



AQUACULTURE FISH WELFARE TRAINING GUIDE

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

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PREFACE

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

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

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

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

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

With best regards,

The AFIWEL Program Team

One Health and Development Initiative (OHDI)

ABBREVIATIONS AND ACRONYMS

AAH – Aquatic Animal Health
ALI – Aquatic Life Institute
AMR – Antimicrobial Resistance
AU-IBAR – African Union – Inter-African Bureau for Animal Resources
AWRA – Animal Welfare Research in Africa
CEA – Centre for Effective Altruism
DoF – Department of Fisheries
DVS – Department of Veterinary Services
EA – Effective Altruism
EU – European Union
FAO – Food and Agriculture Organization
FW – Fish Welfare
FWI – Fish Welfare Initiative
GAWS – Global Animal Welfare Strategy
MDAs – Ministries, Departments, and Agencies
NFAP – National Fisheries and Aquaculture Policy
NGO – Non-Governmental Organization
OHDI – One Health and Development Initiative
Q&A – Questions and Answers
SDGs – Sustainable Development Goals
TWGs – Technical Working Groups
WOAH – World Organization for Animal Health
WTO – World Trade Organization

MODULE 1: OVERVIEW OF AQUACULTURE IN UGANDA

Aquaculture which dates to the year 1941, is one of the fastest growing food sectors and the main sources of protein and livelihood for about 30% of Uganda's population. World per capita fish consumption significantly increased from 9.10kg in 1961 to 20.75kg in 2022 (FAO, 2024). Uganda's annual per capita fish consumption of 12.5kg is higher than the African average of 10.1kg (Adeleke *et al.*, 2020). Comprising over 20,000 fish ponds averaging 500m², Uganda is the third largest aquaculture producer in Africa, behind Egypt and Nigeria, and the second largest in sub-Saharan Africa with 138,558 tonnes in 2021. Fish production from ponds ranges between 1,500kg per hectare per year for subsistence farmers and 15,000 kg per hectare per year for commercial farmers.

Uganda projects to produce over 1,000,000 MT of fish by the year 2030 (MAAIF, 2017). The current investment has led to increased aquaculture production from 800 MT in the year 2000 to 138,558 MT in the year 2021 (Flores Nava & Manjarrez-Aguilar, 2023). Most of the current production comes from fish cages and ponds. It is worth noting that cage fish farming was introduced in Uganda in the year 2006 and a significant amount of investment, especially from the private sector has been realized on the major water bodies, namely: Victoria, Albert, Kyoga and the Nile River. Uganda's aquaculture is supported by fish hatcheries, though most of them are not certified to supply fish seed. Farmed fish in Uganda is marketed mainly in local, regional and international markets. Neighboring countries, namely: Democratic Republic of the Congo, South Sudan, Kenya, Rwanda and Tanzania constitute the main regional market.

Aquaculture Production Systems in Uganda

Aquaculture production systems in Uganda are characterized according to several features based on various aspects among which include: intensity of production, water quality attributes, species of fish cultured and scale of production (MAAIF,

2020). The most defining attribute however, is the level or intensity of production. This defines the level of utilization of production resources to maximize yield per unit volume or area of a production facility. In Uganda, there are mainly three production systems. These include extensive, semi-intensive and intensive production systems. Novel production systems such as aquaponics and recirculating aquaculture systems are, however, slowly finding space in the industry to enhance aquaculture production in Uganda.

Extensive fish production system

This system requires low investment to operate. There is very low resource input and limited monitoring. The stocking density in such units is very low and commercial feeds are hardly used, which results into low fish production (overall yields). Since there is no supplementation of commercial feed, natural food production plays a critical role in fish production in this case. Natural feed production in extensive systems in Uganda is primarily generated through pond fertilization using organic manure. This enhances production of zooplankton and phytoplankton to feed fish under culture (**Figure 1**). In this system, fish welfare is limited since fish is not fed optimally. Usually, over stocking of extensive culture facilities leads to depletion of natural food, thus starving the fish. Feeding in this system is not well programmed and is thus referred to as “leisure feeding”. Although it has some disadvantages, this system leads to minimal environmental impacts, is easy to operate, and promotes biodiversity in fish culture facilities. This system is practiced by majority of subsistence fish farmers and such fish is usually eaten at home, with a few pieces sold in the local market.



Figure 1 This pond is principally extensive but can as well be characterized as semi-intensive (Photo by Rogers K)

Semi-intensive fish production system

This system aims at increasing fish production from ponds and other culture systems. There is a higher level of investment and input as compared to the extensive system (Altan, 2017). It operates beyond naturally occurring food, for it uses supplementary feed. Farmers usually make on-farm feeds to be used in fish culture. Ponds are usually fertilized once a week and have relatively higher stocking densities and yields than extensive production systems (**Figure 2**). In Uganda, most semi commercial farmers owning ponds averaging 1000m² practice this system. They usually have livestock on their farm and use the manure to fertilize the ponds, which stimulates primary food production for the fish. Feeding of fish in ponds is usually done twice or thrice a week. Since there is a higher level of utilization of production inputs, water quality parameters are usually compromised. Monitoring water quality is therefore of paramount importance.



Figure 2 Stocking of fish in a pond under a semi-intensive production system in Uganda. (Photo by Rogers K)

Intensive fish production system

There is a high level of resource input in form of feeds, labour, fish seed, water quality maintenance and monitoring and particularly stocking densities. Fish in this system is fed on high quality nutritious commercial feeds formulated according to the dietary nutrient requirements of the fish (Pomeroy *et al.*, 2014). The level of labour and technical expertise input is significantly higher. There is a planned schedule of fish feeding at varied stages of growth, water maintenance, especially aeration, and comprehensive data collection to keep track of fish performance. The fish in this system are reared for a predetermined market. In Uganda, this culture system yields between 1,200kg to 2,300kg of fish per hectare. There has been a moderate to high investment in cage fish farming in Uganda and this involves the attributes herein referenced. This has also significantly enhanced aquaculture production in Uganda.



Figure 3 Cage fish farming on Lake Victoria characterized as intensive fish production

Integrated fish production systems

In Uganda, novel production systems aimed at increasing fish production have been adopted, majority of which involve integrated fish farming principles and practices. The main integrated system is the Aquaponic system. With the reducing land to farm fish, the use of backyard farming, especially in urban centres revolves around this system.

Aquaponic systems

This symbiotic type of farming involves a combination of aquaculture and hydroponics to grow fish and plants. Aquaponics offers a promising solution to food production challenges, especially in areas with limited arable land or water resources. The principle is that, waste water from the fish is utilized by plants for their growth. In aquaponic systems, plants grow rapidly using dissolved nutrients that are excreted directly by fish or generated from the microbial breakdown of fish excretions. The plants filter the water by extracting the waste with nutrients, thus creating a clean environment for the water recycled into the fish production facility (**Figure 4**). This forms a closed loop system and enhances efficient water use to maximize production.

There are three types of this system according to operation. These include the **media-based system** which utilizes media such as gravel or rock for bacteria growth. This is the simplest form of aquaponics that is used in Uganda. The second type is the **nutrient film technique** (NFT) where the plant roots are exposed to a thin layer of nutrient-rich water that runs through horizontal pipes. The third system is **the raft system** where plants are grown on floating rafts with roots submerged in nutrient-rich water. The last two methods are yet to be widely practiced in Uganda.



Figure 4 An aquaponic system in the backyard of the farmer in Uganda (Photo by Uganda Aquaculture Association)

DISCUSSION QUESTIONS

- i. Which is the most practiced fish production system in your area and why?
- ii. What are the significant challenges faced while practicing this system?
- iii. Are you aware of a symbiotic farming system that involves rearing of fish and growing of plants?
- iv. What is your general overview of this system?

MODULE 2: INTRODUCTION TO ANIMAL WELFARE

Overview, History and Trends of Animal Welfare

The ability of an animal to experience physical and mental wellbeing is comprehensively referred to as animal welfare. Animal welfare represents our ethical responsibility to treat animals with compassion and respect. Holistically, animal welfare history comprises developing legal frameworks, public concern and the generation of scientific knowledge (Vargo *et al.*, 1997). Hitherto, animal welfare science has involved studying how principally farm animals, but to a lesser extent also sport and pet animals and laboratory animals, are affected by various environmental factors (Algers, 2011). The chronological history of animal welfare has followed part or full of this trend;

- In India, animal welfare dates as early as the first millennium BCE (304-232 BCE) where hospitals for animals were built by kings. Orders were issued against animal hunting and slaughter against well stipulated doctrines of non-violence.
- Various legislative attributes and Acts were enacted in the 1600's on behalf of animals for their improved welfare and in principle, these Acts were to facilitate animal welfare for dogs. especially in Japan. In the 1700's, books were authored in support of animal welfare in order to draw public attention to issues of animal welfare.
- It was until the 20th century that substantial progress on animal welfare took place after a commission of inquiry into the welfare of intensively farmed animals (Sherwin *et al.*, 2010). Some of the guidelines recommended that animals required the freedom to “stand up, lie down, turn around, train themselves and stretch their limbs”. In principle these guidelines have since been expounded as the **FIVE FREEDOMS (Figure 5)**.

Despite the fact that there has been tremendous work on advocating for animal welfare, a vast gap in knowledge base among people or farmers handling animals exists and is not any different from aquaculture. This is attributed to limited capacity

building on animal welfare issues, poor policy implementation, limited resources among others. This limits realization of the one health goal of “a sustainable balance and optimization of animal, human and ecosystem health while controlling for economic benefits”.



Figure 5 Five freedoms in animal welfare (Adopted from Euractiv, 2021)

The potential benefits of animal welfare spiral from having healthier animals, minimized environmental impact, more productive animals, sustainability, consumer preference, to animal emotional support. Well treated animals seldom fall sick, thus reducing medical attention from experts, they become more productive, thus generating higher income for farmers (WOAH, 2024). The reduced application of such treatments, especially antibiotics minimizes their bio-accumulation, bio-concentration and biomagnification in their tissues, thus reducing risks to humans at consumption level. Well treated animals require less feed and land to rear and thus release less pollutants into the environment, hence acting as climate change mitigation objects. Providing animals with better infrastructure and improved living conditions, the risks associated with disease transmission from animals to humans is greatly reduced. This is in addition to proper handling before and during slaughter, a precursor to reduced food borne illness and contamination. This safeguarding of

public health reduces the transfer of zoonotic diseases, thus benefitting animals and humans. Balancing the benefits of animals, business and society is key in ensuring animal welfare (Bozzo & Dimuccio, 2023).

