GENERAL GUIDELINES ON BETTER MANAGEMENT PRACTICES FOR FISH PRODUCTION SYSTEMS IN DELTA AND OGUN STATES, NIGERIA

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Produced as part of the outputs from the USAID FIL-supported project titled "Improving Biosecurity: A Science-based Approach to Manage Fish Disease Risks and Increase the Socio-economic Contribution of the Nigerian Catfish and Tilapia Industries"

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TABLE OF CONTENTS

ABOUT THE PROJECT

There is no clear national aquatic animal health management strategy in Nigeria. Furthermore, there is little or no biosecurity management practiced at the production level, except for a few large-scale commercial farms. Although Nigeria is Africa's largest producer of African catfish, hatcheries in Nigeria have long complained of poor fingerling survival rates, slow growth, and poor reproduction, which leads to reduced volumes of quality seed at the hatchery level and suboptimal yields at the farm level. Therefore, this activity aims to better understand the disease and health status of catfish and tilapia aquaculture with a focus on Ogun and Delta states. We will develop strategies to reduce risk of diseases in these two species focusing on a small-scale regional model covering different farming systems on a limited number of farms over a restricted geographical zone to maximize data collection and quality over time. We will refine the model over 24 months, then we will investigate replicating it with national CA and partners for future scaling into state and national schemes. Our model will require capacity development, innovation, and establishing strong international and national partnerships. Reduced risk of disease will increase production and income, which will eventually benefit thousands of Nigerians relying on fish farming for their livelihoods, and it will increase fish availability for consumption.

Project objectives:

1) To understand epidemiology and health economics of catfish and tilapia aquaculture in Ogun and Delta states, Nigeria
2) To understand health status of catfish and tilapia in a regional model by employing presumptive field and laboratory diagnostics
3) To identify pathogens of economic significance circulating in Nigerian catfish and tilapia aquaculture using whole genome sequencing
4) To develop better management practices (BMPs) and build capacity to reduce risks of disease outbreaks in catfish and tilapia aquaculture in Nigeria
5) To develop science-based policies and strategies for reducing fish disease risks in Nigerian aquaculture for longer-term development beyond the life of project.

The activity outputs are:

1) risk factors for disease emergence, outbreaks, and spread (including seasonality issues) with respect to environmental and climate change risks will be identified
2) endemic, emerging, and exotic pathogens will be identified, and economic impacts will be quantified in a regional model
3) key pathogens will be isolated from farming systems and seed supply networks, and whole genomes will be sequenced by next generation sequencing
4) health management interventions in the form of "BMPs" that reduce fish disease risks for fish farming systems and fish seed supply chains will be developed, and capacity building activities tailored to the needs of various stakeholders will be implemented
5) our research findings and capacity development activities will support development and operationalization of a simple and practical national aquatic animal health and biosecurity strategy for implementation by the national competent authorities (CA)

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INTRODUCTION

Nigeria is the largest aquaculture producer in Sub-Saharan Africa, with an average 12% growth per annum in the sector (WorldFish, 2018) and a production of 289,543 metric tonnes per year in 2019, making up to 37.3% of local animal protein supply (FAO, 2021). Catfish, tilapia and carp are the major species produced in the country (Emmanuel et al., 2014; WorldFish 2018), with catfish being dominantly cultured due to its resilience to harsh environmental conditions, good price, taste, acceptance by most tribes and ability to be kept alive for days during marketing (Anetekhai, 2017).

However, domestic production output has not been able to meet the per capita fish consumption of 13 kg per annum, with an annual deficit of over 800,000 metric tons, which is mostly fulfilled through fish importation (WorldFish, 2018). The export market for the products has also been affected due to food safety concerns, for example, On March 1, 2018, the Food Safety and Inspection Service of the US Department of Agriculture (USDA) placed a ban on the export of Siluriformes and fish products from Nigeria (Okai, 2019; The Guardian, 2020). The industry's sustainability and potential to fulfill local and international demand for quality fish is also threatened by aquatic animal disease as farmers suffer significant losses from poor management practices, including biosecurity. The depth of the problem remains unknown due to insufficient disease reporting and documentation of mortality by local farmers, as well as the absence of a functional extension network linking farmers to Veterinary expertise for fish health management.

This manual proposing Better Management Practices (BMPs) was developed as one of the outputs of the 3-year United States Agency for International Development Feed the Future Innovation Lab for Fish (USAID-FIL) project 'Improving Biosecurity: A Science-Based Approach to Manage Fish Disease Risks and Increase the Socioeconomic Contribution of the Nigerian Catfish and Tilapia Industries', in line with one of the project's objectives, which is to develop better management practices (BMPs) and build capacity to reduce the risk of disease outbreaks in catfish and tilapia aquaculture in Nigeria. The project is currently being led by WorldFish headquarters in Malaysia, together with its implementing partners Mississippi State University (MSU) and the University of Ibadan (UI).

Using the Fish Epidemiology and Health Economics (FEHE) online digital survey tool, data on local farming practices, epidemiology and health economics were collected from 399 farms in Delta and Ogun states, Nigeria and analyzed to determine risk factors and biosecurity gaps in local production systems. Focused group discussions (FGDs) with key stakeholders from both states, comprising of farmers, cluster leaders, relevant government officers, academic institutions and resident veterinarians were also conducted as part of the "Biosecurity Measures as a One Health Approach in Mitigating Loss in Aquaculture Production" workshop held on 16-17th Aug 2022 at IITA in Oyo, Nigeria. Information gained from workshop interactions and lessons learnt from project staff and farmers throughout the field survey were then used to contextualize BMPs to address the identified risks. After distillation and synthetization of information from survey findings and stakeholder consultations, sections of this document were organized according to consecutive stages of a production cycle beginning from farm setup, pond preparation to harvest.

Below are the key observations noted in the overall survey findings across both Ogun and Delta states:

- Higher proportion of male to female farmers.
- Almost equal of farmers from younger (40 or less) and older age groups.
- Most farmers had secondary to post secondary levels of education.
- Most farms were commercial and carried out perennial (year-long) farming.
- Majority of farms carried out monoculture of catfish and had earthen pond systems.
- Most farms produced table sized fish and fingerlings.
- Majority of farms used commercial feed.
- Many farms lacked paper records for recording mortality.

The risk factors and biosecurity gaps observed from the study were as follows:

- Lack of biosecurity measures during stocking such as provision of vehicle tyrebath upon entry, fish disinfection, and disposal of water transport water away from ponds and tanks.
- Sharing of equipment and staff with other farms.
- Lack of routine internal biosecurity measures such as vehicle disinfection, provision of footbaths at entry and exit points, and disinfection of hands and equipment.
- Use of seafood offal in feed.
- No proper disposal of dead fish.
- Lack of post-outbreak biosecurity measures such as pond isolation; dead/sick fish removal; equipment disinfection between ponds; treatment of discharged water; shutdown of water movement to and from infected units; and restricting the movement of animals, people and equipment.
- Low implementation of biosecurity measures in between productions cycles such as net cleaning, fallowing, drying or treatment of ponds with lime.
- Rare engagement of veterinarians for fish health management.

Descriptive statistics from the epidemiological study were presented at the regionaland international levels, namely the Aquaculture Africa Magazine webinar series (5 July 2022), and Aquaculture America 2023 (23-26th February 2023) respectively. The findings will also be shared at a national-level stakeholder engagement workshop in 2023. The report on the survey findings is currently being drafted for publication in a peer reviewed journal. In addition, all details of the epidemiological study are being compiled and consolidated as a separate project report.

This manual provides general guidelines for the purpose of setting up or maintaining biosecurity practices for aquaculture farms in the Nigerian context. It may be used as a baseline document for planning of future aquaculture management programmes and standard operating procedures (SOPs), which existing aquaculture farms in Nigeria could implement to maintain sustainable and environmentally responsible farming. It is important to understand that the suggestions in this set of BMP guidelines are generalized and may be implemented across different production systems. The majority of recommendations in this document are regarded as minimal requirements that can be applied to most outdoor production systems, with the exception of some high biosecurity measures that may only be practical for indoor premises with a controlled environment such as hatcheries and broodstock facilities.

The manual was produced for the benefit of farmers, as well as relevant government ministries, departments and agencies, veterinarians and extension officers intending to help farms with the setup of biosecurity facilities and practices. In order to maintain relevance to industry developments, it is recommended that updates should be made to this manual every 3 to 5 years.

Image 1: Catfish in a pond in Delta State

Image 2: Woman feeding catfish in Delta State

FARM INFRASTRUCTURE

SELECTION OF FARM LAND AND GENERAL SETUP OF THE PRODUCTION FACILITY

Image 3: Pond preparation in Delta State

Image 4: Catfish ponds in Ikenne, Ogun State

When setting up a new farm site, it is important to ensure the availability & reliability of basic amenities such as electricity and municipal water, as well as easy access to and from the site via roads that can be accessed by suppliers, service providers, and extension officers. Local governments should always be contacted first to issue permits and to review plans for setting up a farm, especially in an area of high farm density or very close to high human population.

