



# **Antimicrobial Use and Resistance in the Aquaculture Value Chain**

## **A Situation Analysis of Nigeria's Aquaculture Industry**



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## Abbreviations and Acronyms

<b>AFAN</b>	All Farmers Association of Nigeria
<b>AMU</b>	Antimicrobial Use
<b>AMR</b>	Antimicrobial Resistance
<b>AR</b>	Antibacterial Resistance
<b>AST</b>	Anti-sensitivity testing
<b>EIA</b>	Environmental Impact Assessment
<b>FAO</b>	Food and Agriculture Organization of the United Nations
<b>GAP</b>	The tripartite Global Action Plan on AMR
<b>GAP<sup>2</sup></b>	FAO Good Aquaculture Practices
<b>GAPS</b>	Global Aquaculture Practice Scheme
<b>GLASS</b>	Global Antimicrobial Resistance Surveillance System
<b>FMARD</b>	Federal Ministry of Agriculture and Rural Development
<b>FDFA</b>	Federal Department of Fisheries and Aquaculture
<b>FDVPCS</b>	Federal Department of Veterinary and Pest Control Services ( )
<b>HACCP</b>	Hazard Analysis Critical Control Point
<b>MAR</b>	Multiple Antimicrobial Resistance
<b>NAFCS</b>	Nigerian Aquaculture Farms Certification Scheme
<b>NAFDAC</b>	National Agency for Food and Drug Administration and Control
<b>NAP</b>	National Action Plan for Antimicrobial Resistance (2017-2022)
<b>NAS</b>	National Aquaculture Strategy
<b>NCDC</b>	Nigeria Centre for Disease Control
<b>OH</b>	One Health
<b>OIE</b>	World Animal Health Organization
<b>PEA</b>	Political Economic Analysis
<b>RAS</b>	Recirculatory aquaculture systems
<b>SOPs</b>	Standard Operating Procedures
<b>SWOT</b>	Strengths, weaknesses, opportunities and threats
<b>VCN</b>	Veterinary Council of Nigeria
<b>VMAP</b>	Veterinary Medicines and Allied Products Directorate - NAFDAC
<b>WHO</b>	World Health Organization of the United Nations

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## Executive Summary

The growing prevalence of antimicrobial resistance (AMR) has raised tremendous concern globally because of the threats it poses for human, animal, and environmental health. The same antimicrobial classes are used to treat diseases in humans and animals globally. Animal food value chains have also been implicated as a pathway for the spread of AMR to humans. The situation has resulted into a reduction the efficacy and options for antimicrobial treatments in humans and animals. To address this public health challenge, the tripartite One Health organizations advocated for the adoption of the Global Action Plan on Antimicrobial Resistance (GAP) as an initiative to slow the progression and spread of AMR world-wide.

Given its mandate, the Nigeria Centre for Disease Control led Nigeria's initiative to adopt the GAP into a National Action Plan (NAP) for the control of AMR. A national situation analysis was initially done to inform the NAP. The findings from the situation analysis indicated the prevalence of AMR in the country was widespread and affected both the human and animal sectors. The aquaculture value chain was prioritized because among the country's fastest growing animal sector yet there was no information on the status of aquaculture antimicrobial yet fish farmers used antimicrobials.

A Fleming Country Grant was subsequently obtained by NCDC to assess the AMU/AMR situation in Nigeria's aquaculture sector with the view to identifying the options for establishing a population-based aquaculture AMR surveillance system. The Political Economy Approach (PEA) was adopted for the situation analysis given its strengths that promoted stakeholder participation and a holistic analysis encompassing the technical dimensions of aquaculture production and socio-economic perspectives that influenced stakeholder roles that impacted the opportunities and challenges for aquaculture AMU control. The tools used to collect data and undertake the situation analysis were literature reviews, online multi-stakeholder consultative meetings, a sentinel survey, a stakeholder analysis and value-chain analysis. This report discusses the findings from the aquaculture situation analysis and provides recommendations for the control of aquaculture AMR.

The findings suggested that aquaculture AMU was fairly prevalent in the sector and was characterized by misuse. Farmers', gender, education level, and membership of an association were all found to have a significant impact on antimicrobial use on their farm. Producers relied more on themselves or other farmers to diagnose and treat fish. The major entry points for AMU were fish feed and water sources. Transmission pathways to humans and the environmental were also identified. These were associated with the production systems, species farmed, value chain segments, disposal of effluent and other farm waste containing antimicrobials and weak supervision of access and use of antimicrobials. The low level of awareness among stakeholders on aquaculture AMU/AMR was cited as being the major challenges for antimicrobial stewardship in the aquaculture sector.

There was evident need adopting One Health AMU/AMR control across the aquaculture value chain. In summary, the following were recommended to achieve this:

- Build the capacity of the Veterinary and Aquaculture and Fisheries Departments at Federal and State level, VCN and NAFDAC to create public awareness on aquaculture AMR.

- Strengthening capacity for undertaking One Health aquaculture AMR surveillance and research among the country's public agencies and institutions
- Strengthen the capacity of the national veterinary services for infection prevention and biosecurity control in aquaculture establishments
- Improving access to diagnostic services and aquatic veterinary services
- Strengthen training curricula, national policies and local human resource capacities for the implementation of aquaculture antimicrobial stewardship across all levels.
- Strengthen the capacity among the respective public veterinary departments and agencies responsible for the control of animal disease and veterinary inputs to monitor and control the distribution and use of veterinary drugs in aquaculture in order to promote the prudent antimicrobial use, responsible disposal of antimicrobials following an aquaculture Residual Monitoring Plan.

## 1. Background and Introduction

The growing prevalence of antimicrobial resistance (AMR) and its implications for food safety, human, animal and ecosystem health are a global concern. Animal food value chains are among the important pathways for AMR to humans and the environment. This is because antimicrobial treatments used in veterinary medicine generally belong to the same drug classes as those used in human medicine, and their residues find their way into the environment. Natural processes of horizontal gene transfer and mutation in bacteria, coupled with anthropogenic factors further creates a situation where the progression of AMR across the human-animal-environment interfaces is closely intertwined. This makes AMR control complicated (Watts et al, 2017). For this reason, the One Health approach was adopted by the Global Action Plan on Antimicrobial Resistance (GAP) as the basis for all actions to control the prevalence and spread of AMR globally (WHO, 2015). The One Health approach simultaneously integrates human, animal and environmental aspects for a holistic health management. To monitor the progress and impacts of the GAP, The Global Antimicrobial Resistance Surveillance System (GLASS) was developed as a harmonized AMR monitoring and control tool to facilitate a comparative global analysis of global trends (WHO, 2017).

In compliance with the recommendations of the GAP, the Nigerian government conducted a situation analysis of the national AMR status under the auspices of the Nigeria Centre for Disease Control (NCDC). The situation analysis characterized Nigeria's AMR status as broad and highly prevalent in humans, livestock, and the environment. Chronic and community-acquired diseases in humans were found to be caused by similar pathogens and treated by similar antibiotics in domestic animals. The potential risk for the occurrence and spread of AMR through animal food value chains to humans and the environment raised concern. These findings prompted the development of Nigeria's National Action Plan (NAP) for Antimicrobial Resistance 2017–2022. The purpose of the NAP was to prevent and reduce the evolution of antimicrobial resistant organisms and their impact on health care. The close relationship between the occurrence and spread of AMR across the human-animal-environment interfaces justified the establishment of an integrated One Health AMR surveillance system as among NAP's priority actions (NCDC, 2017).

### 1.1. Aquaculture in Nigeria

According to Bradely et al. (2020) and FAO (2018), fish is a major component of the diet of Nigeria's 186 million-strong population. Household fish consumption is estimated to be 13.3 kg/capita/year, lower than the world's average of 20.3 kg/capita/year. However, the national fish consumption average masks the lower consumption rates among the poorer and more vulnerable segments of the society, who typically experience chronic or transitory food insecurity. There are an estimated 14.3 million undernourished Nigerians. Over 50% of children aged 6 – 23 months who live with their mothers have limited access to foods rich in iron and vitamin A (Bradely *et al.*, 2020; FAO, 2018). Fish is easy to digest for the young, and is rich in micronutrients such as zinc, iron, iodine, calcium, vitamin B12 and vitamin A, as well as essential fatty acids and protein.

Fish is therefore an important foodstuff for the health of Nigeria's population. To meet this need adequately for the whole population, the country needs a supply of 3.32 million tons of fish annually. Currently only about one million tons is produced, comprising 750,000 tons from capture fisheries and 300,000 tons from aquaculture. This leaves an annual deficit of around two million tons. To offset this deficit, Nigeria imports over 600,000 tons of fish annually. However, the demand-supply gap keeps widening, as demand consistently rises with population growth and the

growing affluence in urban centres. Importing fish to address shortfalls in supply is therefore unsustainable. The pressure on capture fisheries has consequently increased, and driven illegal unreported unregulated (IUU) fishing. This has also resulted in a depletion of the country's commercial fisheries resources. Worldfish estimated that unless Nigeria's domestic fish production increased by 22% per annum, the country would not be able to resolve its fish demand-supply gap over the next 25 years (FMARD, 2008, Kaleem *et al.*, 2020, Leniss Saeweda *et al.*, 2020 and Worldfish, 2018).

According to the 2008 Nigeria National Aquaculture Strategy (NAS), the country has the potential to produce up to 2.5 million tons of fish from aquaculture (FMARD, 2008). Sustainable commercial aquaculture development is therefore being promoted as the most feasible option for increasing fish supply to augment the fisheries and meet national fish demand. Commercial aquaculture development also opens opportunities for the much-needed youth employment, alternative rural livelihoods, reducing pressure on fisheries resources and potentially, producing an additional commodity for export. Consistent public and private sector investment has seen aquaculture production grow by over 400% over the last fifteen years, from 56,000 tons to 300,000 tons per annum. Nigeria is now Africa's second largest aquaculture producer (FAO, 2020<sup>1</sup>). Most of Nigeria's aquaculture is done in the densely populated and wetter parts of the country that cover the South West, South South, South East, and North Central regions. The major species farmed commercially are the North African catfish (*Clarias gariepinus*), Tilapias (mainly *Oreochromis niloticus*) and the Tiger shrimp (*Penaeus monodon*) (Kaleem *et al.*, 2020). The current policy and development thrust has set aquaculture to become Nigeria's major domestic source of fish well into the future.

## 1.2. Rationale for AMU Surveillance in Aquaculture

The NAS envisages the development of an aquaculture value chain that will become the major source of safe and quality assured food fish and fish products destined for domestic and external markets (FMARD, 2008). The current conducive environment for commercial aquaculture has triggered the expansion and diversification of the country's aquaculture value chain. There are more fish farms, and new aquaculture production systems with higher indices of productivity and profitability that have been promoted and adopted by producers. Farmed fish are consequently exposed to more stressors and farmers are under greater pressure to remain in business as their investment costs and market competition grows. Consequently, the use of antibacterial agents among fish farmers to control diseases and enhance productivity – albeit without adequate professional supervision – has reportedly also risen (Adekanye *et al.*, 2020, Aly *et al.*, 2014). Similar patterns of increased antimicrobial use (AMU) as aquaculture sectors grow have been observed globally. However, given the nascent status of the aquaculture sector, AMU within the aquaculture sector worldwide is not as well regulated as it is in the livestock sector. This is largely attributed to knowledge gaps on antibiotic usage, development of resistance mechanisms, and human health risks in the different aquatic production systems and environments (Done *et al.*, 2015; Cabello, 2006; Manage, 2018; Rasul and Majumdar, 2017; Watts, 2017 ).

Globally, aquaculture now produces more than 50% of the world's food fish (FAO, 2020). The unregulated and unsupervised use of antimicrobials within a sector that is set to grow into a major source of food source for human consumption poses a great risk of AMR (Reantaso, 2017). If the NAS production target of 2.5 million tons of farmed fish is achieved, it implies that aquaculture may produce up to 75% of Nigeria's fish (out of the annual target of 3.32 million tons) (FMARD, 2008).

Hence, if AMU in Nigeria's aquaculture sector continues haphazardly, there are likely to be grave consequences for food safety, and for human, fish and environmental health. The development of strategies to minimize the risk of acquiring or spreading AMR through the aquaculture value chain to safeguard human, animal and environmental health is therefore considered a priority.

