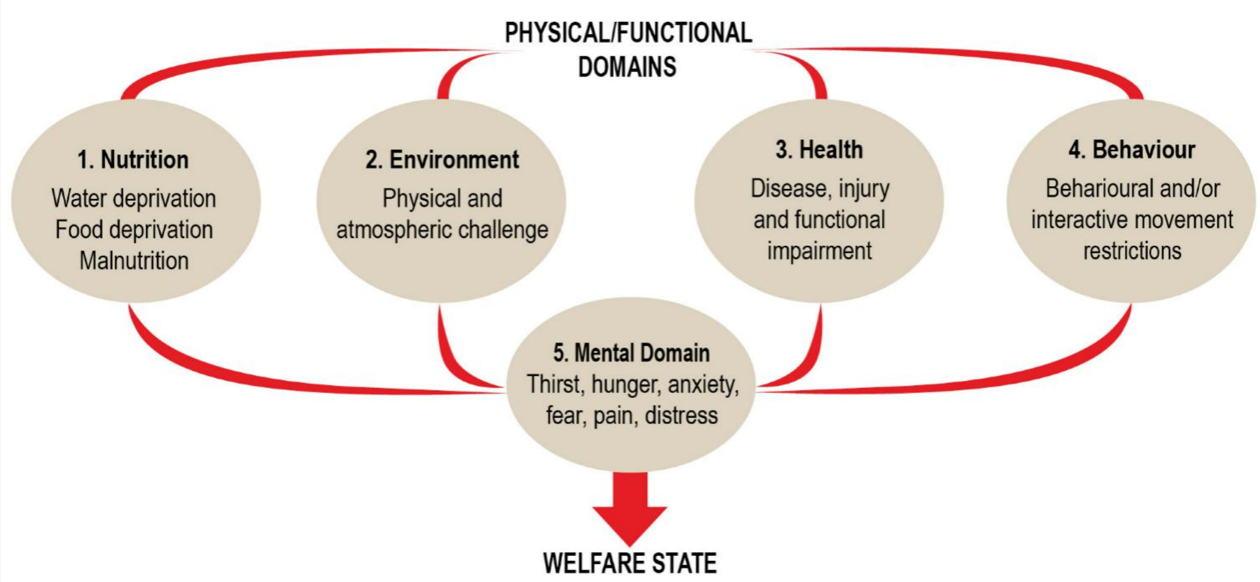

Figure 5 Five Domains of Welfare (Source – Mellor et al., 2020)

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

Comparing and Integrating the Five Freedoms and Domains

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

Table 1 Comparing Five Freedoms and Five Domains (Source – RSPCA)

Five Freedoms	Five Domains
1. From hunger and thirst	1. Nutrition
2. From discomfort	2. Environment
3. From pain, injury and disease	3. Health
4. To express normal behaviour	4. Behavioural interactions
5. From fear and distress	5. Mental state/experiences

KEY ANIMAL WELFARE VIOLATIONS

In many countries, it is seen that several violations of the Five Freedoms of Animals occur to varying degrees. However, animal abuse is becoming less accepted worldwide, and animal welfare is highly regulated in many countries, such as South Africa, where Section 2(1) of the Animal Protection Act 1962 outlines acts of cruelty that are prohibited (Government Gazette Extraordinary, 22 June 1962).

Any person who inflicts one or more of the following actions on any animal listed hereinabove shall be guilty of an offence:

a) Cruelly overloads, overrides, beats, kicks, goads, ill-treats, neglects, infuriates, terrifies, tortures or maims any animal; or
b) Confines, chains, tethers or secures any animal unnecessarily or under such conditions or in such a manner or position as to cause that animal

unnecessary suffering or in any place which affords inadequate space, ventilation, light, protection or shelter from heat, cold or weather; or

c) Unnecessarily starves or under-feeds or denies water or food to any animal; or

d) Lays or exposes any poison or any poisoned fluid or edible matter or infectious agents except for the destruction of vermin or marauding domestic animals or without taking reasonable precautions to prevent injury or disease being caused to animals; or

e) Being the owner of any animal, deliberately or negligently keeps such animal in a dirty or parasitic condition or allows it to become infested with external parasites or fails to render or procure veterinary or other medical treatment or attention which he is able to render or procure for any such animal in need of such treatment or attention, whether through disease, injury, delivery of young or any other cause, or fails to destroy or cause to be destroyed any such animal which is so seriously injured or diseased or in such a physical condition that to prolong its life would be cruel and would cause such animal unnecessary suffering; or

f) Uses on or attaches to any animal any equipment, appliance or vehicle which causes or will cause injury to such animal or which is loaded, used or attached in such a manner as will cause such animal to be injured or to become diseased or to suffer unnecessarily; or

g) Save for the purpose of training hounds maintained by a duly established and registered vermin club in the destruction of vermin, liberates any animal in such manner or place as to expose it to immediate attack or danger of attack by other animals or by wild animals, or baits or provokes any animal or incites any animal to attack another animal; or

h) Liberates any bird in such manner as to expose it to immediate attack or danger of attack by animals, wild animals or wild birds; or

i) Drives or uses any animal which is so diseased or so injured or in such a physical condition that it is unfit to be driven or to do any work; or

j) Lays any trap or other device for the purpose of capturing or destroying any animal, wild animal or wild bird the destruction of which is not proved to be necessary for the protection of property or for the prevention of the spread of disease; or

k) Having laid any such trap or other device fails either himself or through some competent person to inspect and clear such trap or device at least once each day; or

l) Except under the authority of a permit issued by the magistrate of the district concerned, sells any trap or other device intended for the capture of any animal, including any wild animal (not being a rodent) or wild bird, to any person who is not a bona fide farmer; or

m) conveys or carries any animal:

  i. Under such conditions or in such a manner or position as to cause that animal unnecessary suffering; or
  ii. In conditions affording inadequate shelter, light or ventilation or in which such animal is excessively exposed to heat, cold, weather, sun, rain or dust; or
  iii. Without making adequate provision for food, water and rest for such animal; or

n) Without reasonable cause, administers to any animal any poisonous or injurious drug or substance; or

o) Keeps, uses, manages, assists or acts in the management of any premises or place used for the purpose or partly for the purpose of fighting of any animal or receives any consideration for the admission of any person to any such premises or place; or

p) Being the owner of any animal, deliberately or without reasonable cause or excuse, abandons it, whether permanently or not, in circumstances likely to cause that animal unnecessary suffering; or
q) Causes, procures or assists in the commission or omission of any of the aforesaid acts or, being the owner of any animal, permits the commission or omission of any such act; or
r) By wantonly or unreasonably or negligently doing or omitting to do any act or causing or procuring the commission or omission of any act, causes any unnecessary suffering to any animal.

Any person who inflicts one or more of the above-mentioned acts on any animal will be liable on conviction to a fine, imprisonment not exceeding twelve (12) months, or imprisonment without the option of a fine.

LEGAL FRAMEWORKS FOR ANIMAL WELFARE IN SOUTH AFRICA

According to the World Animal Protection Organisation, the main animal welfare legislations in South Africa are the Animal Protection Act No. 71 of 1962, which prohibits animal cruelty on all domestic and wild animals in captivity or under the control of humans; and the Performing Animals Act 1935, amended in 2016, which requires establishments training animals for exhibitions or performance, or training guard dogs, to be licensed. Furthermore, the South African Bureau of Standards (SABS), in cooperation with the National Council of SPCAs (NSPCA), have enacted a series of animal welfare Standards, which provide further details in relation to certain species of animals.

Unfortunately, wild animals that are not in captivity or under the control of any person do not enjoy protection under the APA. The APA thus applies to the owners of wild and domesticated animals and offers protection to the following categories of animals: Equine (horses or any member of the horse family); and Bovine (animals classified as cattle); Sheep; Goats; Pigs; Fowl (larger domestic or egg-producing birds, including but not limited to chickens, ducks, and geese);

Ostriches; Dogs; Cats; Other domestic animals or birds; and any wild animal, bird or reptile in captivity or under the control of any person. However, there are some provisions in other related laws. These include the:

1. **Animal Diseases Act, 1984:** Animal means any mammal, bird, fish, reptile or amphibian which is a member of the phylum vertebrates, including the carcass of any such animal. To provide for the control of animal diseases and parasites, for measures to promote animal health, and for matters connected therewith.
2. **Animal Health Act, 2002:** To provide for measures to promote animal health and to control animal diseases; to assign executive authority with regard to certain provisions of this Act to provinces; to regulate the importation and exportation of animals and things; to establish animal health schemes; and to provide for matters connected therewith.
3. **Performing Animals Protection Act, 1935:** To regulate the exhibition and training of performing animals and the use of animals for safeguarding.
4. **Sea Fishery Act 12 of 1988:** The Act intends to provide for the conservation of the marine ecology and the orderly exploitation, utilisation and protection of certain marine resources; for that purpose, to provide for the exercise of control over sea fishery; and to provide for matters connected therewith.
5. **The South African Veterinary Strategy (2015-2020) (DFFE, 2025):** Good animal welfare requires disease prevention and veterinary treatment, appropriate shelter, management, nutrition, humane handling and humane slaughter/killing. The South African Veterinary Strategy promotes the well-being of animals and humans through creating systems and mechanisms for the provision of effective and efficient veterinary services. The strategy targets to; improve on the technical capabilities to address current and new animal health, welfare and production issues based on

scientific principles; to acquire sufficient financial capital to attract adequate human resources and retain professionals with technical and leadership skills; to promote and strengthen collaboration and partnership between government and non-governmental sector; and to create/maintain an enabling animal and public health environment for the ability to access local and international markets. The plan builds on the priority outcomes as defined by the government, the constitutional and legislative mandate, the National Development Plan, as well as the international conventions and guidelines of the World Organisation for Animal Health (Office international des Epizooties- OIE), Food and Agriculture Organisation of the United Nations (FAO) and Codex Alimentarius. The Veterinary strategy covers the health of all animals in South Africa kept for conservation, entertainment, zoos, food production, farming, and sport. It also covers wild animals and animals used in research where there is a risk of them transmitting disease to other animals or to humans. The strategy also covers the health of animals transported to, from and within South 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 afiwelprogram@onehealthdev.org or contact@animalwelfarecourses.com
- Share your questions on the Discussion Forum on the online training platform for Fish Welfare at www.animalwelfarecourses.com

DISCUSSIONS

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

MODULE 3: INTRODUCTION TO FISH WELFARE

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

What Is Fish Welfare?

Just like the definition for the welfare of animals, a fish (farmed or wild) is in a state of good welfare if it is in good health with all its biological systems working appropriately; can lead a natural life and meet its "behavioral needs" in the environment; is free of negative experiences (such as pain, fear, hunger, thirst, distress); has access to positive experiences (such as social companionship, other positive experiences: relational contentment, environmental compatibility, happy co-existence, and conducive environment); and can adapt to its environment. To guide understanding of Fish Welfare, the Aquatic Life Institute has established specific indicators that are tailored to the welfare of fish and aquatic animals. They are referred to as the "Five Welfare Pillars of Fish", and they include environmental enrichment, feed composition, space requirements and stocking density, water quality, and stunning and slaughter.

Figure 6 The Five Pillars of Fish Welfare (Source - Aquatic Life Institute (ALI))

Benefits of Improved Fish Welfare

From a functional perspective, good welfare in animals is characterised by their ability to cope effectively with infectious and non-infectious stressors, thereby maintaining homeostasis and overall health. In contrast, exposure to prolonged stress or poor husbandry conditions can compromise this coping ability, resulting in impaired health (Segner *et al.,* 2012). When fish are kept in less-than-ideal conditions, their bodies must adjust to the stress in order to maintain balance. These adjustments require a lot of energy. This extra energy demand can reduce the energy available for other vital functions, like protecting the skin, gills, and gut, or supporting the immune system. As a result, their natural defences can become weakened, making them more prone to disease.

1) Improved fish health: Health and function-related parameters can act as operational welfare indicators (OWIs) in aquaculture, providing practical and effective tools for assessing fish welfare (Segner *et al.,* 2012). According to McEwen and Wingfield (2009), stress is defined as a state of threatened homeostasis that is restored through a complex network of physiological changes. In response to a perceived stressor, fish initiate a broad physiological stress response, enabling them to adapt and cope with both predictable and unpredictable environmental changes - a process known as eustress. As part of the primary stress response, cortisol and catecholamines are released into the bloodstream, triggering a cascade of downstream reactions (Pankhurst, 2011). Notably, stress is not inherently detrimental, nor does it immediately signify compromised welfare. In the short term, it serves as a crucial adaptive mechanism to enhance survival chances. However, when stress leads to an allostatic overload, typically caused by prolonged, repeated, or unavoidable stressors, it results in maladaptive effects, including impaired growth, reproductive dysfunction, and compromised immune function (Boonstra, 2013).

2) Improved quality of life: The adoption of high standards of animal welfare improves the quality of life for animals being reared and produces improved end products for consumers. Practices such as environmental management and food supplementation, which ensure a better quality of life for the animals being reared, are directly related to the sustainability of production and the perception of sustainable fish farming (Neto and Giaquinto, 2020). It is reasonable to assume that the rearing system or operation is fulfilling, and has not markedly impacted their welfare needs if the fish look good, are doing well, are in good health, show normal behaviour and are thriving. If not, there is something wrong, and this should be investigated further (Stein *et al.,* 2020). The aquaculture industry requires good water quality for its successful operation, but it also produces waste that can cause environmental deterioration and pose significant risks to the operation. Water quality is a critical factor in aquaculture success, influencing fish health, growth, and overall productivity. A slight change in some of the parameters, especially pH, temperature, and DO, will lead to stress in the organism, and it may be of a physiological or behavioural nature. Deteriorated or altered water quality will affect the growth and reproductive capacity of broodstock, leading to increased susceptibility to diseases (Yusoff *et al.,* 2024).

3) Meeting emerging trade and consumer demands: Animal health is a cornerstone of animal welfare, and in the last decade, fish welfare has gained significant attention. This increased focus has driven the aquaculture industry to adopt various husbandry practices and technologies specifically designed to improve the lives of farmed fish. Enhanced fish welfare is becoming essential to address emerging trade and consumer demands in aquaculture. Recent studies underscore this trend, with national and international authorities establishing legislation and guidelines to ensure high welfare standards (Kadri *et al.,* 2012). For example, the Council of Europe implemented recommendations for fish rearing practices in 2006 (Council of Europe, 2006), and the WOAH has incorporated fish welfare into its Aquatic Animal Health Code, aiming to harmonise welfare standards across its 178-member countries (Cooke, 2016).

Similar to terrestrial animals, fisheries are influenced by social constructs, which shape regulations, product availability, consumer acceptance, and marketing strategies, particularly in industrialised countries. Among the emerging concerns is animal welfare, including pre-slaughter and slaughter practices. While welfare is complex to define and measure, several indicators can reliably assess it in fish. These indicators include behavioural changes (such as reduced feeding, abnormal swimming, or aggression), physical condition (like skin lesions, fin damage, or poor body condition), physiological responses (such as elevated cortisol levels or changes in respiration), growth and reproductive performance, and mortality rates (Martins *et al,* 2012). Monitoring these signs can help identify stress and suboptimal conditions, allowing for timely intervention to improve fish well-being. These indicators are integrated into good production practices, focusing on stress reduction throughout the fish's life cycle. Effective management to minimise stress has been shown to improve the physical quality, nutritional value, and shelf life of fishery products (Rasco *et al.,* 2015).

In the European Union, fish welfare has become a significant issue, driven largely by the demands of retailers and consumers. Studies reveal a growing willingness among consumers to pay more for products associated with higher welfare standards. For instance, a survey in Denmark found that 48% of respondents were willing to pay a premium for farmed rainbow trout with a quality label certifying good welfare practices (Solgaard & Yang, 2011). These findings underscore the importance of integrating welfare considerations into aquaculture to meet consumer expectations, enhance market competitiveness, and promote sustainable industry growth.

4) Improved productivity and sustainable livelihoods: Fisheries and aquaculture are vital sources of food and income in many developing countries, functioning as stand-alone activities or in combination with agriculture and livestock rearing (Allison, 2011). While food security and poverty reduction remain central to global development agendas, their focus has evolved in response to population growth, technological advancements, economic shifts, and environmental changes. Food security highlights the importance of coordinated policy, economic, and social efforts to address consumer demand, improve food access and supply, and enhance nutrition (Grafton *et al.*, 2015).

Animal welfare, a vital aspect of sustainable food systems, is often described through three main lenses: biological functioning, the capacity to express natural behaviours, and, most importantly, affective states-how animals feel. Recognising and promoting positive emotional experiences is increasingly seen as central to ensuring good welfare. Aquaculture has undergone significant evolution, enabling it to emerge as a major provider of high-quality protein, thereby enhancing food security and alleviating poverty (Dwyer, 2020).

Over time, Best Aquaculture Practices (BAP) have been developed and continuously updated to incorporate advancements in science, technology, and industry standards. These practices encompass all aspects of production, including site selection, proximity to other farms, facility construction and maintenance, management protocols, stock selection and acquisition, nutrition, biosecurity, disease control, and processing (Can *et al.*, 2023). Ongoing challenges in aquaculture, such as pollution from uneaten feed and waste, as well as the competing needs of other waterway users (e.g. fishing, recreation, and tourism), continue to be addressed through research and regulation. BAP have been formalised into accredited standards, such as ISO 9000, and is integral to certification programs like those of the Global Seafood Alliance. These standards ensure that aquaculture production remains environmentally sustainable, socially responsible, and economically viable.

5) Food Quality and Safety: Improved fish welfare is essential for ensuring food quality and safety in aquaculture, as it helps reduce contaminants, diseases, and production-related challenges in farmed fish. Stress in fish can lead to immunosuppression, thereby increasing susceptibility to foodborne pathogens and compromising food safety (Estrada, 2023). Significant scientific advancements have been made in fish welfare across various stages of production, including farming, transportation, pre-slaughter handling, and stunning or killing procedures. Research by Daskalova (2019) provides compelling evidence that fish can experience pain and suffering. Stress responses not only raise ethical concerns but also alter post-mortem metabolism, impairing meat quality. Other factors influencing the quality of farmed fish include diet, selective breeding, and husbandry practices (Lie, 2008).

Biosecurity plans are critical for mitigating the economic and environmental impacts of disease outbreaks in aquaculture. These plans focus on prevention, early detection, and effective control measures to combat the global threat of emerging infectious diseases while promoting sustainable production practices. Proper biosecurity measures prevent diseases, protect the environment, and ensure food safety, though they may involve high costs and potential environmental trade-offs. Aly and Fathi (2024) recommend prioritising sustainable biosecurity strategies to enhance disease prevention, minimise environmental impact, and maintain product safety and quality. Monitoring systems and welfare assessment strategies are becoming increasingly important in addressing societal concerns and meeting market demands for animal welfare in food production (Blokhuis *et al.,* 2003).