The Five Freedoms of Animal Welfare

- 1. Freedom from thermal and physical discomfort** – this is achieved through availing animals with a suitable environment comprising good shelter and a comfortable resting area where there is easy access to food and water.
- 2. Freedom from hunger and thirst** – implies that animals should be able to access food and potable water. The food should be of desired quantity, and highly nutritious to meet the dietary requirements of the animal while the water must be free, fresh, clean and with no disease-causing pathogens. This is because animals require food formulated in a balanced diet mode for tissue maintenance and physical health while water facilitates the nourishment of the animal's body cells. The food supplied to the animal should be dependent on various animal factors like size, age, health status and activity level.
- 3. Freedom to express most normal behavior** – entails providing the animal with the space, facilities and company to act in ways that promote their well-being. The space should be sufficient for the animal (fish) to move around, run or swim, and play, thus space provision is paramount for their interaction. This freedom helps the animal to express their normal behavior and promotes studying abnormal behavior such as aggression and cannibalism. Normal behavior in an animal may include playing and grooming.
- 4. Freedom from fear and distress** – ensures that conditions and treatment of an animal reduces mental and physical suffering. Fear is not only unpleasant but can have a great impact on an animal's health. An animal subjected to these conditions will experience poor mental and physical health. Mentally, the animal will be very alert and constantly feel overwhelmed and worried. As a result, physical issues, digestion complications, heart problems, difficulties eating and sleeping will be experienced by the animal.

5. Freedom from pain, disease and injury – requires quick diagnosis and treatment in case of injury, disease or pain. Since there is lack of a defined form of communication between man and animals, it is pertinent to pay special attention to ensure animals are not in pain.

The dimensionality of these freedoms is webbed to acquire good animal welfare and a lack of one means animal welfare is compromised.

The Five Domains of Animal Welfare

Worth to note is the extensive knowledge and research recognizing the five freedoms to animals, however, for an animal to live a useful life, going beyond minimizing negatives and providing them with positive experiences is necessary. This is achieved through an animal welfare assessment framework that facilitates evaluation of risks and opportunities. The five domains present opportunities for animals to engage in activities that provide positive experiences. The model consists of three survival-critical physical domains: health, nutrition, physical environment, behavioral interaction and mental domain (**Figure 6**). These domains interact with the animal's subjective experiences of which the outcome is the animal's present state of welfare (Mellor *et al.*, 2020).

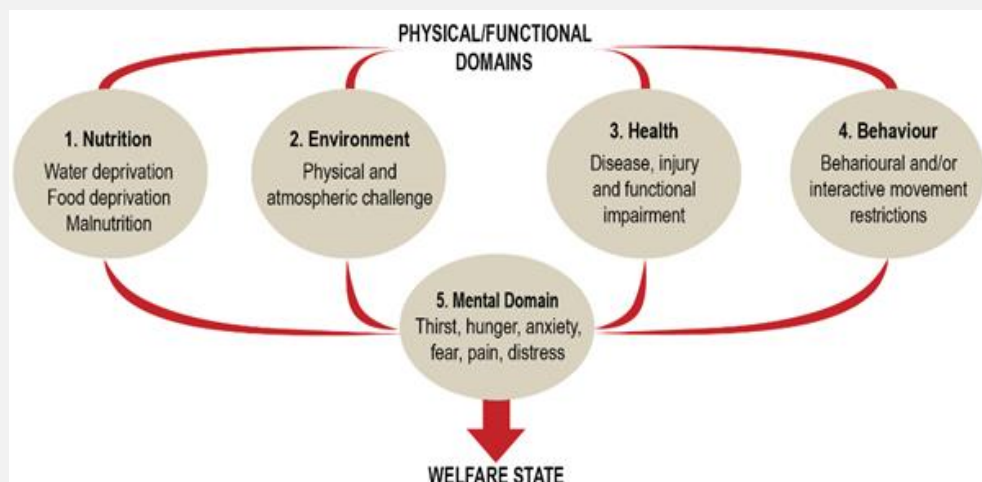


Figure 6 The five domains model (Adopted from Mellor *et al.*, 2020)

The nucleus focus of the main four domains interaction is on the mental domain of an animal. Although the mental domain is structurally separated from the four domains, its evaluation should not be done independently.

KEY FISH AND ANIMAL WELFARE VIOLATIONS

- Poor and inhuman handling during grazing, transportation, and slaughter lead to animal stress.
- Restrictions through the use of confinements to keep animals, especially cages in poultry and fish with restrictions to their natural environment.
- Exposure of animals to harsh and unbearable rearing or resting conditions like overcrowding, which can lead to suffocation, disease spread and stress.
- Untimely treatment of animals in case of sickness or disease outbreak.
- Uncontrolled use of chemicals in treating fish and the aquatic environment where fish dwell.
- Exsanguination where fish is slaughtered in highly vascular areas and left to bleed till death. Fish is not stunned prior to slaughter but rather natural unethical slaughter is exercised.
- Feeding fish in culture facilities on poor quality or low nutritious feeds, ultimately leading to stunted growth and poor feed conversion ratios.
- Starvation of animals and fish prior to their transportation during long distances prior to slaughter or stocking in culture facilities.

Legal Frameworks for Animal and Fish Welfare in Uganda

Prevention of animal cruelty in Uganda is mainly governed by the Animals (Prevention of Cruelty) Act, Cap. 39 which was later reviewed by The Uganda Law Commission (ULC). The purpose of the review was to broadly strengthen the prevention of animal cruelty and its enforcement of the law (Uganda Law Commission, 2022). The Ministry of Agriculture Animal Industry and Fisheries (MAAIF) has guidelines and standard operating procedures on handling and transportation of live animals (MAAIF, 2022). Animal welfare, trade, movement and health in Uganda are guided and regulated by the following legislations, standards and manuals:

1. The Animal Diseases Act, Cap. 38 which provides for the regulation of animal handling and transportation aimed at prevention and control of diseases. The main regulations include obliging animal owners or handlers to report any disease outbreak to the nearest veterinary officer, prohibit movement of animals through infected areas, prohibit movement of animals in the night, empower the veterinary officers to issue health certificates and designate stock routes while transporting animals.
2. The Animals (Prevention of Cruelty) Act, Cap. 39 is the primary act which provides for the prevention of animal cruelty and welfare. The main provisions include empowering authorized officers like fisheries officers to conduct emergency slaughter of animals injured during transportation. It further prescribes penalties for persons who allow free movement of diseased animals. It gives powers to courts of law to order destruction of diseased animals or fish that have been found in possession of a handler.
3. The Fisheries and Aquaculture Act (2023) of Uganda addresses fish welfare through various provisions aimed at ensuring the safety, quality, and humane treatment of fish:
 - i. **Safety and Quality Measures:** Section 60 requires the construction of aquaculture establishments to ensure the safety and quality of live fish and fish products, including sanitary measures to protect fish health.
 - ii. **Prevention and Control of Contaminants:** Section 61 stipulates that aquaculture practices must have measures in place to prevent and control contaminants and disease-causing agents, ensuring a healthy environment for fish.
 - iii. **Conditions of Aquaculture Activity Licence:** Section 63 allows the Chief Fisheries Officer to impose conditions on aquaculture activity licenses to protect the environment and fish health, including the use of appropriate feed and disposal of waste.

- iv. **Notice of Disease:** Section 66 requires owners or persons in charge of aquaculture establishments to notify authorities if they suspect fish are infected with a disease, ensuring prompt action to prevent disease spread.

DISCUSSION QUESTIONS

- What is your opinion on animal welfare, especially fish welfare?
- What gaps do you think government and researchers need to address as regards animal and fish welfare?
- Can you expound on how you think animal or fish welfare is important on your farm in social and economic aspects?
- How best would you compliment the Government of Uganda in its realization of enhanced animal and fish welfare?
- Fish being marginalized in developing acts that address its welfare. Why do you think it is necessary to have an independent act addressing fish welfare?

MODULE 3: INTRODUCTION TO FISH WELFARE

What Is Fish Welfare?

The definition of animal welfare is complex and often disputed. There is no single framework that is commonly agreed-upon. Instead, most definitions fall into one of two broad categories:

1. Feeling-based definitions, in which welfare links to the emotional (or emotion-like) states of the animal under review. Good welfare under these definitions typically requires a reduction in negative experiences (such as stress or fear) and an assurance of positive experiences (such as the presence of counterparts for members of social species).
2. Function-based definitions focus on an animal's ability to adapt to its current environment, in which good welfare requires the animal to be in good health.

The Five Pillars of Animal Welfare in Aquaculture

Drawing reference from the five freedoms of animal welfare, the Aquatic Life Institute provides five key welfare pillars for aquatic animals, especially fish in aquaculture. These comprise feed composition and feeding, space requirements and stocking density, stunning and slaughter, water quality and environmental enrichment (Figure 7).

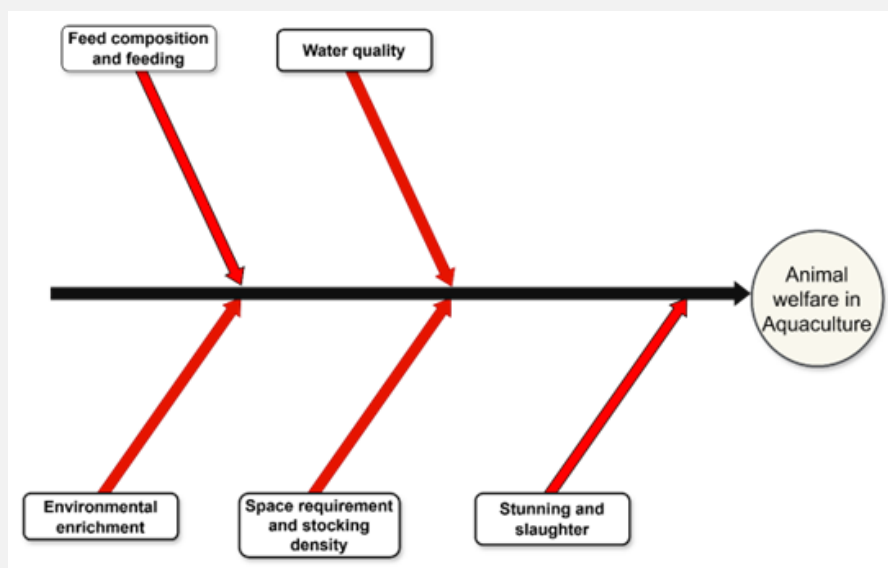


Figure 7 Five pillars of animal welfare in aquaculture (Generated by author)

Benefits of Improved Aquaculture Welfare

Enhanced fish growth: Minimising stress allows for enhanced utilization of food nutrients for tissue development rather than coping mechanisms. This idea is predominantly critical in the aquaculture industry and widely embraced by culturists. This is because higher fish welfare significantly means improved growth rate, better conversion rates, disease resistance, reduced physical injuries and stress response, and consequently, higher economic benefits for stakeholders (Dara *et al.*, 2023).