A good portion of farms in Delta and Ogun states ran semi-intensive and extensive systems, with life stages of fish ranging from fingerlings to table size. It is therefore important that the source of production water be tested for its quality and reliability, to ensure adequate supply and sharing of good quality water resources,which is critical in for managing a high intensity production. Since many of the surveyed farms sourced their production water from a combination of boreholes and rivers, it is highly important that the government should request for environmental impact assessment reports as a pre-requisite for approving the siting of a fish farm not only on the water resource but also on the land structure and soil quality to determine if the selected site is suitable for borehole drilling, land excavation and future water retention.

High number of unregulated drilled boreholes increase the risk of depleting shallow aquifers and subsequently the sinking of the land around it, causing worse flooding and necessitating the need to build higher dikes. Due to the unpredictability of climate change, the frequencies of natural disasters (e.g. floods), rain runoff and drainage patterns at the site should also be evaluated to manage these risks.

The planning of a farm should also include the responsible management of non-production water resources, which includes water supplies for sewerage systems, general washing, and drinking. As many farms were found to be situated around shared natural water resources, it is important that aquaculture effluent and wastes disposal plans should be put in place, for example, an area of the farm could be allocated for the setup of effluent treatment and disposal facilities before discharging into shared water bodies.

RECOMMENDATIONS:

- A survey on the general topography and soil mapping should be carried out on any newly proposed site for building of aquaculture ponds.
- Selection of farming sites should be carried out using professional advice alongside an environmental impact assessment.
- Newly proposed sites should not be in close proximity to sources of industrial, agriculture, livestock or urban runoffs.
- The analysis of the water table, soil structure and quality should be done prior to drilling of boreholes to determine if further extraction of borewater will predispose the land to sinking and flooding from the nearest water resource.
- The soil type should be considered before selecting the location of a pond. The soil mixture should be able to resist erosion and production water seepage into the environment. If seepage or bottom soil quality is an issue, plastic liners may be considered.Areas prone to natural disasters such as flooding should be avoided in site selection.
- To limit the impact of flooding, overcrowded farming areas should not be selected for the construction of a new farm. There should be adequate distance between farms to reduce the risk of disease transmission.
- Water bodies close to residential buildings or urban settlements should be appropriately channeled to make way for water run-off in the event of rising water levels due to rains.
- Parameters (e.g., chlorine, ammonia, nitrite, pH, hardness) of the source of production water (municipal, pond, lake, river or groundwater) should be tested to determine suitability for fish culture and to identify any potential contaminants or pathogens.
- Physical infrastructure and equipment for treatment/improvement of water quality should be available for any identified risk factors found in the source water, such as physical/biological filtration, aeration, UV or ozone treatment, and holding tanks.
- Water retention tanks should be set up for additional storage of water from primary sources.
- Treatment ponds should be constructed to facilitate the holding and treatment of farm effluent water before discharge.
- Sustainable electricity source should be prioritized, such as the use of solar power to run small farm devices or to generate backup electricity.

- If there is no constant supply of municipal water at the farm site, ensure that adequate water is stored or transported from other sites for farm operational use.
- A secondary supply of drinking water should be provided for sanitation and drinking by farm workers that is separate from the production water source.
- Proper channels for non-hazardous wastewater should be built to flow into the sewerage system or areas that pose no environmental risk.
- Tanks should be prepared for appropriate treatment of water contaminated with hazardous chemicals before disposal at suitable disposal sites.
- Higher dikes or spillways should be constructed to redirect overflow from the nearest water body away from the ponds.
- The use of early detection systems such as a water level gauge at the water body (river or lake) may be used to indicate rising height of water levels.
- Where possible, farms at risk of floods may consider transfer of their stock to ponds on elevated ground or use anchored floating cages as a temporary measure to hold their stock.
- As a cluster, farms may opt to form government-led agencies or work as a group to build dikes and fund dredging activities in riverbeds where flooding is a perceived threat.

SETUP OF PRODUCTION UNITS

Image 5: Showing water inflow into a pond using a power-generated water pump at work in a farm, Ijebu, Ogun State

In a survey on 399 farms in Delta and Ogun states in Nigeria, majority (83.91%) of the farms were found to have earthen pond production systems with a perennial farming system (86.72%). For pond production systems, the premises allocated for new pond construction should have good soil quality including neutral pH and proper soil type to retain water and reduce dependency on pond liners. Meanwhile, sediments that are removed from the bottom of existing ponds should be disposed of responsibly or used as compost.

A controlled water inflow and drainage system should be in place to accommodate production activities such as pond preparation, stocking, movement of stock, harvesting and to allow shutdown of specific locations in the event of an outbreak or to manage water exchange. There should also be structural barriers in place at farm entry points and water inlets to prevent the entry of predators and wild fish, which may carry disease into the farm. The banks, inner walls and slopes of ponds should be suitably reinforced to prevent internal erosion and collapse. There should also be control measures to prevent wildlife from burrowing holes within the pond banks.

Image 6: Showing water inflow into ponds using a pumping system powered by a generator. Farm in Apata, Oyo State

All tank and pond production units should be supported with functional water pumps, water inlets and aerators that are regularly maintained and placed strategically within ponds to avoid the water flow from eroding the pond banks (image 6).

Ahead of any production cycle, there should be infrastructure ready for protection against natural disasters such as floods, when escaped farmed fish may carry disease into the wild or other farm systems. Mitigation measures may include the construction of dikes, river dredging, and preparation of emergency fish holding units or transportation equipment.

RECOMMENDATIONS:

- A blueprint of the farm should be developed whereby different production zones (such as the hatchery, growout tanks, and ponds) are clearly segmented to reduce the spread of infection from one section to another.
- There should be a clear label for each production unit (tank and pond) for identification and recording purposes.
- There should be control of water inflow and outflow (through the use of pumps, gates, etc) for each production unit.
- Ponds should be constructed in a rectangular shape with suitable pond outlet structures (drains, gates) for easier harvesting and maintenance of optimal water levels. Similarly, each tank should be equipped for partial water exchange or complete drainage for harvest and post production activities.

- All entries and outlets of each production unit should have structures to accommodate installations of double screens to prevent fish escapes, entry of wild fish/crustaceans and predators, as well as inflow of debris into the production system.
- Tank and pond systems should be equipped with mechanical aeration and circulation systems with backup electricity generators for daily operations and to prevent fish kill under low oxygen conditions.
- To prevent the erosion of pond walls or banks, pond water inlets and aerators should be placed at a suitable location at a distance away from sediment banks. Additionally, the sides of the pond may be lined with plastic covers, vegetation planting or reinforced with stone packing.
- There should not be trees or large, deep-rooted plants growing on the retaining walls of earthen ponds as their roots may weaken the wall structure.
- Ponds should be situated away from sources of organic debris such as leaf litter that may fall into the pond and decompose, affecting the water quality.
- Each production zone should be equipped with its own set of equipment with separate storage racks to minimize the need to share equipment across zones.
- A quarantine facility should be set up for isolation, holding and observation of newly arrived fish before release into the common farm production units. This facility should have its own set of equipment only for internal use that should not be carried outside to other parts of the farm.

SETUP OF STORAGE FACILITIES

Image 7: Feed storage unit at Apata, Oyo State

Image 8: Commercial feed stored into large plastic drums sealed in lids in Abeokuta, Ogun State

Feed and chemicals should be held in separate storage areas with a lockable door where entry can be limited to authorized personnel only, to reduce the incidence of unrecorded use of feed and chemicals on the farm. Storage buildings should be adequately secured and sealed from entry by wild animals and rodents which may contaminate feed and introduce health hazards to farm workers. For stores containing kits, consumables and small equipment used during a production cycle, an updated inventory should be made available for monitoring of total farm usage and indication of low supplies.

If the use of wet feeds is necessary, there should be suitable storage equipment in place to store wet feeds at the appropriate temperature to prevent the growth of molds. Pallets should be available for use in feed stores to prevent the direct contact of feed bags with the surface of the floor and the walls of the store, which may cause condensation and the growth of mold (image 7). There should be suitably sized storage drums available for storing partially used feed and to prevent exposure to pests and contamination (image 8). A good general storage practice is to prioritize utilization of earlier batches of feed to prevent in-store feed expiration or contamination by molds. A reminder of this practice can be indicated using clear signage indicating good record keeping of feed inventory, following a labelling system to reinforce the utilization of earlier stocks of feed.

Storage racks should be installed in the chemical store, with a clear labelling system to prevent confusion and inappropriate usage of chemicals. Aside from clear instructions on chemical usage, measurement instruments and containers, ready stock of clean PPE such as masks and gloves should be prepared for adequate protection of farm workers required to handle hazardous drugs or chemicals.

RECOMMENDATIONS:

- Feed and chemical stores should be separate and both should only be accessed by authorized farm workers who are responsible for recording the usage of feed and chemicals.
- Feed and chemical stores should be secured from pests by preparation of baited traps and repairs of any holes in the walls.
- A separate chest freezer or refrigerator should be clearly labelled and used for storage of finished wet feed or its ingredients.
- All feed bags should be stored on pallets and distanced away from the wall of the store room.

- Partially used feed bags should not be left open in the feed store and should be secured or relocated to a drum with a lid.
- A sign indicating a first-in first-out system in the feed store should be used to encourage utilization of older stocks of feed.
- Labels should be used for indicating feed type, size and arrival dates of every batch of feed.
- Chemical stores should be organized with clear labelling indicating the type of chemicals and signage of hazardous materials.
- Use of clear standard operating procedures (SOPs) for handling chemicals, measurement instruments, apparatus and personal protective equipment (PPE) should be worn during the preparation, use of medicated feeds, chemicals and disposal of dead fish and .
- All stores should have a monthly updated inventory with details of the type of kits, consumables, small equipment in stock, arrival dates, and remaining quantity.