Practical approaches to improving welfare include the implementation of reliable on-farm monitoring systems to evaluate the animals' welfare status and identify potential risks. Transparent communication of welfare standards through labelling and traceability in the food chain is vital for building consumer trust and ensuring the sustainability of aquaculture. By integrating effective welfare strategies and robust biosecurity measures, the aquaculture industry can address ethical concerns, enhance food safety, and secure its role in sustainable food production. Overall, prioritising fish welfare is crucial for ensuring the production of high-quality, safe seafood that aligns with consumer expectations.

6) Sustains a healthy ecosystem and environment: Key environmental factors, such as stocking density and water quality, are critical determinants of fish welfare in aquaculture systems. Water quality parameters, including oxygen and ammonia levels, directly affect fish health and welfare, for example, while higher stocking densities can reduce growth, feed conversion efficiency, and lead to fin erosion (Ellis *et al.*, 2002), their impacts depend heavily on specific environmental conditions. Poor water quality exacerbates welfare issues, as seen in rainbow trout farming, where increased stocking density can negatively affect water quality, provoke aggressive behaviours, and increase non-aggressive stress interactions (Yildiz *et al.*, 2017). Effective welfare management in aquaculture relies on maintaining optimal environmental conditions, monitoring key welfare indicators, and promptly addressing any deviations from these conditions. This holistic approach ensures not only the health and welfare of farmed fish but also the sustainability and productivity of aquaculture systems.

7) Contribution to Sustainable Development: Fisheries and aquaculture play a vital role in advancing nearly all of the United Nations Sustainable Development Goals (SDGs). Organisations like WorldFish have committed to reducing poverty and hunger by promoting sustainable practices in both sectors, with a strong focus on small-scale operations in developing countries, where fish are essential for livelihoods, nutrition, and food security (Kura, 2018). Sustainable fisheries and aquaculture, alongside improved fish welfare, directly support SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), and SDG 5 (Gender Equality). Inland fisheries, in particular, play a central role in achieving these goals by providing income, nourishment, and dietary diversity for millions globally.

The approach to managing fisheries and aquaculture has evolved beyond maximising production and yields. It now encompasses their broader contributions to household incomes, food systems, nutrition, resilience, and inclusive governance (Lynch *et al.,* 2020). Ensuring animal welfare, including the welfare of fish, not only supports these outcomes but also strengthens alignment with SDG 12 (Responsible Consumption and Production) and SDG 14 (Life Below Water), which emphasise sustainable resource use and conservation of aquatic ecosystems (Keeling *et al.,* 2019). Although animal welfare is not explicitly mentioned in the SDGs, the principles underlying sustainable development are inherently compatible with improving animal welfare (Keeling *et al.,* 2019). Recognising the importance of inland fisheries and integrating them into development policies can create synergies across multiple SDGs, ensuring a holistic and sustainable approach to addressing global challenges (Lynch *et al.,* 2020).

8) The right thing for fish: Regardless of whether fish are cultured for the aquarium trade, scientific research, or restocking to enhance fisheries or for aquaculture purposes, ensuring their well-being is essential. Good health is a critical component of fish welfare, with signs of injury, infection, or a compromised immune system serving as key indicators of poor welfare. The immune system, in particular, reflects a fish's capacity to resist disease. Stress, however, can suppress immune function, increasing susceptibility to infections. A high incidence of disease and mortality often signals environmental issues, though even fish in optimal conditions can suffer from outbreaks and epidemics (Huntingford and Kadri, 2014).

The intensive culture of fish for food raises significant concerns regarding animal welfare. High stocking densities in aquaculture settings often prioritise group management over the needs of individual fish, which can lead to welfare compromises. White and Suárez (2022) emphasise that fish welfare should be addressed at the individual level, not just the group level, as welfare pertains to how each fish experiences its environment. Providing individualised care becomes especially challenging in high-density settings, where the sheer scale of operations can overshadow the needs of individual animals.

As fish farming continues to grow, it is essential to balance ethical considerations with industry demands by addressing welfare at both individual and group levels. The aquaculture industry has made progress by adopting Codes of Practice that integrate fish welfare considerations. However, significant challenges remain, particularly in providing individualised care in large-scale systems. To advance fish welfare, robust scientific research is necessary to develop and validate operational welfare indicators that can be effectively implemented under practical farming conditions. These indicators must not only reflect the health and behaviour of fish but also provide actionable insights for improving farming practices (Segner *et al.,* 2012; White and Suárez, 2022). A holistic approach that prioritises both the ethical treatment of individual fish and the sustainability of aquaculture systems is critical for the future of the industry.

Introduction to Fish Welfare Practices

The expansion of aquaculture and the increasing use of fish in research highlight the need for enhanced welfare measures (Toni *et al.,* 2019). Fish welfare is gaining attention across recreational and commercial fishing as well as aquaculture, where proper handling practices are essential for reducing stress, minimising mortality, and ensuring biosafety (Adesina *et al.,* 2017). Key stressors, including poor water quality, handling, transportation, and confinement, have a significant impact on fish health in both aquaculture and the ornamental trade (Stevens *et al.,* 2017). Capture-based aquaculture presents unique welfare challenges, as wild-caught fish are not genetically adapted to intensive farming conditions, rendering them more susceptible to stress compared to domesticated species (Chandararathna *et al.,* 2021). Effective welfare management requires maintaining optimal water quality, appropriate stocking densities, high-quality feed, and protection from diseases and predation (Adesina *et al.,* 2017). Implementing these measures not only improves fish welfare but also enhances overall production efficiency.

Human activities, including fisheries and aquaculture, significantly influence fish welfare. The impact varies depending on the species, life stage, and environmental conditions. For instance, while high stocking densities can negatively affect welfare, maintaining good water quality can mitigate these effects. Conversely, at lower densities, poor water quality may be less of an issue, but increased social interactions could lead to other welfare concerns. Chronic stress, characterised by prolonged activation of the stress response, results in immunosuppression, reduced growth, and reproductive dysfunction (Huntingford *et al.,* 2006). Physiological markers, disease prevalence, and behavioural changes serve as key indicators of chronic stress and overall fish welfare.

According to the Aquaculture Yearbook 2023 published by the Department of Forestry, Fisheries, and the Environment (DFFE), a range of freshwater fish species are commonly farmed in South Africa. Each of these species requires specific welfare considerations to support sustainable and ethical aquaculture practices. Commonly cultivated species include trout, tilapia, catfish, common carp, marron crayfish, and ornamental fish. In addition to these, several other species have been trialled on various farms for research purposes, such as the white stumpnose (*Rhabdosargus globiceps*), South Coast Sea urchin (*Tripneustes* *gratilla*), South African scallop (*Pecten sulcicostatus*), and Mozambique tilapia (*Oreochromis mossambicus*) (DFFE, 2023). Though there are species-specific considerations and contexts to cater for, general welfare practices can be implemented across fish species. From the inception of fish production systems to growing, production, handling, slaughter, and processing, fish welfare practices should be implemented throughout the entire process. Details on specific fish welfare practices for different stages of aquaculture production and management are discussed in subsequent modules.

Q&A Session

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

If 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

- What new knowledge have you gained from this lecture on fish welfare today?
- Drawing experience from your own fish farm (or working with fish farmers), discuss how you plan to adapt and utilise your knowledge of the "Five Pillars of Animal Welfare in Aquaculture."
- Among all the benefits listed, what are the top 3 benefits that you look forward to getting when you implement fish welfare? Why?

MODULE 4: GROWING SYSTEMS AND FISH WELFARE

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

When starting a fish farm, several key factors must be carefully evaluated, as they directly impact fish health, welfare, productivity, and overall return on investment. Water quality is one of the most critical elements in successful aquaculture, as it significantly influences fish growth, disease resistance, and profitability. The quality and availability of the water source are essential in determining the farm's location and production capacity. Assessing water suitability requires analysing physicochemical properties, potential anthropogenic pollutants, and biological factors. Species selection should be based on their adaptability to the available water conditions, ensuring optimal growth and survival. Additionally, site selection, cage design, stocking density, and feeding practices must be carefully planned to create a sustainable and efficient aquaculture system.

Site Selection

Site selection is crucial for the success and sustainability of fish farming operations. Various factors must be considered, including economic, social, environmental, and infrastructural aspects. Important considerations include water quality, sediment characteristics, and the biological requirements of the chosen species. Proper site selection can help avoid stress conditions for cultured species and ensure the commercial viability of aquaculture operations (Maleri, 2008).

Location and structure of growing facilities

One of the most critical steps in establishing a successful fish farm is selecting the right site. The location of your farm significantly impacts productivity, operational efficiency, and long-term viability. Edwards (2015) describes a suitable site as one with a reliable water source, optimal water quality, and proper infrastructure to support the construction of a pond or tank. Additionally, climate and temperature conditions must align with the requirements of the selected fish species. Regulatory compliance is another key factor. In South Africa, marine aquaculture activities, including farming, harvesting, and the transportation of aquaculture species for wholesale trade, are governed by the Department of Forestry, Fisheries, and Environment (DFFE). The DFFE regulates these activities through permits issued under the Marine Living Resources Act, 1998 (Act No. 18 of 1998) (MLRA) and its associated regulations.

Beyond managing the biological aspects of fish farming, business planning is crucial for sustainability. A comprehensive business plan should outline farm objectives, projected expenses, expected revenue, and overall profitability. Key cost considerations include infrastructure, equipment, feed, labour, and marketing. Given the high startup costs, securing funding is often necessary to support the business. Potential funding sources include loans, grants, and specialised agricultural financing programs. Despite the potential for aquaculture growth in Southern Africa, several barriers have hindered its full realisation. One of the primary challenges is the high capital investment required, which limits entry for individuals and communities. Additionally, many aspiring fish farmers lack the necessary technical expertise and industry connections.

Environmental Impact Assessment

The Department of Environmental Affairs has commissioned an Environmental Impact Assessment (EIA) and an Environmental Management Guideline for Aquaculture in South Africa to assist stakeholders in complying with environmental legislation governing aquaculture development. This guideline provides essential background on integrated, responsible, and sustainable environmental management practices (DFFE, 2011). It serves as a structured framework for minimising the environmental impact of aquaculture while ensuring that development aligns with legal requirements.

In South Africa, the EIA process includes two key assessment methods: Basic Assessment (BA) and Scoping and Environmental Impact Reporting (S&EIR). The choice between these processes depends on the scale and potential environmental impact of the proposed aquaculture project. BA is a streamlined evaluation for projects with lower environmental risks, requiring a less intensive review. In contrast, S&EIR is a more comprehensive and detailed investigation, applied to projects with potentially significant environmental impacts. This tiered approach ensures that environmental considerations are proportionate to the scope and nature of each aquaculture initiative.

Construction of culture facilities or growing systems (Pillay, 2008)

The success of an aquaculture project largely depends on selecting a suitable site for a fish farm or hatchery. Several key factors must be carefully considered to ensure sustainability, efficiency, and profitability:

1. Ecological Factors:

- Reliable water supply and quality
- Climate and temperature suitability
- Hydrological characteristics (water flow, depth, and availability)
- Soil properties for pond construction and water retention
- Land availability and suitability for development

2. Biological and Operational Factors:

- Selection of fish species suited to local conditions
- Availability of stocking materials (spawners, fry, or fingerlings)
- Type and scale of the aquaculture project

- Access to skilled labour and technical expertise

3. Economic and Social Factors:

- Alignment with regional development plans
- Land ownership, regulations, and legal restrictions
- Access to essential infrastructure, such as equipment, feed, and hatchery facilities
- Proximity to markets and transportation networks, including all-weather roads

Rearing Systems

Aquaculture, which involves farming aquatic organisms in various water environments, encompasses a diverse range of farming techniques and systems. These systems can be classified based on multiple factors, including species, scale, environment, and water use. However, one of the most common classification methods is by production system, which broadly categorises aquaculture into cage culture, tank culture (including raceway systems), and pond culture (DFFE, 2011).

General considerations for improved welfare in a fish culture System

Section one of the Fish Welfare Initiative (FWI) Report outlines three key conditions essential for improving fish welfare in aquaculture:

- **General Awareness:** A broad understanding of the welfare challenges fish face in aquaculture settings.
- **Species-Specific and Contextual Knowledge:** Detailed insights into the specific fish species, farming system, and local environmental conditions being addressed.
- **Farm-Level Welfare Assessment:** A comprehensive evaluation of the welfare status of fish within the farm environment. Ensuring that all stakeholders have access to this knowledge is crucial for promoting responsible and sustainable fish farming practices.

Common Growing Facilities and Welfare Considerations

Recirculating Aquaculture Systems (RAS)

Ahmed and Turchini (2021) describe Recirculating Aquaculture Systems (RAS) as eco-friendly, water-efficient, and highly productive intensive farming systems that minimise environmental impact. Unlike traditional aquaculture methods, RAS do not contribute to habitat destruction, water pollution, eutrophication, or biodiversity loss caused by escaped captive or exotic species. Additionally, Recirculating Aquaculture Systems (RAS) significantly reduce the risk of disease outbreaks and parasite transmission due to their controlled and bio-secure environment. However, if a disease or infection is introduced into the system, it can spread rapidly within the closed-loop system, making management and containment more challenging and potentially turning it into a high-risk operation. One of the key advantages of RAS is its controlled indoor environment, which makes it less vulnerable to external climatic factors such as rainfall variability, floods, droughts, global warming, cyclones, salinity fluctuations, ocean acidification, and rising sea levels. This stability enhances both fish welfare and farm productivity.

Figure 7 Recirculating Aquaculture Systems (RAS) (Source: DFFE, 2023)

Key Welfare Considerations for RAS Systems (Yanong, 2004)

- **Proper nutrition management:** Ensuring high-quality feed to promote fish health.
- **Rigorous system maintenance:** Keeping the system clean to prevent parasite proliferation.
- **Prompt removal of dead or moribund fish:** Reducing disease risks by immediate disposal.
- **Strict biosecurity measures:** Preventing cross-contamination between systems.
- **Use of disinfectants:** Sanitising equipment such as nets and footbaths, especially at critical locations (e.g. entrances and exits of quarantine buildings, hatcheries, and RAS facilities).

Consultation with specialists

Seeking advice from fish health or aquaculture experts to determine the most effective disinfectants (UF/IFAS Fact Sheet VM-87: Sanitation Practices for Aquaculture Facilities).

Concrete Ponds

A concrete fish pond is an artificial structure specifically designed for fish farming, constructed using reinforced concrete, which is known for its durability and strength. This material ensures long-lasting, stable ponds that offer several advantages over earthen ponds. According to Agbaire et al. (2015), concrete fish ponds provide superior control over water quality parameters, which is essential for maintaining fish health and optimising growth. Additionally, they allow for easier monitoring and management, making them suitable for both novice and experienced farmers (Olaoye *et al.,* 2014).

Another key advantage of concrete ponds is their adaptability in design. They can be built in various shapes and sizes to accommodate different farming needs and space constraints. As aquaculture continues to expand as a sustainable and profitable industry, concrete fish ponds stand out as a reliable option for maximising yield and ensuring fish well-being (Aihonsu *et al.*, 2007). Proper planning is essential when constructing a concrete fish pond. Several critical steps must be followed to ensure its efficiency, functionality, and long-term success.

Concrete pond construction (agric4profits.com)

Figure 8 Concrete fish pond (Source; Aquaculture Year Book, DFFE, 2023)

Step 1: Planning and Design: Define the pond's size, shape, and depth.

Step 2: Site Selection: Choose an appropriate location.

Step 3: Marking and Excavation: Outline the pond and excavate to the required depth. It typically ranges from 1.2 to 1.5 metres, providing sufficient space for the fish to move and grow while maintaining optimal oxygen levels.

Step 4: Installing Formwork: Build the formwork for shaping the pond.

Step 5: Placing Rebar: Insert reinforcement bars to strengthen the structure.

Step 6: Installing Drainage and Inlet Systems: Set up pipes for effective water management.

Step 7: Mixing and Pouring Concrete: Prepare and pour the concrete mix.

Step 8: Curing the Concrete: Allow the concrete to harden and gain strength.

Step 9: Removing Formwork: Carefully remove the formwork after the concrete has cured.

Step 10: Applying Waterproofing: Seal the concrete to prevent water leakage.

Step 11: Filling the Pond: Rinse and fill the pond with water.

Step 12: Stocking the Pond: Introduce fish to the pond.

Step 13: Maintenance: Regularly monitor water quality and fish health.

Fish welfare issues in concrete ponds

Welfare concerns and potential hazards in aquaculture include water quality deterioration, overcrowding, and handling stress (Vis *et al.,* 2020). On-farm husbandry practices and biosecurity measures play a crucial role in directly influencing fish welfare. To mitigate these challenges, experts recommend strategies such as reducing stocking densities, enhancing water quality monitoring, and developing more effective vaccines. Concrete fish ponds often encounter issues such as poor water quality, excessive algae growth, fish diseases, and structural deterioration. Effective solutions include:

- **Water Quality Issues:** Regularly test and monitor water parameters to ensure optimal conditions. Conduct partial water changes as needed and use water conditioners to maintain stability.
- **Algae Control:** Manage algae growth by regulating nutrient levels, minimising direct sunlight exposure, and using water replacement or algaecides when necessary. To prevent excess nutrient build-up, avoid overfeeding and maintain proper waste management practices.
- **Fish Diseases:** Maintain high water quality and prevent overcrowding to minimise disease risks. Quarantine new fish before introducing them to the pond. In case of disease outbreaks, promptly diagnose the issue and apply appropriate treatments or seek professional veterinary assistance.
- **Structural Integrity:** Regularly inspect the pond for cracks or leaks. Use concrete patching compounds for minor repairs and seek professional assistance for significant structural damage.

Aquaponics culture system

Aquaponics is a sustainable and innovative farming method that seamlessly integrates aquaculture (fish farming) with hydroponics (soilless plant cultivation). This closed-loop system maximises water efficiency, boosts crop yields, and offers an eco-friendly alternative to traditional agriculture by reducing reliance on non-renewable resources (Nair et al., 2025; Farmers Magazine, 2024). In this system, fish waste provides essential nutrients for plant growth, while plants naturally filter and purify the water, creating a self-sustaining, symbiotic environment. An ideal aquaponics site requires ample sunlight or access to grow lights, proper ventilation, and proximity to a reliable water source (Shafeena, 2016). In South Africa, where natural sunlight is abundant, harnessing solar energy can enhance plant growth while lowering energy costs, making aquaponics a particularly viable and sustainable solution.

Figure 9 Aquaponics system (Source: Department of Ichthyology and Fisheries Sciences, Rhodes University, 2023)

Factors to consider when setting up an aquaponics system

- **Site Selection:** Choose a location with ample sunlight or access to artificial grow lights, proper ventilation, and a reliable water source.
- **Fish Selection:** Select fish species well-suited to aquaponics and your local climate, such as tilapia, trout, or catfish, ensuring they thrive in your system conditions.
- **Establishing the Nitrogen Cycle:** Allow for an initial cycling period to cultivate beneficial bacteria that convert fish waste into essential plant nutrients, ensuring a stable and healthy ecosystem.
- **System Monitoring and Maintenance:** Conduct regular water quality tests, monitoring pH, ammonia, nitrite, and nitrate levels. Assess fish health and plant growth by maintaining proper feeding schedules and a balanced nutrient intake. Implement biosecurity measures to prevent disease and pests, incorporating integrated pest management strategies.
- **Market Research and Sustainability:** Aquaponics offers dual production benefits; fish and crops. Identify local market opportunities, such as farmers' markets, restaurants, or direct-to-consumer sales, to maximise profitability and long-term viability.