Better fish health: Stress weakens the fish immune system thus increasing the risks of disease outbreaks in aquaculture facilities. Minimizing stress levels in fish culture systems improves faster healing from injuries. This ultimately would lead to lower fish mortalities hence improved income generation for farmers involved in aquaculture (Toni *et al.*, 2019).

Environmental benefits: Reduced fish stress improves feed intake and efficiency; hence less waste is generated from culture facilities. This leads to improved water quality as less waste amounts are released in the aquaculture system and the environment.

Social and economic benefits: Great concerns about fish welfare among consumers are on the rise. This has led to a higher demand for fish raised under good welfare practices and has boosted the aquaculture status as some markets may offer higher prices for fish raised under high welfare standards. This acts as a foundation for better fish welfare management, especially those generating low income from fish due to bad fish welfare (Berlinghieri *et al.*, 2021).

Introduction to Fish Welfare Practices

It is critical that during fish rearing, fish welfare practices have to be adhered to in order to mimic their natural environment. This should be done regardless of the rearing system. The main fish welfare practices of water quality, especially monitoring the most important parameters (pH, temperature, dissolved oxygen, total dissolved solids, and Ammonia concentration), stunning and killing using humane ways, feeding through availing fish with the right feed with the dietary nutrient requirement for tissue

development, protection from predators, proper handling to minimise stress, training of fish in order to minimise stress when individuals appear during feeding.

Having an appropriate culture environment for fish species cultured in Uganda among which include; Nile tilapia (*Oreochromis niloticus*), North African catfish (*Clarias gariepinus*), Mirror carp (*Cyprinus carpio*), Grass carp (*Ctenopharyngodon idella*), Redbelly tilapia (*Coptodon zilli*), Redbreasted tilapia (*Coptodon rendalli*) and Labeo (*Labeo victorinus*). Although these species have different demands in water quality aspects, it is paramount to understand the species-specific environmental demands in order to enhance their welfare during culture.

DISCUSSION QUESTIONS

- Which key aquaculture fish welfare practices do you practice on your farm?
- How have you benefitted from practicing fish welfare on your farm?

MODULE 4: GROWING SYSTEMS AND FISH WELFARE

Prior to fish culture in rearing facilities, suitable culture facilities that enhance fish welfare are required for improved fish production while controlling for economic gains. It is paramount to set operational standards on various aspects for your farm prior to its establishment. Key factors include having a good site for farm establishment, a comprehensive business plan that will be followed during investment, fish stocking biomass standards, feeding protocols, biosecurity and biosafety standards to minimise injury and diseases to fish and personnel. These need to be adhered to for improved fish production in a suitable environment while improving fish welfare. Some of the key aspects that stand out in the Uganda's Aquaculture Sector are the culture facilities where fish are reared, their location, and fish stocking biomass. These are expounded as follows:

Rearing Systems

Muthusamy and Viswanathan (1999) describe a rearing facility as a controlled environment used to care and raise young animals, especially in agriculture. It entails key factors like proper housing and feeding, all done in accordance to the dietary nutrient requirements of the animal. In Uganda, the predominant fish rearing facilities used include; fish cages, earthen ponds, concrete tanks, dam lined, movable tanks and movable ponds. The use of recirculating aquaculture systems in Uganda has not been widely adopted.

Fish cages

A fish cage is an enclosure suspended in water for purposes of rearing fish (**Figure 8**). Cages are culture units having an open framed net at the top and floating on the water surface. Cages are kept slightly below the water by adjustable buoyancy. In Uganda, the usage of cage culture is extremely varied. Rivers, reservoirs, lakes, and valley dams are suitable for culture without altering the natural habitat function. The massive use of fish cages is attributed to specific advantages;

- Given the production being in small units, quick and simple harvesting, this renders methods of flexible adaptation to defined fish markets and thus continued fish supply.
- Cages are a convenient means of wintering; thus, they save the vast investments for separate wintering ponds.
- Fish observation is very possible although high stocking densities are used.
- Harvest is simple and quick, and the technological steps can be mechanized.
- It facilitates the growth of carnivorous fish.
- The cost of nursery pond construction is not necessary as a cage can be used.
- Since fish is reared in fish cages, the land area where ponds would have been constructed is saved for other agricultural purposes.
- Cage culture can be well associated with sport fishing and recreational facilities.
- Cages give higher fish production per unit area (productivity) compared to traditional fish farming methods.



Figure 8 Suspended fish cages on Lake Victoria, Uganda (Photo by SON Fish Farm)

Fish cage stocking densities in Uganda

The biomass of fish to be stocked per m³ is derived from the production per m³. Fish production in a cage is calculated in kilograms per cubic meter (kg/m³). It is estimated that, in one m³, a cage would yield between 30 - 35 kilograms of fish. To achieve the stocking biomass or number of fish in a 5 m X 5 m X 5 m (125 m³) cage, the following formula is used;

Cage volume = 125 m³

Production per m³ = 30 kg

Target of individual fish at harvest = 500 g / 0.5 kg

Size of fish at stocking = 5 g

Biomass stocked = ????

Solution

Biomass at harvest: 125 x 30 = 3750

Number of fish stocked: Biomass at harvest (kg) / Target weight of individual fish at harvest (kg). 3750 / 0.5 = 7500 fish.

Biomass stocked: 7500 x 5 = 37.5 kg

Earthen ponds

A fish pond is a shallow excavation on land used to hold water with a main purpose of rearing or farming fish. Earthen ponds are principally dug from soil and the soil holds the water in which fish dwell (**Figure 9**). The pond should be constructed in a way that it does not impact on the fish welfare.



Figure 9 Earthen fish ponds located in Buikwe, Uganda (Photo by Rogers K.)

The key welfare issues to consider include:

The soils should be loamy-clay, containing at least 20% of clay in order to minimise water seepage which may expose fish to predators and heat from the sun. The 80% of the soil should be loam soil as this helps for easy rehabilitation of ponds in case of leakages. The soil pH range should oscillate between 6.5 to 8.5. The environment should not favour growth of disease-causing pathogens to fish.

The pond dykes should be constructed at angles of 45 degrees to minimise silting of the pond. Ponds whose dykes are constructed at 90 degrees tend to silt the ponds as soil particles keep dropping in the pond due to the pond water-wave action. This makes the pond shallow and exposes the fish to predation.

Prior to its construction, site suitability tests on type of soil, water quality and quantity, relief, vegetation and predation attributes need to be carried out. The site should have good soils, and the water should be enough to fill the pond in 48-72 hours.

The pond should be positioned in a way that the water flow does not cause flooding. The water velocity should not be too high to cause stress to fish during swimming activities.

The water source should be devoid of suspended solids which contain minerals like iron, which cause stress to fish during gaseous exchange.

Concrete fish rearing tanks

In Uganda, concrete tanks have been used in rearing fish, especially in research institutes, semi-intensive and intensive fish farms (**Figure 10**). Tanks are constructed in a way that their edges and surface do not injure fish through abrasion. The tanks must have a smooth in-lining with dull colours to minimise fish stress as fish react differently to different colours. Since tanks have a high-water retention time for water, low dissolved oxygen levels are expected. These low levels lead to hypoxic and anoxic conditions, thus increasing stress levels to fish. Therefore, sufficient volumes of clean water from the water source are required for exchange to enhance and boost oxygen levels in the facility.



Figure 10 Fish concrete tanks (Photo by author)

SITE SELECTION

Selecting a suitable site for culture facility establishment is key as the characteristics of the site may greatly influence fish welfare. Potential threats which may result from site selection on fish welfare need to be addressed prior to enterprise establishment. Priority to such aspects include but not limited to;

Environmental and social impact assessment (ESIA)

Aquaculture being an enterprise that is centered on natural resources poses environmental and social impacts which in turn may affect fish welfare. Conducting a holistic and comprehensive ESIA is paramount to overcome this. These should be well thought over and all situations considered, following well developed and aligned protocols (**Figure 11**). For example, constructing fish ponds in an area may lead to reduction in the water table in the environment and, in addition, socially, arable land is used up in pond construction. This may affect the livelihoods of people since limited land is available for crop farming, hence poor livelihoods (food and income insecurity). Furthermore, rearing fish in ponds that have a limited water supply increases stress levels to fish since the required exchange is not sufficient for their growth and free movement. The over retention of this now untreated water may lead to disease incidences, thus leading to increase morbidity and mortality of fish. The effects and impacts should be spelt out clearly in the ESIA and should not significantly affect fish welfare.