DEVELOPMENT OF A BIOSECURITY PLAN

Image 9: Harvesting of catfish in Ijebu, Ogun State

Aquaculture biosecurity is the protection of farmed aquatic animals from pathogens and risk factors that can cause stress, disease or mortality. In order to protect farms from unmanageable losses, a biosecurity plan which is a set of procedures and practices to manage or prevent the introduction of disease into the farm, should be applied to all farm workers, visitors, animals and equipment. A biosecurity plan should be evaluated regularly so that improvements can be made to reduce identified risk factors in the production system.

A typical biosecurity plan will include the following:

- Quarantine of incoming fish into the farm
- Testing of the source water
- Disinfection of farm equipment and vehicles
- Sanitization procedures for workers and visitors
- Proper storage space and procedures for equipment, feed and chemicals
- Exclusion of wildlife (wild fish, predators and pests) from the farm production area.

A biosecurity plan requires the setup of infrastructure and facilities throughout the farm, with which biosecurity practices can be carried out. The following are the general facilities required for implementation of farm biosecurity:

- Disinfection stations for sanitizing equipment, washing of clothing and hands. At least one station should be set up between production zones, holding zones for sick fish, and those of different health status and sensitivity.
- For indoor and high biosecurity production systems, footbaths should be placed at the main entrance of the facility and at all entry points between each production zone. Each footbath should be positioned in a way that ensures that workers cannot access the next section without stepping through a footbath. Footbaths need to be regularly cleaned and refilled with appropriate disinfectant daily or whenever heavily contaminated with organic matter (Minimal requirements for outdoor production systems: In outdoor locations such as pond areas, footbaths may not be practical due to frequent soiling by high amounts of organic matter. In this case, preparation of a separate set of boots and clothing for changing when moving between outdoor to indoor zones and vice versa may suffice. Farms may also limit the number of visitors entering from outdoor production zones and only allow an authorized number of workers in sensitive indoor production facilities).
- A wheel dip containing disinfectant should be in place for incoming vehicles. Alternatively, a tyre bath station may be set up to disinfect the wheels of vehicles. The wheel dip should be regularly cleaned and refilled with freshly prepared disinfectant solution (Minimal requirements for outdoor production systems: If the setup and maintenance of wheel dips and tyre bath stations prove too costly, an alternate measure would be to prevent outside vehicles from entering pond areas and allocate a designated parking zone for vehicles brought by visitors and service providers, whicb is located far away from ponds)..
- Personal protective equipment, such as gloves, overalls, boot, rain gear and hats should be provided for farm workers. PPEs should be removed after use, cleaned and sanitized regularly, and when moving between production zones.
- Provision should be made for separate equipment and storage for every production unit to prevent sharing of equipment across zones.
- Clear signage should indicate the entry/exit points and the direction in which workers and visitors should move throughout the facility. Movement signage should begin from the most sensitive zone (e.g. hatchery) and end at the least sensitive zone (e.g. ponds)
- Clear signage should indicate the entry of authorized staff at sensitive production areas such as the hatchery and quarantine zones.
- Provision should be made for racks and hooks for storage of small farm equipment (nets, shovel, etc) to prevent contact with the floor. Labelling of equipment according to zone is recommended to prevent cross-contamination.
- Boots, boot racks and shoe storage cabinets should be provided at farm entry points to ensure they are worn by all workers and visitors to the production site.
- A quarantine zone should be provided for isolation, observation and treatment of newly arrived fish.

FARM PRODUCTION

POND PREPARATION & FERTILIZATION

Image 10: Pond preparation in Ika South, Delta State

Image 11: Showcase of ponds in Apata, Oyo State

For earthen pond systems, every production cycle should be preceded by a period of fallowing where ponds are dried out to break the life cycle of harmful microorganisms. During fallowing, pond production is paused to reduce the impact of production on the benthic environment in the pond. Where it is impossible for total dry-out due to rainy weather, seepage or proximity to the water table, treatments such as lime should be applied to kill harmful microorganisms and larger wild organisms surviving in the wet pond bottom or puddles that remain after draining. Pond bottoms are also treated to neutralize the soil acidity (to lower hydrogen sulphide), optimize algal growth, release nutrients from the pond bottom, and to remove phosphate and carbon dioxide from the water.

Disinfectants used for treatment of pond bottoms may include sodium chloride (NaCl), burnt lime (calcium oxide), hydrated lime (calcium hydroxide) or calcium hypochlorite, also known as high-test hypochlorite (HTH). When handling chemicals for pond treatment, farm workers should wear appropriate PPE including eye protection, mask and gloves, especially for caustic chemicals such as lime and chlorine compounds. Generally, the pond bottom pH is raised to 11 or 12 to kill off harmful microorganisms. However, a pH of 8.0-9.5 is optimal for algae growth and release of nutrients from the pond bottom.

Once ponds have been disinfected and left to equilibrate for several weeks, the pond bottom or water should be fertilized to promote the growth of phytoplankton before restocking. The use of inorganic fertilizers is recommended over the use of organic fertilizers, which may spark concerns of disseminating antimicrobial resistance in the farming environment.

RECOMMENDATIONS:

- Fallowing should be carried out in between production cycles, where possible (Minimal requirements for outdoor production systems: Drying of ponds and treatment of wet areas using lime).
- Ponds should be emptied of the previous production water and allowed to dry for 1-2 weeks until the pond bottoms are completely dry or as empty of water as possible.
- After draining and drying the pond, treatment (with lime, NaCl or calcium hypochlorite) should be applied to the pond bottom to raise the pH.
- After the pond has equilibrated after several weeks following treatment, fertilization should be carried out on the pond bottom or pond water before restocking the fish.
- Fish should not be stocked in the pond until primary production of natural food organisms has been reestablished through pond fertilization.

WATER MANAGEMENT

Image 12: Water storage tank in Abeokuta, Ogun State

Image 13: Water storage tank in Abeokuta, Ogun State

Image 14: Water purification units at Uvwie in Delta State

Prior to the selection of any farm site, an assessment of the water resource and intake location should be carried out to determine its suitability for aquaculture production. When considering the best practices for water management, all users of the water resource for various activities should be taken into consideration. Farms should have proper water storage and filtration facilities to remove particulate matter and ensure adequate volume of good quality reserve water supply to accommodate the entire farm. The total farm usage of water should also be within the supply capacity of the water resource, and have minimal impact once released back into the environment.

In the recent survey on aquaculture systems in Delta and Ogun states, it was observed that most farms do not carry out water treatment before discharge (85.71%) and do not shut down the water flow connected to infected production units (94.99%). In the interest of controlling any outbreak, there should be mechanisms available to shut down the movement of water in and out of each production unit so that infected stock and water can be clearly identified and separated to prevent further spread of disease.

Measures to ensure farm effluents do not deteriorate the quality of the water resource should include the maintenance of high water quality standards within the farm, treatment of effluents or wastewater sedimentation before discharge, and selection of proper disposal locations for effluents. It is advisable to ensure that any sourcing and discharge of water is legally compliant before proceeding to build the infrastructure for water supply and release.

RECOMMENDATIONS:

- Ground water should be sourced for farming where possible. However, if the supply capacity of the aquifer is not adequate to support further extraction (as indicated by boreholes that need to be drilled deeper around the same site), the farm should look for an alternative uncontaminated water supply source.
- An hatchery should have access to the cleanest available water resource.
- If the water source is from a river or canal, the water inflow should be taken from a point upstream, distanced away from outflow points from other sites with farming, industrial or agricultural activity.
- All intake water should undergo filtration to remove debris before being directed to production units. Recirculated water in particular, should pass through both mechanical and biological filtration.
- Backwash of water filtration systems should be done periodically to ensure proper function of the filter system.
- Each production unit should be supplied with clean intake water that has not flowed through previous production units.
- Each production unit should have a valve installed at the inlet and outlet points to allow control of water in and out of the unit.
- There should be controlled feeding rates and regular removal of uneaten feed to avoid water quality deterioration.
- Water quality readings for each production area (e.g., dissolved oxygen, temperature, pH, ammonia, nitrite, turbidity) should be regularly taken and recorded to detect any abnormal variations from the optimal range.
- Emergency aeration should be turned on if dissolved oxygen fall below optimal levels, especially during the night in ponds with high phytoplankton load.
- All effluent water, where necessary,should first be treated with suitable and approved chemicals (chlorine, sodium bicarbonate, lime, etc) and be allowed to settle in a sedimentation pond before being released into the environment (Minimal requirements for extensive production systems: In the event that treatment of large volumes of water is not possible, extensive farms may instead use a settlement pond or sediment basin to detain runoff debris and allow suspended solids from wastewater to settle prior to water discharge. This process serves to control the turbidity of runoff water and prevent high amounts of organic matter from the pond bottom (fertilizer, faeces and uneaten feed), potential disease vectors or harmful microorganisms from polluting the surrounding water body. The settlement pond may be disinfected at regular intervals after several cycles of sedimention).