When key factors such as water quality, system design, species selection, and nutrient balance are effectively managed, aquaponics can become a highly efficient, sustainable, and environmentally friendly food production system.

Stocking Density

There is growing public, governmental, and commercial interest in the welfare of intensively farmed fish, with stocking density being a major area of concern. Increasing stocking density is commonly associated with reduced food conversion efficiency, poorer nutritional condition, slower growth, and increased fin erosion; all indicators of compromised welfare. Stocking density is typically expressed as the biomass or number of individuals per unit volume of water at any given time during rearing (Ellis *et al.,* 2002). Both excessively high and low stocking densities can negatively impact fish welfare, depending on the species' natural behaviour (Ashley, 2007; Huntingford & Kadri, 2014).

A study by Ani et al. (2022) examined the effects of different stocking densities on the growth performance of monosex Nile tilapia (*Oreochromis niloticus*) in an aquaponics system integrated with lettuce (*Lactuca sativa*). After eight weeks, the highest specific growth rate (SGR) was observed at a stocking density of 150 fish/m³, followed by 300 fish/m³, with the lowest SGR recorded at 450 fish/m³. These findings suggest that higher stocking densities may negatively affect fish growth, likely due to increased competition for resources and declining water quality.

In Nile tilapia farming, high stocking density is a common stressor associated with several adverse effects, including reduced growth and feed efficiency, a lower condition factor (K), elevated cortisol levels, weakened immune responses, increased mortality, and poorer economic performance in Biofloc and cage culture systems. A Biofloc system in aquaculture is an advanced and sustainable method of fish or shrimp farming that relies on maintaining high-density culture with minimal or zero water exchange, while managing water quality and providing supplemental nutrition through microbial communities. (Manduca *et al.,* 2021; Wu *et al.,* 2018; Moniruzzaman *et al.,* 2015). In a Hybrid Biofloc–Recirculating Aquaculture system (HBR), a stocking density of 229 fish/m³ supported by additional biofiltration has been identified as optimal for Nile tilapia culture (Pai *et al.,* 2024). These results underscore the importance of tailoring stocking densities to specific system designs in order to optimise fish growth and maintain water quality.

The Sharptooth Catfish Welfare and Water Quality (DFFE, 2018)

The sharptooth catfish (*Clarias gariepinus*) is native to the freshwater systems of much of sub-Saharan Africa and has become one of the most widely farmed fish species across the continent. It is extensively cultured in countries such as Nigeria, Zambia, Ghana, and South Africa, and is the most commonly farmed catfish species in Africa (Cambray, 2003). The table below outlines recommended water quality guidelines, focusing on key parameters such as dissolved oxygen, pH, temperature, and concentrations of nitrite and ammonia. These parameters are essential for maintaining optimal water conditions that promote fish health, growth, and sustainable aquaculture practices.

Table 2 Recommended water quality requirements for the African Catfish (Clarias gariepinus)

Parameter	Catfish (*Clarias gariepinus*)
Temperature	26°C – 32°C (Kashimuddin *et al.*, 2021)
Dissolved Oxygen (DO)	2.91 – 4.85 mg/L (Boyd & Hanson, 2010)
Ph	6.5 – 8.5 (Fathurrahman *et al.*, 2020)
Ammonia	0.34 mg/L (Edward *et al.*, 2010)
Nitrite	1.19 mg/L (2% of LC50-96h) (de Lima *et al.*, 2011)
Nitrate	400 ppm (Roques *et al.*, 2015)
Water Hardness	25 – 50 mg $CaCO_3$/L (Copatti *et al.*, 2011)
Turbidity	Below 88 NTU (Jayadi, 2022)

The recommended water quality parameters presented in Table 3 provide a brief overview of key factors to consider in the production of tilapia and carp in South Africa.

Table 3 Recommended water quality requirement for the Oreochromis niloticus (O.n), Oreochromis mossambicus (O.m) and Cyprinus carpio (C.c)

Parameter	Tilapia	Carp
Temperature	20.2°C – 31.7°C (Leonard & Skov, 2022)	28°C – 34°C (Veluchamy *et al.*, 2022)
Dissolved Oxygen (DO)	5 – 7 mg/L (Abd El Hack et al., 2022)	0.5 – 20 mg/L (Homoki *et al.*, 2021)
Ph	6 – 8.5 (El-Sherif et al., 2009)	7 – 8.0 (Heydarnejad, 2012)
Ammonia	0.14 mg/L (Benli *et al.*, 2011)	0.24 ± 0.06 mg/L (Heydarnejad, 2012)
Nitrite	0 – 7 mg/L (Amazon Web Services)	0.18 ± 0.02 mg/L (Heydarnejad, 2012)

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

- Discuss each of your current growing systems for your fish farms. What problems are you facing on your farm now?
- Did you do any analysis or evaluation of your farm sites before you decided? Please share your findings and explain why you chose your current system.

- Based on what has been learned so far, how do you intend to improve the growing system and site of your farm to align with good fish welfare practices?
- Discuss your current stocking density (if you know it).
- Did you consider stocking density before starting your fish farm? How do you determine the optimal stocking density for it?
- Based on what has been learned so far, what challenges have you been experiencing, and how do you intend to improve your fish farm stocking density going forward?

MODULE 4: 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

Effective water quality management is crucial for the success of aquaculture and the welfare of fish, serving as a key determinant of a system's overall productivity. Water quality parameters are typically categorised into physical, chemical, and biological factors, with pH, temperature, and dissolved oxygen being particularly crucial (Yusoff *et al.,* 2024). Even slight fluctuations in these parameters can induce physiological or behavioural stress, negatively impacting fish growth, reproductive capacity, and disease resistance. Boyd and Tucker (2019) emphasise that aquatic organisms thrive and achieve optimal growth when environmental conditions remain within species-specific ranges that define good water quality. Maintaining stable water conditions is therefore fundamental to promoting fish health, minimising stress-related complications, and ensuring sustainable aquaculture operations.

Ensuring fish welfare requires a well-structured management program that emphasises continuous monitoring and attention to detail. Optimal fish health depends on maintaining a clean, balanced aquatic environment, providing high-quality nutrition, and reducing exposure to pathogens. The adoption of innovative aquaculture technologies, such as precise estimation of fish size and biomass, data-driven feeding strategies, and real-time water quality monitoring, can significantly enhance resource efficiency and support sustainable production (Mousavi and Zorriehzahra, 2021). Since each fish species has specific environmental requirements, maintaining key water quality parameters such as dissolved oxygen, carbon dioxide, ammonia, nitrite, nitrate, and pH, within optimal species-specific ranges is critical for promoting healthy growth, maximising productivity, and ensuring long-term success in aquaculture systems.

Stocking density is a critical factor in aquaculture, as it directly affects water quality, fish health, and the integrity of the fish's external protective barriers against pathogens. However, the optimal density is species-specific; what works for one species may be detrimental to another. Higher stocking densities are commonly associated with reduced dissolved oxygen (DO) levels and shifts in other critical water quality parameters, such as increased carbon dioxide concentrations, decreased pH, and elevated ammonia levels. A study by Sundh et al. (2019) demonstrated that elevated stocking densities, especially when combined with deteriorating water quality, induce chronic stress in fish. This stress elicits a primary physiological response and compromises natural defences by weakening both the skin and mucosal barriers, as well as immune function. Maintaining species-appropriate stocking densities is therefore crucial for ensuring fish welfare, reducing disease susceptibility, and promoting sustainable aquaculture operations.

Considerations for Optimal Fish Health and Welfare

Water quality monitoring

Optimal fish production largely depends on the physical, chemical, and biological quality of the water. Fish rely on water for essential biological processes, and their health is influenced by key parameters such as temperature, ammonia, nitrite, nitrate, pH, carbonate hardness, general hardness, dissolved oxygen, and salinity. Water quality concerns in aquaculture can be categorised into four major groups: (1) physical parameters (e.g. pH, temperature, dissolved oxygen, and salinity), (2) organic contaminants, (3) biochemical hazards (e.g. cyanotoxins), and (4) biological contaminants (e.g. pathogens) (Su et al., 2020). Regular monitoring and proactive management of these parameters are essential for maintaining a healthy aquatic environment, ensuring optimal fish growth, and supporting sustainable aquaculture practices.

Source of water and type: The source and quantity of water available are the most important factors to consider when choosing a site for an aquaculture facility. An ideal water source must be uncontaminated by excessive nutrients, chemicals or heavy metals. There are six categories of water sources being used, which are: springs, wells, rivers, streams or lakes, surface runoff, groundwater, or municipal water.

Water budget and storage: Water budgets are valuable tools for estimating the water requirements of ponds that depend on rainfall and runoff as primary sources, as well as for flow-through pond systems. They help assess whether a potential or existing water source can meet the projected demands of aquaculture facilities and aid in comparing the value of available water for different agricultural uses. Additionally, water budgets can estimate the likelihood of pond water discharge, whether through intentional release or overflow, making them useful for evaluating the potential environmental impacts of pond-based aquaculture (Sharma *et al.,* 2013).

Life Stage and Species-Specific Considerations

O. niloticus and O. mossambicus

Water quality requirements vary for different species of fish and even for the different stages of their life cycles. The following list presents general water quality parameters required for farmed tilapia (DFFE, 2018; Feasibility Study).

Salinity: *O.n* and *O.m* are tolerant of brackish (slightly salty) water. The Nile tilapia is the least saline-tolerant of the commercially important species, but grows well at salinities of up to 15 ppt. The Nile tilapia reproduces at salinity levels of 10 to 15 ppt, but the species performs better at salinities below 5 ppt. Fry numbers decline substantially at 10 ppt salinity.

Water temperature: Generally, tilapia stop feeding when the water temperature falls below 17°C. The intolerance of tilapia to low temperatures is a serious constraint for commercial culture in temperate regions. The lower and upper lethal temperatures (i.e. the survival limit) for Nile tilapia are 11-12 °C and 42 °C, respectively, while the preferred temperature range is between 28 °C and 36 °C.

Oxygen Requirement: According to Abd El-Hack et al. (2022), tilapia, particularly Nile tilapia (*Oreochromis niloticus*), can tolerate very low dissolved oxygen (DO) levels, surviving short-term exposures as low as 0.1 mg/L. However, such hypoxic conditions are highly stressful and negatively impact growth, feed intake, and overall health. For optimal performance, DO levels in culture systems should be maintained above 3 mg/L, with the most favourable growth and feed efficiency observed when levels are sustained between 5 and 7 mg/L. Prolonged exposure to DO levels below 3 mg/L compromises immune function, increases disease susceptibility, and reduces productivity, underscoring the importance of effective aeration and water quality management in tilapia aquaculture.

pH Requirement: In general, tilapia can survive in a pH range of water supply ranging from 5 to 10, but perform optimally in a pH range of 6 to 9. Acidic water (with a pH below 5) will require the use of a reservoir where water acidity is neutralised using lime before use. The pH level of the supply water can be measured using a pH test kit or a pH meter.

Ammonia Requirement: Ammonia is highly toxic to tilapia, particularly in its unionised form (NH_3), which increases in concentration with rising pH and temperature. Tilapia can begin to show signs of stress when unionised ammonia levels exceed 0.05–0.1 mg/L, and levels above 1–2 mg/L are considered lethal. Exposure to such high concentrations can lead to significant physiological stress, damage to gill tissues, suppressed immune function, and ultimately mortality. Sudden transfers of tilapia into water with elevated unionised ammonia levels often result in acute stress and can cause mass mortality within a few days. It is therefore essential to monitor and maintain low ammonia levels to ensure the health, welfare, and survival of tilapia in aquaculture systems.

African Sharptooth Catfish (*Clarias gariepinus*)

Water quality requirements vary for different species of fish and even for the different stages of their life cycles. The following list presents general water quality parameters required for African Sharptooth Catfish (DFFE, 2018; Feasibility Study).

Salinity: Salinity is a crucial factor that impacts the survival of various aquatic species, including the sharptooth catfish. For the culturing of sharptooth catfish, the optimum salinity range for larval rearing is between 0 and 2.5 ppt, and a short-term exposure to higher salinities (2.5–7.5 ppt) could be effective in the treatment of ectoparasitic diseases. It is recommended that hatchery rearing of the sharptooth catfish occurs at the optimum low salinities of 4 – 6 ppt rather than in full fresh water, for at least 21 days.

Water temperature: Although the sharptooth catfish is hardy and able to survive in most climatic conditions, temperatures below the optimal survival range can slow down their metabolism and food consumption. As such, the optimal temperature for culturing the fish is between 28 °C and 30 °C. However, they can live in very turbid water and tolerate a temperature range of between 8 °C and 35 °C. Furthermore, the required water temperature range for egg hatching is between 17 °C and 32 °C.

Oxygen Requirement: Oxygen is a key limiting factor in aquatic respiration and metabolic processes, and while *Clarias gariepinus* (sharptooth catfish) is highly tolerant of low oxygen conditions due to its accessory air-breathing organs, maintaining adequate dissolved oxygen levels is essential for optimal growth and health. For optimal results in aquaculture systems, the dissolved oxygen level should not fall below 3 mg/L, as lower levels can lead to stress, reduced feed intake, slower growth, and compromised immune function. Ideally, oxygen concentrations should be maintained at 5 mg/L or higher to support efficient metabolism, robust growth, and overall fish welfare. Oxygen is one of the principal limiting factors in aquatic respiration and metabolic reactions. For optimal growth, it is recommended that the oxygen level for culturing the sharptooth catfish not fall below 3 ppm, but preferably be 5 mg/L or higher.

pH Requirement: The optimum pH range that supports optimum growth rate in the sharptooth catfish is between 6.5 and 8.0. However, if the water becomes more acidic than pH 6.5 or more alkaline than pH 9.0 for long periods, reproduction and growth will diminish.

Ammonia Requirement: The sharptooth catfish (*Clarias gariepinus*) is known for its high tolerance to ammonia toxicity, particularly in comparison to other cultured fish species. It can typically tolerate total ammonia nitrogen (TAN) concentrations up to approximately 2.3 mg/L without significant adverse effects. However, it is the unionised form of ammonia (NH_3), which increases with rising pH and temperature, that is highly toxic. Therefore, while C. *gariepinus* can withstand relatively high levels of TAN, careful monitoring of water pH and temperature is essential to prevent toxic levels of NH_3 from accumulating and affecting fish health (Schram *et al.,* 2010).

Tilapia and Catfish Welfare and Water Quality

A typical grow-out pond system for tilapia that discharges all effluent requires approximately 3,250 to 3,750 cubic metres (m^3) of water per hectare per month. In contrast, recirculating pond systems, which operate with zero water discharge, may use as little as 300 m^3 per hectare per month. In such systems, water is primarily needed to compensate for evaporation and minor seepage losses. However, the actual volume required for top-up is highly dependent on the local climate and evaporation rates, making it specific to the geographic location of the tilapia farm.

How to Measure and Correct Water Quality Parameters

In aquaculture, commonly monitored water quality parameters include temperature, dissolved oxygen, pH, alkalinity, hardness, ammonia, and nitrites. Depending on the culture system, additional parameters such as carbon dioxide, chlorides, and salinity may also require monitoring. While factors like alkalinity and hardness tend to remain relatively stable, others, such as dissolved oxygen and pH, can fluctuate on a daily basis. To ensure optimal conditions, it is crucial to implement a standardised water quality testing protocol tailored to your specific aquaculture system (Aquaculture Extension). If any water quality parameters deviate from the optimal range, farmers must take immediate corrective action to restore balance and prevent potential harm.

Solutions for Out-of-Range Water Quality Parameters in Aquaculture

- **Temperature:** If the temperature is too high, increase aeration or use coolers. If it's too low, use heaters or reduce water exchange to retain warmth.
- **Dissolved Oxygen (DO):** If DO levels are low, increase aeration using paddlewheels, diffusers, or air stones, reduce feeding, remove organic debris, or increase water exchange. If DO levels are too high (supersaturation), reduce aeration to prevent excessive oxygen buildup.
- **pH Imbalance:** If the pH is too low, add agricultural lime (calcium carbonate) and increase aeration to remove excess CO_2. If the pH is too high, introduce acidifying agents like alum (aluminium sulphate) or increase water exchange.
- **Alkalinity and Hardness:** To raise alkalinity and hardness in aquaculture ponds, liming agents are commonly used, but care must be taken in selecting the appropriate material. Agricultural lime (usually calcium hydroxide or calcium oxide) is not water-soluble and can cause a rapid and significant increase in pH, which may stress or harm fish if not properly managed. For a more gradual and controlled adjustment, calcium

carbonate ($CaCO_3$) is preferred, as it dissolves slowly and stabilises both alkalinity and hardness over time. Alternatively, sodium bicarbonate ($NaHCO_3$) can be used to temporarily increase alkalinity with minimal impact on hardness and pH, though its effects are short-lived. If alkalinity or hardness becomes excessive, controlled water exchange or acidification techniques (e.g. using organic acids) may be employed to bring levels within optimal ranges.

- **Carbon Dioxide (CO_2):** If CO_2 levels are too high, increase aeration to drive off excess gas, add lime to buffer pH, and improve water circulation.
- **Chloride and Salinity:** If chloride levels are too low, add salt (sodium chloride) to support fish osmoregulation. If salinity is too high, dilute with freshwater or reverse osmosis to maintain appropriate salinity levels to restore balance. For both tilapia and catfish species, adding sodium chloride (NaCl) can help reduce the toxic effects of nitrite and support ionic balance when chloride levels are low. However, the specific concentration required depends on the species, life stage, and environmental conditions. Tilapia are moderately euryhaline and can tolerate a range of salinities, while catfish (such as *Clarias gariepinus*) are more sensitive to salinity fluctuations. If salinity becomes too high for either species, dilution with freshwater is recommended. Adjustments should always be based on species-specific tolerance thresholds and water quality monitoring (Tavares-Dias, 2022).

These corrective measures help maintain optimal water quality, ensuring a healthy and productive aquaculture system. To reiterate, it is beneficial to always refer to species-specific water quality guidelines and adjust water parameters gradually to avoid stressing the aquatic organisms. Regular monitoring of water quality is essential to prevent issues before they become severe. If you encounter persistent problems or are unsure about the appropriate solutions, consult with an experienced veterinarian, aquaculturist, or aquatic biologist for personalised guidance.

Q&A Session

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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

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

MODULE 6: FEEDING AND FISH WELFARE

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

General Best Practices for Feeding

Feed is one of the most expensive items in intensive fish farming, requiring careful management to ensure both cost-effectiveness and optimal fish growth. The availability of high-quality feed in sufficient quantities is crucial for the proper development and reproduction of fish. To maintain fish welfare and health, the following best practices should be implemented (IFAD, 2025):

- **Feeding Conditions and Monitoring:** Fish should be fed during favourable weather conditions and not during rainfall. During feeding, farmers should observe the fish to ensure they are actively eating. If fish exhibit signs of reduced appetite, feeding should be discontinued, and water quality should be assessed for potential issues.
- **Feed Ingredient Selection:** When choosing ingredients for fish feed, the following factors should be considered:
    - Nutritional Value: ensuring a balanced mix of protein, fat, carbohydrates, and fibre.
    - Availability: whether ingredients are accessible seasonally or year-round.
    - Cost and Transport: the price of ingredients and their transportation expenses.
    - Digestibility: any pre-treatment required to enhance digestibility.