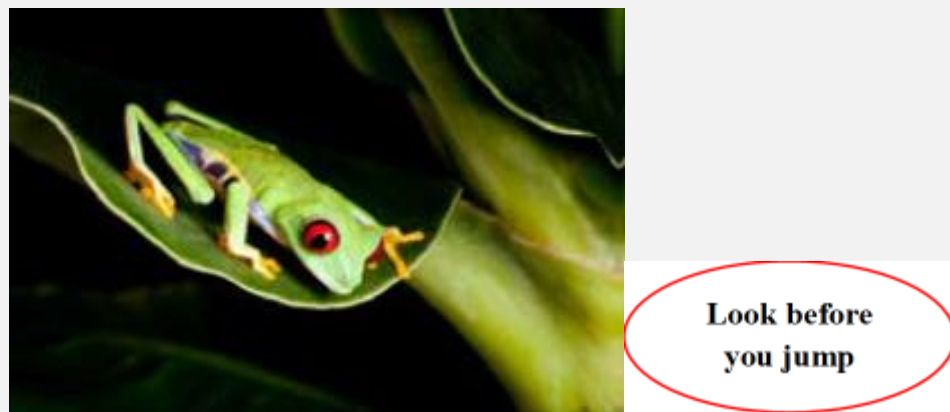


Figure 11 Precautionary measures have to be thought over before setting up an aquaculture farm (Developed by author)

Siting and culture facility design

Site selection in a suitable location with optimal conditions to good fish welfare prior to culture establishment is key. While selecting suitable sites, locations where these sites will be located **MUST** be devoid of point and non-point source pollutants, especially chemical effluents from pharmaceutical industry, wastewater from urban

and sewage sources, agro chemical resulting from farming and other anthropogenic activities, stable water table, clean source of water with enough water to culture fish, industrial waste among others. The release of these effluents in water channels which act as sources of water for fish rearing facilities such as ponds and cages, may lead to direct poisoning, hypoxic or anoxic conditions thus causing high stress levels in fish. Furthermore, the bioaccumulation and bioconcentration in fish myotomes may lead to biomagnification hence undifferentiated tissue development in fish. Some of these poorly divided cell division may lead to body conditions like atresia, hyperplasia or hypoplasia in fish, thus poor fish welfare.

Culture facilities like fish ponds should additionally be sited in locations with a good relief to allow for gravitational flow of water, with minimal velocity which does not allow for expenditure of energy by fish during swimming. The soils should be of good quality (20% clay) to minimise on water seepage since low water levels expose fish to predators, hence the stress that comes with predation needs to be minimized for improved fish welfare. Good water quality and quantity is key as pollutants in water stresses fish by altering their environment. Polluted water may lead to proliferation of dense phytoplankton mats which when not removed suppress light penetration thus no or limited photosynthetic activities. The lack of food in the water environment leads to starvation thus, causing stressing the fish, especially under semi-intensive or extensive culture systems. The culture facility must be designed in a way that minimizes stress to the fish when water is added. A pond that is too deep (more than 2.4 metres) and not constructed at a higher depth tends to stratify, while a shallow pond leads to depletion of oxygen during hot seasons.

These stress fish by altering the environment, thus poor fish welfare is realized. A stratified pond will deter fish from swimming the entire pond thus limited to the thermocline hence, in nest brooders like *Oreochromis niloticus*, breeding is restricted since they cannot make nests at the pond bottom. Ponds should be designed to have harvesting basins in order to minimise handling stress during harvesting. Fish cages

should be designed to have smooth meshes and twine ropes to minimise abrasion leading to injury of the fish. Wounds on fish act as portal entries to disease-causing pathogens leading to disease occurrence, which in turn leads to fish morbidity and mortality. The cages should be installed in water with a minimum depth of >5 m and <8 m, not suspended in fast flowing streams or rivers or direction of water. This leads to fish stress as fish would expend more energies swimming against the current than growing.

DISCUSSION QUESTIONS

- What fish culture facilities do you own at your farm?
- How do they improve fish welfare?
- What key steps do you undertake prior to establishing a fish culture facility?
- What precautionary measures do you undertake to improve fish welfare on your farm?

MODULE 5: WATER QUALITY AND FISH WELFARE

In aquaculture, a good environment with optimal growing conditions is very important to fish welfare. Good water quality equals good fish welfare as fish prefers stable water quality without changes in the physicochemical parameters. Alterations in water quality tremendously shape fish behaviour, a very critical index in determining fish welfare. The prominent water quality parameters of importance are dissolved oxygen, temperature, pH, total dissolved solids, total suspended solids, ammonia, nitrites, electronic conductivity among others (Segner *et al.*, 2019). Fluctuations in these parameters lead to fish stress and impact their welfare. Water provides oxygen to fish which is required for survival (respiration), and also dilutes toxic substances which would cause stress to fish and affect fish welfare.

Water quality monitoring helps the farmer to take desired action to ensure good fish welfare. Besides water quality, water quantity should be enough to fill the pond in 72 hours. A pond should be given a good water retention time and this is highly correlated to the quantity of water. Low volumes of water lead to constant replenishment of the culture facility, especially ponds and this alters the pond environment thus stressing fish since they are poikilothermic organisms. It is important to always check or measure these water quality parameters in-situ and ex-situ to curb spontaneous changes which may cause stress to fish and subsequently affect fish welfare. Measurement of these parameters, especially in-situ, is done using multi-parameter water quality equipment which display digital readings of results to the data collector. Farmers should be well trained on how to use this equipment, especially their calibration for good results. In addition, farmers should be able to take records and follow the trends of their data as this would facilitate in determining the welfare of the fish in the culture facility. Good water quality monitoring and maintenance, especially in intensive systems, favours high stocking densities thus more yield per unit volume with minimal or no stress to fish.

Water quality considerations for optimal fish welfare

It is very important for a farmer or production farm to maintain good water quality for improved fish welfare, a prerequisite for good fish production. A suitable environment with optimal growth conditions enhances fish welfare. It is important to note that different fish species have different suitable physicochemical parameter ranges which are highly correlated to their welfare attributes like growth, breeding, and feeding.

For parameters like pH, at 25°C, a value of 7 is assumed to be neutral, thus the best at which fish welfare is good, below which is acidic and above which is alkaline (**Table 1**). However, since temperatures keep fluctuating, a shift in the pH is experienced. Therefore, a need to maintain an optimal range between 6.5 to 8.5 is important for most fish species. These ranges apply to most warm or freshwater species in Uganda especially; *Oreochromis niloticus*, *Clarias gariepinus*, *Ctenopharyngodon idella*, *Cyprinus carpio*, *Labeo victorianus*, *Oncorhynchus mykiss* among which are cultured in aquaculture facilities.

Table 1 pH tolerance levels in and its effects on Uganda warm water fish species

pH level	Effect on fish
<4.0	Acid death point
4.0 – 5.0	No production
6.5 – 8.5	Desirable range for fish production
8.5 – 11.0	Slow growth
>11.0	Alkaline death point

(Improved from Tarazona & Muñoz, 2008)

Dissolved oxygen is the most critical water quality variable in aquaculture. Oxygen is available in a dissolved state. It is found in microscopic bubbles mixed in between water molecules. It can enter into the system through direct diffusion and as a by-product of photosynthesis. A thorough understanding of factors affecting the concentration of dissolved oxygen in water is required. In addition, understanding the influence of dissolved oxygen on feeding (more to nutrition) to fish under culture is of

great importance for good fish welfare (Boyd, 1998). This means that the level of dissolved oxygen in the water can be increased through mechanical aeration, e.g. paddle wheels, agitators, vertical sprayers, impellers, airlift pumps, air diffusers, liquid oxygen injection, etc., naturally through considerable wind and wave action, and presence of aquatic plants and algae among others. However, caution should be considered on the latter since it can also cause oxygen depletion when the phytoplankton population becomes too dense. On the other hand, oxygen is removed through respiration and decomposition. Oxygen concentration may be reported in terms of milligram per litre (mg/L) or its equivalent, parts per million (ppm). The oxygen concentration measurement in both units is the same.

MODULE 6: FEEDING AND FISH WELFARE

Fish in culture facilities require feed for somatic growth, maintenance, reproduction and daily functions. Feed is available as natural or/and artificial (commercial). Natural feed usually comes from pond water fertilization using organic and inorganic fertilizers. Some of the organic fertilizers include animal wastes from poultry, piggery, cattle, rabbits, and goats among others while inorganic fertilizers include commercial types such as NPK, DAP and Urea. These are applied at various quantities to enhance natural feed production. Usually, poultry waste which has the best Nitrogen content is applied at rates of 350g/m² while inorganic fertilizers can be applied at rates of 20g/m². The common natural feed in culture facilities occurs as phytoplankton and zooplankton. The facility should not be over fertilized as this would lead to algal blooms thus reducing dissolved Oxygen in the facility, hence fish stress leading to poor fish welfare. The natural feed in fish culture facilities is not sufficient for fish to grow, thus the need for supplementation of commercially formulated feeds. The formulated commercial feed should be formulated and applied according to the dietary nutrient requirements and age of the fish concerned.



Figure 12 Feeding fish on commercially formulated feeds (Monitor Publications, 2024)

Good quality ingredients should be used in diet formulation. Usually, younger fish (fry and fingerlings) and breeding (broodstock) fish require high protein content feeds for tissue and gonadal development respectively. Although all fish exhibit carnivorous behaviour, herbivore fish like Tilapia's protein requirement is different from North African catfish. Tilapia fish require crude protein (CP) levels oscillating between 25 – 40% CP, while for omnivores like catfish, it is between 40 - 45% CP, depending on development stage, physiological condition and production system. The protein content in the feed should be enough to effect growth and improve fish welfare. Fish in culture facilities, unless it is an experiment, are fed to satiation and average body weight (ABW). Fish fry and broodstock fish are fed between 11% to 1% of their ABW. Fish fry should be fed at 11% ABW and this is reduced as the fish grows. In addition, the protein content in the feed should be reduced since fish do not require more proteins for tissue development when they reach grow out or broodstock size. The amount of crude fat in the diet should as well not exceed 8% and not affect the protein sparing effect.

Best Fish Feeding Practices

In order to improve fish welfare while feeding, the following steps must be followed;

- Feed fish by response. Good fish response means fish are in a good condition, the feed is good and thus good welfare. Fish which offer a poor response should not be fed.
- Avoid feeding fish having varied sizes in the same facility. Stress that results from competition for feeds between small and big fish impacts on fish growth as smaller fish are outcompeted by finicky fish.
- Do not feed fish on very cold days. Because they are cold blooded, fish metabolic rate slows down during cold weather. They are unable to digest food during such conditions, and are not physically active to be able to respond when offered feed. Undigested and uneaten feed deplete the culture facility of Oxygen and release toxic chemicals that stress and harm fish. Fish being

poikilotherms, tend to use the generated heat for warmth rather than expend energy on feeding.