BROODSTOCK AND HATCHERY MANAGEMENT

Image 15: Catfish broodstock held in outdoor concrete tanks in Abeokuta, Ogun State

Image 16: Catfish broodstock concrete tanks in Abeokuta Ogun State in Ilase, Ogun State

Image 17: Indoor concrete tanks to keep catfish fryin Ilase, Ogun State

When planning the construction of a breeding facility, factors such as climate, water quality, suitable feeds, and availability of broodstock, access to technology, skilled workforce and identified markets for fry/juvenile should be considered. For a sustainable industry, there should be a reserve of good parent stock from various locations with a well-planned breeding programme to prevent inbreeding and to continue producing good quality offspring that are able to perform adequately in the aquaculture environment. Only suitable species with value to the industry and high demand should be considered for breeding, with considerations to the environment and biodiversity. In the case of Delta and Ogun states, it was observed that most farms were focused on the culture of catfish due to its hardy nature, with the major species in Delta being the North African catfish (94.56% of farms) and the main species in Ogun being the hybrid catfish (78.17%) followed by the North African catfish (40.08%).

It is important to ensure that the breeding of the species in demand is legally compliant and that the breeding programme does not pose any threat to the surrounding environment in terms of genetic contamination, predation, displacement, competition or physical environmental damage. The target species selected for breeding should also be able to meet the demands of the industry in terms of production capacity, as well as affordability for local consumers in the event that the export market is not an available option.

RECOMMENDATIONS

- Broodstock facilities should have a genetics improvement programme in place to ensure continuous production of good quality fry.
- Farm owners should gather essential information about the target species being cultured in terms of susceptibility to disease and their optimal culture conditions in order to produce stocks that are of good health.
- Only broodstock from trusted and certified sources should be used.
- In-breeding should be prevented through systematic and specific selection of family lines, or establishment of separately sourced parent stock banks for male and female broodstock.
- There should be proper selection practices in place for determining healthy and mature broodstock (active, strong, good length, size 1.5-2kg, gravid females).
- All brood stock brought to the hatchery facility should be quarantined in a separate holding area and screened for pathogens of concern (e.g. *Aeromonas hydrophila, Edwardesiella ictaluri*) before mixing it with existing stocks.
- During quarantine, the broodstock should be closely observed for abnormal behaviors or clinical signs of a disease process. If there is an indication of disease, the appropriate treatment should be administered by a Veterinarian.
- Periodic health checks on broodstock should be carried out to ensure that they are free from notifiable disease.

EGG & FRY PRODUCTION

Image18: Newly hatched catfish frys in Ilase, Ogun State

Image 19: Catfish fry in a nursing tank in Ilase, Ogun State

Image 20: Catfish fingerlings in Ilase Ogun State

Biosecurity practices should be at the highest level within the hatchery, with regular disinfection of equipment and boots of workers entering the facility and allowing entry only to authorized personnel. If any worker is required to work in multiple production zones, their movement should begin in the hatchery to ensure no cross contamination is brought in from other areas.

The hatchery should be provided with the cleanest and best quality water, while proper handling & hygiene should be practiced throughout the facility. After spawning, cleaning and disinfection of eggs should be carried out to reduce the number of eggs dying. At the larval and fry stage, regular monitoring should be carried out to identify any signs of disease or early mortality.

RECOMMENDATIONS

- Worker and visitor disinfection facilities such as footbaths and handwashing stations should be prepared at the entrance of the hatchery (Minimal requirements: Provision of a separate set of boots and clothing at the entrance, limiting the number of visitors and only allowing an authorized number of workers in the egg and fry production facility).
- If egg and fry are purchased from outside suppliers, there should be a specific parking zone allocated for the transport vehicle.
- Signage should be installed to indicate the entry and exit points of the hatchery

- Water supply to the hatchery should be filtered through mechanical and biological filters and treated (using UV and ozone), where possible.
- The hatchery should have its own set of equipment kept in a separate storage, and should never be shared with other production areas.
- Equipment should be disinfected at allocated stations in between every usage.
- Once healthy eggs have been identified, dead eggs should be separated and discarded to avoid contaminating healthy eggs with mold.
- To improve the hatching rate, eggs may be treated using permitted disinfectants such as sodium chloride (1000ppm for 30 minutes), potassium permanganate (2ppm for 15 minutes) (Rasowo et al., 2007), or acriflavin which has no particular suggested dosage as an egg disinfectant but has been recommended at different doses (5ppm for 1 minute, or from 750ppm for 15 minutes) for treatment of eggs of other fish (Subasinghe and Sommerville, 1985; Tattanon and Tiensongrusmee, 1984).
- Eggs should be cleaned of debris and milt kept in physiological saline (6g/L) to improve fertilization (Amachree et al., 2018), prior to placement in incubation jars or containers.
- The water flow in incubation jars or containers should be adjusted to a suitable rate to maintain the movement of eggs and larvae.
- The weight of eggs should be recorded for easier estimation of numbers.
- Monitoring records should be kept to observe the health status of eggs and fry.

STOCKING

Image 17: Catfish hatchery in Delta State

All stocks of fry and juveniles should have a trusted source, either from the farm's own hatchery or from a reputable supplier. When sourcing fish from external suppliers, good biosecurity practices including disinfection and quarantine of new stock should be applied during arrival to prevent the transfer of disease into the farming system. All newly

arrived fry or fingerlings should be quarantined first before they are placed into the common production area with existing farm stocks. They should be treated if any are suspected of carrying disease. New stocks of fish should be handled with care and not be stressed to avoid inducing diseas outbreaks and/or facilitating spread of disease.

Stocking densities should be appropriate to the species and size of fish being farmed. For example, bottom dwelling fish may require more space per square meter versus free swimming fish in the water column that may be stocked according to the volume of water per cubic meter. Before stocking to maximum density, farmers should also consider the affordability and availability of the total amount of good quality feed that will be required to sustain the stock throughout the entire production cycle. Among farms that were surveyed in Delta and Ogun states, those that did not report unusual mortality had an average stocking density of approximately 2997 fish/m^3 and did not exceed stocking density of 4502 fish /m^3.

Surveyed farms that mixed existing and new stocks of fish reported higher unusual mortality (25%) compared to farms that did not mix stocks (only 9.86% unusual mortality). Meanwhile, farms that continued to stock additional batches of fish after the main stocking event also observed higher unusual mortality (38.89%) than farms that did not (only 8.4% unusual mortality). From those observations, all-in all-out farming systems are recommended to prevent mixing of previous and new stocks of fish. Simultaneous stocking for each production cycle should be practiced where possible so that each stock of fish is clearly separated from the next to help curtail the spread of pathogens from one production batch to another. Only batches of fish with equal health status should be considered for combination in a single production unit.

RECOMMENDATIONS:

- Fry and fingerlings should be sourced from a reputable facility that provides healthy stock with health documentation, where possible.
- Biosecurity infrastructure should be set up at various farm entry points for proper disinfection of transport vehicles, suppliers, workers, equipment and incoming fish to limit cross-contamination from other sites.
- Fish should be stocked at the recommended stocking density for that species. Overstocking should be avoided to manage feed costs and to prevent stress leading to faster spread of disease.
- If new fish must be added into the main stock, the additional stocks of fish should be quarantined and observed until determined as healthy for introduction into the existing stock.
- If mixing of different stocks becomes necessary, only batches with equal health status should be combined after close observation. Fish with different health status should be kept in separate holding facilities.
- All newly arrived fish should be observed in a separate quarantine zone for several days and determined as healthy before placing them into common production units. The fish should be carefully observed for any signs of disease or abnormal behaviour throughout the quarantine period.
- Treatment should be applied to infected fish according to treatment guidelines and prescription byveterinarians where necessary to prevent transfer of pathogens to healthy stock.
- All transport water should be properly treated and disposed of once the new fish have been transferred from their transport packaging to the quarantine area.
- To avoid temperature stress, new stocks should be allowed to acclimatize to the ambient farm water temperature before release.
- Good fry management including adequate feeding and checking of water quality, which should be carried out daily to minimize stress on fry.

FEED MANAGEMENT

Image 18: Catfish feeding using commercial feed in Delta State

Image 19: A commercial feed used in catfish farming in Ogun State, Nigeria

Feed makes up a significant amount of the production cost in most aquaculture farms. The quality of feed is an important factor in determining fish growth and feed conversion ratio (weight of fish produced for each kilogram of feed used). However, it is also important to ensure good source, storage and handling of feed throughout production. A number of factors should be considered when selecting the type of feed, including the nutritional requirement of the target farmed species at different life stage; the quantities required for achieving the desired production output; sustainability, affordability and availability of feed; and further processing and storage requirements.

Feed types may range from pelleted or extruded commercial feeds to live and wet feeds made at the farm. The use of extruded feeds with stable and clearly identified ingredients are encouraged over the use of wet feeds that may contain uncertain amounts of uncooked animal products. The use of offals or uncooked animal products in feed should be avoided as it may become a risk factor by carrying unknown pathogens into the production system. Meanwhile, processed feeds have lesser risk of leaching, provide better Feed Conversion Ratio (FCR), can easily be collected if left uneaten in tanks and have lower risk of disease transmission. The purchase of small amounts of commercial feeds may be economically unfeasible for individual farms; hence, clusters or cooperations representing an adequate number of farms with the same feed requirement may apply for access to credit for purchase of larger quantities of the same feeds from commercial suppliers in order to overcome the issue of high cost of commercial feeds.