### **1.3. The Aquaculture PEA Framework**

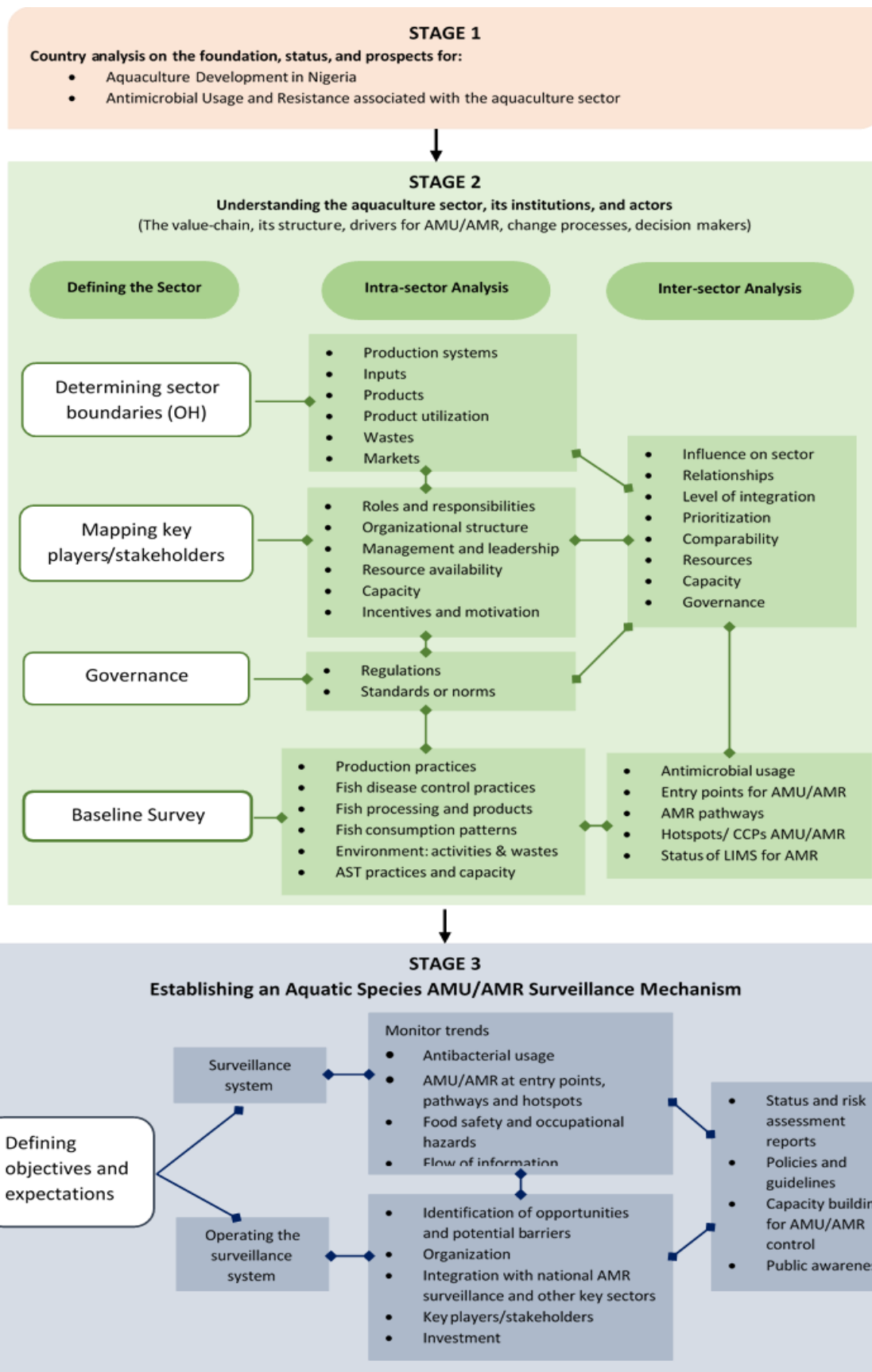
The Nigeria Center for Disease Control (NCDC) is the country's national public health institute, with the mandate to lead the preparedness, detection and response to infectious disease outbreaks and public health emergencies. In collaboration with the Federal Ministries for Agriculture, Environment and Health, the NCDC prioritized the need for integrating the aquaculture sector into the national One Health AMR surveillance system in accordance with the recommendations of the NAP (NCDC, 2017). Financial and technical support were obtained from the Fleming Fund to undertake a situation analysis of the AMR diagnostic capacity and to establish a population-based AMR aquatic species surveillance system that would generate data on resistance in aquatic species and pathogens relevant to human health. The initial emphasis for this support was the aquaculture value chain.

Recognizing that the drivers for aquaculture AMU and hence AMR were likely to be influenced by political, social, and economic factors, a Political Economic Analysis (PEA) framework was adopted. PEA facilitates the simultaneous use of social, political, and economic tools that allow for effective intra and inter sectoral stakeholder and institutional analyses, to identify critical entry points for action and obtain stakeholder consensus on approaches to address these factors. PEA fosters more feasible and sustainable development outcomes (Moncrieffe and Lutterell, 2005).

As an approach, the PEA was consistent with the NAP's recommendations on the need for adopting holistic approaches that account for the social, technical, and economic dimensions of a sector (in this case aquaculture) within the context of One Health to address AMR (OIE, 2015; FAO/WHO, 2015 and FAO, 2011). Furthermore, aquaculture production systems by nature are highly complex, dynamic, and interconnected with the environment which makes it difficult to rely on broad assumptions. Thus, though several studies have been conducted on AMR in aquaculture, it is universally acknowledged that knowledge gaps still remain on the actual contribution and risk determinants for AMR accruing to the aquaculture sector (Watts, 2017).

Mott MacDonald has used the PEA approach for establishing an AMR surveillance system in Bangladesh, with positive outcomes. The approach was modified to suit Nigeria's local context. The sectors stakeholders agreed on a three-staged approach as Nigeria's aquaculture PEA framework for establishing its aquaculture AMR surveillance, namely:

1. Undertake a country situation analysis.
2. Obtain an understanding of the aquaculture sector in relation to One Health and AMU/AMR.
3. Establish an AMU/AMR aquatic species surveillance system (see Figure 1).



**Figure 1: PEA framework integrated with the One Health Approach used to establish an Aquatic Animal Species AMR Surveillance in Nigeria (adapted from Moncrieffe and Luttrell, 2005, and Brunton *et al.*, 2019)**

## 2. Objectives of the Situation Analysis

The specific objectives of the situation analysis were to:

1. Establish the status and factors influencing the development and trends of AMU/AMR in aquaculture.
2. Identify and map the aquaculture value chain stakeholders.
3. Establish the roles, responsibilities, and capacities for AMU/AMR among aquaculture value chain stakeholders and institutions.
4. Identify prospects for establishing, harmonizing, and integrating an aquatic species into the National AMU/AMR surveillance system.

## 3. Study Methodology

The following tools were used to generate data and information for the situation analysis:

### 3.1. Literature Review

A detailed review of secondary information was undertaken to extract information on:

- a) The aquaculture sector; its stakeholders and their roles in production; and the use and control of AMU/AMR within the sector.
- b) The status and governance of the aquaculture sector; its value chain, actors, products, challenges and opportunities therein for the control of AMU/AMR following a One Health approach.
- c) Government policies, strategies and programs on aquaculture development and for AMU/AMR control within the sector. In particular, the National Action Plan on AMR (NAP) and fisheries, aquaculture, and animal health policies.
- d) National and international best practices for the control, reporting and stewardship of AMU/AMR in aquaculture and other animal food-value chains. Notably, the NAP, OIE and FAO guidelines on AMU/AMR in aquatic animals and aquaculture.
- e) Any other information relevant to the assignment.

### 3.2. Stakeholder Mapping Analysis

Key informant interviews and multi-stakeholder consultative workshops were conducted to:

- Introduce the exercise on the need for AMU/AMR control within aquatic animal species production.
- Guide the process of identifying the key stakeholders and their interests (positive or negative) in the aquaculture value chain. This includes their interests/stakes, values, power relations and the consequent influence of stakeholders and their support for AMU/AMR control in the aquaculture sector.
- Map and identify how best to engage the various stakeholders for aquatic species AMU/AMR surveillance, reporting and stewardship.
- Obtain grey (unpublished) literature on the status and opportunities for the control of AMU/AMR in the aquaculture sector.
- Assess knowledge, attitudes, and practices of stakeholders.

Online multi-stakeholders consultative meetings. These provided an opportunity for engaging the sector's stakeholders and for obtaining their input from the onset for the development of the

aquatic species PEA framework, identification of key informants for stakeholder interviews, sourcing unpublished documents for review and the development of the survey tools and methodology.

Key informants were identified from public and private sectors and the different segments of the aquaculture value chain, namely: fish farmers, personnel from line departments and agencies, professional associations, professionals from animal health diagnostic laboratories, veterinarians and fisheries professionals. A checklist was developed to guide the interviews (Appendix 1).

### 3.3. Sentinel Survey

Semi-structured questionnaires were developed and administered to the primary stakeholders of the aquaculture value chain. The questionnaires were designed to establish the status of knowledge, attitudes, and factors that influenced practices with respect to aquaculture AMU/AMR. Specifically, the survey sought to:

1. Verify and map the aquaculture value-chain and its stakeholders, and ascertain their roles in AMU/AMR.
2. Establish AMU/AMR entry-points, pathways, and hot spots in the aquaculture value chain.
3. Identify critical points for control in surveillance.

A comprehensive list of the survey tools for each key stakeholder category in the aquaculture value chain was subsequently (Table 1 and Appendix 2). Similar questions were asked across the value chain to corroborate information given by stakeholders and to help clarify potential pathways for transmission of AMR.

The tools were pre-tested during enumerator training prior to being validated for use in the sentinel survey. Nineteen enumerators were trained to administer the survey tools. They comprised personnel from the Veterinary and Fisheries Departments of the Federal Ministry of Agriculture and Rural Development (FMARD). Some of the enumerators had previously participated in the AMU/AMR livestock survey. The experiences of the latter formed a benchmark for the review and finalization of the aquaculture survey tools and approaches for conducting the aquaculture AMU/AMR survey.

A total of 538 questionnaires were administered within Lagos and Oyo States (Table 1). Lagos and Oyo were purposively selected as sentinel sites for the survey in consideration of:

- a) the level of commercial aquaculture development within these States whereby different production systems are used and species farmed.
- b) the extent of marketing and trade of farmed fish products including the distribution and trade of live fish to other States.
- c) the laboratories selected for assessment are within these States, in particular the National Fisheries AMR Laboratory located at the Federal Department of Fisheries, Lagos.
- d) the limited time available for conducting the aquaculture survey, hence advantage of a location where a representation of the sectors multiple public and private sector stakeholders could be found close proximity of each other.

**Table 1: Description of the Survey Sample**

Stakeholder Category and List of Tools	Population Size <sup>a</sup>			Number of Respondents		
	Lagos State	Oyo State	Total No.	Lagos State	Oyo State	Total No.
Fish farmers	3,500	200	3,700	295	41	336
Fish feed manufacturers	360	100	460	10	8	18
Veterinary input suppliers	300	200	500	26	15	41
Fisheries/aquaculture extension officers	20	10	30	4	4	8
Field veterinarians	450	300	750	6	11	17
Animal diagnostic/fisheries laboratories	10	10	20	0	4	4
Farmed fish/fish processors and traders	400	300	700	45	34	79
Livestock and poultry farmers in the vicinity of fish farms	n/a <sup>b</sup>			14	8	22
Fish farmers associations	n/a <sup>b</sup>			3	3	6
Fish Market administrators	n/a <sup>b</sup>			3	2	5
<b>TOTAL NUMBER RESPONDENTS INTERVIEWED</b>						<b>536</b>

<sup>a</sup>Population size was based on estimates given by the respective State Departments of Fisheries. This could not be authenticated due to inadequate data available at the departments.

<sup>b</sup> n/a – The sampling was not based on the total number of livestock and poultry farmers, fish farmer associations or fish markets in the respective state due to constraints in time and resources. Rather, it was the farmers, associations and fish markets in the vicinity of the fish farms sampled that were visited.

Due to shortfalls in record-keeping practices among respondents, the quality of data obtained was variable. Respondents largely gave answers in qualitative terms. The data obtained provided information on:

- **Aquaculture production systems**, production practices and levels of production
- **Knowledge, attitudes, and practices** of AMU/AMR across the aquaculture value chain
- **Factors affecting access to diagnostic services** in support of prudent and judicious use and disposal of antimicrobials and/or their by-products.
- **Potential entry points, hot-spots and pathways** of AMU/AMR within the aquaculture value chain.

Details of the specific survey tools used, and sampling methodology are given in appendix 3.

DAI’s ethical guidelines were observed during all engagements with stakeholders when collecting data and gathering information.


### **3.4. The Value Chain Analysis**

The data collected above was synthesized to describe practices and assess the AMU/AMR risks at the different nodes of the aquaculture value chain as outlined in table 2 below. Aquaculture production systems vary based on the species farmed, water sources, management practices, effluent characteristics and often, targeted market. The risk factors for AMU/AMR at the production

side of the aquaculture value-chain were consequently likely to vary depending on location, socio-economic status of producers, and markets. Similarly, post-harvest handling and processing methods, marketing approaches, and consumer preferences may influence the predisposition of humans to AMR.