- Feed the right amounts. Over feeding of fish leads to large amounts of uneaten feed. This feed negatively impacts on water quality hence leading to hypoxic or anoxic conditions, thus mortality. Disease causing pathogens can as well emerge from the uneaten feed and affect fish.
- Fish should not be fed when water quality in the culture facility is poor. This would lead to fish gasping for Oxygen leading to stress and thus poor fish welfare.
- Spot feeding should be avoided for fish to have equal access to feed, especially the small fish. During feeding, different spots should be identified in a culture facility to cater for all sizes of the fish.
- Fish should be fed on feed pellets that can be swallowed and ingested by the fish. The gape of the mouth should be commensurate with the size of the pellets. Bigger fish require pellets from >2mm, while fry start with powder or crumbles, because their digestive system is not well developed to break down pellets.
- The fish feed should have a better feed conversion ratio, and offer high digestible results.

Fish Feed Storage

Formulated fish feeds should be stored in dry and not moist areas on plastic pallets to avoid molding. Moulds may lead to mycotoxin contamination which greatly affects fish welfare. The formulated feed used in aquaculture should follow the “*First in First out*” (FIFO) principle. Nutrient deterioration in feeds starts with storage. Feeding fish on old low-quality feed leads to poor growth hence low fish yields experienced. Fish welfare will be affected as the ability for the fish to extract nutrients for their growth is minimized.

DISCUSSION QUESTIONS

- How do you ensure that feed fed to fish meets the dietary nutrient requirements of fish and their specific ages?
- What challenges have you faced in using poor quality feed and how have you overcome them on farm?
- What are some of the best feeding practices that you carry out on your farm to ensure good fish welfare?
- How do you store your feed to avoid quality deterioration?
- Why is it important to use commercially formulated feeds on your farm?

MODULE 7: FISH WELFARE DURING HANDLING AND TRANSPORTATION

Fish Handling

Most fish demonstrate an emergency response when threatened. This may follow a sudden disturbance from a net, noise or other unexpected activity, or when they are removed from water. The response usually involves an increase in stress levels, which will have a negative effect on the welfare of the fish and also the flesh quality (Humane Slaughter Association, 2016). Fish handling should be done in a way that significantly minimizes stress. Since fish movement from one facility to the other, farm to farm, from farm to markets and exhibitions, tagging, vaccination, slaughter is seldom avoided, fish should be exposed to minimal stress during these processes.



Figure 13 Crowding of fish harvested from a concrete-lined fish pond in Uganda (Photo by Samuel P. Wamala)



Figure 14 Crowding of fish harvested from a fish pond in Uganda (Monitor publications - updated January, 2021)

Live fish should not be kept out of water for more than 15 seconds unless anaesthetised as this is deemed to cause significant amounts of stress hence affecting the fish physiology. Fish removal from water causes the highest emergency physiological response and should only be carried out when absolutely necessary (Ashley, 2023). Care must be taken at all stages to avoid abrasions and removal of scales in addition to the fish's protective mucous coat, which serves as a physical and chemical barrier to infection as well as being important in osmoregulation and locomotion.

Fish crowding during periods of transfer, stripping, and grading must be minimized by use of large containers holding a few fish. Crowding is stressful and leads to damage of scales, skin ulceration, eye and snout bruising and damage (EFSA, 2009). Where applicable, fish should be handled with wet hands and species appropriate nets, keeping the fish moist during handling. Unless crowding is carefully controlled, fish will be exposed to a decrease in Oxygen levels and a rapid rise in stocking density. In Uganda, fish handling from culture facilities through various processes is minimal as experts in this field (welfare) are minimal or completely lacking.

Live Fish Transportation

Live fish experience some form of transportation across distances which may be short or long, for short, long hours or days. Live fish transport is used to transfer aquaculture mainly high value fish from either wild capture fisheries, or aquaculture rearing facilities for purposes of re-stocking, for slaughter in restaurants and hotels, for breeding, live experiments among others. Live fish transport enables fish and fish products to be transported long distances in a controlled environment which helps to maintain product quality, freshness and prevent death and spoilage that would occur in non-live products. Stress to live fish during transportation occurs at various stages of harvesting – pre-transportation treatment (pond draining, starvation to rig gut of food and waste), packing and exhaustion from the journey during transportation. Transport can occur at different stages between harvesting and consumption. Starvation of fish for prolonged periods of starvation is unacceptable from a welfare point of view.

Starvation periods should be kept as short as possible and should not exceed 72 hours. Inappropriate starvation periods can deplete immune function and body condition (European Union, 2021). For certain species, transportation of farmed fish between facilities is a regular and routine part of their production cycle. Young rainbow trout, for example, are often transported to on-growing farms to be fattened to slaughter weight, and salmon smolts are moved from freshwater sites to seawater cages as they develop; fully grown salmon then often require further transportation to a separate processing plant for their eventual harvest. Whilst this transport is common and frequent, the process is extremely stressful for fish and may negatively affect survival rates of the population as a whole. In salmon smolt, for example, it takes more than 48 hours for amounts of the stress hormone, cortisol, to return to pre-transport levels.

In Uganda, a wide range of transport means are used as fish and fish products are transported on foot, by bicycle, canoe, motorcycle, rail, pick-up truck, boat, lorry, refrigerated trucks, and baskets. Transportation of live fish precisely revolves around

using polythene bags filled with Oxygen, perforated jerrycans, live fish transportation tanks (**Figure 15**) mounted on pick-ups and supplied with Oxygen from cylinders (**Figure 16**). Usually, the transportation of catfish fingerlings involves the use of jerrycans without or with minimal aeration for very long distances owing to scarcity of nearby hatcheries and inadequate transport logistics. This leads to fish stress, thus impacting on the entire fish welfare.



Figure 15 Live fish transporting tank

The live fish transporting tanks have a perforated aeration system that is connected to Oxygen supply cylinders. It contains a perforated outlet, meshed to release waste water during transportation.



Figure 16 Live fish transporting tank with Oxygen cylinders mounted on a pick-up (NaFIRRI, Uganda)

Precautionary aspects during live fish transportation process

All personnel handling fish throughout the transportation process should ensure that potential negative impacts are minimized.

1) The responsibilities of the competent authority for the exporting and importing jurisdiction include:

- i. Establishing minimum standards for fish welfare during transport, including examination before, during and after their transport, appropriate certification, record keeping, awareness and training of personnel involved in transport.
- ii. Ensuring implementation of the standards, including possible accreditation of transport companies.

2) Owners and managers of fish at the start and at the end of the journey are responsible for:

- i. The general health of the fish and their fitness for transport at the start of the journey and to ensure the overall welfare of the fish during transport, regardless of whether these duties are subcontracted to other parties.

- ii. Ensuring trained and competent personnel supervise operations at their facilities for fish to be loaded and unloaded in a manner that avoids injury and causes minimum stress.
 - iii. Having a contingency plan available to enable humane killing of the fish at the start and at the end of the journey, as well as during the journey, if required.
 - iv. Ensuring fish have a suitable environment to enter at their destination that ensures their welfare is maintained.
- 3) Transporters, in cooperation with the farm owner/manager, are responsible for planning the transport in a way that ensures that fish transportation can be carried out in accordance with fish health and welfare standards including:
- i. Using a well-maintained vehicle that is appropriate to the species to be transported.
 - ii. Ensuring trained and competent staff are available for loading and unloading, and to ensure swift humane killing of the fish, if required.
 - iii. Having contingency plans to address emergencies and minimise stress during transport.
 - iv. Selecting suitable equipment for loading and offloading of the vehicle.
- 4) The person in charge of supervising the transport is responsible for all documentation relevant to the transport, and practical implementation of recommendations for welfare of the fish during transport (Southgate, 2008).

It is worth noting that;

- 1) Transportation of live fish should be well planned and prepared to minimise fish stress and mortality.
- 2) 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.
- 3) Some species or life stages may need to be physiologically prepared prior to entering a new environment, such as by feed deprivation or osmotic acclimatization.

DISCUSSION QUESTIONS

- Can you identify fish welfare challenges associated with fish harvest and transportation?
- How do you ensure good fish welfare during harvesting and transportation on your farm?
- What precise areas do you think need to be improved on your farm in order to enhance fish welfare?

MODULE 8: SLAUGHTERING AND FISH WELFARE

Fish slaughter

Slaughter is the process of killing fish after harvesting. Several methods are used to slaughter fish, but most have been found to be inadequate and inhumane. Methods such as asphyxiation in air, carbon-dioxide stunning, gill-cutting (exsanguination), salting which leads to desiccation and live chilling are now recognized to be inhumane and as such should not be used. Acceptable slaughter methods should render the animal insensible without causing avoidable pain or suffering. According to the World Organisation for Animal Health (OIE) (WOAH, 2024), persuasive stunning and electrical stunning systems are best able to provide humane slaughter.

Fish stress factors at pre-slaughter

When fish are subjected to stress, vigorous swimming increases anaerobic glycolysis, leading to lactic acid production and a consequent decline in muscle pH, which is accompanied by a faster onset of rigor mortis. The combination of stress and intense physical activity at pre-slaughter can increase the degree of protein denaturation. This leads to increased access of proteolytic enzymes to protein substrates, leading to faster muscle softening, which is detrimental for fish muscle. Prior to slaughter, harvested fish are subjected to various stress or pre-slaughter factors such as starvation, crowding, low dissolved Oxygen, repeated handling, transportation among others. These factors or procedures significantly negatively impact fish welfare. These processes tend to impact far more pain to the fish than the slaughter process itself. Increased overcrowding and high stocking densities pre-slaughter increase cortisol levels, and reduce the expression of catalase and glutathione peroxidase enzymes which are important indicators for activation of cellular antioxidant defense system and protection against oxidative stress (Goes *et al.*, 2019).

In addition to denaturation and proteolysis, muscle proteins also undergo oxidative damage after slaughter and subsequent meat aging. Protein oxidation is responsible

for many biological changes, such as protein fragmentation or aggregation and decreased protein solubility, which affects meat quality. Oxidation may also play a role in controlling the proteolytic activity of enzymes and may be linked to meat tenderness.