All feeds should be stored in hygienic conditions and kept secure from pests to reduce contamination, which could compromise feed quality. Wet feeds should be kept at the appropriate storage temperatures to reduce spoilage and to prevent the growth of mold. Storage conditions and the use of fresh feeds are an important factor in the health of farmed stock, based on observations in Delta and Ogun states where farms that stored feed for 2 weeks or less reported lower unusual mortality (9.09%) compared to farms that stored feed for longer periods (11.90% and 15.38% unusual mortalities for storage of 2-4 weeks and 1-3 months respectively). A first-in-first-out system should be applied in the feed store, whereby every feed batch is labelled with the arrival dates and older feed stock is used first. All commercial feeds in the store should be inventorized with details of each type and size of feed, their remaining quantity, arrival and expiry dates to keep track of feed usage and new orders. The quantity of feed purchased at a time should be based on the total farm usage and the manufacturer's recommended shelf life.

A feeding schedule should be in place to determine the feeding rate and times. Generally, younger fish feed on a higher percentage of their body weight compared to older fish. The industry standard feeding rates according to the fish life stage can be referenced from manufacturer information or on the feed packaging. The amount of feeding should always be subject to fish behaviour, response to feed, water quality, and future plans for fish handling and movement. All feeding activities should be recorded daily with details of the type of feed and amount used for each production unit. This information can later be accessed and used with production weight information to determine the performance of the feed through calculation of the FCR.

RECOMMENDATIONS:

- Feeds and feed ingredients should be sourced from trusted suppliers.
- The use of processed feeds is recommended as these present lower biosecurity concerns and fish perform better in terms of FCR and water quality.
- Dead fish from disease outbreaks should never be used as feed.
- If freshly made feeds are necessary, the finished feeds or its ingredients should be kept in sanitary conditions at proper storage temperatures.
- Baited rodent traps should be set up at feed storage areas as a pest control measure.
- Any gaps/openings on the feed store that could allow pests to gain access should be covered.
- To minimize contamination, feed bags should be kept off the floor surface using pallets and away from walls to prevent condensation leading to growth of molds.
- Expired, spilled or contaminated feed should never be used for feeding and should be promptly discarded.
- If wet feeds are used, it should be utilized immediately or stored in chillers at $4^{o}C$ until the time of use.
- All feeds should be kept in inventory and utilized on a first-in first-out basis.
- Only the required amount of feed should be purchased to avoid expiration and long storage.
- Feeding should be done according to the appropriate feeding rate for each life stage of fish.
- Daily feeding should be distributed in two or more feeding sessions, instead of a single session.

- Fish should be frequently sampled and weighed to make any required adjustments on the feeding rate and feed size.
- Fish should never be overfed as uneaten feed can cause deterioration in water quality, stress the fish and raise production costs in feed wastage.
- Feeding should be suspended for a particular production unit if the water quality is poor or if the fish will be handled or transported in 2 days' time.
- All uneaten feed should be removed regularly to prevent deterioration of water quality,
- Observations of fish behaviour should be carried out during feeding to observe palatability of the feed, and to identify abnormal or potentially unhealthy individuals.
- The feed type and amount should be documented for every production unit.

TRANSPORTATION OF FISH BETWEEN PRODUCTION UNITS

Preparations should begin 2 days before the transfer of any batch of fish, by withholding feeding activities. This will be important to allow all feed to be purged and to limit the amount of excretions (undigested feed, ammonia) in the transport water that may cause subsequent mortality in the transported fish. The appropriate transfer tank, poly-bag, suitable water quality, oxygenand stocking densities should be taken into account to reduce the level of stress on fish transported over long distances. Factors that should be considered when determining transport stocking densities are the tank size, type of species being transported, life stage, quality of the transport water and environmental stressors such as temperature, ammonia or oxygen.

During the transfer process, fish handling should be minimized and done gently using disinfected equipment. Keeping the water temperature cool will help to reduce the metabolism of the transported fish, lower the intake of dissolved oxygen and decrease the production of ammonia and carbon dioxide in the water. To reduce stress on the transferred fish, adequate oxygenation should be provided and acclimatization to the temperature of the new production unit should be carried out.

RECOMMENDATIONS

- Feeding should be stopped for 1-2 days before fish handling, grading, movement within the facility and shipping to other sites.
- The duration and number of times fish is taken out of water should be reduced as much as possible to reduce stress on the transported fish.
- All transportation equipment (nets, buckets, hauling tanks) should be adequately cleaned, rinsed, and disinfected before use.
- Hauling tanks of appropriate size with good quality transport water should be used for transportation of fish.
- Aeration should be provided for transport tanks or pure oxygen injected into sealed poly-bag.
- Transport water should be kept cool by covering the transport tanks or using ice packs for long-distance travel.
- A backup aeration system for transportation should be prepared in case of malfunction of the existing system or delay in the transport.
- Temperature of transport water should be adjusted or brought to the ambient temperature before fish are released into a new production unit.

DISPOSAL OF DEAD FISH

Image 20: Dead catfish in Ijebu, Ogun State

Fish mortality may be a common occurrence at the farm due to a number of factors, including the presence of pathogens, predation, cannibalism, poor water/feed/fry/juvenilesquality, old age, and pollution. Therefore, checking, removal and recording of dead fish should be done daily for every production unit to estimate true losses. Fish that are left in the water too long may become unaccounted for due to decay or being eaten by other fish, hence presenting inaccurate mortality numbers.

After recording mortalities, dead fish should be properly collected and disposed of using biosecure methods, such as burning off-site or burying with lime, in order to avoid disease transmission to other ponds or farms. In this regard, a concerning observation among farming systems in Delta and Ogun states was that 19.30% of farms discarded dead fish into the nearest water body while 10.28% did not remove dead fish, which raises concerns of spreading possible pathogens to other farms sharing the same water source. Another 2.51% and 1.25% of farms used dead fish to feed other animals and to be sold as feed, while only 6.52% of those farms burnt their dead fish off the farm site and another 0.5% burnt fish on the farm for disposal.

In the event of high mortalities, veterinarians should be informed so that they can advise the farm on the appropriate steps to mitigate losses and to carry out investigations on the cause of mortalities. Although some farmers may opt to keep dead fish samples for examination by veterinarians, those samples should be kept live or harvested as freshly as possible to ensure that the quality of the fish tissues do not deteriorate and can still be used for accurate diagnosis.

RECOMMENDATIONS:

- Mortalities should be monitored daily and documented with identification details of the production unit, fish batch, number of mortalities and date of occurrence.
- Dead fish should be collected daily in proper bins allocated for fish disposal. These bins should be labelled and regularly disinfected after disposal of dead fish.
- Dead fish should never be disposed of into water bodies or used as feed.
- Dead fish from outbreaks should never be used as feed for other animals.
- All disposals should be kept on record indicating the method of disposal, amount of disposed fish and date of disposal.
- Veterinarians will notify the local competent authorities as soon as possible of high mortality events, especially when notifiable pathogens are involved.
- Freshly dead fish may be kept aside, while moribund fish may be separated for observation and sampling for disease diagnostics by veterinarians.
- All materials and equipment used for collection and disposal of fish should be disinfected and sun dried after usage.

DISEASE MANAGEMENT

Disease control should begin with stress management in fish, as high stress levels can cause susceptibility to disease and impact growth. Stress factors include poor water quality, poor feeding, high stocking densities, improper handling and encounters with predators. When stressed, energy that would normally be used for growth, reproduction or immune reactions would be instead used to survive the stressful environment, such as swimming (escaping from predators) and respiration. Where possible, good farm management practices should be applied to reduce stress on fish and non-antibiotic approaches such as probiotics, plant-based treatments, and vaccinations should be considered for prevention and control of disease.

Fish should be inspected regularly to detect diseases at an early stage. Indications of disease may include physical clinical signs (such as scale loss, fin rot, lesions and ulcers), abnormal swimming behaviour (such as loss of balance, isolation and increased respiration), and low appetite. Upon suspicion of a disease, farmers should contact fish health experts as soon as possible to carry out further investigation, sampling and diagnostics. However, it was found that 96.24% of farms in Delta and Ogun states did not engage any veterinarians as service providers. In order to connect farmers with skilled professionals who have the mandate to handle animals disease and can help to investigate, collect samples, provide diagnosis and recommend treatments, farmers should have a pre-established method to contact veterinarians, such as via a local extension network of resident veterinarians for aquatic animal health.

Only approved chemicals should be applied in the treatment of fish or disinfection of farm site, using the amounts and methods recommended by the manufacturer's guidelines and label. Usage of antibiotics should only be done on the advice of a veterinarian and after receiving results of diagnostic tests to ensure that the targeted disease is treatable by antibiotic medication. Through awareness campaigns and direct advice from the competent authorities, farmers should be made to understand that antibiotics are ineffective against viral disease as a treatment and that not all antibiotics may be effective against a specific bacterial disease.