An understanding of the sector's value chain from this perspective was used to identify and elaborate the key entry points, potential hotspots, and drivers for AMU/AMR in Nigerian aquaculture. Critical points for control were consequently identified bearing in mind the specific AMR risks for fish, human, animal and environmental health following One Health. The value-chain analysis also made it possible to identify priority pathogens for surveillance, drivers for AMU/AMR and assess the capacity among stakeholders for AMR/AMU control

**Table 2: Proposed Outline for the Aquaculture Value Chain Analysis**

					
<b>Animal Interface (Production System)</b>					
Species					
Water source					
System design					
Inputs					
Management protocols					
Products					
<b>Environmental Interface</b>					
Disposal and handling of waste					
Human activities around establishments					
Geographical location and other attributes					
<b>Socio-Economic Interface</b>					
Enterprise performance					
Markets					
Product utilization					
Formal and informal governance					

Key players					
<b>Health Aspects</b>					
Occupational hazards					
Animal diseases					
Environmental health practices					

*\*For further details, see appendix 4.*

### **3.5. Data Analysis**

An integrated analysis was conducted, including a SWOT analyses of the aquaculture sector's policies, institutional frameworks and governance structures. Data collected during the survey was analyzed statistically to assess trends and correlations, to establish the contribution and attribution of different factors to AMU/AMR in aquaculture. The statistical analyses were done using Excel™ and SPSS™. The results are discussed in the following sections.

## **4. Aquaculture Production Practices and their Impact on the Status of Aquaculture AMU/AMR**

This chapter describes the aquaculture sector, its stakeholders, and current AMU/AMR practices based on survey findings.

### **4.1. Aquaculture Production and Marketing**

#### **4.1.1. Characteristics of the aquaculture production enterprises**

The majority of fish farms profiled in the survey (87%, 293/336), were owned and run by the farmer. Both men (80%, 268/336) and women (20%, 68/336) owned farms. In addition, commercial farm owners and their managers were more likely to have had tertiary education (71%, 239/336) and some form of training in fish farming (86%, 290/336). The farms sampled had been in operation for around eight years. These findings reflect the general status in the country (Kaleem et al., 2020)

#### **4.1.2. Description of the production systems used**

Fish can be farmed in what are categorized as open, semi-closed and closed aquaculture systems (Flimlin et al., 2008).

##### **4.1.2.1. Open systems**

Open systems occur where water is allowed to freely flow through from a natural water body, and fish are reared using management practices that are similar to nature. Fish are stocked at low densities and units receive little maintenance, and no feed or fertilizer inputs. Pens and extensively managed fishponds fall into this category. Open systems are most common among rural subsistence farmers. Farmers with earthen ponds in this category tend to practice polyculture, where more than one fish species is raised concurrently in the same pond. Shrimp are similarly cultured in the coastal zones of the country.

##### **4.1.2.2. Semi-closed systems**

Semi-closed systems are generally used produce fish commercially at stocking densities higher than occur in nature. Water sources to such facilities include rivers, boreholes, springs and lakes for cages. The major fish rearing units used under this system include ponds, static or flow-through tanks, and cages in lakes. Monoculture, fish feeding, and some level of water quality management broadly describe the basic management practices associated with this systems. Water exchange among the common water quality management practices used in these systems to flush out solid and metabolic wastes released within production units as a result of fish feeding.

Nigeria's commercial catfish production is done ponds and tanks managed under this category. Commercial tilapia farming is done in ponds and cages. Both surface and underground water sources supply these farms.

The farmers interviewed in the sentinel survey fell within this category. Ninety-eight percent (331/336) of farmers interviewed commercially raised catfish, 14% (47/336) tilapia, and 1.2% (4/336) other catfishes. Eight-five percent (287/336) of farmers farmed in ponds, 28% (94/336) in tanks, and 4.2% (14/336) in cages. In addition, 95% (321/336) of the farmers interviewed fed their fish with artificial feed (either imported or locally manufactured). These findings reflected the general status quo in the country.

#### 4.1.2.3. Closed systems

Closed systems employ intensive management whereby the farmer must meet all the biological requirements for production. The vital production management practices for these include the use of nutritionally complete diets, water quality management using aeration and biological filtration, and waste management. Recirculatory aquaculture systems (RAS) are among the aquaculture production systems used in Nigeria that fall within this category. RAS are largely practiced close to major urban centers with a high demand for table fish production and in commercial catfish hatcheries. Commonly, RAS farms source their water from underground sources. None of the farmers interviewed in the survey operated RAS systems

#### 4.2.1.4. Integrated fish farming systems

Integrated fish farming is also practiced in Nigeria. This is done in earthen fish ponds. The by-products of poultry, livestock, and pigs raised on the same farm are used major inputs for fish production. Seven out of the 287 (2.4%) farmers surveyed who had ponds practiced integrated aquaculture. Fish-cum-crop farming is also practiced by some farmers within the country (Zira *et al*, 2015).

#### 4.1.3. The inputs used by farmers

Table 3 broadly summarizes the inputs used by farmers and their sources.

**Table 3: Inputs used by farmers**

Inputs	Remarks
<b>Broodstock (20.5%, 69/336)</b>	In some instances, hatchery producers produced their own broodstock and/or purchased broodstock from other farmers.
<b>Fingerlings/fry (89.6%, 301/336)</b>	Grow-out producers purchased fingerlings from hatcheries. Some hatcheries had a grow-out section and stocked their own fingerlings.
<b>Feeds (95.5%, 321/336)</b>	Imported and local feed from retail shops and millers in the locality respectively.
<b>Drugs (49.1%, 165/336)</b>	Veterinary shops, chemists, and pharmacies in the locality.
<b>Disinfectants (25.3%, 85/336)</b>	Markets and drug stores in the locality.
<b>Inorganic fertilizers (1.2%, 4/336)</b>	Agro-input suppliers in locality. Used in earthen ponds with tilapia.
<b>Manures (10.1%, 34/336)</b>	Manure was also purchased from neighboring poultry farms or at markets. Fish farmers with animals used their own manure. Used in semi-intensive earthen ponds and integrated

aquaculture systems.
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#### 4.1.4. Post-harvest handling and marketing of farmed fish

Fish from ponds was harvested with drag nets (96.6%, 318/336). The harvested fish was then weighed and sold directly to buyers who came to the farm. From the farm, the fish was either transferred straight to marketers as live or fresh fish, or processed into frozen or smoked products prior to sale. The process of fish smoking involved fish was washed, slaughtered by salting, degutted, washed again, folded, smoked, cooled, and finally packaged. Bowls, buckets and kegs were used as containers to hold live and dead fish after harvest. Some farmers and traders (9.5%, 32/336) carried fish from the farm in sackcloth. Live fingerlings were transported in plastic bags filled with oxygen. Transportation of fish from farms to processing plant or the market was done by cars/trucks (90.2%, 303/336), tricycle (27.4%, 92/336), and motorcycle (19.1%, 64/336).

Basic food-sanitation measures were employed by 147 farmers (36%, 147/336) during post-harvest handling. Aspects of this included the used of treated borehole water, limiting the source of water to those that supplied clean water, washing and disinfecting equipment before and after use, and using clean containers for harvesting and salting. However, 1.2% (4/336) of farmers confirmed they did add antimicrobials to the water in holding units during transportation and marketing. Their reasons for doing so were to reduce stress, mortality, and to lengthen the dissolved oxygen retention time in water during long distance live fish haulage. The markets to which respondent farmers sold their fish and fish products were their local markets, Abuja, Ibadan Oyo, Lagos, Warri, Port Harcourt, Asaba Delta, Ogun, Northern part of the country, and internationally to other African countries, Europe, and the USA.

**Table 4: Inputs and tools used in the processing and marketing of farmed fish products**

Product (n= 336)	Frequency (%)	Input/ingredient post-harvest
<b>Live fingerlings</b>	13.8% (53/336)	Brood stock, feed, hormones, drugs
<b>Live table fish</b>	94.4% (317/336)	Fingerlings, fry, post-juveniles, feed, drugs, salts, nets, plastic bowls, knives, ponds, manpower, additives, seasoning
<b>Fresh whole</b>	11.3% (38/336)	Fingerlings, fry, post- juveniles, feed, drugs, salts, nets, plastic bowls, knives, ponds, manpower, additives, seasoning, vegetable oil
<b>Fillet</b>	1.5% (5/336)	Fingerlings, feed, net, salt
<b>Chilled</b>	0.6% (2/336)	Net, feed, bowls, wheel-barrow, freezer, generator cutlass, pumping machines, rain coats, farm boats
<b>Smoked</b>	23.8% (80/36)	Table fish, kiln, charcoal, seasoning, oven, salt, pepper
<b>Other – Melange, not yet</b>	1.2% (4/336)	N/A

In some cases (58.9%, 198/336), farmers' clients demanded that produce or products met market standards.

Some farmers (25.9%, 87/336) processed their produce on farm. The sources of water they used for processing fish were: pond water (18.2%, 61/336), river/stream (12.5%, 42/336), borehole (53.9%, 181/336), well (11.6%, 39/336) and tap water (1.8%, 61/336). The others (10.1%, 34/336) did not process or used spring water.

#### 4.1.5. Status of record keeping

Most farmers (86.3%, 290/336) kept some records. However, the type of records kept, the frequency with which records were updated, and the quality of records kept varied between farms. Of the farmers who kept records [n = 290], the majority kept production, feeding and financial records as opposed to water quality and fish health records (Table 5).

**Table 5: Status of record keeping among fish farmers**

<b>Records kept n = 290</b>	<b>Frequency (daily, weekly, monthly, irregular, never)</b>	<b>Content (circle/tick as appropriate or add an extra)</b>
<b>Production (unit) 254 (87.6%)</b>	Daily 39.0%, (99/254) Weekly 30.3%, (77/254) Monthly 15.4% (39/254) Others (15.4%, 39/254) – fortnightly and Irregular	Species stocked 46.1% (117/254) Age of fish 69.3% (176/254) Fertilization 25.2% (64/254) Stocking 92.9% (236/254), harvest 88.6% (225/336) sampling 43.7%, (111/254) growth 60.2% (153/254) others 3.2% (8/254) - production cycle)
<b>Feeding 250 (86.2%)</b>	Daily 62.8% (157/250) Weekly 27.6% (69/250) Monthly 4.4% (11/250) Others 5.2% (13/250) – fortnightly, per purchase, any other day and quarterly	Feed type 87.6% (219/250) Quantity of feed administered 97.2% (243/250) Feeding response 54.0% (135/250)
<b>Water quality 95 (32.8%)</b>	Daily, 27.4% (26/95) Weekly 33.7% (32/95) Monthly 19.0% (19/95) Others 19.0% (18/95)– irregular and when necessary	Oxygen 75.8% (72/95) pH and NH <sub>3</sub> (47.4% (45/95) Temperature 70.5% (67/95), Flow rate 52.6% (50/95)
<b>Fish health, diseases, treatments 113 (39.0%)</b>	Daily, 38.9% (44/113) Weekly, 14.2% (16/113) Monthly, 9.7% (11/113) Others 37.2% (42/113) – fortnightly, as situation demands, irregular	Species 37.2% (42/113), Symptoms 44.3% (50/113) Number affected 81.4% (92/113) Mortality 89.4% (101/113) Diagnosis/disease 35.4% (40/113) Treatment given 62.8% (71/113)

<b>Financial 256 (88.3%)</b>	Daily 58.2% (149/256) Weekly 19.9% (51/256) Monthly 13.7% (35/256) Others 8.2% (21/256) – after each production cycle, fortnightly, as occasion demands	Expenses 98.1% (251/256) Income 252 (98.4%)
<b>Others 2 (0.7%)</b>	N/A	Facilities, farm diary

#### 4.1.6. Farmers associations and networks

Several of the fish farmers interviewed (63%, 213/336) networked through associations. Of these, 82% (175/213) belonged to a fish farmer association; 30.5% (65/213) to a mixed farmers association; 8.5% (18/213) to a traders and marketing association; and 6.2% (13/215) to a professional association. Based on information given by respondents, Abundant Fish farmers Association, Adamma Fish Farmers Cooperatives, All Farmers Association of Nigeria (AFAN) were among the fish farmer associations that existed within the study area included). Farmers stated they joined associations in order to network with other producers so as to enhance their production and earnings through the exchange of information. Fish farmer associations had a significant influence on farmers' management practices (see Table 5 above and Appendix 5).

#### 4.2. Biosecurity Control on Fish Farms

A number of measures were applied by the farmers in the study as interventions to ensure fish welfare and prevent the occurrence and spread of diseases. The measures farmers used for biosecurity control:

- To prevent the entry and spread of disease, pests and predators into the farm**  
 To control vectors, the following methods were used: perimeter fencing, bush clearing and keeping premises clean, covering out-door production units with netting, traps and scarecrows. To prevent entry and spread of disease on farm disinfection, fumigation, salting, clean water source, foot dips and stocking healthy fish were used.
- To prevent of diseases/pathogens entering the farm through water sources**  
 This done by medicating the water with antibiotics, flushing or exchanging fresh water through production units whose water quality had deteriorated, bush clearing, pipe cleaning, netting, disinfection, salting, movement restriction, isolation of affected fishes, use of herbal concoctions, liming, sorting and fencing.
- To control disease spread on the farm**  
 This was done by blocking connecting pipes to ensure water supply and drainage to individual ponds was independent, bush clearing, covering out-door units with netting, salting, disinfection, fumigation, minimize sharing of equipment, fencing, use clean water source, information sharing with other farmers, isolation and treatment of sick fish, and providing adequate space on the farm for quarantine ponds.
- Disposal of dead or sick fish**  
 This was done by burying (60.1%, 202/336), burning (8.6%, 29/336), throwing directly into drainage channels (54%, 18/336), feeding to other animals and/or fishes (12.8%, 43/336), thrown into bush (23.5%, 79/336), thrown into open rubbish pit (2.7%, 9/336), did nothing (1.2%, 4/336). In 9.2% (31/336) of cases, dead or sick fish were also disposed of by

converting them as fish meal for feeding to other animals, bait or were consumed at home by the farm owner.