Humane fish slaughter

The overwhelming majority of farmed fish produced throughout the world are killed with little or no consideration for their welfare. Fasting periods can be excessive, transport stressful and killing inhumane. With increasing public awareness of fish sentience and aquaculture, there is a growing demand for more ethical fish products not only sustainably produced but also with good animal welfare. A humane slaughter is essential when farming to higher animal welfare standards, however fish welfare at slaughter varies substantially across the world and in different sectors (Compassion in Food Business, 2017). The key ethics of humane fish slaughter are that death should either be instantaneous or, if insensibility is induced progressively, it should be without anxiety or pain (FAWC, 1996). The effective evaluation of insensibility and stunning is important to prevent any suffering or distress that might occur when invasive killing methods, such as bleeding or evisceration, are used. Insensibility may be measured using evident indicators such as fish behaviour, or through measuring brain activity using electroencephalography. There is concern that visible indicators, such as opercular movement, righting responses, and spontaneous movement, may not be reliable signs of insensibility (Wahlthinez *et al.*, 2024). In this regard, humane fish slaughter is paramount and has some potential benefits;

- i. High quality fish fillets due to minimal pre-slaughter stress. Little or minimal volumes of blood are clogged up in the fish tissues hence providing a bright and clear fish fillet.



Figure 17 High quality fish fillet (Adopted from Goes et al., 2019)

- ii. Minimal over bleeding of the fish during slaughter if better slaughter methods like electrical stunning are used.
- iii. Minimizes on unnecessary pain and cruelty to fish since the process is fast.
- iv. Improves eating quality, as has been found for farmed fish. In some long line and trolling fisheries, the relatively humane slaughter method of spiking is used soon on landing in order to improve the flesh quality by reducing the pre-slaughter activity.

Overview of fish slaughter in Uganda

Usually there is no clearly defined protocol available to farmers or fishermen on the best way to slaughter fish. In aquaculture, harvested fish is either stitched onto grass strands through their gills or just dropped into ice pre-slaughter. For more resilient species like North Africa Catfish (*Clarias gariepinus*), stunning, using a metallic hammer or stones is common. In some instances, hitting the fish on the ground until it is dead is another cruel way of pre-slaughter. Harvested fish is placed on the ground and left to die on the ground in the open due to air asphyxiation. The fish is usually slaughtered inhumanely and left to bleed till death. Other fish species like the Lungfish (*Protopterus aethiopicus*) are stunned with large stones and sometimes large sticks till death. In order to minimize this, there is a need to embrace the more sophisticated humane methods of fish pre-slaughter processes and slaughter methods. These may

include persuasive stunning with a club, spiking the brain, persuasive and electrical stunning machines.

DISCUSSION QUESTIONS

- How do you slaughter your fish on farm?
- Given this training, what shortcomings do you face during fish slaughter?
- How would you improve on fish slaughter on your farm?
- How would you want to be helped in improving fish slaughter for improved fish welfare on your farm?

MODULE 9: ENVIRONMENTAL ENRICHMENT AND FISH WELFARE

Environmental enrichment (EE) refers to stimulating the brain through physical and social surroundings. It entails complex inanimate and social stimulation which consists of housing conditions that facilitate enhanced sensory, cognitive, motor and social stimulation. EE can improve fish welfare in aquaculture systems. Its objective is to provide new sensory and motor stimulation in order to help meet the fish behavioral, physiological, morphological and emotional needs, whilst reducing stress and frequency of irregular behaviors (Arechavala-Lopez *et al.*, 2022). In fish farms, rearing environments are usually designed from a human perspective and based on economic requirements, mainly for practical reasons for the farmer, with little consideration for animal welfare. Throughout aquaculture production cycles, many farming operations can be stressful for fish, and EE may not only help them cope with these stressful events but also improve their overall fish welfare. However, there are many other enrichment strategies that provide excellent attention to fish welfare especially physiological aspects (Ojelade *et al.*, 2022). These include; sensory, occupational, social and dietary/nutritional enrichments (Gerber, 2015).

Types of Environmental Enrichments

Physical enrichment – involves adding structures like plants, tree branches, logs and gravel to the rearing facility. Alternating the pond, tank or cage bottom with a unique creation of crevices through which fish can swim and hide. Changing lighting in the facility as it enhances fish behavior thus, improved fish welfare.

Social enrichment – introduction of new different fish species in the culture enhances fish communication and thus improves fish welfare. Fish appreciate species' behavior, including mating, courtship, feeding among others. This is more plausible when fish do not exhibit cannibalism behavior, enhances behaviors like shoaling and foraging hence encouraging inter-species good welfare (Aude *et al.*, 2023).

Dietary enrichment – introduction of various flavored feed, swim-like feed pellets and substrates, different pellet sizes, addition of attractant oils in water to improve fish

feeding in the culture facility. Variations in the time fish is fed, area where fish is fed, and varying feeders enhance fish welfare. Introducing feeding bowls and trays in a culture facility minimizes energy expenditure by the fish, thus improving their welfare.

Sensory enrichment – involves the introduction of various sounds like music to fish. This is most pronounced in Koi farming in Thailand. This includes; changing the background of the rearing facility like a fish tank, changing the cover of the facility and provision of air bubbles curtains, especially in Rainbow trout culture (Amichaud *et al.*, 2024). The change in various stimuli like sight, sound, and touch enhances fish welfare. Introduction of moving objects and varied visual patterns in water relaxes the fish brain thus causing minimal stress and ultimately increased fish welfare.

Benefits of Environmental Enrichment in Fish

Overall, EE aims at improving fish welfare through enhancing fish survival, and overall fish performance. Precisely, EE has significant benefits among which include;

- Reduced fish aggression due to the shelters provided by the physical structures. This is very important for fish which are territorial and also for less aggressive species.
- Due to the provision of hiding places, fish feel safer, causing reduced stress which leads to low level production of stress hormones like cortisol.
- The adventure of added structures such as pipes and logs increase fish activity, thus leading to more exercise and body activity.
- Increased body growth since the rate of movement facilitates food breakdown for tissue development.
- Predictable feeding can reduce aggression and bursts of accelerations before mealtime. It can also reduce oxidative stress and enhance immune responses.
- Improved social learning which in turn causes improved adaptive social behavior.

DISCUSSION QUESTIONS

- What type of environmental enrichment is carried out on your farm and why?

- How would you improve on environmental enrichment on your farm?

MODULE 10: FISH HEALTH AND WELFARE

Animal health and welfare are highly interconnected concepts. Good fish health is understood as the lack of disease or injury, and the ability of the animal to perform its physiological functions at normal levels. Good health and welfare can be supported if responsible farming practices are followed at all times. These include husbandry methods that encourage the monitoring of health and welfare, the application of site-specific biosecurity plans, implementation of disease prevention schemes, adherence to good welfare practices, and responsible use of therapeutants when needed, amongst other requirements. Fish health and welfare is very crucial as concerns regarding sustainability and ethically responsible aquaculture production, and needs to be taken seriously (Johansen *et al.*, 2006). Significant concerns are usually linked to biosecurity, production intensity and changing environmental conditions, thus leading to new fish diseases and welfare challenges (Muniesa *et al.*, 2022). Prioritizing measures with positive effects on fish health and welfare is essential for both ethical reasons and aquaculture sustainability, leading to healthier fish, higher yields, better meat quality, and more efficient feed utilization and through that, a reduced environmental footprint.

Environmental changes and society's concerns about sustainability and ethically responsible production are making fish health and welfare issues increasingly more important. Biosecurity challenges, increasing production intensity, and shifting environmental conditions are of special concern as they may create new illness and welfare issues, and may have an increasing impact on the possibilities of carrying out ethically responsible treatment, and for maintaining good fish health and welfare. Yet issues like vaccination are key in sustainable disease management in aquaculture (Assefa & Abunna, 2018). Priority to actions that improve fish health and welfare is crucial for aquaculture sustainability and for ethical reasons. Choosing the right measures results in healthier fish, higher yields, better quality, and more effective use of feed, all of which will lessen the environmental impact of aquaculture.

Increased fish mortality on Uganda's fish farms is a challenge to the aquaculture sector. The existing gap between the actual survival in fish production and the ability of fish to survive is worth investigating. One of the main causes of fish low production on farms in Uganda are infectious diseases resulting from high-stocking densities, deterioration in environmental factors, poor hygiene in fish farms and of equipment among others. In order to achieve better fish health and welfare, it is important to address these areas.

Biosecurity and Fish Welfare

Biosecurity in aquaculture consists of practices that minimise the risk of pathogen transfer (e.g., bacteria, viruses, fungi, and parasites), establishment, and their spread. These include practices for reducing the stress on fish, thus making them less susceptible to pathogens/disease. Biosecurity and health management are recognized by the Food and Agriculture Organisation (FAO) as recent priorities for appropriate aquaculture governance (Muniesa *et al.*, 2022). The challenges and problems of managing good biosecurity are extensive and multifactorial predisposing farmed stocks to an increased risk of infection with consequential stock losses (Subasinghe *et al.*, 2023). Fish diseases continue to be one of the greatest causes of economic loss for the aquaculture industry. While some fish pathogens are well known problems, other diseases are emerging or spreading to previously unaffected areas. Outbreaks can happen rapidly and spread quickly, often resulting in high mortalities. It is difficult to predict when disease might occur, however the routine use of biosecurity measures can reduce the risk of introduction and economic impact of these diseases.

Table 2 Differentiating between sick and healthy fish

	Healthy fish	Sick fish
Activity	Swim actively, sharp and responsive	Swim slowly and lethargic responses
Body Surface	Intact	White layered patches appearing as lesions
Body colour	Bright and glossy	Dull, dark and discolored
Feed intake	Very good appetite	Poor appetite
Organs	Internal organs are healthy and normal	Internal organs are damaged and this is in relation to specific diseases

Importance of Biosecurity to Fish Welfare

The main reasons for biosecurity application in aquaculture is to minimise the risk of disease introduction and spread, improve fish health, protect against new diseases like Viral haemorrhagic Septicaemia - VHS, improve human health and safeguard against economic loss, among other uses. High stocking densities intensify stress, making fish more susceptible to disease. Since treatment options are limited for most aquaculture diseases, prevention remains the best line of defense for the aquaculture producer.



Figure 18 Testing of fish for disease pathogens (Adopted from AFD, 2000)

Biosecurity measures can also help promote fish health and protect your economic investment. There are a number of regulations and trade requirements for fish, as well as a growing demand for specific pathogen free (SPF) fish (Moss *et al.*, 2012). Oftentimes, these requirements involve the implementation and documentation of biosecurity procedures on the farm. Maintaining healthy fish and acquiring pathogen free status can improve or ensure a producer's reputation for providing high quality fish and fish products. While most zoonotic diseases of fish are food safety issues, there are a number of fish pathogens that can cause illness in humans when in contact with infected fish. Examples include; *Edwardsiella ictaluri*, *Mycobacterium marinum*, and *Aeromonas spp.* pathogens.