In order to mitigate the spread of disease within a farm, disinfection of equipment should always be carried out in between separate production units where possible. Any stock that are unhealthy or suspected of infection should be quarantined and documented, while mortalities from infections should be recorded and disposed of following biosecurity protocols. Another major biosecurity concern is the uncontrolled movement of workers and equipment throughout the farm after an outbreak, as was reported in majority (97.99%) of farms in Delta and Ogun states. Workers should be generally restricted from entering production areas affected by any outbreak, unless they have special authorization. The movement of staff should always begin from the cleanest zone and end at the most contaminated zone (e.g., from hatchery to ponds). Authorized workers entering and exiting areas of infection should strictly follow biosecurity protocols including handwashing and disinfection of protective gear by footbath.

RECOMMENDATIONS:

- Stress on farmed fish should be reduced where possible.
- All daily observations of unusual fish behaviour and clinical signs of disease should be recorded for every production unit.
- The contact details of a l veterinarian should be available in the event of a disease outbreak.
- All major disease outbreak events (especially those of notifiable diseases) should be reported by the veterinarians to competent authorities.
- Samples should be collected from sick fish by a skilled person to determine the presence of pathogens through diagnostic tests.
- Usage of any medications for treatment of fish should be done with the consultation of veterinarians.
- The use of any chemical for treatment or disinfection should be done according to the label guidelines and intended purpose of the chemical.
- Where possible, non-antibiotic alternatives (probiotics, plant-based substances, vaccines etc) of improving fish health should be applied.
- All infected fish should be isolated and treated in a quarantine unit that is separate from the common production area, until the fish have adequately recovered from the infection.
- Records of disease outbreaks indicating the infected units, batch of fish, time and duration of the event should be kept for every outbreak event.
- Dead fish from disease outbreaks should be documented and collected daily from each production unit. Proper disposal procedures should be followed either by burying with lime or burning off-site.
- In the event of severe untreatable disease, culling of fish stocks should be considered to curb further spread of disease to other production units or neighbouring farms.
- Separate equipment storage racks should be set up for every production zone and each equipment should be labelled to prevent sharing with other production areas.
- All equipment and production units (tanks and ponds) exposed to infected fish should be properly disinfected using appropriate dosage and duration of disinfection.
- Only authorized personnel should be allowed to access sensitive production sites.
- If movement between zones cannot be restricted, workers should move from the cleanest zones toward more contaminated areas.
- Disinfection stations should be set up for personnel and equipment between zones and between holding units of different health status (separate container, disinfectant, water supply).

MANAGEMENT OF AQUACULTURE CHEMICALS

Image 21: A chemical used in Aquaculture in Delta State, Nigeria

Image 22: Antibiotics used in aquaculture in Delta State, Nigeria

A health management programme should be aimed at maintaining the health of farmed fish through good husbandry practices that requires minimal use of therapeutic drugs or chemicals. However, the use of aquaculture chemicals has often become necessary for prevention and treatment of disease in fish and water. The maintenance of farm hygiene and biosecurity of equipment and premises also require the regular use of chemical disinfectants which should be applied safely following the manufacturer guidelines.

It is the farmer's responsibility to apply only approved products for its intended use in aquaculture, according to the guidelines on the label or from the manufacturer. However, the usage of any regulated therapeutic drugs on farmed fish should follow a prescription from a veterinarian , which should include the type of drug, dosage, correct method of administration, duration and withdrawal period. Meanwhile, all treatments with chemicals should be carried out according to the guidelines provided on the label to avoid negative impacts on fish and water quality.

Treatment products should only be accessed and administered to fish by authorized workers who have been trained to handle treatment products safely and according to guidelines. Before application of any treatment on the entire batch of fish, it should be first applied on a small sample of fish to ensure the efficacy and safety of the dosage. Production units containing treated fish should be clearly labelled for easy identification, and all details of fish treatments should be recorded detailing the purpose of use, dosage, duration, recommended withdrawal period, the batch of fish and production unit where it was applied.

RECOMMENDATIONS:

- Antibiotic drugs should not be applied unless they are approved for that specific use by a veterinarian and should be administered only for control of bacterial infections.
- The use of non-prescriptive chemicals should follow the guidelines provided on the label or by the manufacturerand be used for its intended purpose.
- Fish that are undergoing treatment should be clearly identified by labelling or treatment records.
- Treated fish should not be harvested until after the withdrawal period has passed.
- Details on the application of any therapeutic drug should be documented, including the type, amount used, date of usage, and withdrawal period.
- All treatment products and chemicals should be properly labelled and stored in a locked room or cabinet to which only authorized staff may have access.
- Any medicated feed should be stored separately from non-medicated feed, and clearly labelled for easy identification.

- Proper handling procedures for each type of chemical should be clearly indicated through each product's warning labels and in the Material Safety Data Sheet (MSDS) which should be kept in an accessible area.
- Workers handling chemicals should apply personal safety measures and wear appropriate personal protective equipment (PPE) such as gloves, goggles or face masks where necessary.
- An inventory of all treatment products and chemicals should be updated monthly to keep track of the remaining stock and new orders that need to be made.

POST-PRODUCTION ACTIVITIES

As explained in the earlier section of this guideline (see 'Pond preparation and fertilization'), fallowing is an important practice that should be carried out at the end of each production to break the life cycle of existing pathogens in the farming system, . It is a recommended biosecurity procedure in fish health management that provides a temporary pause in farm production in order to mitigate the environmental effects of organic pollution (food and faeces) accumulated from previous fish farming activities and allows the pond bottom to naturally recover until the start of the next production cycle. However, this measure may only be feasible for large-scale commercial farms with many ponds or indoor production systems. For small-scale farms with single or few earthen ponds, long-term fallowing may not be possible as the practice is costly in terms of loss of production; however, drying the pond at the end of each cycle and treating the remaining wet areas of the pond using lime can be an effective alternative. Where possible, a minimum of 4 weeks is recommended for fallowing a production site, and involves the removal of all fish stocks and water so that no remaining infectious pathogens will be harboured in the pond. If fallowing is carried out, it should happen after pond treatment and disinfection to prevent any remaining risk of infection from being carried forward to the next production cycle.

Although not all fish farmers may be directly involved with post-harvest processing activities, it is crucial to note that the quality of fish produced is assessed not just by in-farm practices but also by the fish processing techniques carried out after the harvest stage. In a workshop consultation with aquaculture stakeholders from Delta and Ogun states, it was reported that the demand for catfish had dropped drastically due to a number of reasons, including the affordability of catfish for local consumers, and the loss of the export market into the U.S. The preset market price of catfish at 1400-1500 naira/kg had been agreed upon by the Congress of the Southwest Fish Farmers Association on 3 August 2022 due to the rising cost of farm inputs, however the price is considered expensive for local consumers who may opt to purchase more affordable species in the market.

The export market for the catfish industry had also been affected since the continuing ban by the USFDA from March 2018 due to the lack of traceability documentation and the smoking technique used to process fish, which resulted in concerning levels of benzo-a-pyrene, a carcinogenic polycyclic aromatic hydrocarbon (PAH) being accumulated in the final product. However, through the Commercial Agriculture Development Project under the World Bank, fish processors have been trained on the use of new smoking kilns which have significantly reduced smoke levels, as well as the use of barcodes on packaging of processed fish to address traceability concerns. Consistency in implementation of these newly acquired skills and practices is pivotal in changing consumer perception toward catfish produce, and subsequently reacceptance of the commodity back into the export market.

RECOMMENDATIONS:

- At the end of every production cycle, ponds should be emptied of water and all fish stocks.
- Pond bottoms should be treated with appropriate chemicals that help with benthic recovery prior to the fallow period.
- A minimum of 4 weeks is recommended for fallowing before the start of the next production cycle (Minimal requirements for outdoor production systems: Drying of ponds and treatment of wet areas using lime prior to the next production cycle).
- After each production cycle, all production records relevant to that cycle should be compiled and clearly organized for traceability purposes.
- If the farm is involved in fish processing activities, fish should be processed according to practices that meet local and international food safety requirements and certification standards required by the buyer.

PRODUCTION RECORDS

Traceability is an important element when tracking the spread of an infection in a farm across production units and fish batches. The movement of a specific batch of fish throughout a production cycle can be captured in production records, which documents important observations for visiting aquatic veterinarians during outbreak investigations. Production records may also be used to evaluate farm performance, detect changes in fish behaviour and to spot early indicators of stress and disease, so that mitigation measures can be applied.

All farm documentation should be kept in an organized filing system for easy reference during future farm inspections and to inform decision-making at the farm level. Organized compilation of information from farm documentation may not only be used to impart traceability information to buyers, but can also be utilized by producers to compare the effects of previous and improved farm practices (feeding, stocking density, handling of disease) on farm production in a cost-benefit analysis.