### **4.3. The Use and Entry Points for Antimicrobials in the Aquaculture Value Chain**

#### **4.3.1. Entry points for antimicrobials in the production segment of the aquaculture value chain**

##### ***4.3.1.1. Socio-economic factors***

The farmers' gender, education level, attitudes, and membership to an association were found to have a significant impact on antimicrobial use on farm.

Farmers who were less than 40 years old ( $p < 0.001$ ), and those who had at most secondary education ( $p < 0.008$ ), were more likely to use antimicrobials. Those with a lower level of education relied more on advice from other farmers and on their own previous experiences with AMU. Those with trained farm personnel were also more likely to use antimicrobials ( $p < 0.01$ ). Information and experiences on fish disease diagnosis and treatment was exchanged among farmers in farmers associations. Farmers aged less than 40 years with secondary education or less; and/or who were members of an association or had trained personnel running the farms were more likely to be active computer/internet users. Misuse of antibiotics was associated with self-medication without veterinary prescription and laboratory results, as well as sourcing information from other farmers, associations and the internet.

Aquaculture production in earthen ponds, and the practice of discharging effluent into the environment, were anthropogenic factors that increased the likelihood of AMU transmission from fish farms and development of AMR hotspots in the aquaculture environment (see Appendix 5).

as the reasons farmers gave for adopted AMU as a common production practice were improved yields (30.5%, 57/187), survival (85.0%, 159/187), profits (34.8%, 65/187), shelf-life (1.6%, 3/187), appearance of product (9.6%, 18/187), taste (0.5%, 1/187) and reductions of disease spread or severity (55.6%, 104/187). One respondent (1/187) used antimicrobial to aid fish digestion and only one of the 187 had experienced no benefit from AMU.

##### ***4.3.1.2. Treatment practices and the handling of antimicrobials on-farm***

**Production systems** –Antimicrobials had been used by 55.4% (186/336) of the farmers interviewed. The person's on-farm who had access to stores and were responsible for administering antimicrobials when self-treatment occurred were the farmer themselves (90.9%, 60/66), manager (13.6%, 9/66), trained staff (18.2%, 12/66), or anyone at the farm (4.6%, 3/66).

There was significant association between farming in ponds and AMU. However, it should be noted that the majority of farmers (85%, 287/336) who participated in the survey had fish ponds, compared to 28% (94/336) who farmed in fish tanks. Thus, ponds as a factor that influenced AMU per se, was in this case, more likely to be because ponds constituted the dominant production unit used among the farmers who participated in the survey.

**Drivers for AMU** – Farmers ( $n = 186$ ) stated that they used antimicrobials when they observed of symptoms of disease (83.9%, 156/186), mortality (47%, 89/186), to promote growth (10.2%, 19/186), and for prophylaxis (31.7%, 59/186). A minority of the farmers (4.3%, 8/186) used antimicrobials only after other measures such as salting had failed.

Table 6 below lists the various antimicrobials different stakeholders used or recommended to farmers to control cases of disease and/or for prophylaxis. Fish famers selected antimicrobial treatments based on recommendations from other farmers, their previous experiences, veterinary input suppliers, veterinarians, and extension workers respectively (Figure2). Only 14.5% (27/186) of the famers who had used antimicrobials mentioned that they had engaged the services of a diagnostic laboratory prior to administering antimicrobial treatments. Those who had samples submitted for laboratory diagnosis were more likely to have first consulted a veterinarian.

**Table 6: Comparative list of antibacterials used, sold, or recommended by respective stakeholders**

Antibacterial	AMU/AMR by Various Stakeholders									
	Fish farmers	Feed manufactures	Veterinary input suppliers	Diagnostic Laboratories <sup>∞</sup>	Veterinarians*	Extension workers	Fish farmers associations	Fish processors and traders	Market Administrators	Livestock/poultry farmers
<b>1. Penicillins</b>										
Amoxicillin	+ <sup>a,g</sup>					n/a	+		n/a	+
Ampicillin	+ <sup>b</sup>						+			
Cloxacillin	+ <sup>b</sup>						+			
Pencillin	+ <sup>g</sup>				+					
Procaine penicillin	+		+				+			
<b>2. Tetracyclines</b>										
Tetracycline	+ <sup>d</sup>		+							
Oxytetracycline	+ <sup>h,i</sup>	+	+				+			+
Doxyclyne				±	+					
<b>3. Cephalosporins</b>										
Cephalexin	+ <sup>g</sup>		+							
<b>4. Quinolones</b>										
Ciprofloxacin	+ <sup>g</sup>		+		+					
Enrofloxacin <sup>TM</sup>	+ <sup>e</sup>			+	+					+
<b>5. Macrolides</b>										
Tylosin	+ <sup>d</sup>			±						+
Erythromycin	+ <sup>j</sup>		+		+					
<b>6. Aminoglycosides</b>										
Neomycin	+ <sup>d</sup>		+							
Streptomycin	+ <sup>h,i</sup>		+							
Gentamicin				±						+
<b>7. Nitrofurans</b>										
Furaltadone	+		+	±	+					
Nitrofurantoin					+					

8. Nitrobenzenes										
Chloramphenicol	+		+							
Florfenicol					+					
Colistin (polymyxin E)	+ <sup>j</sup>									
Aquaceryl™ (?)	+									

**Notes to the table**

\*Veterinarians sometimes do AST before recommending antimicrobials to farmers

‡Antimicrobials that have shown resistance during AST

\*Antimicrobials used in the farmed fish value chain

Composition of antimicrobial trademarked products farmers mentioned they used to treat their fish. These represent additional forms in which specific antimicrobials listed above may enter the aquaculture value chain.

<sup>a</sup>**Amoxyl™** (amoxicillin)

<sup>b</sup>**Ampiclox™** (ampicillin and cloxacillin)

<sup>c</sup>**Aquaceryl™** is marketed as a product comprising broad spectrum fish antibiotics for prevention of diseases.

<sup>d</sup>**Embaceryl™** is a broad-spectrum water-soluble mixture of antibiotics (tylosin, tetracycline and neomycin) and multivitamins. Recommended veterinary use is for livestock, poultry and rabbits.

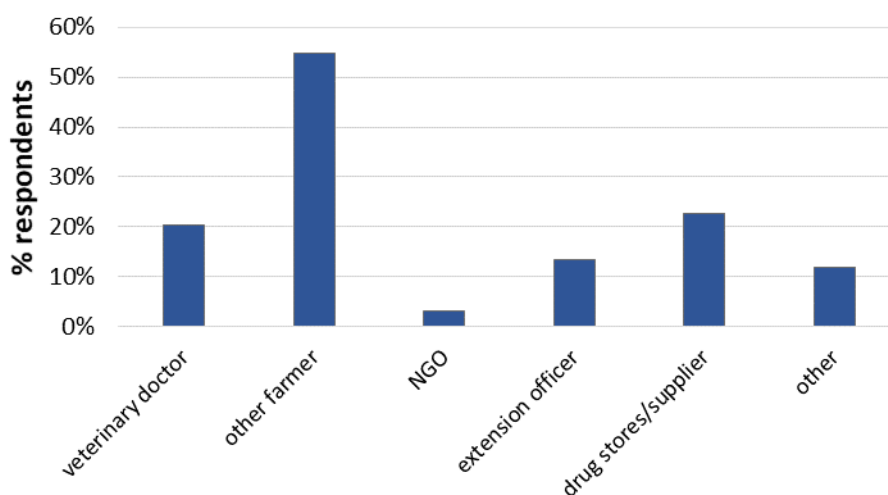
<sup>e</sup>**Enroflox™** (enrofloxacin). Extra-label veterinary drug.

<sup>f</sup>**Enrofloxacin™**. Enrofloxacin is currently approved by the [FDA](https://www.fda.gov/oc/ohrt/20050901) for the treatment of individual pets and domestic animals in the United States. In September 2005, the FDA withdrew approval of Baytril for use in water to treat flocks of poultry, as this practice was noted to promote the evolution of fluoroquinolone-resistant strains of the bacterium [Campylobacter](https://en.wikipedia.org/wiki/Campylobacter), a human pathogen (Wikipedia <https://en.wikipedia.org/wiki/Enrofloxacin>)

<sup>g</sup>**Fishbiotic™** comprises the following range of antibiotics sold in independent unit to control various bacterial infections in fish: Amoxicillin 500 mg, Cephalexin 250 mg, Ciprofloxacin 250 mg, and Penicillin 250 mg. Marketed for the cure of bacterial, viral and fungal infections in fish in Nigeria.

<sup>h</sup>**Fishcure™** comprises oxytetracycline, streptomycin and vitamin C. Its marketed for the prevention and cure of bacterial infections in fish.

<sup>i</sup>**Keproceryl™** Water-soluble mixture of antibiotics (colistin, oxytetracycline, erythromycin and streptomycin) and multivitamins. Recommended for veterinary use in cattle, sheep, goats, horses, and poultry.



**Figure 2. Farmers' sources of advice on antimicrobial use**

The factors farmers took into account when deciding which treatment to administer were: the disease farmers thought they fish had (51%, 95/186), medication costs (11.8%, 22/186), when no

reduction in mortality was observed while using a treatment (61.8%, 115/186), to reduce/mitigate against spread (52.2%, 97/186), to improve growth rate (9.7%, 18/186), and availability of a medication (3.8%, 7/186). Other factors (5.9%, 11/186) considered were changes in water quality, treatment of ponds after harvest, and in cases of severe disease.

The routes farmers used to administer antimicrobial treatments to fish were through the fish (3.2%, 6/186), water (58.6%, 109/186), and feed (82.3%, 153/186). A few farmers administered antimicrobials to fish through to reduce stress and mortality during post-harvest handling (0.5%, 1/186), processing (1.1%, 2/186), and at market (0.5%, 1/186).

About 64% (119/186) of the farmers of used antimicrobials said they did take account of withdrawal periods before sending fish to market. However, 27.4% (51/186) mentioned they had sold off fish to the market while fish were undergoing treatment. The water in which fish had been treated was disposed of directly into the environment, except in around 8% of cases where it was used to water crops and vegetables. Unused or expired drugs were also disposed of into the environment by pouring into drainage or canals, thrown into the bushes on the farm, given to other farmers, or by burying.

About 27.4% (51/186) of the farmers who had used antimicrobials said they had experienced situations where their antimicrobial of first choice did not work.

#### ***4.3.1.3. Entry of antimicrobials through aquaculture production inputs***

##### **Fish feeds**

Eighteen fish feed manufacturers were interviewed. They belonged to the following categories: on-farm feed producers (n = 3), small-scale unmechanized (n = 2), medium-scale manufacturing (n = 8), and large-scale manufacturing (n = 5). Of these, 61% (11/18) also produced poultry feeds and 33% (9/18) livestock feeds. Their major ingredients used for the manufacture of fish feeds were assorted cereals and grains, oil cakes, mineral and vitamin premixes, and binders (Appendix 6). Forty-four percent (8/18) of feed manufacturers produced treated feed. Some of the feed manufacturers who produced treated feeds did so routinely as a preventive measure against infections. Oxytetracycline was the antimicrobial of choice for the production of treated feeds (Table 6). The quantity of antimicrobial added to a feed consignment during manufacture was done based the manufacturers experience. Veterinarians sometimes ordered medicated fish feed. In such situations, the veterinarian provided the specifications.

Five out of the eighteen (27.8%) feed manufactures interviewed reportedly maintained records of the medicated feed they produced. Not all the fish feed produced commercially was labeled. Manufacturers who labeled their feed registered the production date, expiry date, composition of main ingredients, and name of manufacturer on the label. Some of them mentioned the drugs added to the feed on the label. Unwanted feed ingredients, unused or expired additives and drugs were thrown into general rubbish bins or buried for disposal.

##### **Entry of antimicrobials from water sources and land activities into the environment**

Fifteen percent of the farmers (50/336) interviewed were aware of the fact that the water source from which they extracted water for farming fish received drainage from other land-based establishments further upstream. Examples cited included:

- during the rainy season or when there were specific incidents of flooding, run-off containing effluent from surrounding farms and industries drained into major water sources and into the inlet and drainage channels on fish farms.
- effluent from poultry houses upstream was discharged by poultry farmers directly into public waters that supplied fish farms.
- effluent from neighboring farms drained into pond because of sloppy terrain.
- Occasionally, there was ground water seepage into water channels and ponds on the farm.

Only 6.9% (23/336) did not know whether the water source supplying their farms received effluent from other land-based activities.

Twenty one terrestrial farmers participated in the sentinel survey. Their farms that were located in the vicinity of the fish farms that were part of the survey. The majority of the terrestrial farms visited were commercial poultry farms (19/21) that reared broilers (42.1%, 8/19), layers (15.8%, 3/19), pullets (68.4%, 12/19), cockerels (15.8%, 3/19), turkeys (21.1%, 4/19), and a poultry hatchery (5.3%, 1/19). Small ruminants (goats and sheep) were reared on some of these farms.