Appropriate feeding is critical for good welfare (Aquatic Animal Alliance, 2025).

- **Proper feeding:** Insufficient quantities of feed or feed in unavailable forms (e.g. excessively large pellets or feeding in a location where smaller fishes are out-competed) can lead to poor health and welfare.
- **Over-feeding:** Providing too much feed can cause poor water quality, which in turn will affect health and welfare. Producers should strive to provide appropriate feed formulations in the correct amounts, ensuring that all fish on the farm have access to them.
- **Starvation:** Starvation periods should only be used when absolutely necessary and when advised by a vet, with 72 hours as the absolute maximum.

Composition and Quality of Feed Ingredients

- **Ingredient Measurement and Mixing:** Each ingredient must be carefully weighed individually to match the exact quantities specified in the recipe. Ingredients should then be mixed in strict accordance with the prescribed proportions to ensure a balanced formulation.
- **Mixing Order for Homogeneity:** Ingredients present in smaller quantities, such as vitamins, minerals, and salts, should be added first. These should then be combined with ingredients in progressively larger proportions to create a homogeneous mixture.
- **The final formulation**: This should be tailored to meet the nutritional needs of the targeted fish species (e.g. tilapia, African catfish, and common carp) and their respective growth stages (larvae, starter, grower, and finisher).
- **Species-Specific Feed Formulation:** Each fish species and growth stage requires a distinct feed formulation to ensure optimal growth and health. A well-balanced recipe should include multiple ingredients that provide essential nutrients for proper development.

Nutritional Requirements of Common Aquaculture Species

Sharptooth Catfish *(Clarias gariepinus)*

- Being omnivorous, this species requires a formulated feed in culture conditions where natural food is not available.
- An optimal diet should have a high protein content with a well-balanced amino acid profile. Under ideal conditions, maximum growth rates and efficient feed conversion are achieved with diets containing 35–42% crude protein (DFFE Feasibility Study, 2018).

Nile and Mozambique Tilapia (Oreochromis niloticus and O. mossambicus)

- Protein is essential for tilapia growth and quality.
- Diets for small fingerlings may require up to 50% protein, while commercial food fish ponds typically use feeds containing 26–30% crude protein, with only a small fraction (less than 10%) derived from animal sources.
- In recirculating and flow-through systems, where water quality is actively managed, protein content and the proportion of animal protein may be slightly higher.
- Energy Requirements for Tilapia: For optimal economic growth, tilapia require a digestible energy (DE) level of 8.2 to 9.4 kcal per gram of dietary protein (DFFE Feasibility Study, 2018).
- Feed Form and Pellet Size: Fish feed should ideally be in floating pellet form to allow monitoring of consumption and minimise waste. The pellet size should be carefully adjusted to match the fish's mouth size, increasing progressively as the fish grow. By following these guidelines, farmers can ensure efficient feeding practices that support fish health, growth, and overall productivity in aquaculture.

Fish Feed and Specific Welfare Considerations

The use of animals in aquaculture feed, such as fishmeal, fish oil, insects, and other animal-derived ingredients, raises significant concerns regarding welfare and sustainability. According to the Aquatic Animal Alliance (2025), animals used in feed production are sentient beings, and their welfare should be considered throughout the supply chain. To minimise suffering, it is recommended that the number of animals used in feed formulations be reduced or eliminated where possible, including terrestrial, aquatic, and insect-based sources. Fishmeal and fish oil, commonly derived from wild-caught forage fish, contribute to the overexploitation of marine ecosystems and involve the harvesting of vast numbers of small sentient animals (Tacon & Metian, 2009; Shannon *et al.,* 2021). While nutritionally valuable, the environmental and welfare costs have led to calls for reduced dependence on these ingredients. Insect-based protein, such as that derived from black soldier fly (*Hermetia illucens*) larvae, has gained attention as a promising alternative due to its efficient feed conversion and lower environmental impact (Lu *et al.,* 2022; Abd El-Hack *et al.,* 2020; Rehman *et al.,* 2023).

Feeding rates:

- **Feeding Frequency**: Fish should be fed at least twice daily (at 9:00 a.m. and 3:00 p.m.) or three times daily (at 9:00 a.m., 12:00 p.m., and 4:00 p.m.). However, fry and fingerlings require more frequent feeding at least five times a day (8:00 a.m., 10:00 a.m., 12:00 p.m., 2:00 p.m., and 4:00 p.m.) due to their small stomach capacity.
- **Feeding Rates and Pellet Size:** As fish grow, their feeding rate decreases. At the starter stage, fish should be fed approximately 8% of their body weight per day, gradually reducing to 3% at the grower stage and 2% at the finisher stage. Pellet size should be adjusted to match the size of the fish's mouth and its stage of growth to ensure efficient feeding and minimise waste.

Feed storage (IFAD, 2025):

- Feed ingredients should be stored in a dry, well-ventilated area, protected from direct sunlight and rodents to maintain freshness. Ideally, they should be purchased within a week before feed production.

- The storage area should be kept clean, dry, and well-ventilated. If necessary, the storage duration should be minimised to preserve feed quality.
- Feed should be stored a few centimetres off the ground, preferably on pallets, and sacks should not be placed directly against walls to prevent moisture buildup.

Q&A Session

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

Discussion Points

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

- How can we innovate on alternative feeding that meets optimal welfare standards for fish production?

MODULE 7: FISH WELFARE DURING HANDLING AND TRANSPORTATION

This module provides general welfare considerations and guidelines for the proper handling and transportation of fish, including best practices that minimise stress, maintain water quality, and ensure safe, humane movement.

Handling and Fish Welfare

Welfare Considerations in Fish Handling

When handling is necessary, it should be conducted with minimal stress and disturbance, both for the fish being handled and those in the surrounding environment. Handling should be kept as brief as possible, and if it exceeds a few seconds, to minimise stress and potential injury (AAA, 2025). Personnel responsible for stunning and killing fish must be experienced, competent in fish handling, and knowledgeable about fish behaviour. They should also understand the fundamental principles required to carry out these tasks humanely. Since some stunning and killing methods may pose risks to personnel, training should include occupational health and safety protocols relevant to the methods used. Holding facilities must be specifically designed and constructed for the target fish species or species groups. The facilities should be appropriately sized to accommodate the required number of fish for processing within a given timeframe without compromising fish welfare. Operations should aim to minimise stress and physical injury. To achieve this, the following recommendations should be implemented (WOAH, 2015):

- **Facility Design and Maintenance:** Nets and tanks should be designed and regularly maintained to prevent physical injuries.
- **Water Quality and Stocking Density:** Water conditions must be suitable for the specific fish species, and stocking densities should prevent overcrowding.

- **Fish Transfer Equipment:** Equipment such as pumps and pipes should be properly designed and maintained to ensure safe and efficient fish transfer while minimising injury.

Once caught, fish undergo significant stress during handling, which can lead to common injuries such as damage to the eyes, fins, and muscles, as well as scale loss. Additionally, handling can compromise the protective mucous coating on the skin, an essential barrier against pathogens, thereby increasing the fish's susceptibility to infections and disease (Fish Site, 2025).

Transportation and Fish Welfare

Transporting fish is a crucial aspect of aquaculture, ensuring the movement of fry and fingerlings from hatcheries to ponds for stocking, as well as the transfer of brood fish to hatcheries for spawning. In some cases, live harvested fish must also be transported to markets for sale. The success of fish transport depends largely on their ability to withstand or adapt to stressful conditions, which varies across life stages. Larvae and brood fish nearing spawning are particularly delicate and require careful handling. To improve survival rates during transport, fish are typically fasted for 1 to 2 days before transit to empty their intestines, reducing metabolic waste and maintaining water quality. Live fish transport, commonly conducted by road using vehicles, is a routine practice in aquaculture but can have significant implications for fish welfare. Fish are frequently moved between farms or delivered to markets for further growth or sale (King, 2009).

There are two primary methods of live fish transport:

- ✓ **Open System:** Water-filled containers equipped with an external oxygen source, such as oxygen tanks.
- ✓ **Closed System**: Sealed plastic bags partially filled with oxygen before transport (Berka, 1986; Sampaio & Freire, 2016).

Phases of live fish transport

Live transport involves three key phases, each presenting potential stressors:

- **Pre-transport:** Includes grading, crowding, netting, fasting, handling, and loading/packing.
- **During transport**: Fish experience challenges such as water quality fluctuations, transport densities, and physical handling.
- **Post-transport**: Unloading and acclimatisation can further impact fish well-being.

Common stressors during transport include rough handling, air exposure, poor water quality, inappropriate stocking densities, sudden temperature shifts, and rapid water movement (Santurtun *et al.,* 2018). These stressors trigger physiological responses indicative of stress, such as elevated cortisol and blood glucose levels. Excessive stress can compromise fish vitality and increase mortality rates (Refaey Li, 2018; Harmon, 2009).

Welfare Considerations in Fish Transportation (WOAH, 2015)

Adequate planning is a crucial factor in ensuring the welfare of fish during transportation. The pre-transport preparation, duration, and route of a transport should be determined by the purpose of the transport, e.g. biosecurity issues, transport of fish for stocking farms or resource enhancement, or slaughter/killing for disease control purposes. Before the transport starts, plans should be made in relation to:

- Type of vehicle and transport equipment required.
- Route, such as distance, expected weather and/or sea conditions.
- Nature and duration of the transport.
- Assessment of the need for acclimatisation of fish to water quality at the site of unloading.
- Need for care of the fish during the transport.
- Emergency response procedures related to fish welfare.
- Assessment of the necessary biosecurity level (e.g. washing and disinfection practices, safe places for changing water, treatment of transport water).

Vehicle design and maintenance, including handling equipment

a) Vehicles and containers used for the transport of fish should be appropriate to the species, size, weight and number of fish to be transported.
b) Vehicles and containers should be maintained in good mechanical and structural condition to prevent predictable and avoidable damage to the vehicle that may directly or indirectly affect the welfare of transported fish.
c) Vehicles (if relevant) and containers should have adequate circulation of water and equipment for oxygenation as required to meet variations in the conditions during the journey and the needs of the animals being transported, including the closing of valves for biosecurity reasons.
d) The fish should be accessible to inspection en route, if necessary, to ensure that fish welfare can be assessed.
e) Documentation that focuses on fish welfare and thus carried with the vehicle should include a transport logbook of stocks received, contact information, mortalities and disposal/storage logs.
f) Equipment used to handle fish, for example, nets and dip nets, pumping devices and brailing devices, should be designed, constructed and maintained to minimise physical injuries.

Water

a) Water quality (e.g. oxygen, Carbon dioxide (CO_2) and unionised ammonia (NH_3) level, pH, temperature, salinity) should be appropriate for the species being transported and the method of transportation.
b) Equipment to monitor and maintain water quality may be required depending on the length of the transport.

Preparation of fish for transport

a) Before transport, feed should be withheld from the fish, taking into consideration the fish species and life stage to be transported.

b) The ability of the fish to cope with the stress of transport should be assessed based on health status, previous handling and recent transport history of the fish. Generally, only fish that are fit for transport should be loaded. Transport for disease control purposes should be in accordance with WOAH regulations

c) Reasons for considering the unfitness of fish for transport include:
   - Displaying clinical signs of disease.
   - Significant physical injuries or abnormal behaviour, such as rapid ventilation or abnormal swimming.
   - Recent exposure to stressors that adversely affect behaviour or physiological state (for example, extreme temperatures, chemical agents).
   - Insufficient or excessive length of fasting.

Species-specific recommendations

a) Transport procedures should take account of variations in the behaviour and specific needs of the transported fish species. Handling procedures that are successful with one species may be ineffective or dangerous for another species.

b) Some species or life stages may need to be physiologically prepared prior to entering a new environment, such as by feed deprivation or osmotic acclimatisation.

Loading the fish

The issues which should be addressed to avoid injury and unnecessary stress to the fish include:

- Crowding procedure in a farm pond, tank, net or cage prior to loading.
- Equipment (such as nets, pumps, pipes and fittings) that are improperly constructed (e.g. sharp bends or protrusions) or improperly operated (e.g. overloading with fish of incorrect size or number of fish)
- Water quality: Some species of fish should be acclimatised if there is a likelihood of the fish being transported in water of a significantly different temperature or other water parameters.

- The density of fish in a vehicle and/or container should be in accordance with scientific data, where available, and not exceed what is generally accepted for a given species and a given situation.
- Loading should be carried out, or supervised, by operators with knowledge and experience of the behaviour and other characteristics of the fish species being loaded to ensure that the welfare of the fish is maintained.

If the killing of fish is necessary during transport, it should be carried out humanely in accordance with animal welfare guidelines.

Figure 10 Dusky Kob harvested from an earthen pond in Kwa-Zulu Natal (Source: Zini Fish Farms)

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

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

MODULE 8: SLAUGHTERING AND FISH WELFARE

This module provides key welfare considerations and guidelines for the humane slaughter of fish, focusing on best practices that minimise pain, stress, and suffering. It outlines appropriate stunning methods, handling techniques, and compliance with ethical and regulatory standards to ensure a humane end-of-life process.

Overview of Humane Fish Slaughter

Chapter 7.3 of the World Organisation for Animal Health (WOAH, 2015) Aquatic Animal Health Code addresses the welfare considerations during the stunning and killing of farmed fish intended for human consumption, as described below. This chapter outlines internationally recognised guidelines to ensure that fish are handled humanely at the time of slaughter, minimising pain, stress, and suffering. It provides science-based recommendations on acceptable methods of stunning and killing, as well as requirements for handling, equipment, and staff training to uphold animal welfare standards across aquaculture operations.

Stunning/killing method

a) Percussive stunning

Key fish welfare concerns/requirements: The blow should be of sufficient force and delivered above or adjacent to the brain in order to render immediate unconsciousness. Fish should be quickly removed from the water, restrained and given a quick blow to the head, delivered either manually by a club or by automated percussive stunning. The effectiveness of stunning should be checked, and the fish should be re-stunned if necessary. It can be a stun/kill method.

Advantages: Immediate loss of consciousness. Suitable for medium to large-sized fish.

Disadvantages: Hand-operated equipment may be hampered by the uncontrolled movement of the fish. Wrongful stunning may result from a blow that is too weak. Injuries may occur. Manual percussive stunning is only practicable for the killing of a limited number of fish of a similar size.

b) Spiking or coring

Key fish welfare concerns/requirements: The spike should be aimed at the skull in a position to penetrate the brain of the fish, and the impact of the spike should produce immediate unconsciousness. Fish should be quickly removed from the water, restrained and the spike immediately inserted into the brain. It is a stun/kill method.

Advantages: Immediate loss of consciousness. Suitable for medium to large-sized fish. For small tuna, spiking them underwater avoids exposing the fish to air. The pineal window of tuna facilitates spiking for this species.

Disadvantages: Inaccurate application may cause injuries. Difficult to apply if the fish are agitated. It is only practicable for the killing of a limited number of fish.

c) Free bullet

Key fish welfare concerns/requirements: The shot should be carefully aimed at the brain. The fish should be positioned correctly, and the shooting range should be as short as practicable. It is a stun/kill method.

Advantages: Immediate loss of consciousness. Suitable for large-sized fish (e.g. large tuna).

Disadvantages: Shooting distance; calibre needs to be adapted. Excessive crowding and the noise of guns may cause a stress reaction. Contamination of the working area due to the release of body fluids may present a biosecurity risk. May be hazardous to operators.

Electrical Stunning/Killing method

a. Electrical stunning

Key fish welfare concerns/requirements: involves the application of an electrical current of sufficient strength, frequency and duration to cause immediate unconsciousness. It can be a stun/kill method. Equipment should be designed and maintained correctly.

Advantages: Immediate loss of consciousness. Suitable for small to medium-sized fish. Suitable for large numbers of fish, and the fish do not have to be removed from the water.

Disadvantages: Difficult to standardise for all species. Optimal control parameters are unknown for some species. May be hazardous to operators.

b. Semi-dry electrical stunning

Key fish welfare concerns/requirements: The head of the fish should be the first to enter the system, allowing electricity to be applied to the brain first. Involves the application of an electrical current of sufficient strength, frequency and duration to cause immediate unconsciousness. Equipment should be designed and maintained correctly.

Advantages: Good visual control of stunning and the ability to re-stun individual fish.

Disadvantages: Misplacement of the fish may result in improper stunning. Optimal control parameters are unknown for some species. Not suitable for mixed sizes of fish.

The humane killing of farmed fish varies by species and is guided by methods that minimise pain and stress. Percussive stunning is considered humane and effective for species such as carp and salmonids, while electrical stunning is also appropriate for carp, eel, and salmonids. For large pelagic species like tuna, humane slaughter methods include spiking or coring, which involves the destruction of the brain, and the use of a free bullet to ensure immediate insensibility. These methods are recognised under the WOAH Aquatic Animal Health Code as appropriate techniques for reducing suffering during slaughter (WOAH, 2015).

Benefits of Humane Slaughter of Fish

Humane slaughter methods aim to minimise fear and pain by ensuring a quick and efficient death. Research shows that humane practices not only improve fish welfare but also enhance product quality. While aquaculture methods have been designed to reduce stress, slaughter technology has primarily focused on quality control, efficiency, and processor safety (Poli *et al.,* 2005). Implementing humane slaughter offers benefits for fish, farmers, and consumers, including:

- **Improved flesh quality**: Humane slaughter is linked to firmer, more translucent fillets with brighter colour and reduced flesh gaping (Humane Slaughter Association, 2019).
- **Better welfare and increased economic value**: Adopting welfare protocols at slaughter enhances fish well-being, improves consumer perception, and benefits aquaculture economics (Mercogliano *et al.,* 2024).
- **Ensure the ethical treatment of animals:** Ethical treatment in aquaculture and wild-capture fisheries is guided by principles of animal welfare, which consider fish as sentient beings capable of experiencing pain and distress.

- **Compliance with legal standards:** Humane slaughter methods comply with various national and international regulations, including the World Organisation for Animal Health (WOAH) guidelines on fish welfare, EU and UK legislation such as Council Regulation (EC) No 1099/2009, which mandates stunning before slaughter, and national aquaculture and fishery policies that ensure humane handling aligns with local regulatory requirements (Cooke, 2016).

Pre-Slaughter Welfare Considerations

The rapid expansion of aquaculture has heightened awareness of fish welfare at slaughter, with most efforts focused on developing, refining, and implementing stunning technologies to ensure humane processing. However, this emphasis on the moment of stunning overlooks a critical reality: the slaughter process extends far beyond the final moments of stunning and killing. It includes prolonged pre-slaughter operations, which can last hours or even days, significantly impacting fish welfare.