Fish Diseases in Aquaculture

Fish diseases affect the growth and survival of fish under rearing facilities. Fish diseases lead to low fish harvests and high costs are incurred during drug treatment of infected fish. In Uganda, heavy economic losses are experienced by fish farmers. In addition to the impact on rural communities from large-scale fish losses due to disease, diseases also have considerable impact on investor's confidence. There are many factors contributing to the disease challenge including:

- Increased globalization of trade and markets;
- Intensification of fish-farming practices;
- Introduction of new species for aquaculture;
- Expansion of the ornamental fish trade;
- Unanticipated interactions between cultured and wild populations of aquatic animals;
- Poor or lack of effective biosecurity measures;
- Slow awareness on emerging diseases;
- Irresponsible use of veterinary drugs; and

- Climate change.

Regular monitoring of fish health is an effective way to identify diseases and apply appropriate treatments or management interventions. Some of the common fish diseases that affect fish farms in Uganda include:

Table 3 Common freshwater fish diseases in Uganda

Disease type	Cause	Clinical signs	Treatment	References
Viral Diseases				
Viral hemorrhagic septicemia – VHS	<i>Viral hemorrhagic septicemia virus</i>	Lethargic, abnormal swimming behaviour, fish colour is darker than normal, spiralling, dark red liver.	Quarantines of wild harvested fish before stocking on fish farms.	(Smail & Snow, 2011)
Epizootic hematopoietic necrosis – EHN	<i>Epizootic hematopoietic necrosis virus</i>	Sudden death, especially in Rainbow trout, hemorrhage in the gills, lethargy and darkening of the fish body.	Culling, disinfection, quarantines and farm good management practices, e.g. low stocking densities, good biosecurity measures.	(Becker et al., 2019)
Bacterial Diseases				

Bacterial gill disease	<i>Flavobacterium branchiophila</i>	Lethargy, dyspnea, coughing and flared opercula, mucus strands from gills.	Use of antiseptic and surfactant baths like chloramine T and benzalkonium chloride. Avail adequate oxygen to fish.	(Zamparo <i>et al.</i> , 2024)
Mycobacteriosis (Fish tuberculosis)	<i>Mycobacterium</i>	Presence of acid-fat mycobacteria in granuloma of the fish.	Cull and disinfect culture facilities (10,000ppm or 60-855 alcohol).	(Francis-Floyd, 2017)
Fungal Diseases				
Saprolegniosis	<i>Saprolegnia sp.</i>	White-mat like structures on the fish, epidermal damage, lethargy and restricted movement due to overgrown mycelium, listless.	Proper fish handling to minimise physical injury, hygienic environment, stock disease-free seed, maintain water flow.	(Lindholm-Lehto & Pylkkö, 2024)

Parasitic Diseases				
White spot disease	<i>Ichthyophthirus multifilis</i>	Round-hairy grown brown coloured parasite, irritation and itching, flashing.	Dip treatment in 2-3% salt solution for 1-2 minutes, apply lime at 30-50 mg/L, Dip treatment of	(Sánchez-Paz, 2010)
Whirling disease	<i>Myxobolous cerebralis</i>	Circular or whirling movement, erratic swimming, darkening of tail region, deformity of skeleton and mortality.	Potassium permanganate at 1 ppm.	(Sarker et al., 2015)

Biosecurity Measures for Fish Health and Disease Control in Aquaculture

Biosecurity in aquaculture involves management actions to prevent the introduction of disease-causing agents to aquaculture facilities. Key measures include:

Quarantine and movement restriction: Confine new aquatic animals with unknown health status before introducing them to the stock. Quarantine duration ranges from 15 days to 3 months, with strict observation and diagnostic tests (Asiva, 2015).

Disinfectants and pesticides: Use physical or chemical agents to remove microorganisms on inanimate objects and fish eggs. Common disinfectants include quaternary ammonium compounds, formaldehyde, hydrogen peroxide, chlorine,

and iodine (El-Dakour *et al.*, 2015). Some dosages include the use of quick lime (Calcium Oxide) at a rate of 500g per square metre. squared. For culture gear and pipes, use 100ml formaldehyde for every 0.4 tonnes of water. Immerse the equipment for 1 hour and later rinse thoroughly in water. To prevent the spread of infections from outside the farm, these disinfectants can be applied in footbaths at the entrances both to the farm and key points within the farm such as hatcheries that are frequented by staff and visitors. The disinfectant solution should be carefully prepared and maintained, checked regularly and replaced when needed. For more effective use of a footbath, it is advised to consider a two-stage process (scrubbing of solid particles followed by disinfection).

Surveillance for diseases: Regular surveillance helps identify potential disease routes and detect new diseases early. It includes passive surveillance (using existing data) and active surveillance by conducting specific surveys (Assefa & Abunna, 2018).

Sanitation and water treatment: Clean and dry ponds properly, ensure high-quality, well-aerated water, and implement sanitation protocols for equipment.

Stocking density reduction: Lower stocking densities to control ectoparasite infections and increase water flow for better parasite flushing.

Implementing these biosecurity measures can significantly reduce the risk of disease outbreaks and ensure fish welfare and health in aquaculture.

Antimicrobial Resistance and Fish Welfare

Antimicrobial resistance (AMR) is a natural process where microorganisms such as viruses, bacteria, fungi and parasites evolve and develop mechanisms to resist the effect of antimicrobial drugs. AMR is one of the top global public health and development threats. The misuse and overuse of antimicrobials in humans, animals and plants are the main drivers in the development of drug-resistant pathogens (Murray *et al.*, 2022). Infections become more difficult to treat even with standard medication. In traditional aquaculture, unfavorable conditions and exposure to pathogens often lead to disease outbreaks, prompting the use of antibiotics to maintain fish health. Diseases are a primary constraint to the culture of many aquatic

species and as a result, there is widespread use of anti-microbial veterinary medicines in aquaculture across the globe. Imprudent use of these veterinary medicines in aquaculture is a contributing factor in the spread of antimicrobial resistance. This practice not only fosters resistant bacteria but also poses risks to ecosystems and public health. For example, the use of antibiotics in aquaculture when they are not needed to promote fish growth, fecundity than to treat infections enhances AMR. Some studies conducted in Ethiopia among community members indicated that a small proportion (39.8%) of the population was aware of AMR (Simegn & Moges, 2022). Knowledge enhancement in AMR among communities is paramount. In aquaculture, intensive culture systems provide a platform for AMR.

Why AMR is a challenge in aquaculture

The high stocking densities and the reliance on antimicrobials create an environment for pathogen growth (bacteria, viruses and parasites) and survival (Okon *et al.*, 2022). Acute infections can lead to poor fish welfare and loss of fish stock. Antimicrobial residue release in the environment, in addition to resistant bacteria through fish farm water release can lead to the spread of resistant bacteria to other fish farms using the same drainage as a source of water. The residues can as well contaminate other water resources and pose a health risk to not only aquatic life, but human life too.

The consumption of fish contaminated with antibiotic resistance bacteria or parasites possess a challenge to treat (zoonoses). These bacteria and parasites can cause discomfort to human beings, morbidity and subsequently death. The unethical use of antibiotics can lead to contamination of marine and freshwater life. The bioaccumulation and bioconcentration of these antibiotics can lead to biomagnification in fresh water and marine fish tissues, hence impacting on fish welfare. When such marine fish is consumed, human health is compromised as well.

DISCUSSION QUESTIONS

- Do you have any biosecurity measures on your farm? If yes, describe them in detail.

- Do you experience fish disease outbreaks on your farm? If yes, how do you control disease outbreaks?
- How would you want to be helped in managing disease outbreaks on your farm?
- How do you handle fish for stocking on your farm?

REFERENCES

- Adeleke, B., Robertson-Andersson, D., Moodley, G., & Taylor, S. (2020). Aquaculture in Africa: A Comparative Review of Egypt, Nigeria, and Uganda Vis-À-Vis South Africa. *Reviews in Fisheries Science and Aquaculture*, 29(2), 167–197. <https://doi.org/10.1080/23308249.2020.1795615>
- Algers, B. (2011). Animal welfare - Recent developments in the field. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*, 6(May 2011). <https://doi.org/10.1079/PAVSNNR20116010>
- Altan, O. (2017). *Diversification of Aquaculture Activities and Production Methods Extensive Aquaculture Extensive Aquaculture * Hundreds of ponds ; ** Hectares of pond surface ; and.*
- Amichaud, O., Lafond, T., Fazekas, G.L., Kleiber, A., Kerneis, T., Batard, A., Goardon, L., Labbé, L., Lambert, S., Milla, S., & Colson, V. (2024). Air bubble curtain improves the welfare of captive rainbow trout fry and fingerlings. *Aquaculture*, 586(March). <https://doi.org/10.1016/j.aquaculture.2024.740828>
- Arechavala-Lopez, P., Cabrera-Álvarez, M.J., Maia, C.M., & Saraiva, J.L. (2022). Environmental enrichment in fish aquaculture: A review of fundamental and practical aspects. *Reviews in Aquaculture*, 14(2), 704–728. <https://doi.org/10.1111/raq.12620>
- Ashley, P.J. (2023). *Fish welfare : Current issues in aquaculture Fish welfare : Current issues in aquaculture. July.* <https://doi.org/10.1016/j.applanim.2006.09.001>
- Asiva Noor Rachmayani. (2015). *Procedures for the quarantine of live aquatic animals.*
- Assefa, A., & Abunna, F. (2018). Maintenance of Fish Health in Aquaculture: Review of Epidemiological Approaches for Prevention and Control of Infectious Disease of Fish. *Veterinary Medicine International*, 2018. <https://doi.org/10.1155/2018/5432497>
- Aude, K., Mathilde, S., Mélanie, R., Vitor, F., & Bessa, H. (2023). *Archimer Cognitive enrichment to increase fish welfare in aquaculture : A review.* 575(October).