Twelve (57%, 12/21) of the terrestrial animal farmers visited also farmed fish on their farms. These farmers all farmed catfish (12/12) and two (2/12) additionally farmed tilapia in tanks and ponds.

Most of the poultry farmers (77.3%, 17/22) used antimicrobials on their farms to control diseases. The antimicrobials used were similar to those used by fish farmers. In some cases, they also used the same antimicrobials as growth enhancers, for prophylaxis and/or to treat diseases for both the poultry and fish (Table 6 and 7). Antimicrobial treatments were administered to birds through drinking water. Left-over treated drinking water was discarded in the same manner as the other farm effluent.

**Table 7: Antimicrobials used to treat poultry diseases**

Antimicrobial Used	Disease(s)
Amoxicillin	Reduced production
Cocoryl™, Embacine forte™	Coccidiosis
Ivermectin™, Levamisol™	Lice, worm
Tylosin™, Gentamycin™, Tylox™, Sulfanol™	Chronic respiratory disease
Doxygen™	Fowl typhoid and other enteric diseases
Gendox™	Fowl cholera
Oxytetracycline, Enrofloxacin	Bacterial infection
Oxytetracycline	Prophylaxis

The poultry farmers interviewed shared experiences they had had that they associated with antimicrobial resistance. According to them, most antibiotics on the market were not as effective as they were in the past. Their assumption was that this was due to antimicrobial resistance or a reduction in quality by manufacturers. The reason given for the routine AMU to promote growth and for prophylaxis among poultry farmers was the poor quality of poultry feeds on the market that lowered productivity and poultry health which in turn significantly lowered survival rates.

Ten out of the 12 farmers (83.3%) who raised both poultry and fish on their farms, used the by-products from their poultry production as inputs for farming fish on their own farms. They also gave

or sold the poultry by-products as inputs to other fish farmers. The poultry by-products used as aquaculture inputs included dead birds and maggots from poultry manure that were fed to fish, and the poultry manure that was used to fertilize ponds.

The terrestrial farmers interviewed discharged effluent from their establishments directly into open fields, canals, ponds, drainage, into the surrounding environment, and used to water vegetable gardens. The farm effluent eventually drained into canals, rivers, surrounding soil and bushes. Some fish farms downstream (27.3%, 6/22) used the surface water into which effluent had been discharged as their source of water for fish farming. The terrestrial farmers (86.4%, 19/22) were aware of fish farms located in their vicinity.

#### **4.3.2. Entry points of antimicrobials into the post-harvest and market (consumption) segment of the aquaculture value chain**

After harvest, table fish were dispatched to fish processing plants or directly to food markets by the farmer or traders. A total of 79 fish processors and traders who handled farmed fish were interviewed.

##### **4.3.2.1. Fish marketing and consumer preferences**

The farmed fish products at the markets were live catfish, dried catfish, and fresh tilapia. According to the fish processors and traders interviewed (n = 79), consumers selected a fish species or product depending on their preference for fresh fish, perception of the health benefits of a fish/product, its availability, and shelf-life. Most traders interviewed (63.3%, 50/79) sold live catfish in bowls or tanks, fresh whole tilapia (19.0%, 15/79), dried catfish packaged in sealed nylon packs (44.3%, 35/79), and un-packaged dried catfish (19.0%, 15/79).

The marketers generally did not know how consumers specifically prepared fish at home. However, the traditional fish dishes commonly prepared required the fish to be washed thoroughly first before it was cooked as barbeque, pepper soup, soup broth, stew, or vegetable soup. Some of the consumers bought and ate dried catfish directly at the market stall.

##### **4.3.2.2. Post-harvest fish handling and marketing practices among traders**

After harvesting, fish were weighed, counted, and transferred to containers with water (i.e. for live catfish transportation), or without water in the case of tilapia.

The water used by processors and traders for holding and processing catfish was from boreholes (53.2%, 42/79), wells (35.4%, 28/79), streams/rivers (16.5%, 13/79), ponds (10.1%, 8/79), or portable tap water (10.1%, 8/79). Rain water was cited as a water source for processing by two respondents (2.5%, 2/79).

Only 10.1% (8/79) of the processors and traders interviewed had ever tested the quality of water they used for fish processing and transportation. In all cases, samples were submitted to laboratories for used for microbial testing. This notwithstanding, 26.6% (21/79) of processors and traders reported that they routinely treated their production water with several substances to ensure good water quality during long distance live fish haulage, to reduce fish stress and ensure a good quality product. The substances they used included tetracycline, chloramphenicol, paracetamol, salt, valium and groundnut oil (see Table 8). The antimicrobials and other drugs used in this segment of the value chain were purchased without prescription from local chemists or pharmacies. Advice on AMU in this segment of the aquaculture value chain was based on the processor/traders own experience (31.7%, 25/79), advice given by other processors/marketers

(10.1%, 8/79), drug store owners (6.3%, 5/79), marketing associations (3.8%, 3/79), extension officers (1.3%, 1/79), and veterinarians (1.3%, 1/79).

These observations in relation to statistical analysis indicate strong link between AMU in the post-harvest end of the aquaculture value chain and the distribution and marketing of live catfish for human consumption ( $p < 0.001$ ) (Table 9).

**Table 8: Antimicrobials and other chemicals used in handling, processing and marketing of catfish**

Product	Reason for use	Source
<b>Chloramphenicol</b>	Reduce fish stress and improve survival	Chemist, pharmacy
<b>Tetracycline</b>	Reduce fish stress and improve survival	Chemist, pharmacy. One case from vet store due to signs of ill health
<b>Valium™</b>	Reduce fish stress and improve survival	Chemist, pharmacy
<b>Groundnut oil</b>	Reduce foaming of water	Local market
<b>Palm oil</b>	Reduce fish stress and improve survival	Local market
<b>Molasses</b>	Reduce fish stress and improve survival	Local market
<b>Okra</b>	Reduce cannibalism and improve survival	Local market
<b>chemicals for treating water</b>	Improve water quality and improve survival	Water Department
<b>Lime</b>	Improve water quality	Agro-input suppliers, local market
<b>Salt</b>	Improve water quality, reduce fish stress and improve survival	Local market

**Table 9: Determinants for AMU in the post-harvest segment of the aquaculture value chain**

Variables	Categories	AMU in fish positive n = 21 (%)	AMU in fish Negative n = 58 (%)	Odds ratios (95% confidence interval)	P value
<b>Location</b>	Lagos	13 (61.9)	32 (59.2)	1.32 (0.48 – 3.67)	0.78
	Oyo	8	26		
<b>Aware of government guidelines</b>	Yes	3 (14.3)	20 (34.5)	0.32 (0.08 – 1.21)	0.14
	No	18	38		
<b>Sells fish alive</b>	Yes	20 (95.2)	30 (51.7)	18.67 (2.35 – 148.43)	0.001*
	No	1	28		
<b>Sells fish freshly dead</b>	Yes	4 (19.1)	11 (19.0)	1.01 (0.28 – 3.59)	1.000
	No	17	47		
<b>Sells dried packaged fish</b>	Yes	6 (28.6)	29 (50.0)	0.40 (0.14 – 1.18)	0.15
	No	15	29		
<b>Sells dried fish</b>	Yes	5 (23.8)	10 (17.2)	1.50 (0.45 – 5.05)	0.74
	No	16	48		

### **4.3.3. Entry of antimicrobials from the aquaculture value chain into the environment**

When antimicrobials were used on farms, they were more likely to be discarded directly into the environment ( $p < 0.0001$ ) or onto farm vegetation ( $p < 0.03$ ). The water through which anti-microbials were administered was drained into rivers (19.4%, 36/186), bushes/fields (28.5%, 53/186), used to water vegetables and other crops (8.1%, 15/186) or drained into gutters (59.1%, 110/186). Such effluent into holes or dug canals by only 5.9% (11/186) of farmers who used antimicrobials. Unwanted or expired antimicrobials were disposed of on-farm by throwing into waste bin or refuse dump (33.9%, 63/186); burning (22.0%, 41/186); burying (20.4%, 38/186); throwing into bushes on the farm (10.2%, 19/186); and given to other farmers (3.2%, 6/186). In 30.7% (57/186) of cases, drugs not used before their expiry date were dissolved in water and thrown into the drainage. Farmers who were aware of government guidelines on disposal of effluent were less likely to dispose of the effluent directly into the environment, including after administering treatments to their fish ( $p < 0.06$ ) Appendix 5).

Fish processors and traders also discarded treated water directly into drainage channels or streams or bush.

## **4.4. Antimicrobial Resistance in the Aquaculture Value Chain**

### **4.4.1. AMR in farmed fish**

Around one-fifth of farmers (19.9%, 67/336) claimed they had experienced AMR on their farms. Their experience of AMR was associated with the non-response of fish to antimicrobial treatments. In some instances, such farmers had lost the entire cohort of fish of non-response of fish to antimicrobial treatments. Measures that had been used to address treatment failure among such included the switch to stronger antibiotics, herbs or salt. Loss of profit and mortality were reportedly extremely high when antimicrobial treatments failed on-farm.

Advice on how to overcome treatment failure was obtained from other farmers, association executives, veterinarians, drug stores, extension officers, consultants, the internet or laboratories.

### **4.4.2 Potential transmission of AMR from fish farms to humans and the environment**

Nearly two-thirds of farmers (63.7%, 86/135) said they did take account of withdrawal periods. Disposal methods used by farmers discussed in section 4.5.1.2. above created a potential pathway for the transmission of AMR from fish farms to humans and the environment.

## **4.5. Pathways and Hotspots for AMU/AMR Associated with the Aquaculture Value Chain**

This section describes the factors that were found to be significant in increasing antimicrobial use and resistance. Fish farms are a significant pathway through which AMU/AMR entered the aquaculture value chain and spread into the food chain and environment.

The findings of the study indicate the following as AMU/AMR entry points, hotspots, and drivers (Table 10).

**Table 10: Potential entry points, hotspots and drivers for AMU/AMR in the aquaculture value chain**

	<b>Aquaculture Production System</b>	<b>Product Unit</b>	<b>Post-harvest handling and processing</b>	<b>Distribution and marketing</b>	<b>Consumer</b>	<b>Environment</b>
<b>Entry Points</b>	<ul style="list-style-type: none"> <li>• Water sources</li> <li>• Manufactured fish feeds</li> <li>• Poultry/livestock farm by-products that are used as aquaculture inputs</li> </ul>	<ul style="list-style-type: none"> <li>• Fish feeds</li> <li>• Treatments</li> </ul>	<ul style="list-style-type: none"> <li>• Water sources</li> <li>• Treatments</li> </ul>	<ul style="list-style-type: none"> <li>• Live fish transportation and live fish holding tanks</li> </ul>	<ul style="list-style-type: none"> <li>• Fish consumption</li> </ul>	<ul style="list-style-type: none"> <li>• Effluent</li> <li>• Disposal of unwanted and/or expired antimicrobials</li> </ul>
<b>Hotspots</b>	<ul style="list-style-type: none"> <li>• Drainage and sediment from upstream poultry/livestock farms</li> </ul>	<ul style="list-style-type: none"> <li>• Fish feeds</li> <li>• Ponds because resident time of water is long</li> <li>• Farm effluent treatment units</li> <li>• Effluent</li> </ul>	<ul style="list-style-type: none"> <li>• Fish in holding units</li> <li>• Effluent</li> </ul>	<ul style="list-style-type: none"> <li>• Live catfish holding tanks</li> <li>• Effluent from tanks</li> </ul>	<ul style="list-style-type: none"> <li>• Species and product of choice</li> </ul>	<ul style="list-style-type: none"> <li>• Surface waters and wetlands</li> <li>• Soils/sediment</li> <li>• Wildlife/other animals that may consume dead fish or drink/eat from affected places</li> </ul>
<b>Drivers</b>	<ul style="list-style-type: none"> <li>• Management systems</li> <li>• Economic benefits</li> </ul>	<ul style="list-style-type: none"> <li>• Survival and growth rates</li> <li>• Poor quality feeds in market</li> <li>• Declining efficacy of antimicrobials</li> <li>• High cost and limited accessibility to professional advice and lab</li> </ul>	<ul style="list-style-type: none"> <li>• Reduce stress for live table fish</li> <li>• Consumer preferences</li> <li>• Survival and returns</li> <li>• Economic benefits</li> </ul>	<ul style="list-style-type: none"> <li>• Reduce stress and mortality live holding tanks</li> <li>• Market fish</li> <li>• Profits</li> </ul>	<ul style="list-style-type: none"> <li>• Taste of fish</li> <li>• Cost</li> </ul>	<ul style="list-style-type: none"> <li>• Proximity and ease of disposal of farm fish products</li> <li>• Cost of disposal</li> </ul>

		testing				
		• Economic benefits				

#### 4.6. Access to AMU/AMR Services for Producers

Farmers' practices around AMU/AMR were influenced by the sources of information and advisory services farmers could access on fish husbandry and marketing. Notable sources were the internet, aquaculture extension services, veterinary services and laboratory services.