According to the Welfare Footprint Organisation (WFO, 2025), pre-slaughter operations, where fish endure sustained aggression, physical trauma, fear, social stress, and poor environmental conditions, likely impose a far greater burden of suffering than the moment of stunning itself. While an effective stunning procedure may cause only brief pain and distress, fish may have already suffered for hours or even days prior to being stunned.

Before stunning, fish undergo multiple pre-slaughter procedures that significantly impact their welfare, including:

Purging/Starvation Period

Fish are fasted before slaughter to empty the gut, reducing contamination risks and maintaining product quality. The recommended fasting period is 24–48 hours to balance gut clearance with minimising welfare impacts. Starvation also lowers metabolic rate and oxygen demand, helping fish cope with subsequent handling and transport.

Crowding Stress during Collection

Harvesting involves crowding fish before netting or pumping them onto transport vessels. Crowding should be gradual, avoiding excessive density, which can cause distress. Signs of severe distress, such as leaping or thrashing, indicate overcrowding. Fish should not be crowded for more than 2 hours, and repeated crowding should be avoided to prevent stress.

Poor Water Quality and Low Oxygen Levels

Increased fish density during crowding leads to rapid oxygen depletion and declining water quality. Oxygen levels should remain above 2.5 mg/L to prevent stress. Signs of distress, such as gasping for air or frequent surfacing, indicate oxygen levels are too low. If stress behaviours appear, nets should be loosened to provide more space.

Physical Trauma from Netting Operations

Fish experience repeated attempts at catching, leading to prolonged stress and injuries. Those caught last endure longer periods of crowding and handling stress. Careful handling can reduce bruising, scale loss, and fin damage.

Dewatering and Air Exposure

Most stunning and slaughter methods involve removing fish from water while still conscious, causing significant stress. Fish should be dewatered as close to the stunning point as possible to minimise suffering. If exposed to air, the maximum duration should not exceed 15 seconds.

Stress from Pumping and Repeated Catching

Nets should have a smooth surface to prevent abrasions and injuries. When fish are lifted from the water, exposure should be limited to 15 seconds or less.

Transportation-Related Stressors

Transport exposes fish to vibrations, temperature fluctuations, and stress associated with handling. Proper transport conditions can minimise physiological stress and mortality risks.

The slaughter process extends far beyond the moment of stunning, encompassing multiple pre-slaughter stressors that significantly impact fish welfare. Addressing these stressors through improved handling, better environmental management, and reduced exposure to harmful conditions is crucial for ensuring humane slaughter practices in aquaculture.

Common Fish Slaughter Methods

The methods used to stun and slaughter fish vary widely, with significant differences in their welfare impacts. Some methods result in prolonged suffering, while others are more effective at minimising distress and pain. Below is an overview of commonly used techniques, their effects on fish, and associated welfare concerns.

Asphyxiation in Air

Asphyxiation in air occurs when fish are removed from water and left to suffocate. This method is extremely aversive, triggering violent escape behaviours and maximum stress responses (Kestin *et al.*, 1991). As fish are deprived of oxygen, their gills collapse, preventing oxygen exchange. The time to death varies with temperature: 2.6 minutes at 20°C, 3 minutes at 14°C and 9.6 minutes at 2°C. Due to its high welfare impact, asphyxiation in air is considered an inhumane slaughter method.

Asphyxiation on Ice

In this method, fish are immersed in an ice-water slurry or packed live in ice flakes. This practice is common for species such as rainbow trout, gilthead sea bream, sea bass, barramundi, and channel catfish. Temperate species take longer to lose brain function in ice than in air. There is no definitive evidence on the aversive nature of ice immersion, but it is hypothesised to be painful (Robb & Kestin, 2002). Rapid cooling paralyses muscles, making behavioural indicators of distress difficult to observe, though a stress response has been documented.

Live chilling

Live chilling involves immersing fish in chilled water to immobilise them before slaughter. While this method reduces movement for easier handling, it poses serious welfare concerns:

Cold shock prolongs consciousness, increasing the time fish remain aware of pain (Robb et al., 2000). Salmon subjected to live chilling from warm seawater to 1°C exhibited elevated cortisol levels, indicating stress (Skjervold et al., 2000). Live chilling is not an acceptable method for rendering fish unconscious before slaughter.

Carbon-Dioxide Stunning

Carbon dioxide stunning involves saturating water with CO_2, creating an acidic and hypoxic environment that leads to narcosis. Fish exhibit intensely aversive behaviour and escape responses for at least 30 seconds. The process often causes gill haemorrhaging and increased mucus production (a sign of stress). The time to brain function loss is 4.7 minutes for trout (Robb & Roth, 2003; Erikson et al., 2006). Due to its prolonged distress, CO_2 stunning is not recommended for humane slaughter.

Bleeding without Prior Stunning

This method involves removing fully conscious fish from water and manually cutting the gill arches, heart, or tail blood vessels to induce bleeding. Fish struggle intensely for an average of four minutes. Catfish continue responding to pain for at least 15 minutes after gill-cutting (Lambooij *et al.,* 2004). This method is highly inhumane unless preceded by an effective stun.

Percussive Stunning

Percussive stunning involves delivering a rapid, forceful blow to the head, causing a concussion and immediate unconsciousness. If performed correctly, this method is irreversible and highly effective. However, if the strike is too weak or improperly placed, fish may regain consciousness and must be re-stunned immediately (HSA, 2005; Van De Vis *et al.,* 2003). Proper training and equipment are essential to ensure humane application.

Electrical Stunning and Killing

Electric stunning, known as electronarcosis, temporarily disrupts brain function, while electrocution permanently destroys brain function, stopping the breathing reflex. Electronarcosis is reversible, meaning fish must be bled immediately before regaining consciousness. Electrocution is irreversible and results in immediate death. If equipment malfunctions or is poorly managed, fish may be paralysed but still conscious, preventing them from displaying distress while experiencing pain. Electrical stunning is considered one of the most humane methods when correctly applied (HSA, 2005).

Pre-Slaughter Sedation with Anaesthetics

Pre-slaughter sedation reduces stress and handling-related distress but does not render fish unconscious or kill them. Sedated fish exhibit significantly less distress when removed from water for stunning. The anaesthetic AQUI-S has been found to be non-stressful for most fish. However, EU legislation prohibits anaesthetics for slaughter (EFSA, 2004) due to regulatory barriers and potential public concerns about consuming sedated fish. While sedation alone is not a humane slaughter method, it may be beneficial when used in combination with stunning and killing techniques.

Overview of Fish Slaughter Process in South Africa

According to Section 13 (Harvesting and Slaughter) of the DFFE Manual (2016) on the South African Aquaculture Marine Fish Monitoring and Control Programme, the following regulations must be strictly observed, as stipulated in the relevant legislation:

- Regulation 962 of the Foodstuffs, Cosmetics, and Disinfectants Act, 1972 (Act No. 54 of 1972)
- The Fertilisers, Farm Feeds, Agricultural Remedies, and Stock Remedies Act, 1947 (Act No. 36 of 1947)
- The Medicines and Related Substances Control Act, 1965 (Act No. 101 of 1965)

These regulations provide the legal framework governing the harvesting, slaughter, and handling of cultured marine fish in South Africa, ensuring compliance with food safety, animal welfare, and environmental standards.

- Appropriate harvesting techniques shall be applied, and appropriate equipment shall be used to minimise physical damage due to prolonged periods out of water in the live state.
- Live fish shall not be subjected to extreme heat or cold conditions or sudden variations in temperature and salinity prior to the slaughter process.
- Fish shall be free from excessive mud and weed soon after being harvested by washing with clean seawater or freshwater under suitable pressure.
- Fish shall be purged, where necessary, to reduce gut contents and pollution of fish during further processing.
- Fish shall be handled in a sanitary manner.
- Harvesting shall be rapid so that fish are not exposed unduly to high temperatures or environmental conditions that may cause contamination of the fish.
- Any dead or dying fish shall be removed from the production pond before the fish are harvested and handled.
- Harvesting shall be undertaken efficiently and humanely.
- The fish are either removed from the production or purging water by net or fish pump and slaughtered in an approved manner.
- The water used in the bins shall be potable water or clean seawater that meets the requirements of Sections 6.2 and 6.3.
- All equipment and holding facilities shall be easy to clean and disinfect and shall be cleaned and disinfected regularly as appropriate. Bins used in the slaughtering process shall be clean and free of any source of contamination.
- The temperature stipulated in Section 15 shall be achieved.
- There shall be no incisions made into the fish, nor shall the fish be harmed and/or damaged in any way during harvesting.
- Should any drugs be used for euthanasia, Section 9 shall be complied with.

General Guidance for Humane Slaughter Methods for Fish

Many commonly used methods for stunning and slaughtering farmed fish are unacceptable due to their aversive nature. These include:

- Asphyxiation in air or on ice
- Live chilling
- Carbon dioxide stunning
- Live chilling combined with carbon dioxide stunning
- Bleeding without prior stunning

Based on current research and available systems, percussive and electrical stunning, when properly applied, are among the least aversive methods for slaughtering fish (Brijs *et al.,* 2021)

Ongoing innovations may provide better alternatives, including combining methods to ensure that fish are stunned and killed quickly, efficiently, and with minimal suffering. Electrical stunning methods can be classified into two categories:

Electronarcosis (stunning only) – Fish are temporarily stunned and must be immediately followed by a secondary killing method.

Electrocution (stun/kill) – Fish are permanently rendered insensible by an electrical current, eliminating the need for further procedures to ensure humane slaughter (Humane Slaughter Association, 2016).

When using these systems, it is crucial for fish handlers to recognise the signs of an effective stun and know how and when to re-stun if necessary. Although percussive stunning may seem straightforward, operator error or equipment failure can severely compromise fish welfare and impact product quality. Proper training and adherence to best practices are essential for humane and effective slaughter.

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

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

MODULE 9: ENVIRONMENTAL ENRICHMENT AND FISH WELFARE

This module will introduce the concept of environmental enrichment and its importance in promoting fish welfare. It explores practical strategies that support natural behaviours, reduce stress, and improve overall health and productivity in aquaculture systems.

Environmental enrichment (EE) in aquaculture refers to the intentional modification of a captive fish's environment to enhance its physical health and psychological well-being. This involves providing sensory, structural, and motor stimulation that supports the expression of natural, species-specific behaviours. According to the Office of Animal Care and Use (OACU, 2023), the primary goal of environmental enrichment is "to enhance animal well-being by providing animals with sensory and motor stimulation, through structures and resources that facilitate the expression of species-typical behaviours and promote psychological well-being through physical exercise, manipulative activities, and cognitive challenges according to species-specific characteristics." For fish, this can include the use of shelters, varied tank substrates, water flow variations, social groupings, and visual or tactile stimuli that mimic natural habitats and encourage exploration, schooling, foraging, and other natural behaviours.

In aquaculture, environmental enrichment encourages the expression of natural behaviours in captive fish, promoting positive welfare outcomes that are essential for conducting valid and reproducible research while informing better management practices. Traditional rearing tanks in aquaculture are typically homogenous and lack stimulation, which can negatively impact fish welfare. The introduction of enrichment features within these systems has gained increasing recognition as an effective strategy to mitigate the adverse effects of captivity, such as stress from overcrowding or transportation, as well as limited opportunities to escape dominant conspecifics (Eidsmo *et al.*, 2023). Research has shown that rearing environments with added structural complexity and novelty can reduce stress, enhance behavioural diversity, including the expression of natural behaviours and improve cognitive function, ultimately fostering positive welfare states in fish (Oliveira *et al.,* 2023; Zhang *et al.,* 2022).

Due to the diverse range of environmental enrichment (EE) strategies available and the broad spectrum of species that can benefit from them, the field of EE science is continually evolving. Unlike other sectors that house captive fish, such as laboratory and ornamental fish industries, aquaculture focuses on fish production for human consumption. As a result, considerations extend beyond ethical concerns like animal welfare to include factors such as industry reputation, production efficiency, growth performance, feasibility, and certification requirements (Näslund and Johnsson, 2016). While comprehensive reviews exist on specific aspects of EE, such as physical enrichment or colour preferences in cultured fish, no study to date has examined all five recognised EE categories: physical, sensorial, occupational, social, and dietary enrichment in an integrated manner (McLean, 2021).

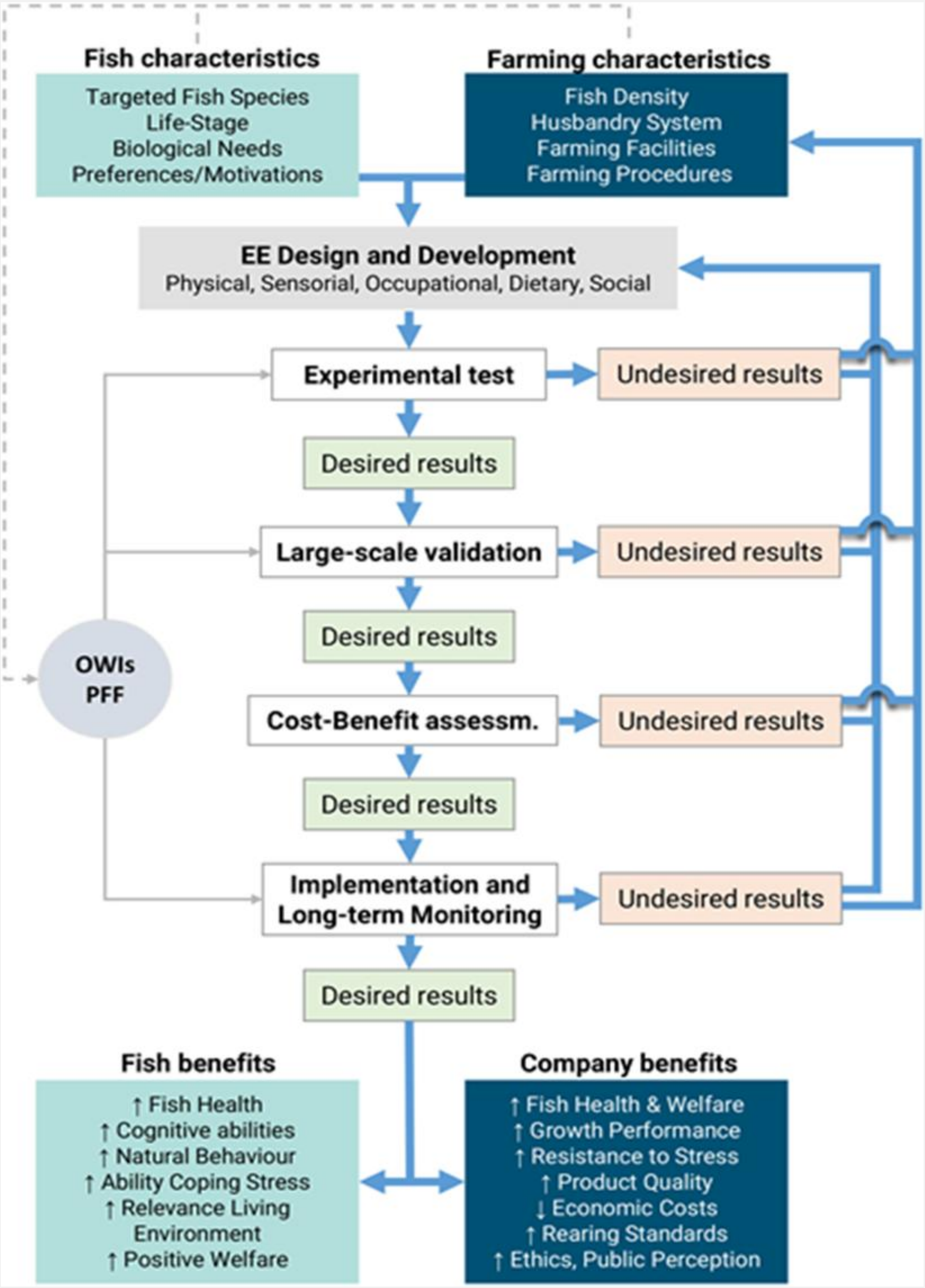

Figure 11 Decision-making scheme about the procedures (Source: Arechavala-Lopez et al., 2022)

Types of Environmental Enrichment

Environmental enrichment in fish can increase the suitability of rearing environments by mimicking natural environments (e.g. background colour) and increasing the variability of environmental conditions (e.g. cover, which provides areas of darkness and cooler water), thereby providing more choices to fish over their environment. Common environmental enrichment for fish can be grouped into five categories:

Physical/Structural Enrichment

Physical enrichment (PE), also known as structural enrichment, is a form of environmental enrichment that involves adding physical complexity to the housing environment of captive animals. This can include artificial plants, shelters, or other structures that enhance habitat heterogeneity. The presence of physical structures has long been recognised for its potential benefits in fish rearing. A more complex environment can provide shelter from water currents, reduce aggression among individuals, and serve as landmarks for territory establishment. Physical enrichment involves introducing structures, objects, or modifications that increase the environmental complexity of the rearing system (Arechavala-Lopez *et al.,* 2022; Jones *et al.,* 2021).

In their natural habitats, many fish species utilise substrates or shelters, and they may similarly benefit from physical enrichment in captivity. This enrichment strategy can incorporate a variety of features in different shapes and sizes, generally classified into two main types:

- **Structures**: These provide shelter or contribute to environmental heterogeneity and complexity.
- **Substrates**: More suitable for bottom-dwelling or substrate-dependent species, substrates play a crucial role throughout their life cycle or at specific stages, such as incubation.

Sensory enrichment

Sensory enrichment involves stimulating one or more of an animal's senses through a variety of visual, auditory, olfactory, tactile, and taste stimuli (Wells, 2009; Arechavala-Lopez *et al.,* 2022). Light characteristics, in particular, play a crucial role in the overall performance, development, and welfare of fish larvae, with optimal results observed when conditions closely resemble their natural environment. In juvenile and adult fish, daily cycles of locomotor activity and food anticipation are also directly influenced by lighting conditions.

Dietary enrichment

Dietary enrichment refers to the type of food or feeding strategy, including distribution, quantity, and frequency, that primarily influences foraging behaviour and food intake in fish. It is distinct from nutritional enrichment, which concerns the internal composition of the diet. Feeding strategies are critical components of dietary enrichment, as feeding schedules, regimens, and procedures can significantly impact fish welfare either positively or negatively (Arechavala-Lopez *et al.,* 2022).

As fish grow, their spatial distribution within a rearing environment changes due to increased size and corresponding space requirements. This has direct implications for feeding strategies. For instance, smaller fish may cluster in different areas of the pond compared to larger individuals, necessitating adjustments in feed distribution to ensure uniform access and minimise competition or food wastage. Therefore, effective dietary enrichment must be dynamic and responsive to the growth stages of fish, adapting feeding methods accordingly to maintain optimal welfare and performance.

Occupational enrichment

In nature, fish encounter various physical and psychological challenges, and occupational enrichment seeks to replicate these experiences in captivity to prevent monotony and boredom. This type of enrichment includes psychological elements that provide fish with challenges or control over their environment, as well as physical activities that encourage exercise, such as variations in water flow (Arechavala-Lopez *et al.,* 2022).