RECOMMENDATIONS:

All workers should be trained to keep regular updates on the following records throughout the production cycle:

- Quarantine records of incoming fish.
- Fish stock inventory containing details on the source of the stock, number of fish in a batch and location in the farm (pond or tank number).
- Fish movement records to track the various locations of a fish batch throughout the facility from the time of stocking until the latest production stage.
- Feeding records
- Records of clinical signs observed on fish.
- Daily fish mortality and disposal records (number of mortalities) for every production unit (tank or pond)
- Disposal records (effluents, organic waste).
- Diagnostic lab tests that were carried out with details on the date, location and batch of fish that was sampled, the type of test carried out, and the findings from that test.
- Water quality records on basic parameters such as dissolved oxygen, temperature and pH, as well as other indicative parameters such as ammonia levels
- Fish treatment records with details on the type, dosage, amount used, location and batch that was treated, method of treatment (bath, dip or feed), date of treatment and withdrawal period where applicable.
- Records of all farm inputs including inventories and usage of consumables such as feeds, fertilizers, supplements, and chemicals.
- Records of other non-treatment activities carried out to mitigate disease or mortalities (e.g., disinfection, cleaning, maintenance of farm equipment

GENERAL FARM PRACTICES

DISINFECTION OF TOOLS AND EQUIPMENT

Regular disinfection of equipment and tools used in daily farm operations is a critical biosecurity measure as these may easily carry over risk factors from one production unit to another and can cause rapid spread of disease. This was evident in Delta and Ogun states where farms that shared equipment and staff with other farms reported higher unusual mortality (14.41%) compared to farms that did not (7.99% unusual mortality). Where possible, equipment from different production zones should be clearly identified and have separate storage units to prevent mix up and sharing across production areas. In the event that the same equipment has to be used in multiple production zones, proper disinfection procedures should be carried out before moving to the next facility. After proper washing and drying, all tools should be kept organized in hygienic storage conditions for easy access and to prevent rodent infestations.

Each farm should display a visible maintenance schedule for regular upkeep of equipment and replacement of parts that are worn out. Checking and maintenance of equipment should be carried out on time to prevent breakdowns and ensure farm operations are not disrupted by mechanical failure. In the event of equipment breakdown or maintenance, a contingency plan should be in place to guide workers on how to continue farm production and safeguard stock survival. For this purpose, equipment operation manuals, spare parts and temporary replacement equipment should be stored in an easily accessible area for convenient reach by workers.

RECOMMENDATIONS:

- Commonly used farm equipment such as nets and buckets should undergo disinfection after each use in between production units.
- After disinfection and drying, equipment should be stored off the surface of the floor either by hanging or storage in bins and racks for sanitary purposes.
- The quarantine zone and each common production area should have its own set of equipment that is stored in its own separate rack and should never be shared with other production areas.
- To avoid mixing and sharing of equipment and tools across production areas, each set of equipment should be labelled according to the sections where they should be used.
- There should be storage racks and disinfection stations for common equipment (nets, buckets) and protective wear (boots) in every production area and entry point.
- The use of offsite equipment at the farm should be avoided where possible. If equipment from outside the farm must be used (such as equipment brought in by harvesters), ensure that they are properly sanitized at disinfection stations located away from the farm production units, while ensuring the wash water does not flow into the production areas.
- A maintenance schedule for all equipment should be followed to ensure that all equipment is maintained or repaired on time.
- The maintenance log should be updated with details of equipment and spare parts purchases, maintenance checks and repair services when malfunction occurs or worn components are discovered.
- Workers should be properly trained on the correct way to use equipment and how to handle equipment malfunction to prevent prolonged equipment breakdowns that lead to fish stress or mortality.
- Workers should be aware of the location of equipment manuals and spare parts which should be stored in an accessible area.
- A list of the contact details of equipment service provider should be prepared and placed in an accessible area.
- There should be backup stock of equipment essential to farming operations (such as generators, pumps and aerators) available for use during the time that the primary equipment are sent for maintenance or repairs.

STAFF AWARENESS & CAPACITY BUILDING

Farm workers are an integral resource in aquaculture farms that provide manpower for handling farmed fish and equipment. Workers require aquaculture skills and experience to ensure that farm operations are carried out efficiently and sustainably. Hence, capacity building is a necessary part of farm biosecurity to equip both new and existing workers with the knowledge, skills and practices required to maintain optimal farm production and biosecurity. For this purpose, a regular training programme should be developed to train all farm workers on topics relevant to farm operations and fish culture. These trainings may be carried out by internal or external instructors, and should be structured in a way that benefits both general workers as well as technical staff.

RECOMMENDATIONS

- A worker training programme consisting of several sessions each year should be devised to provide workers with the skills and knowledge of proper farm management practices.
- Training programmes should include new topics and refresher courses that will help to ensure that high standards of farm biosecurity are maintained.
- Training sessions may cover a variety of topics, including the importance of biosecurity, conditions for culturing the target fish species, water quality, basic hygiene, farm movement, proper handling of fish, clinical signs of disease and other relevant issues related to best farm practices.
- Worker attendance for each training should be made compulsory and documented on an attendance sheet.

MANAGEMENT OF MOVEMENT WITHIN THE FARM

The continuous movement of people and vehicles into and within the farm premises is a risk factor that should be managed to ensure that no infectious pathogens are carried into and between the farm production zones. This should be done by providing entry only to authorized visitors and workers, while ensuring that all vehicles and persons strictly follow biosecurity procedures from before the point of entry until they exit the farm premises. Protective gear such as boots should be worn by workers and visitors throughout the farm premises and sanitized regularly by stepping through disinfection stations at the entry point of each production zone.

Care should be taken to ensure that all farm visitors are escorted and that all workers follow the correct workflow movement throughout the farm to minimize any possible spread of disease. Routine workflow for workers within the farm should begin in areas with the highest biosecurity concerns (hatchery) to the areas of lower biosecurity concerns (e.g. ponds). For example, workers carrying out production activities in multiple production areas (cleaning, handling, feeding) should start working with the youngest fish first and move to the diseased fish last.

RECOMMENDATIONS

- Only authorized visitors and vehicles should be allowed access to the farm production site.
- Vehicles brought in by suppliers, harvesters, transporters or other farmers should enter through specified entry points.
- Vehicles potentially exposed to infected sites should be properly sanitized outside the farm premises, removing all mud and water while ensuring that wash water does not flow into the farm production areas.
- All visitors or workers entering the farm from another site should make an entry in the visitors log book indicating the date of entry, affiliation, and if they came from another farm site. The visitors log book should be kept up to date to accommodate contact tracing in an event of a disease outbreak.
- Visitors may include suppliers, fish health specialists, extension workers or other individuals who are not working at the farm.
- Biosecurity procedures should be clearly displayed and explained to visitors before entering the farm premises.
- Necessary PPE such as boots and accompanying facilities (changing area, footbath, handwashing area) should be provided at the entry point for use by non-workers.
- Upon entry, all visitors must be escorted by a farm worker, follow all biosecurity procedures, and only be brought to specific production zones with authorization from the farm owner or manager.

- All movement within the farm should follow the direction indicated by signage from the most sensitive or cleanest zones to the least sensitive or most infected zones.
- Both workers and visitors should enter and leave each production zone following the specified entry and exit points.
- Only authorized staff should have access to sensitive zones or quarantine units.
- Specific sanitized clothing or overalls should be used by workers to ensure they do not carry disease vectors from external farm sites.
- Workers moving from one production area to another should carry out proper hand washing and equipment sanitation in disinfection stations prepared at entry points.
- All disinfection stations and sanitizing equipment should also undergo periodic cleaning to prevent cross contamination between production zones.

MANAGEMENT OF WILDLIFE, PESTS AND PREDATORS

Image 23: Barrier netting for ponds in Delta State, Nigeria

The management of wildlife entry into farm premises is an important biosecurity measure as animals such as birds, rodents and lizards may be vectors of disease. This was observed among farms that were surveyed in Delta and Ogun states, where a higher percentage of unusual mortality (10.85%) was reported by farms that observed predators and scavengers compared to those that did not report any such wildlife (only 7.80% unusual mortality). For the same reason, all non-farmed aquatic animals such as pets and livestock should not be allowed on farm production areas.

The farm perimeter should be regularly checked and maintained to ensure that there are no gaps providing entry to predators of fish or pests that spoil farm resources. On specific premises that are vulnerable to pests, rodents should be excluded or eradicated through a pest control programme to prevent contamination and wastage of feeds.

RECOMMENDATIONS:

- Barriers (e.g. secure fencing, bird nets, wire mesh at water intake points) should be installed around the farm premises to prevent the entry of wildlife, predators and scavengers.
- Any gaps in the physical infrastructure that may provide wild animals entry into the farm should be secured.
- Additional physical barriers (such as bird nets) or scare tactics should be set up for protection of fish stocks against predators.
- Baited traps should be prepared in areas prone to rodents such as the feed store.
- All capture and disposal of rodents should be documented to gauge the effectiveness of pest control measures and the level of infestation.

CONTINGENCY PLANNING

EMERGENCY RESPONSE TO HIGH MORTALITY AND DISEASE OUTBREAKS

Even when the best management practices have been implemented, disease outbreaks may still occur. Therefore, it is vital to have a contingency plan in order to mitigate losses in a timely manner before the infection spreads and causes severe financial impact on the farm. With a contingency plan, the farm will be able to address unexpected events or disasters that may include environmental stress, farm leakage, sudden mortalities, disease outbreaks and other issues. Examples of contingency measures include immediate isolation and treatment of sick fish, applying physical modifications to the immediate culture environment (e.g. switching on of paddlewheel aerators to increase dissolved oxygen), reporting the problem to the local extension officer or competent authorities, and transferring of stocks to reduce losses to uncontrollable environmental factors.