##### 4.6.1. Information on fish husbandry and diseases control practices

Farmers obtained advice on the different aspects of their enterprises from various sources (see Table 11). The sources of information and skills on fish farming for farmers were the internet, fisheries extension and/or veterinary personnel, other farmers and public training centers including universities. The topic areas farmers sought information on included fish feed, water quality management, general fish farm maintenance, record keeping, fish health management, treating fish, post-harvest handling, and value-addition and marketing. The advice was sometimes paid for.

**Table 11: Sources of information on fish husbandry and marketing practices for farmers**

Source of Information n = 336	Production	Marketing/market information	Fish Health and Biosecurity control	Antimicrobial use	Environmental issues	Government regulations/standards
<b>Other farmers</b>	248 (73.8%)	247 (73.5%)	230 (68.5%)	203 (60.4%)	202 (60.1%)	182 (54.2%)
<b>Newspapers</b>	21 (6.3%)	20 (6.0%)	20 (6.0%)	17 (5.1%)	26 (7.7%)	29 (8.6%)
<b>Internet</b>	124 (36.9%)	108 (32.1%)	107 (31.9%)	93 (27.7%)	82 (24.4%)	76 (22.6%)
<b>Feed manufacturers</b>	62 (18.5%)	56 (16.7%)	53 (15.8%)	45 (13.4%)	37 (11.0%)	35 (10.4%)
<b>Agro-input dealers</b>	34 (10.1%)	36 (10.7%)	27 (8.0%)	28 (8.3%)	20 (6.0%)	16 (4.8%)
<b>Extension workers</b>	57 (17.0%)	55 (16.4%)	57 (17.0%)	52 (15.5%)	67 (19.9%)	66 (19.6%)
<b>Veterinarians</b>	43 (12.8%)	29 (8.6%)	51 (15.2%)	54 (16.1%)	27 (8.0%)	26 (7.7%)
<b>Consultants</b>	27 (8.0%)	20 (6.0%)	15 (4.5%)	19 (5.7%)	10 (3.0%)	13 (3.9%)
<b>Radio</b>	19 (5.7%)	18 (5.4%)	10 (3.0%)	9 (2.7%)	14 (4.2%)	22 (6.6%)
<b>Associations</b>	144 (42.9%)	142 (42.6%)	137 (40.8%)	121 (36.0%)	123 (36.6%)	126 (37.5%)
<b>Institutions (training colleges, universities)</b>	N/A	N/A	60 (17.9%)	N/A	N/A	50 (14.9%)
<b>NGOs</b>	45 (13.4%)	38 (11.3%)	30 (8.9%)	28 (8.3%)	30 (8.9%)	27 (8.0%)
<b>Other*</b>	11 (3.3%)	15 (4.5%)	13 (3.9%)	28 (8.3%)	40 (11.9%)	49 (14.6%)

\*Others include no information; NAFDAC, Lagos State Ministry of Agriculture. N/A = no information obtained.

The source of information on management practices for fish significantly influenced the likelihood for AMU among them farmers ( $p < 0.02$ ). Farmers who relied on other farmers, the internet, or farmers associations for advice were more likely to use antimicrobials without seeking professional advice ( $p < 0.001$ ,  $p < 0.04$  and  $p < 0.01$  respectively). These sources of information offered an entry point for disseminating information on best practices as an intervention against AMU and to promote behavior change among farmers (Table 11 above).

The majority of famers 90.8%, 305/336) interviewed did not consider access to information as a constraint. Sometimes farmers had meet direct costs in order to access information. Examples of such costs included consultation fees (N 117,500 on average), purchase of manuals and internet charges. While information was generally accessible, the major bottleneck for farmers was the quality of information and advisory services. Though helpful, farmers noted limitations in content and poor or inadequate technical support from extension services as major challenges. They observed that some of their fellow farmers and extension agents hoarded knowledge and recommended that, government should do more on information dissemination to farmers

Three-quarters of fish feed manufacturers interviewed (77.8%, 14/18) provided information to their fish farmer clients on feed storage, preservation, and feeding guidelines. They similarly advised fish feed transporters and agro-input suppliers on methods to protect feed from becoming wet/damp, to avoid overloading, proper feed storage and on how to identify spoilt or sub-standard fish feed. The feed manufacturers interviewed mentioned they received mainly positive feedback on the performance of the feeds they produced. The complaints they had received sometimes concerned the dustiness of feed following rough handling during transportation, reduced pellet binding which tended to happen when they raised protein levels and on the need to improve the standard and quality of feeds and feed manufacturing methods used.

#### **4.6.2. Diagnostic services and prescriptions and remedial actions for AMU**

##### **4.6.2.1. Farmers**

The products and services veterinary input suppliers offered to fish farmers included the supply of feeds (75.5%, 31/41), drugs (56.1%, 23/41), feed additives (43.9%, 18/41), consultancy (34.1%, 14/41) and fishing equipment (22.0%, 9/41). Fish feeds and drugs had the highest turnover. The veterinary input suppliers interviewed stated they obtained all their supplies directly from the parent company or through its sales representatives.

Other than advice they directly gave fish farmers when they came to purchase inputs, the veterinary input suppliers had little knowledge of how farmers actually used these inputs on-farm. The advice they gave farmers was recommended practices such as choice of drugs, additives to performance and profit, correct drug usage, observation of withdrawal periods, and interpretation of prescriptions.

The veterinary input suppliers noted that fish farmers would ordinarily have been advised on what feeds and drugs to purchase by veterinarians (43.9%, 18/41), other farmers (39.0%, 16/41), others (26.8%, 11/41) and extension officers (2.4%, 1/41). The drugs commonly purchased by fish farmers were to treat fungal infections, Ich (*Ichthyophthirius multifiliis*), skin infections, stunted growth, and symptoms associated water quality issues (notably low pH and low oxygen) (see table 6).

Sixty-one percent of veterinary input suppliers noted that farmers often came to purchase medications without prescriptions, even where a veterinarian had reportedly been consulted prior.

Their observation was that fish farmers obtained advice on treatments from fellow farmers, association executives, veterinarians, drug stores, extension officers, consultants, the internet, and laboratories, which concurred with farmers responses above. They noted that farmers tended to self-diagnose based on changes in fish behavior (82.9%, 34/41) and symptoms (24.4%, 10/41).

Only 24% of veterinary input suppliers kept records of the drugs purchased for the treatment of fish.

#### **4.6.2.2. Fisheries/aquaculture extension officers**

According to the extension officers interviewed (n = 8), extensive and semi-intensive pond-based, intensive tank, and cage systems were used in the study area. The fish diseases they commonly came across were crack head, fungal diseases, Ich, fin rot and ectoparasitism. Water quality control, salting of ponds, vitamin supplementation and herbal extracts were used to control these disease conditions. Eighty-seven percent (7/8) of the extension officers noted that fish farmers, processors, and traders were aware of and did use antimicrobials without doing laboratory tests first. They observed that it was veterinarians or fish health specialists who tended to collect and submit samples to disease diagnostic laboratories.

#### **4.6.2.3. Field veterinarians**

According to the field veterinarians interviewed (n = 17), the most common fish health problems were broken head, Ich, fungal infections, parasitic diseases, water quality problems, fin and tail rot. Forty-one percent of veterinarians (7/17) mentioned that they always did laboratory tests before prescribing antimicrobials. On the other hand 35% (6/17) of field veterinarians largely made their diagnoses and recommended treatments based on previous experience and only submitted samples for laboratory diagnosis when unsure of case or needed to reassess treatments. Table 6 lists the antibiotics veterinarians stated they had prescribed to fish farmers. The table compares these with those antibiotics recommended to farmers from advisors and what farmers administered out of their own accord.

Fifty three percent (9/17) of the veterinarians had access to a basic field fish disease diagnostic kit that comprised a water quality kit, microscope, and postmortem kit to support their case analysis. Among these, however, some lacked oxygen and pH meters due to their high cost. This obstacle was overcome by submitting water samples for water quality testing diagnostic laboratories when need. The following are the samples submitted for laboratory analysis by veterinarians depended on the suspected cause of disease and included: samples of water from the source, affected production units and effluent, fish feeds, whole fish and/or fish products. Tests commonly requested for were for microbial analysis.

#### **4.6.2.4. Laboratories**

Seventy-five percent of the laboratory managers (n = 4) noted that it was veterinarians who mostly submitted samples for testing, followed by farmers. The commonest samples submitted for testing were whole fish and water. Fish samples were generally submitted in good condition for laboratory diagnosis (75%, 3/4). Fish samples were delivered alive (75%) or chilled on ice (25%). Most requests were for water quality testing, microbiology, parasitology, and antibiotic sensitivity testing.

Table 12 summarizes laboratories' perspectives on the status of aquaculture AMR based on the results obtained from microbial isolation and anti-sensitivity testing (AST) of fish samples submitted farmed fish and water samples.

Table 12: AMR patterns associated with cases of fish disease

Disease causing microbes and parasites isolated	AMR patterns observed
<p><i>Aeromonas hydrophilia</i></p> <p><i>Aeromonas sp.</i></p> <p><i>Escherichia coli</i></p> <p><i>Pseudomonas aeruginosa</i></p> <p><i>Vibrio sp.</i></p> <p><i>Gyrodactylus sp.</i></p> <p><i>Dactylogyrus sp.</i></p>	<ul style="list-style-type: none"> <li>• There has been a change in antibiotics used by farmers over time</li> <li>• Drug dosage rates and exposure times required for effective treatment have also increased</li> <li>• Fewer of the antibiotics on the market are sensitive</li> <li>• Enrofloxacin is sensitive</li> <li>• Gentamicin is sometimes sensitive Gentamicin is found to be sensitive for situations where farmers do not use antibiotics regularly on their farms</li> <li>• General resistance against Gentamicin, Furaltadone, Doxycycline, Tylosos™</li> <li>• Some <i>E. coli</i> cultures are resistant to all the antibiotics used in the antibiogram</li> </ul>

## 5. The Governance and Institutional Set-up of the Aquaculture Sector: Implications for AMR Control

### 5.1. Governance

Aquatic animal disease control, biosecurity and public health in the aquaculture sector are principally regulated under the Inland Fisheries Act, 2004 and the Inland Fisheries (Aquaculture) Regulations, 2016. These regulations stipulate that The Federal Department of Fisheries and Aquaculture (FDFA), of the Federal Ministry of Agriculture and Rural Development (FMARD) as the Competent Authority. The regulations give provisions for ensuring the safety of aquaculture produce and products. They cover the registration, approval, certification and surveillance to monitor and control the Sanitary and Phyto-sanitary (SPS) status of aquaculture establishments across the aquaculture value chain. Table 12 summarizes the implications of these regulations for aquaculture antimicrobial use and resistance.

Other policies and regulations that govern AMU in aquaculture are:

#### Policies

- National Fisheries and Aquaculture Policy
- National Animal Health Policy
- Environmental Health policy

#### Regulations and guidelines

- Sea and Fisheries Decree (1992/1971)
- Land Use Act (1978)
- Water Resources Decree (1993)
- Environmental Impact Assessment (EIA) Decree (1992)

- Guidelines for Environmental Pollution Control in Nigeria (1991)
- Fish movement
- Disease control
- Food safety bill
- Animal Feed
- Veterinary Formulary
- Aquaculture regulations and certification guidelines for farms
- Certifications guidelines for fish products and processing establishments
- Guidelines for aquatic animal health monitoring
- Animal Disease Control Act 1988 as amended
- OIE Aquatic Animal Health Code
- OIE Manual of Diagnostic Tests for Aquatic Animals 2019

#### **Strategies, Programs and Plans**

- National Action Plan for Antimicrobial Resistance 2017-2022
- Residue Monitoring Plan (in draft)
- National Aquaculture Strategy
- National Aquaculture Development Plan (NADP)

Table 13: Implications of sector policies, regulations, and guidelines for aquaculture AMU/AMR control

Provisions in Regulations/Policy	Implications for aquaculture AMU/AMR	Remarks
<p><b>1. Inland Fisheries Act. CAP 110, Laws of the Federation of Nigeria, 2004; Inland Fisheries (Aquaculture) Regulations, 2016 (needs review)</b></p>	<p>(+)</p>	<ul style="list-style-type: none"> <li>- Based on OIE Aquatic Code.</li> <li>- Specifically caters for the surveillance, monitoring and control of aquatic animal diseases, biosecurity and food-safety.</li> <li>- Notable are the registration of farms, Aquaculture Residue Monitoring Plan that covers antimicrobials, SPS aquaculture program, and fishery end-product monitoring, treatment of effluent.</li> <li>- Feed mill monitoring program follows the FAO Good Aquaculture Practices (GAP<sup>2</sup>) that specifies monitoring AMU; similarly so are fish feeds and ingredients.</li> <li>- Recommends multi-disciplinary teams for monitoring, comprising a veterinary officer as head of the team and fisheries inspector with background in aquaculture.</li> <li>- Certification program of the aquaculture sector following Nigerian Aquaculture Farms Certification Scheme (NAFCS) and Global Aquaculture Practice Scheme (GAPS), Hazard Analysis Critical Control Point (HACCP) and Environmental Impact Assessment (EIA) for fish farms above 20 hectares.</li> </ul>
<p><b>1.1. First schedule (regulations 3) compliance requirements for the establishment of fish farms</b></p>	<p>(+)</p>	<ul style="list-style-type: none"> <li>- Recommends the following of the GAP principles.</li> <li>- Specifies farms be sited away from sites that present the risk of biological hazards entering production system, including through contamination of water sources or from other environmental sources.</li> <li>- Monitoring of fish and human health hazards associated with farm location and production practices is recommended.</li> <li>- Limits excessive use of veterinary drugs and other chemicals beyond maximum permissible limits</li> <li>- Recommends that aquaculture facilities should not be established close to human habitation or animal husbandry facilities to avoid contamination of faecal origin.</li> </ul>
<p><b>1.2. Second schedule (Part II and III) General conditions for aquaculture</b></p>	<p>(+)</p>	<ul style="list-style-type: none"> <li>- Only veterinary drugs permitted by the Federal Department of Veterinary and Pest Control Services (FDVPCS) allowed in feeds, and to be administered based on the</li> </ul>