Social enrichment

Social enrichment encompasses not only the presence of other fish and their interactions but also the availability of space to engage or avoid social contact with conspecifics or different species. Understanding a species' natural social behaviour is crucial, whether it tends to be solitary, shoal in small or large groups at different life stages, or cohabits with other species in the wild. In contrast, many farmed species that do not naturally shoal or associate with other species tend to be territorial and may exhibit aggressive behaviour toward conspecifics. In high-density farming conditions, such aggression and cannibalism can pose significant challenges to fish welfare (Arechavala-Lopez *et al.,* 2022).

Benefits of Environmental Enrichment

Environmental enrichment (EE), also known as behavioural enrichment, provides species-specific challenges, opportunities, and stimulation to enhance overall well-being. It involves introducing dynamic environments, cognitive challenges, and social interactions to promote natural behaviours and physiological health. When implemented effectively, EE offers several benefits for fish welfare and aquaculture productivity, as outlined below:

1. **Improved Growth Performance:** Environmental enrichment has been shown to enhance growth rates in fish by reducing stress levels, improving food conversion efficiency, and stimulating growth-related hormone activity (Zhang *et al.,* 2020).
2. **Enhanced Animal Welfare:** A meta-analysis revealed that fish reared in enriched environments exhibit significantly better welfare indicators, including reduced stress markers, improved immune function, and higher survival rates compared to those in barren conditions (Zhang *et al.,* 2022).
3. **Increased Neural Plasticity and Cognitive Function:** Exposure to enriched environments has been linked to enhanced neural development and cognitive abilities in fish, promoting learning/conditioning and adaptive

behaviours beneficial for both captive and wild populations (Salvanes *et al.*, 2013).

4. **Reduced Aggression and Stress:** EE mitigates aggressive behaviours and lowers stress responses, fostering a more harmonious rearing environment. Reduced stress not only enhances fish welfare but also minimises injuries and improves overall productivity (Arechavala-López *et al.*, 2022).
5. **Mitigation of Captivity-Induced Behavioural Issues:** Structural enrichment helps reduce undesirable traits that fish develop in captivity, such as excessive aggression, stress-related energy expenditure, injury susceptibility, and increased disease risk (Näslund and Johnsson, 2016).

Implementing EE strategies in aquaculture not only enhances fish welfare but also provides economic advantages by improving growth performance, reducing mortality rates, and fostering more resilient fish populations.

Species Recommendations for Environmental Enrichment

Catfish (Clarias gariepinus)

Environmental enrichment (EE) plays a crucial role in improving fish welfare and productivity in aquaculture. For catfish, particularly *Clarias gariepinus*, substrate enrichment has been shown to positively influence growth, behaviour, and physiological responses. Studies indicate that juveniles reared in substrate-enriched tanks exhibit higher survival rates, greater mean weight gain, and reduced aggression (Ojelade *et al.*, 2022). EE strategies for catfish aim to enhance their welfare, growth, and overall health by incorporating elements that simulate natural habitats and promote natural behaviours. Key recommendations include:

- **Structural Enrichment:** Incorporating substrates, shelters, and varied tank structures provides catfish with essential hiding spots and territorial boundaries, reducing stress and aggressive interactions (Näslund Johnsson, 2016).

- **Dietary Enrichment:** Offering a varied diet, including live prey and novel food items, stimulates natural foraging behaviours and enhances nutritional intake. Understanding the species' nutritional requirements at different life stages is essential for optimising feeding protocols. The provision of high-quality, palatable, nutrient-rich, and well-balanced diets supports growth, health, and overall well-being throughout the fish's life cycle (Gisbert *et al.*, 2022).

As adapted from the Aquatic Life Institute (ALI), additional key recommendations for the environmental enrichment of Catfish are summarised in Table 4 below.

Table 4 Environmental Enrichment Recommendation for Catfish Species

African Catfish (*Clarias Gariepinus*)		
Enrichment Category	**Juvenile**	**Adult**
Enclosure Colouration	Black or dark-coloured tanks to reduce stress and promote higher survival rates (FishEthoBase, 2021).	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 (FishEthoBase, 2021).	Use a combination of mud, shale, sand and aquatic plants to provide a natural substrate for 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 aquaculture (Musuka and Musonda, 2020).

Table 5 Environmental Enrichment Recommendation for Tilapia Fish Species

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

Lighting	Increased light intensity (280-1390 lx) reduces aggressive interactions between pairs of juvenile males. Natural photoperiod is 9-15 hours. Provide access to natural (or at least simulated) photoperiod and daylight. (FishEthoBase)	Blue light reduces stress by preventing the confinement-induced cortisol response (Volpato and Barreto, 2001) Natural photoperiod is 9-15 hours. Provide access to natural (or at least simulated) photoperiod and daylight. Avoid 1,400 lux, as it increases aggression compared to 280 lux. (FishEthoBase)
Water Augmentation	Depth: Provide at least 2-6 m, ideally up to 20 m, bearing in mind the planned stocking density. Individuals should be able to choose swimming depths according to life stage and status. (FishEthoBase)	Depth: Provide at least 2-6 m, ideally up to 20 m, bearing in mind the planned stocking density. Individuals should be able to choose swimming depths according to life stage and status. (FishEthoBase)
Structures	An enriched environment increases resource value, which in turn prompts more intense fights. (FishEthoBase)	Fish cultured in environments enriched with artificial water hyacinth and shelter presented higher latency to trigger confrontations, and the confrontations were less intense in the section with enrichment items (Neto and Giaquinto, 2020).
Shelter	An enriched environment increases resource value, which in turn prompts more intense fights (FishEthoBase).	For the most natural solution, provide roots or submerged branches, bushes, or trees; alternatively, provide artificial shelters within the system (e.g. artificial reefs or plastic pipes for catfish). (FishEthoBase)

Feeding System	Ensure that you provide sufficient feed from approximately 4-8 days after hatching. Self-feeders could prevent stressful food competition (FishEthoBase)	Tryptophan-supplemented food was found to reduce confrontations (Neto and Giaquinto, 2020). Install a self-feeder and make sure all Nile tilapia adapt to it. (FishEthoBase) Provide sand, mud, and bamboo poles so that individuals may search for food. (FishEthoBase)

Carp Fish

Environmental enrichment (EE) plays a vital role in enhancing the welfare, growth, and overall health of carp by introducing elements that mimic natural habitats. Structural enrichment, such as incorporating substrates, shelters, and varied tank structures, provides essential hiding spots and territorial spaces, helping to reduce stress and aggression (Gerber *et al.,* 2015).

Dietary enrichment through a diverse diet, including live prey and novel food items, stimulates natural foraging behaviours and improves nutritional intake, contributing to better growth and overall health (Jobling *et al.,* 2012; Lall *et al.,* 2009). Sensory enrichment, which involves introducing environmental stimuli such as varying light conditions or water flow patterns, engages the carp's sensory systems, promoting exploration, activity, and cognitive stimulation (Arechavala-Lopez *et al.,* 2022). Social enrichment, achieved by maintaining appropriate stocking densities and structured social groupings, fosters natural social interactions, reduces stress, and enhances overall well-being. As adapted from the Aquatic Life Institute (ALI), key recommendations for environmental enrichment of carp are outlined in Table 5 below.

Table 6 Environmental Enrichment Recommendation for Carp Fish Species

Common carp (*Cyprinus carpio*)		
Enrichment Category	**Juvenile**	**Adult**
Enclosure Coloration	For lower stress and higher growth, avoid red and black tanks (FishEthoBase).	For lower stress and higher growth, avoid red and black tanks (FishEthoBase).
Substrate Provision	For the most natural solution, provide sand, mud, gravel, and submerged vegetation (FishEthoBase).	For the most natural solution, provide sand, mud, gravel, and submerged vegetation (FishEthoBase).
Lighting	The natural photoperiod ranges from 7 to 17 hours. Provide access to natural (or at least simulated) photoperiod and daylight (FishEthoBase). For lower stress and higher weight in juveniles, prefer 200 over 80 lux (FishEthoBase).	The natural photoperiod ranges from 7 to 17 hours. Provide access to natural (or at least simulated) photoperiod and daylight (FishEthoBase). Allow common carp a resting period at night or in the dark (FishEthoBase).
Water Augmentation	Depth range: in the wild, found at 0-1.3 m, adults up to 25 m. Provide at least 1.5 m, ideally up to 5 m or more, bearing in mind the planned stocking density. Individuals should be able to choose swimming depths according to their life stage (FishEthoBase).	Depth range: in the wild, found at 0-1.3 m, adults up to 25 m. Provide at least 1.5 m, ideally up to 5 m or more, bearing in mind the planned stocking density. Individuals should be able to choose swimming depths according to their life stage (FishEthoBase).
Structures	Cover: Avoid complete cover for differences in the daily rhythms (FishEthoBase).	Cover: Avoid complete cover concerning differences in the daily rhythms (FishEthoBase).
Shelter	Juveniles used plants as shelters (FishEthoBase).	For the most natural solution, provide vegetation; alternatively, consider providing artificial shelters both inside

		and outside the system (FishEthoBase).
Feeding System	Food competition: Ensure sufficient feed is provided from approximately 1 to 7 days after hatching. To improve stress tolerance, enrich feed for fry with 4% fructo-oligosaccharides (FishEthoBase).	The most natural solution is to provide food at 1) varying intervals or 2) constant intervals, both day and night, while making sure not to disturb the resting part of the population. Alternatively – and for lower stress and higher growth – install a self-feeder and make sure all common carp adapt to it.

In conclusion, environmental enrichment (EE) has emerged as a promising approach to enhancing fish welfare in aquaculture. It is a critical strategy that significantly improves the welfare, health, and productivity of farmed fish by simulating natural environments and promoting species-specific behaviours. EE helps reduce stress, boost growth, and foster overall well-being. The integration of structural, dietary, sensory, and social enrichment techniques not only enhances the physical and psychological health of the fish but also promotes more sustainable and efficient aquaculture practices. Ultimately, the adoption of EE in aquaculture leads to healthier fish populations, improved production outcomes, and more ethical farming practices.

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

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

MODULE 10: FISH HEALTH AND WELFARE

This module introduces the concepts of fish health and fish welfare, and explains the key differences between these two concepts. While fish health focuses on the biological and pathological conditions of the animal, fish welfare considers the broader physical, environmental, and behavioural needs required for fish to live and thrive. Understanding both is essential for responsible aquaculture management and for ensuring ethical, safe, and sustainable production systems.

Animal Health and Welfare

Animal welfare refers to an animal's physical and mental well-being, as well as the quality of life it experiences under human care or captivity (Mellor, 2016). As a guiding principle for legislation and regulations, animal welfare aims to minimise suffering and ensure animals receive proper living conditions and treatment. In aquaculture, fish welfare is closely linked to fish health and their ability to cope with stressors while maintaining homeostasis. Poor husbandry conditions can disrupt internal balance, forcing energy-intensive physiological adjustments that weaken immune function and compromise epithelial barriers.

According to the World Organisation for Animal Health (WOAH, 2018), animal welfare is defined as the physical and mental state of an animal in relation to its living and dying conditions. An animal experiences good welfare when it is healthy, comfortable, well-nourished, and safe, free from pain, fear, and distress, while also being able to express behaviours essential to its physical and mental well-being. Good animal welfare requires disease prevention, appropriate veterinary care, proper shelter and nutrition, a stimulating and safe environment, and humane handling, slaughter, or euthanasia.

Health is generally defined as the absence of disease or the normal functioning of an organism, assessed by observing a population of individuals to establish a standard (Assefa and Abunna, 2018). Animal health refers to an animal's ability to cope with its environment, encompassing physiological, behavioural, and emotional responses to external challenges, including diseases. It is a key aspect of animal care and management, playing a vital role in global health, economic development, food security, food quality, and poverty reduction while contributing to climate change mitigation and biodiversity conservation (Charlier *et al.,* 2022). Optimal health and welfare enhance an animal's physical and mental well-being, ultimately improving its quality of life (Boissy *et al.,* 2007). Among the major challenges in aquaculture, infectious diseases pose the greatest threat, causing multibillion-dollar losses annually. To mitigate the impact of fish diseases, it is crucial to adopt scientifically proven and evidence-based health management strategies.

Biosecurity for Fish Health and Welfare

Biosecurity refers to any management action taken to prevent the introduction of disease-causing agents into an aquaculture facility (Phu *et al.,* 2016). At the farm level, biosecurity measures involve a combination of practices, including strict quarantine procedures, equipment sanitation, egg disinfection, traffic control, water treatment, the use of clean feed, and proper disposal of mortalities. These protocols should be implemented when introducing new stock and consistently maintained to reduce pathogen loads and prevent cross-contamination between stocks.

The majority of aquaculture diseases can be effectively managed through the meticulous application of biosecurity measures. One key strategy for disease control is reducing stocking density, which helps limit disease outbreaks in aquaculture systems. Lower stocking densities are particularly effective in controlling ectoparasite infections, especially when combined with increased water flow to enhance parasite flushing (Oidtmann *et al.,* 2011).

Effective biosecurity measures safeguard aquaculture facilities by preventing the entry and spread of pathogens absent from a particular system. Rather than focusing solely on treating diseases after they occur, a proactive, preventive approach is recommended (Assefa and Abunna, 2018). Minimising losses due to infectious diseases requires addressing health constraints through scientifically proven, locally applicable strategies. As the saying goes, "prevention is better than cure," emphasising the importance of disease prevention over treatment (Romero *et al.,* 2012).

Key approaches to controlling infectious fish diseases include improved husbandry and management practices, movement restrictions, the use of genetically resistant stock, dietary supplements, non-specific immune-stimulants, vaccines, probiotics, prebiotics, medicinal plant products, biological control agents, antimicrobial compounds, and water disinfection (Kumar *et al.,* 2016). These measures collectively help minimise the introduction, establishment, and spread of pathogens in aquaculture systems.

Common Biosecurity Measures and Practices

Quarantine and Movement Restrictions

The primary goal of quarantine is to minimise the risk of introducing infectious diseases into established fish populations. This process involves isolating newly introduced aquatic animals with an unknown health status before integrating them into the main stock. During quarantine, strict observation and appropriate diagnostic testing are essential. The quarantine period typically ranges from 15 days to three months, depending on risk assessments and health screening results (Hadfield *et al.,* 2011).

Use of Disinfectants and Pesticides

Disinfection involves the application of physical or chemical agents to eliminate microorganisms, primarily on inanimate objects. In aquaculture, disinfectants are also used to treat fish eggs and to prevent the spread of pathogens within rearing facilities (Dvorak, 2009). Commonly used disinfectants include quaternary ammonium compounds, formaldehyde, hydrogen peroxide, isopropyl alcohol, glucoprotamine, chlorine, iodine, and iodophors. When using chlorine, neutralisation is necessary to prevent fish toxicity. Similarly, equipment treated with iodine-based compounds must be thoroughly rinsed before use to avoid toxic effects (Scarfe et al., 2008).

According to the FAO (2023), the Progressive Management Pathway for Aquaculture Biosecurity (PMP/AB) requires the appropriate use of disinfectants and chemical agents to align with a risk-based biosecurity approach. This includes developing site-specific protocols that minimise environmental and health risks while ensuring effective pathogen control. The guidelines emphasise the importance of standard operating procedures (SOPs) for the preparation, application, neutralisation, and disposal of disinfectants. Proper training of personnel, regular monitoring, and documentation are also critical to ensure compliance and efficacy in disease prevention strategies (FAO, 2023).

Disease Surveillance in Aquaculture

Effective disease surveillance is a cornerstone of biosecurity, providing essential health data for disease control, quarantine measures, and health certification. Routine surveillance helps identify potential disease entry points, detect emerging pathogens early, and enable timely intervention before outbreaks become widespread (Oidtmann *et al.,* 2011). Regular monitoring should be an integral part of national aquatic animal health services to reduce disease transmission risks.

The FAO (2023) emphasises that effective disease surveillance must be risk-based, systematic, and integrated into broader national biosecurity frameworks under the Progressive Management Pathway for Aquaculture Biosecurity (PMP/AB). The guidelines advocate for harmonised data collection, laboratory diagnostics, and transparent reporting systems to support early warning, preparedness, and response. The FAO also underscores the importance of public-private partnerships and stakeholder engagement in surveillance activities to enhance compliance and ensure sustainability across diverse aquaculture systems (FAO, 2023).

Water Quality Monitoring and Management

Water quality plays a crucial role in maintaining fish health and preventing disease. Poor water conditions weaken fish, making them more susceptible to infections. To maintain optimal conditions:

- Regularly test key water parameters, including pH, oxygen levels, and temperature.
- Use appropriate filtration systems to remove toxins and prevent waste accumulation, and take measures to prevent bird droppings from contaminating the water, unless intentionally applied for fertilisation purposes.
- Implement proper water exchange methods to reduce pathogen accumulation.

Additionally, testing incoming water sources for harmful bacteria and parasites helps prevent the introduction of diseases.

Preventing Cross-Contamination

Cross-contamination occurs when pathogens spread through equipment, feed, or farm personnel. To minimise this risk:

- Sanitise equipment – Disinfect nets, buckets, and tools before and after use.
- Secure feed storage – Keep fish feed in sealed, dry containers to prevent contamination.

- Follow an all-in, all-out stocking method – Stock and harvest fish in batches to limit disease spread.

Protecting Wild Fish Populations

Aquaculture does not operate in isolation; diseases can spread to wild fish populations through water movement or the escape of farmed fish. To prevent this:

- Use secure enclosures: Prevent farmed fish from escaping into natural water bodies.
- Dispose of waste responsibly: Treat wastewater before releasing it into the environment or use it for horticulture.
- Limit antibiotic use: Overuse of antibiotics can contribute to antimicrobial resistance (AMR), threatening both farmed and wild fish populations.

By implementing rigorous biosecurity measures, monitoring water quality, and preventing cross-contamination, fish farmers can protect their stock while supporting sustainable aquaculture practices.

Benefits of Biosecurity in Fish Farms

Without proper biosecurity, fish farms become hotspots for disease outbreaks. Bacterial, viral, and fungal infections can spread rapidly, leading to:

- **High mortality rates:** Entire fish populations can be lost within days.
- **Economic losses:** Farmers face reduced yields and increased treatment costs.
- **Environmental risks:** Diseases from farmed fish can spread to wild populations, disrupting ecosystems.

Prioritising aquaculture biosecurity significantly reduces these risks, ensuring healthier fish populations, improved profitability, and a more sustainable aquaculture industry.

Fish Diseases and Impacts

Finfish serve as hosts to a wide range of ectoparasites and endoparasites, which are naturally present in aquatic ecosystems. In healthy fish, these parasites generally have minimal impact. However, under stressful conditions, such as those encountered in captivity, public aquariums, the ornamental fish trade, and aquaculture, parasitic infections can become problematic (Lieke *et al.,* 2020). In aquaculture, diseases account for up to 50% of production losses (Assefa and Abunna, 2018). High stocking densities and poor water quality create ideal conditions for parasites to proliferate and reach pathogenic levels. Additionally, the transportation of fish and equipment facilitates the spread of infectious pathogens (Subasinghe *et al.,* 2001). To mitigate losses caused by infectious diseases, it is crucial to implement scientifically validated and locally applicable disease prevention and control strategies. The challenges facing aquaculture, including climate change, limited water resources, and increasing demand, necessitate epidemiological approaches to safeguard the health of aquatic animals (Assefa and Abunna, 2018).