<https://doi.org/10.1016/j.aquaculture.2023.739654>

- Becker, J.A., Gilligan, D., Asmus, M., Tweedie, A., & Whittington, R.J. (2019). Geographic distribution of epizootic haematopoietic necrosis virus (Ehnv) in freshwater fish in south eastern australia: Lost opportunity for a notifiable pathogen to expand its geographic range. *Viruses*, 11(4). <https://doi.org/10.3390/v11040315>
- Boyd, C.E. (1998). Water quality in ponds for aquaculture. *Research and Development Series*, 43, 482.
- Bozzo, G., & Dimuccio, M.M. (2023). Implementation of Animal Welfare: Pros and Cons. *Agriculture (Switzerland)*, 13(4), 10–12. <https://doi.org/10.3390/agriculture13040748>
- Business, C. in F. (2017). *Driving Innovation in Humane Fish Slaughter*: 1–8.
- Commission, U. L. (2022). *Animal (Prevention of Cruelty) Act*, Cap. 39.
- Dara, M., Carbonara, P., La Corte, C., Parrinello, D., Cammarata, M., & Parisi, M.G. (2023). Fish Welfare in Aquaculture: Physiological and Immunological Activities for Diets, Social and Spatial Stress on Mediterranean Aqua Cultured Species. *Fishes*, 8(8). <https://doi.org/10.3390/fishes8080414>
- EFSA. (2009). The Welfare of Farmed Fish. *Applied Animal Behaviour Science*, 83(August), 153–162.
- El-Dakour, S., Saheb, A.I., & Al-Abdul-Elah, K. (2015). Effects of commonly used disinfectants on bacterial load, hatchability and survival of Bluefin Sea bream (*Sparidentex hasta*) eggs. *Aquaculture Research*, 46(6), 1281–1291. <https://doi.org/10.1111/are.12302>
- European Union. (2021). Particular welfare needs in animal transport: aquatic animals. *Workshop on Animal Welfare during Transport of 25 May 2021*, May.
- FAO. (2024). *WORLD FISHERIES AND AQUACULTURE*.
- FAWC. (1996). Report on the welfare of farmed fish. *Farm Animal Welfare Council*, 43.
- Flores Nava, A., & Manjarrez-Aguilar, J. (2023). Latin American and the Caribbean call to increase the contribution of fisheries and aquaculture to food and nutrition

- security. *FAO Aquaculture News*, 67(June), 22–23. www.fao.org/publications
- Francis-Floyd, R. (2017). Mycobacterial infections of fowl. *Journal of the Hellenic Veterinary Medical Society*, 57(2), 127. <https://doi.org/10.12681/jhvms.15017>
- Gerber, B. (2015). *Environmental Enrichment and Its Effects*. 41(0).
- Goes, E.S. dos R., Goes, M.D., Castro, P.L. de, & ... (2019). *Effect of pre-slaughter stress on quality of tilapia fillets*. October.
- Humane Slaughter Association. (2016). Humane Harvesting of Farmed Fish. *Online Guides*, 44(209563), 19. <https://www.hsa.org.uk/removal-from-water/removal-from-water>
- Johansen, R., Needham, J.R., Colquhoun, D.J., Poppe, T.T., & Smith, A.J. (2006). Guidelines for health and welfare monitoring of fish used in research. *Laboratory Animals*, 40(4), 323–340. <https://doi.org/10.1258/002367706778476451>
- Lindholm-Lehto, P.C., & Pylkkö, P. (2024). Saprolegniosis in aquaculture and how to control it? *Aquaculture, Fish and Fisheries*, 4(4), 1–22. <https://doi.org/10.1002/aff2.200>
- MAAIF. (2017). *REPUBLIC OF UGANDA MINISTRY OF AGRICULTURE , ANIMAL INDUSTRY AND FISHERIES*. July.
- MAAIF. (2020). *Aquaculture Training Manual for Extension Agents in Uganda*. 785, 27–30.
- MAAIF. (2022). *MINISTRY OF AGRICULTURE, ANIMAL INDUSTRY AND FISHERIES Guidelines and Standard Operating Procedures for Handling and Transporting Live Animals in Uganda*. THE REPUBLIC OF UGANDA.
- Mellor, D.J., Beausoleil, N.J., Littlewood, K.E., McLean, A.N., McGreevy, P.D., Jones, B., & Wilkins, C. (2020). The 2020 five domains model: Including human–animal interactions in assessments of animal welfare. *Animals*, 10(10), 1–24. <https://doi.org/10.3390/ani10101870>
- Moss, S.M., Moss, D.R., Arce, S.M., Lightner, D.V., & Lotz, J.M. (2012). The role of selective breeding and biosecurity in the prevention of disease in penaeid shrimp aquaculture. *Journal of Invertebrate Pathology*, 110(2), 247–250.

<https://doi.org/10.1016/j.jip.2012.01.013>

- Muniesa, A., Furones, D., Rodgers, C., & Basurco, B. (2022). An assessment of health management and biosecurity procedures in marine fish farming in Spain. *Aquaculture Reports*, 25(August 2021), 101199. <https://doi.org/10.1016/j.aqrep.2022.101199>
- Murray, C.J., Ikuta, K.S., Sharara, F., Swetschinski, L., Robles Aguilar, G., Gray, A., Han, C., Bisignano, C., Rao, P., Wool, E., Johnson, S.C., Browne, A.J., Chipeta, M. G., Fell, F., Hackett, S., Haines-Woodhouse, G., Kashef Hamadani, B.H., Kumaran, E. A.P., McManigal, B.,
- Naghavi, M. (2022). Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. *The Lancet*, 399(10325), 629–655. [https://doi.org/10.1016/S0140-6736\(21\)02724-0](https://doi.org/10.1016/S0140-6736(21)02724-0)
- Muthusamy, P., & Viswanathan, K. (1999). Influence of rearing system on the egg quality traits of commercial layers. *Indian Veterinary Journal*, 76(6), 533–536.
- Ojelade, O. C., Durosaro, S.O., Akinde, A.O., Abdulraheem, I., Oladepo, M.B., Sopein, C.A., Bhadmus, A.S., & Olateju, M. (2022). Environmental enrichment improves the growth rate, behavioral and physiological response of juveniles of *Clarias gariepinus* under laboratory conditions. *Frontiers in Veterinary Science*, 9. <https://doi.org/10.3389/fvets.2022.980364>
- Okon, E.M., Okocha, R.C., Adesina, B.T., Ehigie, J.O., Alabi, O.O., Bolanle, A.M., Matekwe, N., Falana, B.M., Tihamiyu, A.M., Olatoye, I.O., & Adededeji, O.B. (2022). Antimicrobial resistance in fish and poultry: Public health implications for animal source food production in Nigeria, Egypt, and South Africa. *Frontiers in Antibiotics*, 1 (November), 1–19. <https://doi.org/10.3389/frabi.2022.1043302>
- Pomeroy, R., Dey, M.M., & Plesha, N. (2014). the Social and Economic Impacts of Semi-Intensive Aquaculture on Biodiversity. *Aquaculture Economics and Management*, 18(3), 303–324. <https://doi.org/10.1080/13657305.2014.926467>
- Sánchez-Paz, A. (2010). White spot syndrome virus: An overview on an emergent concern. *Veterinary Research*, 41(6). <https://doi.org/10.1051/vetres/2010015>

- Sarker, S., Kallert, D.M., Hedrick, R.P., & El-Matbouli, M. (2015). Whirling disease revisited: Pathogenesis, parasite biology and disease intervention. *Diseases of Aquatic Organisms*, 114(2), 155–175. <https://doi.org/10.3354/dao02856>
- Segner, H., Reiser, S., Ruane, N., Rosch, R., Steinhagen, D. and V. (2019). *Welfare of fishes in aquaculture*, FAO. 1189.
- Sherwin, C.M., Richards, G. J., & Nicol, C.J. (2010). Comparison of the welfare of layer hens in 4 housing systems in the UK. *British Poultry Science*, 51(4), 488–499. <https://doi.org/10.1080/00071668.2010.502518>
- Simegn, W., & Moges, G. (2022). Awareness and knowledge of antimicrobial resistance and factors associated with knowledge among adults in Dessie City, Northeast Ethiopia: Community-based cross-sectional study. *PLoS ONE*, 17(12 December), 1–16. <https://doi.org/10.1371/journal.pone.0279342>
- Smail, D.A., & Snow, M. (2011). Viral haemorrhagic septicaemia. *Fish Diseases and Disorders*, 3, 110–142. <https://doi.org/10.1079/9781845935542.0110>
- Southgate, P.J. (2008). Welfare of Fish During Transport. *Fish Welfare*, 185–194. <https://doi.org/10.1002/9780470697610.ch11>
- Subasinghe, R., Alday-Sanz, V., Bondad-Reantaso, M.G., Jie, H., Shinn, A.P., & Sorgeloos, P. (2023). Biosecurity: Reducing the burden of disease. *Journal of the World Aquaculture Society*, 54(2), 397–426. <https://doi.org/10.1111/jwas.12966>
- Tarazona, J.V., & Muñoz, M.J. (2008). *Reviews in Fisheries Science Water Quality in Salmonid Culture* (Issue May 2013).
- Toni, M., Manciocco, A., Angiulli, E., Alleva, E., Cioni, C., & Malavasi, S. (2019). Review: Assessing fish welfare in research and aquaculture, with a focus on European directives. *Animal*, 13(1), 161–170. <https://doi.org/10.1017/S1751731118000940>
- Vargo, C., Taylor, S., & Haines, D. (1997). Book Review/Compte rendu de livre. *Contemporary Accounting Research*, 14(2), 203–213. <https://doi.org/10.1111/j.1911-3846.1997.tb00533.x>
- Wahlitzne, S.J., Cohen, S., Hardy-Smith, P., Huynh, C., & Kells, N.J. (2024). Evaluation of insensibility in humane slaughter of teleost fish, including the use of

electroencephalogram with a case study on farmed barramundi (*Lates calcarifer*). *Aquaculture*, 590(April), 740993. <https://doi.org/10.1016/j.aquaculture.2024.740993>

WOAH. (2024). Animal welfare: a vital asset for a more sustainable world. *Animal Welfare-Vision*, 1–8. <https://www.woah.org/app/uploads/2024/01/en-woah-visionpaper-animalwelfare.pdf>

Zamparo, S., Orioles, M., Brocca, G., Marroni, F., Castellano, C., Radovic, S., Mandrioli, L., Galeotti, M., & Verin, R. (2024). Novel insights on microbiome dynamics during a gill disease outbreak in farmed rainbow trout (*Oncorhynchus mykiss*). *Scientific Reports*, 14(1), 1–15. <https://doi.org/10.1038/s41598-024-68287-w>



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