<b>production operations</b>		<p>national regulations.</p> <ul style="list-style-type: none"> <li>- Record keeping is promoted.</li> <li>- Quality assurance following HACCP of production system and of products emphasized.</li> </ul>
<b>1.3.Third Schedule (Regulations 15 &amp; 16) Veterinary Drugs</b>	<b>(+)</b>	<ul style="list-style-type: none"> <li>- Specifies that the use of veterinary drugs in aquaculture shall comply with national regulations and international guidelines on <i>International Code of Practice for Control of the use of Veterinary Drugs (CAC/RCP38-1993)</i> and the <i>Guidelines for the Establishment of Regulatory Program for Control of Veterinary Drug Residues in Foods (CACGL 16-1993)</i>.</li> <li>- Prior to administering drug, system has to ensure that withdrawal time for batches treated can be verified; medicated feed manufacturers guidelines are followed (especially with respect to withdrawal periods).</li> <li>- Only nationally registered drugs and distributors should be permitted.</li> <li>- Administration of drugs to control diseases permitted only on basis of a confirmatory diagnosis.</li> <li>- Provision for residual monitoring for drug levels in treated animal with recommendation to postpone harvest for batches with MRL above recommended levels.</li> <li>- A post-harvest control to reject all fish that don't comply to veterinary drug residual levels as recommended by the Competent Authority.</li> </ul>
<b>1.4.Fourth Schedule (Part II) Special Condition for Handling Processed Aquaculture Products</b>	<b>(-)</b>	<ul style="list-style-type: none"> <li>- No guidance on AMU during handling and processing which needs to be addressed.</li> </ul>
<b>1.5.Fifth Schedule Regulations 20 and 22(8)) Quality Control and Monitoring of Production Condition</b>	<b>(±)</b>	<ul style="list-style-type: none"> <li>- Provides for monitoring and surveillance of sanitary and Phyto-sanitary status of fish farms by the Department of Fisheries '<i>Fish Quality Assurance and Fish Disease Management Division</i>' in lieu of biosecurity control, traceability and quality assurance of aquaculture produce to ensure compliance to all laid down regulations in the Act.</li> <li>- Does not specify AMU as among parameters to be monitored during the above-mentioned surveillance by the FDFA in collaboration with the FDVPCS</li> </ul>
<b>1.6.Sixth Schedule (Regulations 22(9)) Handling and Transportation</b>	<b>(-)</b>	<ul style="list-style-type: none"> <li>- No guidance on AMU during handling and transportation which needs to be addressed.</li> </ul>
<b>1.7.Seventh Schedule (Regulations 22(9)) Storage and Transportation</b>	<b>(±)</b>	<ul style="list-style-type: none"> <li>- Only healthy and undamaged fish to be chosen for live transportation. Damaged, sick and dead fish should be removed from batch prior to holding and transportation.</li> <li>- No guidance on AMU during holding and transportation of live fish and this needs to be addressed.</li> </ul>

<b>2. Criteria and Guidelines for Certification of Aquaculture Products in Nigeria (FMARD, unpublished)</b>	(±)	<ul style="list-style-type: none"> <li>- Includes measures such as recommendations for pond siting, construction materials, water sources that would mitigate against exposure of aquaculture production systems to antimicrobials and resistomes.</li> <li>- Need to be strengthened to ensure terrestrial farms from which animal by-products are sourced for use as aquaculture inputs are sourced also abide by best practices for AMU/AMR control. Service providers involved in the supply animal by-products to aquaculture producers should also abide by best practices for AMU/AMR control.</li> <li>- Content on hatchery and fingerling production needs to be strengthened to reflect AMU/AMR concerns associated with this aspect of the value chain (i.e. notably as potential hotspot and pathway to other aquaculture establishments and the environment).</li> <li>- Content for feed mills need be strengthened to specify keeping of records on AMU in feed manufacturing and distribution, and to include guidelines on the production, distribution, and safe disposal of medicated feeds.</li> <li>- Need to address AMU more specifically in post-harvest aspects, notably quality control, handling, processing, transportation and storage; including fish health and welfare, production water quality and water effluent standards.</li> </ul>
<b>3. Draft Policy on Fish Disease Management</b>	(±)	<ul style="list-style-type: none"> <li>- Based on the OIE Aquatic Code for aquatic animal disease and biosecurity control in aquaculture establishments, which measures already take into account need to minimize AMU/AMR in the aquaculture value-chain.</li> <li>- Considering status of AMU/AMR in Nigeria's aquaculture value chain, the draft policy would need to elaborate specific guidelines for AMU/AMR control.</li> </ul>

In compliance with the Inland Fisheries Act described in Table 13 above, the Federal Department of Fisheries and Aquaculture has set up a fish farm certification program that certifies production facilities and practices. It has also established a fish farm inspection program that verifies the status of biosecurity control on-farm. The former obtains a general record of drugs and chemicals used in production, while the latter monitors' disease status and treatments used. Unfortunately, the checklists used by both programs are not designed to collect information that would enable quantitative monitoring of AMU or assessment of AMR status. This should be considered.

The other policies and regulations generally cover AMU/AMR control requirements for aquaculture. However, they need to be strengthened to align with the NAP. Specifically, they need to offer more precise recommendations and actions for controlling and monitoring the antimicrobials and treatment regimens identified as most appropriate for the aquaculture sector, within the context of AMU/AMR entry points, pathways and hotspots for fish, human and environmental health.

## 5.2. Private Sector

Relevant private sector entities include farmer associations, fish feed millers and marketers and professional associations. Farmer associations operate as key influential and informative groups that advance the interests of farmers. They also serve as a channel through which FMARD disseminates information to the wider fish farming population, and vice versa.

The professional associations perform a similar function. In addition, the professional associations act a regulator for the professional conduct of their members.

## 5.3. Research and Training Institutions

### 5.3.1. Training institutions

Tertiary training institutions that offer diploma and undergraduate courses in aquaculture or veterinary medicine cover various aspects of aquatic animal health. The content detail varies with the specific course. However, AMR in aquaculture does not feature strongly in the curricula of intermediary and degree training programs for farm managers, farmers or professionals (Table 14).

**Table 14: Status of curricula on aquaculture AMU/AMR control**

Level of training	Scope of training on the control of aquatic animal diseases	Comments for AMU/AMR
<b>Fisheries Technology Higher National Diploma</b>	Disease conditions that affect aquatic animals, epizootiology First line routine diagnosis in field and lab Routine diagnosis: parasitology and microbiology	Need to build more awareness on prudent use. Public health significance of AMU not specifically mentioned. This needs to be addressed.
<b>Fisheries Programme Students Handbook (2013 – 2018), Department of Fisheries, Lagos State University, Ojo Faculty Sciences</b>	Focuses on production and food-safety aspects are more comprehensively covered. Course units covering aspects on aquatic animal diseases are electives	Students graduate with a general awareness on maintaining fish welfare. Little practical knowledge on identification of aquatic animal diseases and their control

<b>Department Of Fisheries</b>		
<b>Lagos State University</b>	Fish microbiology, mycotoxicology and pathology. Mainly focus on production and post-harvest handling and processing	Need to build more awareness on prudent use and public health significance of AMU is not specifically mentioned, neither are fish food-safety and public health issues associated with aquaculture
<b>University of Port Harcourt, Faculty of Agriculture, Fisheries Department, Department of Fisheries Handbook (2018/19) Session</b>	Mainly focus on production and post-harvest handling and processing	Need to build more awareness on prudent use and public health significance of AMU which is not specifically mentioned. Food-safety and public health

*Adapted from Fisheries Technology Higher National Diploma*

All the Faculties of Veterinary Medicine in Nigeria are to do offer some training in aquatic animal health, medicine and production including at post-graduate MSc and PhD levels. The National aquatic OIE focal point who is also the Head of Fish Disease Branch at the FDFA, has established good linkages with the national academic and research institutions.

**Table 15: SWOT analysis of research and training institutions**

<p><b>Strengths</b></p> <ul style="list-style-type: none"> <li>• Few Faculties of Veterinary Medicine in Nigeria offer /pathology/medicine/production at undergraduate, post-graduate levels)</li> <li>• Schools of Animal Health also have Fish Health and production in their curriculum</li> <li>• Fisheries and aquaculture training institutions</li> <li>• Research within Universities and Government research centres on the various aspects (i.e. technical, socio-economic, environmental) of aquatic animal health, AMU/AMR inc</li> </ul>	<p><b>Weaknesses</b></p> <ul style="list-style-type: none"> <li>• Ability of the public and private sector to recruit and effectively engage graduates of fisheries and aquaculture</li> <li>• Ability of public and private sector to effectively adopt and implement recommendations</li> <li>• Functional linkages between different resource personnel in the field and with respective value chain actors (farmers, fish processors, traders, etc)</li> <li>• Ability of the sector to retain personnel and service providers (i.e. remuneration, clientele, adequately equip facilities and provide personnel with the equipment and tools to effectively execute their tasks , etc)</li> <li>• Effectiveness of communication channels</li> </ul>
<p><b>Opportunities</b></p> <ul style="list-style-type: none"> <li>• Existing pool of graduates and researchers with knowledge and skills</li> </ul>	<p><b>Threats</b></p> <ul style="list-style-type: none"> <li>• Sustainability of actions (inadequate resources, laboratory capacity, massive importation of fish and fishery products etc.)</li> </ul>

## 6. Stakeholders, their Roles and Levels of Awareness on Aquaculture AMU/AMR

### 6.2. Status of Stakeholder Awareness on AMU/AMR

Stakeholder awareness of AMR in aquaculture was generally low (table 16). Several respondents only became aware of it during the course of the survey and stakeholder interviews.

**Table 166: Level of awareness on aquaculture AMU/AMR among stakeholders**

Stakeholder	Level of AMU/AMR Awareness*		
	High	Medium	Low
Fish farmers			Low
Feed manufacturers		Medium	
veterinary input suppliers			Low
Diagnostic laboratories	High		
Fisheries extension officers			Low
Veterinarians	High		Low
Fish farmers associations			Low
Livestock and poultry farmers			Low
Fish processors and traders			Low
Training Institutions			Low
Chemists/pharmacies			Low

*\*Level of awareness is based on proportion of responses on AMR among respondents.*

#### 6.2.1. Farmers

Some farmers had not heard of the term antimicrobial resistance. The survey on AMR showed they understood antimicrobial use to mean the usage of antimicrobials to treat their fish or prevent diseases. They considered antimicrobials as useful agents because they reduced the negative impact of disease incidences which improved production and returns. . Generally, the farmers understood AMR as referring to when the antimicrobials they used did not work. According to them, the major negative impacts of AMR were increased cost of production arising from prolonged presence of a disease and its negative impacts, and increased costs of treatment. The impacts of human health were only mentioned by a couple of farmers, and none related AMR to environmental health. The need for proper diagnosis and professional help was also only recognized by a couple of farmers. Organic farming was mentioned as a solution to AMR. There was little awareness among farmers of government guidelines.

## 6.2.2. Feed manufacturers

Feed manufacturers were generally aware of what AMR was and how to avoid it (table 16). To avoid AMR, they recommended avoiding self-medication and instead consulting a technical expert, proper calculations to accurately determine amounts to be administered; limiting use of antimicrobial agents in feed, and sensitization and raising awareness on AMU and AMR. The level of awareness among feed manufacturer was gauged as medium because they medicated their feed products to improve feed performance rather than solely for treatment (see section 4.3.1.4. for more details).

## 4.3.1. Other stakeholders

High awareness of AMR was only found among one-fifth of fish farmers (19.9%, 67/336), and all the veterinarians and diagnostic laboratories consulted (100%, 4/4). They had experienced AMR and were able to describe their experiences.