The Impact of Disease on Aquaculture Sustainability

Disease outbreaks pose a significant threat to sustainable aquaculture globally, resulting in substantial economic losses. One of the biggest challenges in finfish aquaculture is the management and control of infectious diseases. Salmonids, carp, catfish, tilapia, and marine finfish farming are all affected by a variety of viral, bacterial, parasitic, and fungal diseases (Rodger, 2016). The rapid growth of the aquaculture industry has also heightened the risk of disease outbreaks, which can be caused by both pathogenic and nonpathogenic factors (Ziarati *et al.,* 2022).

Pathogenic conditions include bacterial, viral, fungal, and parasitic infections (FAO, 2020). These diseases can spread rapidly through the movement of infected hosts, causing devastating effects on aquaculture productivity and creating challenges for industry growth (Subasinghe *et al.,* 2009). Nonpathogenic factors, such as environmental stressors and poor nutrition, also contribute to disease susceptibility. High stocking densities, for example, weaken fish immune systems and increase vulnerability to infections.

Identifying and Managing Common Fish Diseases

Recognising and addressing fish diseases is essential for effective disease management in aquaculture. However, it is crucial to emphasise that any disease treatment must be firmly based on a solid and accurate diagnosis. Before any intervention is undertaken, the first and most important step is to gather comprehensive information to identify the causative pathogen or parasite. This includes observing clinical signs, conducting water quality assessments, and, when possible, preserving dead or moribund fish for laboratory analysis to determine the specific disease affecting the farm.

The most common fish diseases encountered in aquaculture include:

- **Fungal infections**: Often linked to poor water quality, injuries, or environmental stress.
- **Bacterial infections:** May present as ulcers, haemorrhaging, fin rot, or systemic infections.
- **Parasitic infections:** Typically manifest as skin lesions, erratic swimming, weight loss, and impaired growth.
- **Viral infections**: Frequently result in high mortality rates due to their highly contagious nature.

Accurate identification of the disease agent ensures that appropriate treatment measures are selected, minimising unnecessary chemical use and reducing the risk of resistance or further outbreaks.

Fungal Infections in Aquaculture

Fungal infections (mycoses) are common in aquaculture, particularly in temperate regions. Fish were the first known vertebrates to be infected by fungi (Albouy *et al.,* 2013). These aquatic fungi can infect all life stages, including eggs, fry, fingerlings, and adult fish. They often act as secondary pathogens, exploiting hosts weakened by injury, stress, or poor water quality (Gozlan *et al.,* 2010). The most prevalent fungal diseases in fish include:

a. Saprolegniasis

Causative Agent: *Saprolegnia* spp. (Özdemir *et al.,* 2022).

Symptoms: Cotton-like white or grey growths on the skin, fins, or gills; lethargy; loss of appetite; and erratic swimming (Manna *et al.,* 2023).

Figure 12 Fish gills infected with Saprolegniasis (Photo credit: Brittany Chesser, (2020)

Treatment: Antifungal agents such as malachite green, formalin, and potassium permanganate (Ali *et al.,* 2020; González-Palacios *et al.,* 2019). Salt baths (>3 ppt) can also help control infections.

Prevention: Maintain optimal water quality, avoid overcrowding, and ensure proper feeding to reduce stress and prevent infections (Earle and Hintz, 2014).

b. Branchiomycosis (Gill Rot)

Causative Agent: *Branchiomyces* spp.

Symptoms: Gill necrosis, respiratory distress, lethargy, and gasping at the water surface (Sheikha & Mankodi, 2021).

Treatment: No direct cure exists; management focuses on optimising environmental conditions, including maintaining a pH of 5.8–6.5, ensuring adequate dissolved oxygen, and preventing algal blooms. Disinfection, tank drying, and calcium oxide treatments help control outbreaks (Mahboub, 2021).

c. Ichthyophoniasis (Swinging Disease)

Causative Agent: *Ichthyophonus sp.*

Symptoms: Roughened skin ("sandpaper effect"), white-to-grey lesions on internal organs, neurological issues such as erratic movements, and spinal curvature (Blazer *et al.,* 2002; Ameen *et al.,* 2018).

Treatment: No effective treatment currently exists. Control measures include pasteurising contaminated food to prevent disease transmission (Ameen *et al.,* 2018).

d. Exophialosis

Causative Agent: *Exophiala* spp. (Roberts, 2012).

Symptoms: Darkened colouration, erratic swimming, lethargy, yellow-to-white granulomas in visceral organs, and kidney enlargement (Saraiva *et al.,* 2019).

Treatment: Disease management depends on the severity of the condition. Antifungal medications, such as Itraconazole and Posaconazole, can be administered orally or via topical bath treatments. Environmental improvements play a critical role in disease control.

Bacterial Infections in Aquaculture

Bacterial diseases pose significant challenges in aquaculture, impacting fish health, productivity, and overall farm efficiency. Below is an overview of common bacterial diseases in farmed fish, including their causative agents, symptoms, and treatment options.

a. Columnaris Disease

Causative Agent: *Flavobacterium columnare*

Symptoms: Red or pale ulcers on the skin, yellowish mucus on the skin, gills, and mouth, necrosis or erosion of the gills, and characteristic "saddleback" lesions, pale white bands encircling the body (LaFrentz *et al.,* 2022).

Figure 13 Tilapia infected with Ichthyophthirius multifiliis show white spots on skin and fins (left). Flavobacterium columnare infection causes lesions in the caudal fin (Source: globalseafood.org)

Treatment: Early-stage infections may be managed with chemical treatments such as potassium permanganate or hydrogen peroxide. In chronic cases, systemic antibiotics like florfenicol or oxytetracycline are recommended. Preventive measures include reducing organic matter in the water and minimising fish injuries.

b. Motile Aeromonas Septicemia (MAS)

Causative Agents: *Aeromonas* spp., including *A. hydrophila* and *A. salmonicida*

Symptoms: Haemorrhages on the skin, eyes, and fins; distended abdomen; flared scales due to oedema (dropsy); red, inflamed anus. Internally, muscle tissues and visceral organs may show redness, and the body cavity may contain bloody fluid (Le *et al.,* 2018).

Treatment: Antibiotics such as sulfonamides, oxytetracycline, or oxolinic acid are administered via medicated feed. Proper withdrawal periods must be observed before harvesting treated fish.

c. Enteric Septicemia of Catfish (ESC)

Causative Agent: *Edwardsiella ictaluri*

Symptoms: Abnormal swimming patterns such as whirling or "head-chasing-tail" movements, "star-gazing" behaviour, red or white shallow ulcers, a characteristic hole in the head, and severe abdominal distension due to fluid accumulation (Hawke, 2015).

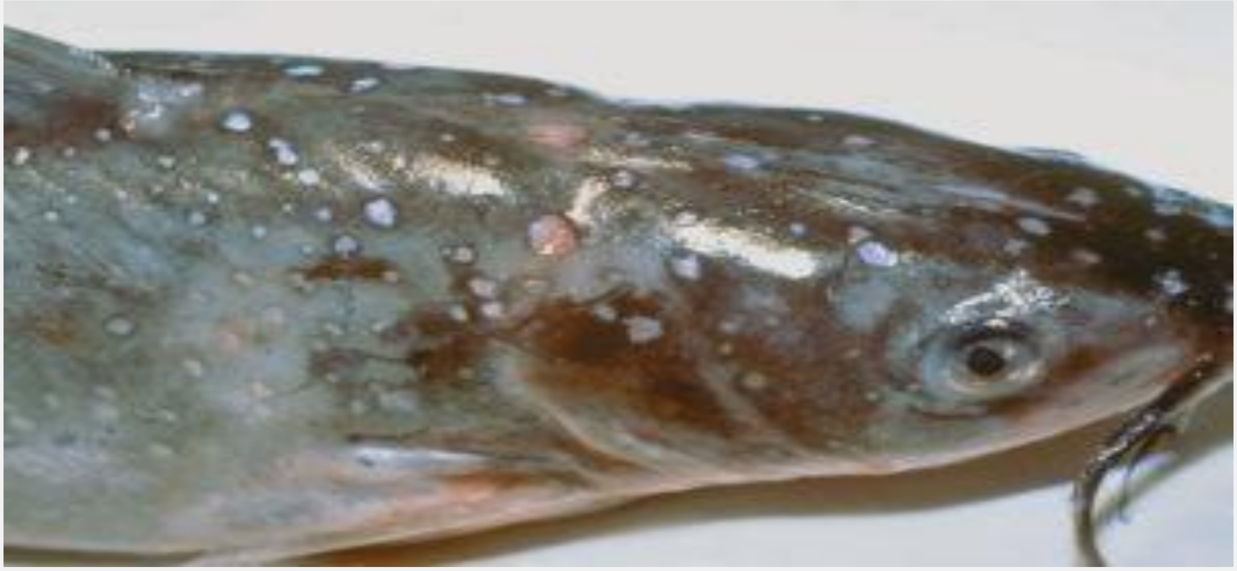

Figure 14 Enteric septicemia is a prevalent disease in catfish production. Its signs of infection include lesions on the skin (Source: globalseafood.org)

Treatment: Medicated feed containing antibiotics such as florfenicol, Romet, or oxytetracycline.

d. Vibriosis

Causative Agents: *Vibrio* spp., including *V. anguillarum*, *V. harveyi*, *V. vulnificus*, *V. parahaemolyticus*, and *V. alginolyticus*

Symptoms: Lethargy, skin ulcerations, fin rot, loss of appetite, haemorrhages, and congestion in the liver, kidney, and spleen, leading to systemic infections and high mortality rates (Ina-Salwany *et al.,* 2019).

Treatment: Antibiotic therapy based on bacterial sensitivity testing. Preventive strategies include reducing stress and overcrowding. Vaccination with formalin-killed Vibrio strains is widely used in the salmonid industry.

e. Bacterial Gill Disease (BGD)

Causative Agent: *Flavobacterium branchiophilum*

Symptoms: Swollen and mottled gills with patchy bacterial growth, hyperplasia, adhesions, deformities in gill lamellae, high mortality in young fish, and sustained morbidity (Starliper & Schill, 2011).

Treatment: Maintaining optimal water quality and avoiding overstocking are crucial. A single treatment with potassium permanganate, followed by the addition of salt (2–5 ppt), can help control infections. Antibiotics may be used to manage secondary bacterial infections.

f. Mycobacteriosis

Causative Agents: Mycobacterium spp., including *M. marinum*, *M. fortuitum*, and *M. chelonae*.

Symptoms: Erratic swimming, abdominal swelling, weight loss, skin ulcers, and the formation of white granulomas in the liver, kidney, and spleen.

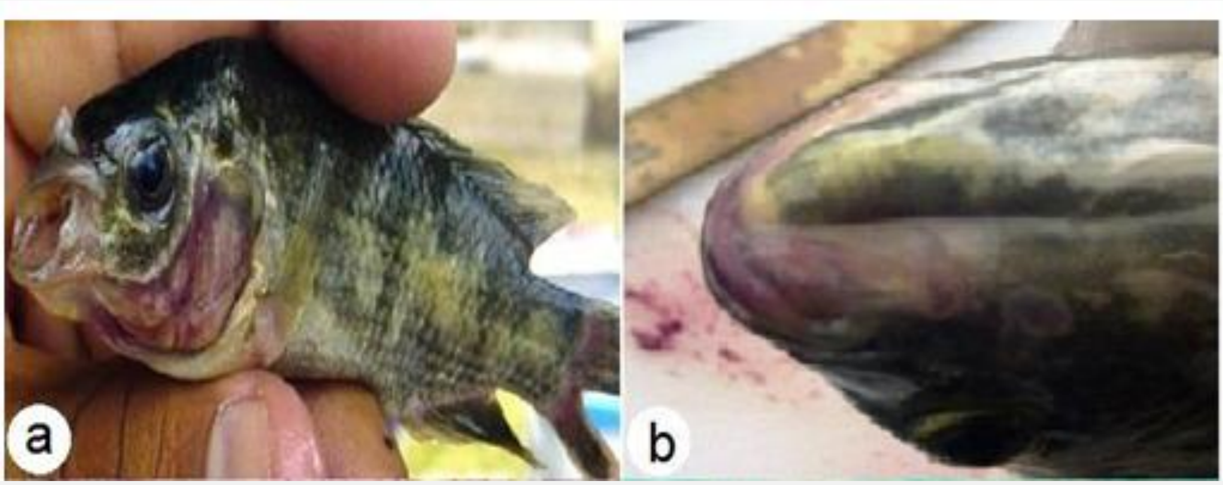

Figure 15 Mycobacteriosis in Nile tilapia (Oreochromis niloticus) (Source: Lara-Flores et al., 2014)

Treatment: No effective treatment exists. Preventive measures focus on maintaining optimal water quality, reducing stress, and preventing the introduction of infected fish into the system.

Parasitic Diseases in Farmed Fish

Parasitic infections pose a significant threat to aquaculture, resulting in substantial economic losses and compromising fish health. Below is an overview of common parasitic diseases in farmed fish, including their causative agents, symptoms, and treatment options.

a.Ichthyophthiriasis (White Spot Disease)

Causative Agent: *Ichthyophthirius multifiliis*, a ciliated protozoan (Elsayed *et al.*, 2006).

Symptoms: Small white spots on the skin, gills, and fins; flashing (rubbing against surfaces); increased mucus production; respiratory distress.

Treatment: Raising water temperature above 85°F can disrupt the parasite's life cycle. Effective chemical treatments include formalin, copper sulfate, and potassium permanganate. However, caution is needed in integrated systems to prevent harm to plants.

b. Amyloodiniosis (Marine Velvet Disease)

Causative Agent: *Amyloodinium ocellatum*, a dinoflagellate protozoan.

Symptoms: Dusty or velvety appearance on the skin; lethargy; anorexia; respiratory distress; flashing behaviour (Bessat and Fadel, 2018).

Treatment: Copper sulphate and chloroquine (for non-food fish) are effective. Freshwater dips can also benefit marine species.

c. Trichodiniasis

Causative Agent: Trichodina spp., motile ciliated protozoans.

Symptoms: Excess mucus production; flashing; respiratory distress; general loss of condition (Valladão *et al.,* 2016).

Treatment: Formalin and copper sulphate baths are commonly used.

d. Ichthyobodiasis (Costia)

Causative Agent: *Ichthyobodo spp.,* flagellated protozoans.

Symptoms: Excess mucus production; flashing; respiratory distress; general loss of condition (Adamek *et al.,* 2019).

Treatment: Effective treatments include formalin, copper sulphate, potassium permanganate, and salt baths.

e. Monogenean Infestations (Flukes)

Causative Agents: Monogenean parasites, including *Gyrodactylus spp.* and *Dactylogyrus* spp.

Symptoms: Scraping against objects, rapid gill movements, mucus covering the gills or body, and reddened skin. Severe infestations can cause gill damage and mortality (Reed *et al.,* 2009).

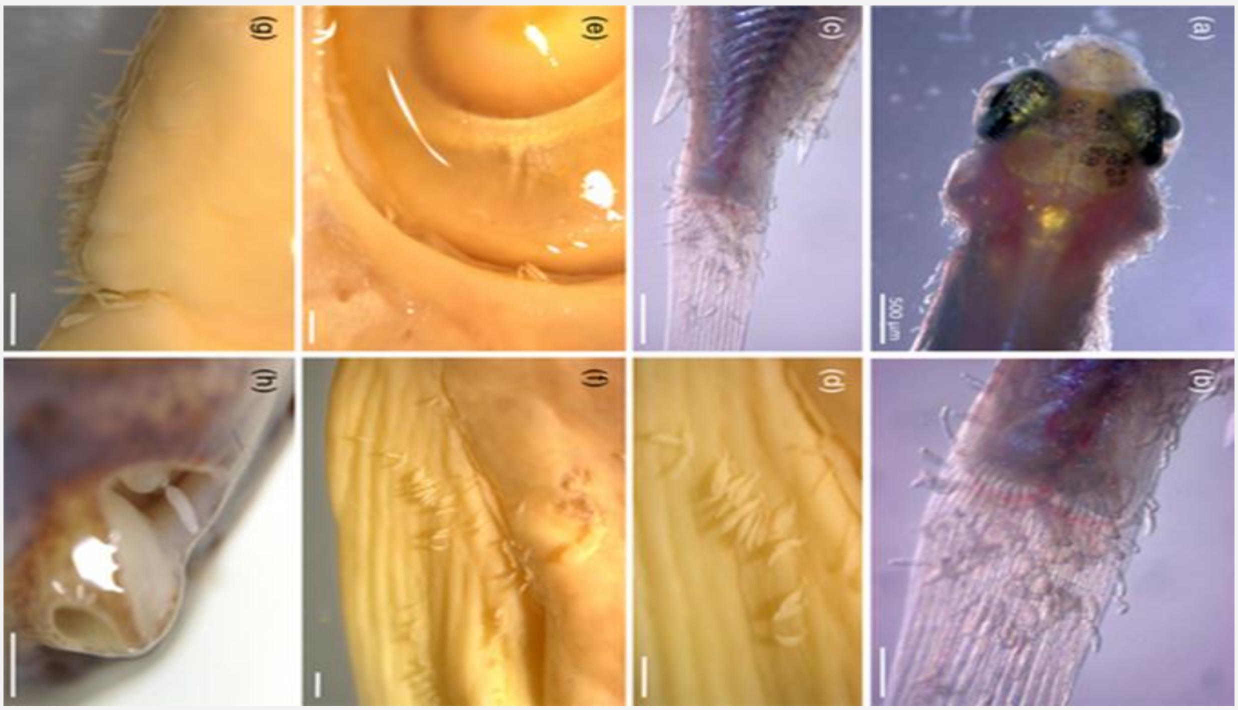

Figure 16 Heavy infection of Gyrodactylus cichlidarum in Oreochromis niloticus (Shinn et al., 2023)

Treatment: Potassium permanganate baths (10 mg/L for 10-30 minutes) are effective.

f. Nematode Infections

Causative Agents: Common genera affecting farmed fish include *Anguillicoloides*, *Eustrongylides*, and *Anisakis* (Paladini *et al.,* 2017).

Symptoms: Lethargy; reduced feeding; emaciation; visible worms in the gastrointestinal tract; cysts or nodules in muscle tissues; abdominal distension; haemorrhaging.

Treatment: Benzimidazole-based anthelmintics, commonly used in livestock, have shown efficacy against certain fish nematodes, such as *Anguillicoloides crassus.*

g. Ergasilosis

Causative Agent: *Ergasilus* spp., parasitic copepods (Piasecki and Avenant-Oldewage, 2008).

Symptoms: Scraping against objects; whitish-green thread-like parasites hanging from the gills.

Treatment: Potassium permanganate baths (10 mg/L for 10-30 minutes) are recommended.

h. Leech Infestation

Causative Agent: Parasitic leeches.