A typical contingency plan for a disease outbreak may include the following steps:

- Workers should be made aware of a list of response actions that should be carried out in the event of any unusual occurrence such as high mortality, high number of escapees, and flooding. This list of actions may be displayed in a prominent area on the farm for all workers to use as a reference.
- Contact details of the relevant experts and local competent authorities such as the nearest resident veterinarian should be clearly displayed for the purpose of reporting high mortalities or outbreaks of notifiable disease.
- Farm workers should be able to identify and report clinical signs of disease in order to curb an outbreak in the early stages.
- Upon observation of clinical signs, immediate measures should be taken to identify and trace the route of infection from the point of entry.
- All tanks and ponds that exhibit signs of disease should be identified, and infected fish should be immediately quarantined and administered with the appropriate treatment.
- The movement of infected fish throughout the farm should be traced back to identify other potential areas of infection or cross-contamination.
- After identification of potentially infected areas, the movement of fish and production water in and out of those locations should be stopped.
- Biosecurity and disinfection procedures should be carried out on all infected animals, areas and equipment at the farm.
- Live fish exhibiting signs of disease should be sampled for examination by a veterinarian.
- Information on the susceptibility of the farmed species to potential diseases, mode of infection and treatment possibilities should be obtained where possible.
- Identification of a disease should always be confirmed by diagnostic tests on fish sampled by a veterinarian with supplementary information from previous fish health records.
- Information in fish production records from the past 10-14 days can be used to build a case history and provide supplementary data for the diagnostic process.

- If fish are provided with treatment for the infection, farmers should follow the recommended withdrawal periods and harvest times for the treated fish.
- Infected fish should never be released or disposed of into the wild. Dead fish from outbreak should be properly disposed of following biosecure disposal procedures, while live fish should be quarantined and treated until recovery.
- Water from the infected production unit should be treated using recommended chemicals with proper dosages before discharge.
- All tanks or ponds exposed to the infection should be emptied, disinfected and dried adequately before being restocked with new fish.
- All contingency measures carried out to manage any outbreak or mortality event should be documented.

MANAGEMENT OF FISH ESCAPEMENT

Although the farm infrastructure should be initially designed to prevent farmed fish from escaping into the environment, an escapement prevention plan is also important to minimize the frequency and impact of escaped farmed fish on the surrounding water body. The introduction of escaped non-native species could disrupt native populations and local ecosystems through uncontrolled breeding, predation, overgrazing, and competition for food and habitats. Losses due to fish escapes also heavily impact the economics of production especially when a significant amount of cost in the form of feeds and other farm expenses have been invested in the escaped stock. Hence, additional screens and traps for mitigation of fish escapement should be set up at farm outflow points as a secondary barrier so that escaped fish may still be recovered within the farm premises. As a precaution, routine checks for damages and gaps on the barriers of inflow and outflow points, as well as the walls of each farm production unit should also be carried out before the start of each production cycle.

RECOMMENDATIONS:

- Double screening with mesh nets or wires should be installed at the water outlets of each production unit.
- Escape mitigation equipment such as fish traps, mechanical filters and gates placed outside of production units at the outflow point or in settlement ponds before water discharge can be used to capture escapees still lingering in the farm system.
- If a significant number of fish is involved in an escape event, a record should be kept on the date of escape, species, number of escapees, production unit involved and the relevant authorities that were notified.
- Production units should be routinely inspected to locate possible escape points and repaired where necessary.

MANAGEMENT OF FLOODS

Floods may be a common occurrence in aquaculture farms situated near water bodies highly affected by tidal movements and rain. The location of new farm sites should be selected outside flood-prone areas where possible, and farm infrastructure should be built to withstand the influx of water and the force of current movement. Farms already established on flood–prone land should have flood mitigation measures in place to prevent and buffer against major losses, and should consider relocation if flood-related losses outweigh the capabilities of existing infrastructure to provide protection against flooding events.

RECOMMENDATIONS:

- The construction of higher dikes or additional spillways to redirect excess water should be carried out in farms that regularly experience flooding.
- Where possible, farms flood-prone areas should schedule the harvest and sales of fish ahead before the onset of rainy seasons or events of high tidal fluctuation.
- Temporary holding facilities and vehicles for fish transportation and the setup of physical barriers to prevent fish escape may be considered in the event that all fish cannot be harvested or transferred out of the flood prone area.

- In extreme cases where flooding poses a regular threat to farm production, the relocation of existing farms to areas with lesser exposure to floods (e.g. beyond intertidal zones) should be considered.
- Farm cooperations may consider applying for insurance for protection against natural events, or applying for government funding for flood mitigating measures which may include river dredging and reconstruction of damaged dikes.

FIRE MANAGEMENT

There should be a plan for management of fire outbreaks, especially for farms located close to forested areas or those that utilize a significant amount of woodwork in the farm infrastructure. The plan should include regular training on fire awareness, provision of functional firefighting equipment, basic occupational safety measures and application of common sense practices to prevent the occurrence of fires on farm premises. Workers should also be trained on standard fire fighting and evacuation procedures, and have access to emergency contact numbers in the event of a fire on farm premises.

RECOMMENDATIONS:

- All workers should be made aware of the fire emergency procedures in place.
- All firefighting equipment should be regularly maintained by certified service providers.
- Farms should have an adequate number of functional fire extinguishers throughout the farm premises.
- Fire extinguishers should be placed at suitable locations where flammable substances are stored and used, such as near engine rooms, chemical stores and fuel storage areas.
- All farm workers should be regularly trained by certified instructors on how to safely operate fire extinguishers and evacuation protocols.
- The contact details of the nearest firefighting and emergency services should be clearly displayed on farm premises.
- Burning activities should not be carried out near flammable material.
- Smoking should not be allowed in areas with higher risk of fire outbreaks, such as the engine room, chemical store and near fuel storage bins.

CLUSTER-LEVEL PLANNING AND SHARING OF RESOURCES

When sharing a water resource, consideration should be given to other existing users of the same water body as well as the environment surrounding it. The resource should be used fairly and sustainably by all stakeholders to ensure that their usage has no adverse effect on the water body, including the spread of disease, deterioration of water quality and effect on environmental ecosystem and biodiversity. Such impacts are multiplied when farms are densely populated around the same water resource.

In the fish epidemiology and health economics survey carried out on production systems in Delta and Ogun states, at least 11 local government areas (LGAs) were sampled, including Ika South, Oshimili South, Udu, Ughelli North, Uvwie, and Warri South in Delta state; and Ijebu-Ode, Ikenne, Ipokia, Odogbolu and Shagamu in Ogun state. Within those LGAs, some farms were clustered around shared natural water resources such as river systems. Among the farms that were surveyed, a higher unusual mortality was reported by farms that shared the same water bodies. In order to counter the impacts of operating in a high density farming zone around a shared water resource, farms are encouraged to carry out best management practices (BMPs), manage resources and schedule production activities as a cluster, as a way of managing the costs of inputs and mitigating the spread of risk factors across farms. For example, farms within the same cluster can opt to carry out their production cycles simultaneously with fallowing in between to help break the life cycle of pathogens.

In terms of disease management, the impact of consultation and diagnostic costs on an individual farm could be reduced if jointly funded by a cluster instead of a single farmer. Disease reporting can also be made more efficient if

every cluster has a systematic procedure in place for quick notification of unusual mortality events or disease outbreaks followed by standard response measures that can be followed by affected farms to increase biosecurity measures and mitigate losses.

Clustering also enhances the interactions of farmers with the other actors in the value chain. From the perspective of financing, farms will have the means to access bank loans under a cluster, where consistent and organized farm records will provide the required documentation for securing those loans. Other cost management benefits available to a farm cluster may include application for credit from commercial feed suppliers who provide good quality feed, and the sharing of transportation costs for feed ingredients and fry from trusted sources that may be located at further distances away from the farms. Farm clusters that observe good management practices may also be eligible to apply for certification schemes representing high quality produce that adhere to consumer food safety standards and possibly explore contract farming where a market can be secured for their harvest.

For effective application of BMPs at the cluster level, all farms within the cluster should agree unanimously to apply biosecurity protocols to all stages of production and to take joint responsibility of maintaining the water body, which may include an agreement to treat all farm effluents before discharge and proper disposal of dead fish to prevent contaminating the water source. The collective agreement by all farms to plan and apply BMPs as a cluster can bring benefits in the form of lowered mortality, improved production, reduction of losses in expenditure (due to mortality and sitewide disinfection), and public trust in the safety of the farm produce. Aside from practices scheduled at the cluster level, each farm should also carry out individual biosecurity measures with regularity as required, including quarantine procedures on newly arrived stock, and responsible treatment with chemicals and drugs as prescribed by fish health specialists or veterinary officers.

In planning of BMPs at the cluster level, farms in the same cluster can aim to have some of the following objectives:

- Similar goals (e.g., to prevent entry of exotic pathogens and lower losses to disease).
- Cost efficient methods (e.g building of higher dikes to control flooding).
- Shared biosecurity practices (e.g., proper offsite disposal of dead fish).
- Shared biosecurity facilities (e.g., use of the same water filtration and treatment facility by adjacent farms before discharge)
- Sharing and dissemination of information (e.g., reporting clinical signs of disease for early control measures and providing alerts to other farms).
- Scheduling of production activities (e.g., similar stocking and fallowing times to the life cycle of pathogens).
- Cooperation with suppliers (e.g., obtaining fry from the same supplier with trusted sources).
- Certification (‘green’ credentials to instill consumer confidence).

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