Symptoms: Visible leeches on the skin, causing irritation and potential secondary infections (Hayes *et al.,* 2006).

Treatment: Bathing fish in a 2.5% salt solution for 15 minutes can cause leeches to detach from their hosts. Remaining leeches can be carefully removed with forceps. Alternatively, trichlorfon (0.25 mg/L) is effective.

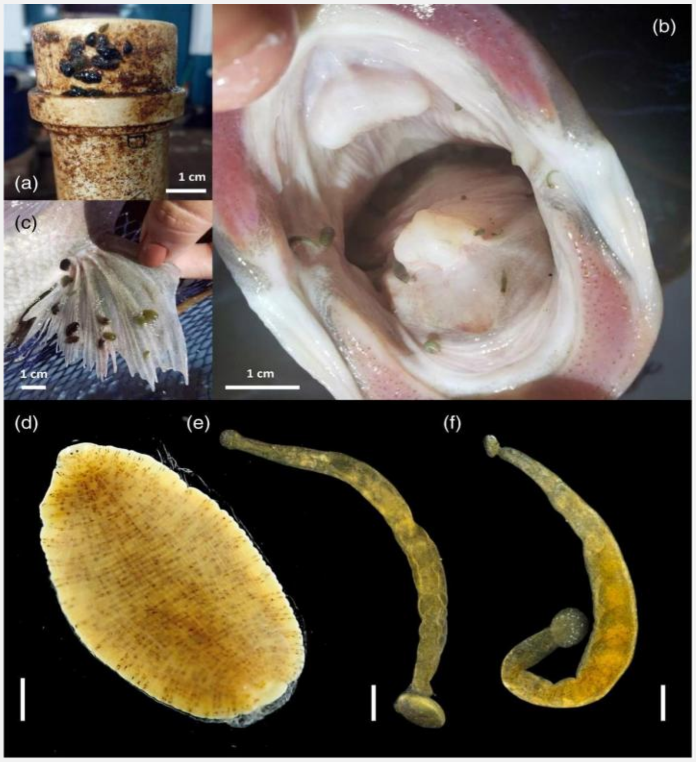

Figure 17 Leech infections of Oreochromis niloticus. (a–d) Helobdella sp. from stock cultured in Brazil (Shinn et al., 2023)

Viral Diseases in Farmed Fish

Viral infections pose a significant challenge in aquaculture, frequently resulting in substantial economic losses and severe health impacts on fish populations. Below is an overview of common viral diseases affecting farmed fish, including their causative agents, symptoms, and treatment or prevention strategies.

a. Viral Hemorrhagic Septicemia (VHS)

Causative Agent: Viral Haemorrhagic Septicemia Virus (VHSV), a rhabdovirus affecting multiple fish species.

Symptoms: Infected fish exhibit bulging eyes, bloated abdomens, and a bruised appearance with reddish discolouration in the eyes, skin, gills, and fins.

Figure 18 Infectious hematopoietic necrosis virus (IHNV) outbreak in farmed rainbow trout (Ahmadivand et al., 2017)

Treatment and Prevention: There is no specific antiviral treatment for VHS. Prevention relies on strict biosecurity measures and disinfection protocols, such as using chlorine bleach, which has been shown to effectively eliminate VHSV (Kim and Faisal, 2011).

b. Infectious Hematopoietic Necrosis (IHN)

Causative Agent: Infectious Hematopoietic Necrosis Virus (IHNV), a bullet-shaped, negative-sense single-stranded RNA virus (Dixon *et al.,* 2016).

Symptoms: Affected fish may display abdominal distension, bulging eyes, skin darkening, abnormal swimming behaviour, anaemia, and pale gills.

Treatment and Prevention: There is no effective treatment for IHN. Preventive measures include strict isolation of infected fish, enhanced hygiene practices, and regular screening to detect the virus early.

c. Spring Viremia of Carp (SVC)

Causative Agent: Spring Viremia of Carp Virus (SVCV), a highly contagious rhabdovirus affecting carp species (Ahne *et al.,* 2002).

Symptoms: External haemorrhaging, pale gills, and ascites (fluid accumulation in the abdominal cavity) are common clinical signs.

Treatment and Prevention: No specific treatment is available. Preventative strategies include developing DNA vaccines and immune-stimulatory therapeutics to enhance the fish's immune response.

d. Viral Nervous Necrosis (VNN)

Causative Agent: Betanodavirus, the causative agent of Viral Nervous Necrosis (VNN), also known as Viral Encephalopathy and Retinopathy (VER).

Symptoms: The disease causes vacuolating necrosis of neural cells in the brain, retina, and spinal cord, leading to high mortality rates of up to 100% in larval and juvenile fish, with significant losses in older fish (Costa *et al.,* 2016).

Treatment and Prevention: There is no effective treatment for VNN. Research efforts are focused on vaccine development; however, no commercially available vaccine currently exists.

e. Infectious Salmon Anaemia (ISA)

Causative Agent: Infectious Salmon Anaemia Virus (ISAV), a member of the Orthomyxoviridae family.

Symptoms: Affected fish exhibit lethargy, listlessness, and abnormal sinking behaviour, abdominal distension, haemorrhagic spots around the eyes, pale gills, and petechiae (small red or purple spots due to bleeding under the skin). Internally, signs include ascites, swim bladder oedema, splenomegaly (enlarged spleen), and a uniformly dark liver (Nylund *et al.,* 1994; Cottet *et al.,* 2011).

Treatment and Prevention: A commercial vaccine is available for ISA. Diagnosis is based on clinical signs, histopathology, and viral isolation using cell culture techniques.

Notifiable and Environmentally Linked Diseases in Aquaculture

In the management of fish health, notifiable diseases play a critical role in national and international biosecurity systems. According to the World Organisation for Animal Health (WOAH) and the FAO's Progressive Management Pathway for Aquaculture Biosecurity (2023), notifiable diseases are those that must be reported to national or international authorities due to their potential for rapid spread and significant socio-economic or ecological impact. These include viral infections such as Infectious Hematopoietic Necrosis (IHN), Epizootic Ulcerative Syndrome (EUS), Koi Herpesvirus Disease (KHVD), and Infectious Salmon Anaemia (ISA). Surveillance and early detection of such diseases are essential for effective response and containment. In addition to infectious diseases, environmentally induced diseases such as gas bubble disease, hypoxia, and ammonia toxicity are important yet often underreported contributors to fish morbidity and mortality. These conditions arise from poor water quality, overcrowding, or inadequate farm management and can predispose fish to opportunistic infections (Overstreet and Hawkins, 2017).

Antimicrobial Resistance

Understanding Antimicrobials and Antimicrobial Resistance (AMR)

Antimicrobials (AMs) are pharmaceutical agents used to kill or inhibit the growth of microorganisms, including antibiotics (ABs), antivirals, antifungals, and antiprotozoals (Henriksson *et al.,* 2018). In aquaculture, AMs are primarily used for prophylactic and metaphylactic treatments. Since no antibiotics are specifically designed for aquaculture, those developed for other veterinary applications are often repurposed (Tendencia and de la Peña, 2001).

Antimicrobial resistance (AMR) occurs when microorganisms develop mechanisms that enable them to withstand the effects of antimicrobials. This resistance is frequently mediated by antimicrobial resistance genes, which are carried on mobile genetic elements such as plasmids, transposons, and integrons. These genetic elements enable the spread of resistance through horizontal and vertical gene transfer, thereby increasing the persistence of resistant strains in aquatic environments (Amagliani *et al.,* 2012).

AMR Challenges in Aquaculture

The emergence of AMR in farmed fish presents a significant challenge for the aquaculture industry. High bacterial infection rates in intensively farmed fish drive the frequent use of antibiotics, leading to the accumulation of antibiotic residues in aquatic ecosystems. This, in turn, promotes the proliferation of antibiotic-resistant bacteria (Preena *et al.,* 2020). Additionally, AMR in aquaculture can extend beyond fish farms, affecting clinically relevant bacterial strains in natural environments. Through horizontal gene transfer, resistance genes may spread to pathogenic bacteria, increasing the risk of antibiotic-resistant infections in humans and animals (Santos and Ramos, 2018).

In aquaculture, antimicrobials are typically administered orally to entire fish populations via medicated feed. However, fish are inefficient at metabolising antibiotics, resulting in a significant portion of the antimicrobial agents being excreted into the surrounding water, often in their active form (Romero *et al.,* 2012). This persistent environmental contamination further accelerates the development and spread of AMR.

Primary Drivers of Suboptimal Antimicrobial Use in Aquaculture

Species Vulnerability

The intensification of aquaculture has led to the cultivation of a limited number of species, many of which originate from tropical and subtropical regions, making them more susceptible to bacterial disease outbreaks (Leung and Bates, 2013). Immune responses vary significantly among farmed species, with only vertebrates possessing an adaptive immune system capable of producing antibodies to combat bacterial infections. This biological limitation increases reliance on AMs in certain aquaculture sectors.

Production Practices and Technology

The use of antimicrobials in aquaculture depends on factors such as farmers' knowledge, farming methods, and disease prevalence. In some cases, AMs are used prophylactically as a preventive measure rather than as a treatment for active infections. Prophylactic use is particularly prevalent in shrimp, salmon, and other high-value aquaculture sectors (Cabello *et al.,* 2013). However, improved farming practices, including better water quality management, biosecurity measures, and vaccination programs, can significantly reduce disease risks and minimise the need for AMs (Defoirdt *et al.,* 2011).

Regional Vulnerability

The prevalence and severity of bacterial diseases vary by region, influencing antimicrobial use patterns. For example, Atlantic salmon farms in Chile experience high infection rates of *Piscirickettsia salmonis*, the causative agent of Salmon Rickettsial Syndrome (SRS), which can lead to massive die-offs if untreated (Rozas and Enríquez, 2014). In contrast, SRS outbreaks are less frequent in northern

Europe, likely due to environmental differences, improved quality of juvenile fish, and superior farm management practices.

Institutional Vulnerability

Beyond biological and environmental factors, institutional weaknesses contribute to excessive antimicrobial use. Key issues include limited access to veterinary services, poorly regulated sales of antimicrobials, and inadequate enforcement of antimicrobial use policies. Although many countries regulate acceptable antimicrobial residue levels, enforcement often focuses on export products, leaving domestically consumed seafood less scrutinised (Boison and Turnipseed, 2015). Strengthening regulatory frameworks and ensuring proper oversight of AM use in aquaculture are critical to mitigating AMR risks.

The overuse and misuse of antimicrobials in aquaculture pose significant threats to fish health, environmental sustainability, and human well-being. AMR development in aquaculture is driven by species susceptibility, production practices, regional disease prevalence, and institutional regulatory gaps. Addressing these challenges requires a multi-faceted approach, including improved farming techniques, stricter antimicrobial stewardship, enhanced biosecurity, and robust regulatory enforcement. By adopting sustainable disease management strategies, aquaculture can continue to meet the rising global demand for seafood while minimising the risks associated with AMR.

How Does Antimicrobial Resistance (AMR) Spread from Animals to Humans?

Waterborne Transmission: Drinking Water and Wastewater Contamination

Water plays a critical role in the transmission of antimicrobial resistance (AMR) from animals to humans. Antibiotic-resistant organisms can enter drinking water sources, particularly those derived from surface water, where resistance genes integrate into natural bacterial ecosystems (Suzuki and Hoa, 2012). Inadequate wastewater infrastructure exacerbates this problem, allowing antibiotic residues to contaminate water supplies and facilitate the spread of AMR. Poor sanitation and ineffective wastewater treatment further contribute to the persistence of resistant bacteria in aquatic environments.

Animal Husbandry and Waste Management

A significant portion of antibiotics administered to livestock is poorly absorbed by their digestive systems, resulting in substantial amounts being excreted in faeces and urine. Unlike human waste, animal waste often undergoes minimal treatment, leading to higher concentrations of antibiotic residues entering the environment (Sørum *et al.,* 2002). These residues can transfer antimicrobial resistance genes from farming environments to humans via water sources, soil, and the food supply, posing a substantial risk to public health.

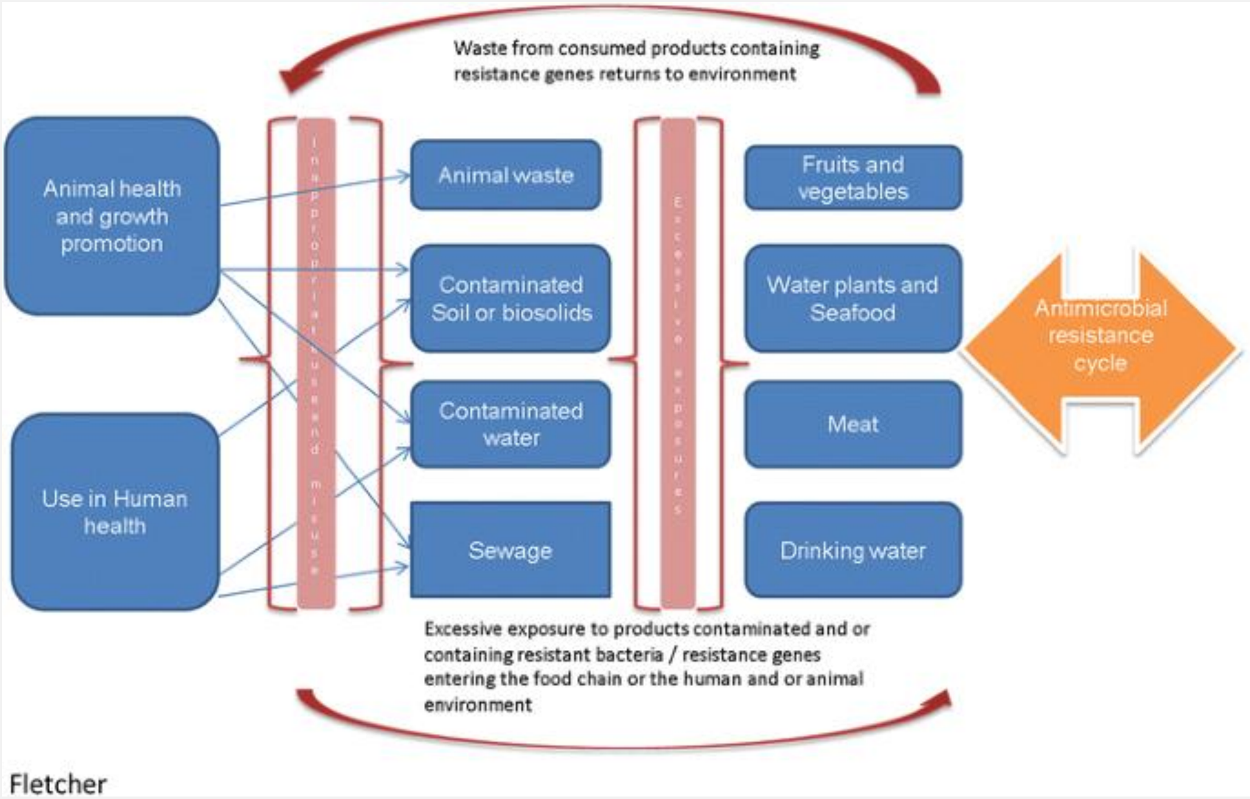

Figure 19 Complex interactions amongst environmental and health related factors that contribute to the spread of antimicrobial resistance

Food Safety and the Role of the Food Chain

While human antibiotic use is the primary driver of AMR, the long-term use of antibiotics in food-producing animals, particularly for growth promotion and prophylaxis, contributes significantly to the emergence of resistant bacteria. These bacteria can spread to humans through the food chain, either via direct consumption or through the transfer of resistance genes to human pathogens (Kemper, 2008). Gaps in surveillance and data-sharing regarding resistance in foodborne bacteria further complicate the management of AMR (WHO, 2014). In some cases, antibiotics have even been added to ice used for preserving fish in markets, inadvertently exposing consumers to low doses of antimicrobials through seafood consumption (Suzuki and Hoa, 2012; Fletcher *et al.,* 2012). While proper cooking can eliminate many resistant bacteria, antibiotic residues in food remain unaffected by heat treatment, allowing continued exposure.

Combating AMR: The Role of Aquaculture Farmers

Aquaculture farmers play a crucial role in mitigating antimicrobial resistance while ensuring the sustainable production of seafood. By adopting responsible practices, they can minimise the reliance on antibiotics, improve fish health, and reduce the environmental impact of AMR. Key strategies include the following (Milijasevic *et al.,* 2024):

1. Adhering to Strict Antimicrobial Use Guidelines

- Use antibiotics only when prescribed by a veterinarian. Avoid prophylactic and excessive antibiotic use.

2. Enhancing Farm Biosecurity Measures

- Implement strict quarantine protocols for new stock.
- Regularly disinfect equipment and facilities.
- Minimise stress and overcrowding in fish populations.

3. Promoting Vaccination Programs

- Utilise vaccines to prevent bacterial infections, reducing the need for antibiotics.
- Develop and adopt region-specific vaccination strategies.

4. Using Alternatives to Antibiotics (ABs)

- Introduce probiotics and prebiotics to enhance gut health and immunity.
- Apply immune stimulants to boost fish resistance to diseases.
- Explore natural antimicrobial solutions such as essential oils (EOs), peptides, and phage therapy.

5. Optimising Feeding Practices

- Provide balanced, high-quality diets to improve fish immunity.
- Avoid overfeeding, which degrades water quality and increases fish stress.

6. Integrating Genetic Approaches

- Select disease-resistant fish strains through selective breeding and genetic improvements.

7. Monitoring Water Quality

- Maintain optimal water parameters (e.g. temperature, pH, oxygen levels).
- Reduce organic waste accumulation, which fosters bacterial infections.

8. Improving Wastewater Treatment

- Implement filtration and disinfection systems to prevent the spread of resistant bacteria.
- Ensure aquaculture effluents do not introduce resistant pathogens into natural water bodies.

Conclusion

The responsible use of antimicrobials in aquaculture is essential to curbing the rise of antimicrobial resistance, which poses threats to fish health, environmental sustainability, and human well-being. The overuse and misuse of antibiotics accelerate the emergence of resistant pathogens, thereby reducing treatment efficacy and facilitating the spread of resistance through aquatic ecosystems and the food chain. To combat AMR effectively, a holistic approach is needed, one that integrates antimicrobial stewardship, enhanced biosecurity, vaccination programs, alternative disease control strategies, optimised feeding practices, and sustainable wastewater management. By adopting these best practices, the aquaculture industry can continue to meet the growing global demand for seafood while safeguarding public health, protecting the environment, and ensuring long-term industry sustainability.

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

- Do you have any biosecurity protocols or systems on your farm?
- Have you experienced any disease outbreaks on your fish farm before? If you have, share your experience on how you discovered the onset of the disease (e.g. what were the signs), if and how you diagnosed the cause of the disease, and what you did to treat the disease and combat the spread.
- Do you engage qualified professional(s) to provide diagnostic and treatment services for your fish farm? If you don't, why? What are the alternative options you employ?
- Discuss your current use of antibiotics. Do you consider it currently as antimicrobial stewardship or misuse?

- Do you have a record-keeping system for your fish health, disease reports and antibiotic use?

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