However, for the majority of stakeholders, AMR was a general concept that they had not yet internalized as a specific challenge affecting the aquaculture value chain (**Error! Reference source not found.** above). . As such, even where there were existing guidelines or knowledge that stakeholders could independently apply to minimize AMU/AMR, these were not comprehensively applied. For example, adherence to withdrawal times and use of appropriate methods for the disposal of unused medications or effluent was not fully followed. In addition, veterinary input suppliers and human pharmacists/chemists also sold antimicrobials to farmers and fish processors without prescription. Thus, even though one would expect veterinary input suppliers and human pharmacist/chemists to rank high, they were ranked low in the case of aquaculture because their inability to apply the principle of *'judicious'* AMU to aquaculture given their professional backgrounds (see table 16 and section 4.3.1. for more details).

Stakeholders also expressed concern over the low levels of public awareness of AMR. They recommended stakeholder sensitization and public awareness-raising as key actions for instituting change.

## 6.1. Stakeholders and their roles in aquaculture AMU/AMR

The primary actors in aquaculture AMU/AMR were described as those who directly advised, dispensed, used and/or disposed antimicrobials for the production of fish or fish products at any segment of the aquaculture value chain. The sectors primary actors were consequently identified as being fish farmers, aquaculture extension workers, veterinarians, chemists and pharmacists, veterinary input suppliers, feed manufacturers and fish processors and traders.

The secondary stakeholders on AMU/AMR in the aquaculture value chain were described as those who influenced and/or controlled the use and access to antimicrobials for producers either directly or indirectly. They included policy managers, government agencies and regulators, training and research institutions, consumers, producer and professional associations and the media.

Table 17 below lists the roles aquaculture stakeholders were found to play in aquaculture production and aquaculture AMU/AMR. It is based entirely on the responses given by stakeholders who participated in the study.

**Table 17: Stakeholders and their current role in aquaculture AMU/AMR practices**

<b>Stakeholder Category</b>	<b>Roles in aquaculture production and AMU/AMR control in the aquaculture value-chain</b>	<b>Remarks</b>
<b>1. Primary Stakeholders</b>		
<b>Fish Farmers</b>	Disease identification, advice, procurement and administration of antimicrobials for treatment, prophylaxis and increased production	Based on experience of other farmers Regulated by FMARD
<b>Feed manufacturers</b>	Procurement of antimicrobials, production of medicated feeds, promote feed use	Regulated by NAFDAC
<b>Aquaculture extension workers</b>	Advisory services in production and the detection and management of diseases	Information based on guidelines by FMARD
<b>Veterinarians</b>	On-farm diagnosis, and submission of samples for laboratory disease diagnosis, supply, and administration of antimicrobial treatments	Regulated by Veterinary Council of Nigeria (VCN)
<b>Veterinary/Agro-Input suppliers</b>	Supply and distribute drugs, feeds and other aquaculture inputs to farmers and service providers Advise farmers on choice and use of antimicrobials	Based on experiences of other clients Regulated by Veterinary Medicines and Allied Products (VMAP) Directorate, NAFDAC
<b>Human Chemists/Pharmacies</b>	Supply of antimicrobials and other drugs to producers	Regulated by NAFDAC Pharmacists Council
<b>Fish processors and traders</b>	Administration of antimicrobials and non-antimicrobial drugs as anti-stressors, reduce mortalities, improve shelf-life and product quality	Regulated by FMARD, Certification guidelines
<b>Animal disease diagnostic laboratories</b>	Confirmatory disease diagnosis and AST	Public and private laboratories supervised by VCN.
<b>2. Secondary Stakeholders</b>		
<b>Federal, state and local government departments in the Ministry of Agriculture and Rural Development</b>	Policy formulation, disease surveillance and biosecurity control, maintain database of aquaculture facilities, certification of aquaculture facilities and products, producer guidelines (Best Practices)	Fisheries Department of FMARD is competent authority
<b>Government agencies (NAFDAC)</b>	Regulatory agency for the control of quality, importation, manufacture and distribution of pharmaceutical products and animal feeds	Regulatory function (VMAP)
<b>Research and training institutions</b>	Training of personnel (extension agents, veterinarians and farmers), laboratory	Consultancy services to producers and

	diagnostic services, research	practitioners
<b>Fish farmers, traders and professional associations</b>	Information sharing, advocacy, maintain database of their members and SOPs	Articles of Association
<b>Professional bodies</b>	Promote and regulate welfare of members.	Veterinarians, pharmacists, aquaculturalists, health professionals FMARD for fish inspectors
<b>Media</b>	Public awareness, information dissemination and advocacy	Ministry of information FMARD NCDC Producer and professional associations
<b>Consumers</b>	Demand safe and wholesome products.	Consumer associations CPC FMARD NCDC

*Table 1* Table 18 illustrates the specific roles primary and secondary stakeholders were found to play in the use and disposal of antimicrobials at the different segments of the aquaculture value chain.



<p><b>AMU</b></p>	<ul style="list-style-type: none"> <li>• Procurement, importation, and manufacture</li> <li>• Supply AM</li> <li>• Prescribe AM (decide when and how they are used)</li> <li>• Diagnosis (determine when they should be used)</li> <li>• Advisory/recommendations</li> <li>• Market and Distribute AM</li> <li>• Storage of AM (bulk)</li> <li>• Disposal of expired AM</li> </ul>	<ul style="list-style-type: none"> <li>• Purchase</li> <li>• Administer</li> <li>• Disposal</li> <li>• Storage on farm</li> <li>• Biosecurity measures on-farm</li> </ul>	<ul style="list-style-type: none"> <li>• Purchase and administer in processing and transportation</li> <li>• And sanitising premises and facilities</li> <li>• Contaminated water</li> <li>• Bio-safety measures at plant</li> </ul>	<ul style="list-style-type: none"> <li>• Purchase and administer during transportation</li> <li>• Biosafety measures</li> <li>• Clean fish holding and transportation containers</li> </ul>	<ul style="list-style-type: none"> <li>• Preparation methods</li> </ul>
<p><b>AMR</b></p>	<ul style="list-style-type: none"> <li>• Motivation for prescription/ethics</li> <li>• AMU distributed without prescriptions</li> <li>• Extra-label use Capacities/skills</li> </ul>	<ul style="list-style-type: none"> <li>• Selection of AM</li> <li>• Observation of withdrawal periods</li> <li>• AMU without prescriptions</li> <li>• Extra-label use</li> <li>• AMU for prophylaxis and growth promoters</li> <li>• Methods of administration, storage and disposal</li> <li>• Observation of withdrawal periods</li> </ul>	<ul style="list-style-type: none"> <li>• Residues in products, by-products, and effluent</li> <li>• Methods used to dispose of and treat waste and effluent</li> <li>• AMU without prescriptions, especially for live catfish</li> <li>• Use of human antimicrobial products</li> <li>• Withdrawal periods not observed</li> </ul>	<ul style="list-style-type: none"> <li>• Distribution of products and inputs with residues</li> <li>• AMU without prescriptions, especially for live catfish</li> <li>• Use of human antimicrobial products</li> <li>• Withdrawal periods not observe</li> </ul>	

### 5.3.2. Research

A significant amount of research has been conducted on AMU/AMR within the aquaculture value chain in Nigeria (see Table 19 below). Much of this research has been carried out by the veterinary faculties at university level. This is an indication of increasing awareness and growing concerns on aquaculture food-safety within these institutions. However, most of the research is not yet in the public domain and needs to be integrated into national aquaculture AMU/AMR control strategies and transformed into Standard Operating Procedures (SOPs).

**Table 199: Examples of recent research assessing the status of AMU/AMR in aquaculture in Nigeria**

Titles	Key words	Authors
1. Antibiotic Usage and Oxytetracycline Residue in African Catfish ( <i>Clarias gariepinus</i> in Ibadan, Nigeria)	Oxytetracycline, residue, drug usage, food-safety awareness, residue, <i>Clarias gariepinus</i> , Ibadan	Olatoye and Basiru, 2013
2. Antimicrobial Resistance in Food Animals and the Environment in Nigeria: A Review	Antimicrobial resistance, antibiotics residue, food animals, environment, bacteria, Nigeria	Oloso <i>et al</i> , 2018
3. Antibacterial Resistance in African Catfish Aquaculture: A Review	African catfish, aquaculture, antibacterial resistance, piscine	Anyanwu and Chah, 2020
4. Aquaculture management practices associated with antimicrobial residues in Southwestern Nigeria	Aquaculture production, <i>Clarias gariepinus</i> , antimicrobial drugs, food safety, risk	Okocha <i>et al</i> , 2021
5. Bacteriological quality and antibiotics susceptibility profile of small-medium scale Commercial fish farms in Nigeria	Aquaculture, fish, foodborne diseases, AMR, pond water, total bacterial count	Fakorede <i>et al</i> , 2020
6. Detection and Antimicrobial Resistance of <i>Vibrio</i> Isolates in Aquaculture Environments: Implications for Public Health	Vibrio sp., fish ponds, multidrug resistance	Igbinosa, 2016
7. Food safety impacts of antimicrobial use and their residues in aquaculture	Antimicrobial residue, antibiotic resistance, public health, aquaculture, food safety	Okocha <i>et al</i> , 2018
8. Field assessment of antibiotic use in fish farms in Southwestern Nigeria	Aquaculture, good agricultural practices, antibiotics, resistance to antibiotics, tetracycline, Nigeria	Adewolo and Okunlola, 2020
9. A survey of on farmers awareness on dangers associated with the use of antimicrobial agents in fish hatcheries, Ijebu-Obe, Nigeria	Public health, food safety, advocacy, drug abuse	Durojaiye <i>et al</i> , 2020
10. The Nigerian catfish ( <i>Clarias gariepinus</i> ) pisciculture systems: reservoirs of multidrug-resistant bacteria	<i>Clarias gariepinus</i> , antibiotics, aquaculture, cytotoxicity, enterobacteria, enzymes, multidrug-resistant bacteria	Imade and Akinnibosun, 2018
11. Characterization and Multiple Antibiotic Resistance of Bacterial Isolates Associated with Fish Aquaculture in Ponds and Rivers in Port Harcourt, Nigeria	Fish pond aquaculture, antibiotic resistance, diseases	Obgonna and Inana, 2018

## 6.2. The Status of Networking Among the Aquaculture Sector's Stakeholders

The level of networking among stakeholders on aquaculture production, marketing and AMU/AMR was low. Networking among stakeholders was based upon an individual's personal linkages across the major stakeholder groups, rather than as a streamlined flow between the respective stakeholder categories. Fish farmers networked with each other through farmers associations as a means of sharing information and exchanging experiences. This objective was reaffirmed by the survey results that found farmers' AMU practices to be strongly influenced by their membership to an association (see section 4.6.1. above).

It was apparent that there was a knowledge gap concerning the roles stakeholders could play to promote for aquaculture AMR stewardship. Without this knowledge and stakeholder networking, it would be practically impossible to implement AMR surveillance. The outcomes from the stakeholder analysis should enable the development of a stakeholder database.

## 7. Current Capacity for Prudent Use of Antimicrobials

### 7.1. Diagnostic Laboratories

A major concern for the provision of aquatic veterinary services to farmers was: *'Who are the professionals being engaged by producers in the sector?'* Farmers faced difficulties in getting professional help and so resorted to self-help to diagnose and treat fish diseases. Often, they got advice from the wrong experts and thus several farmers had had bad experiences. They raised key concerns about the need for standardizing certification, disease diagnoses and treatment protocols.

The status of aquatic animal diagnostic and food-safety laboratories need improvement if they are to get accreditation and become ISO-certified. Currently, samples have to be sent for testing overseas whenever fish was destined for export. This was costly and time consuming. It would be better for the sector and for the implementation of biosecurity and AMR measures if fish health and food quality laboratory services were locally available.

The laboratories visited during the survey were able to run basic Level I diagnostic procedures for fish diseases. They had the capacity for water quality testing, bacterial isolation, antibiotic sensitivity testing, gross pathology (post-mortems), parasitology, hematology and serum biochemistry. One also provided proximate analysis of animal feeds. The fish pathogens that had been isolated in these laboratories were *Aeromonas hydrophilia*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Vibrio* sp., as well as the parasites *Gyrodactylus* sp., *Dactylogyrus* sp. Data on the number of cases was not obtained during the survey, however, the National Fisheries Laboratory (Lagos) was able to provide annual trends from their records (section 8.5 below). Not all animal diagnostic laboratories diagnosed aquatic animal diseases. This made accessibility for veterinarians and farmers needing these services extra challenging difficult.

The Fleming Fund is in the process of rehabilitating the National Fisheries Laboratory and Ibadan University's veterinary diagnostic laboratory and currently provide capacity building towards accreditation. These laboratories are designated to become national reference laboratories for aquatic species AMR.

## 7.2. Reporting

Antimicrobial use and antimicrobial resistance are under-reported in the aquaculture sector. A critical factor affecting stakeholders' confidence in reporting was the lack of confirmatory evidence on diseases, given that most diagnoses were presumptive and consequently so were the treatments given. The fact that not every state in the country has an adequately equipped animal diagnostic laboratory to provide credible diagnostic and AST services for the aquaculture sector is therefore a major concern.

## 8. SWOT Analysis of AMU/AMR Status in the Aquaculture Value Chain

### 8.2. Aquaculture Production and Marketing Systems

The risks associated with AMU/AMR in the aquaculture value chain were ranked based on the production systems (table 20).

Table 20: Risks associated with aquaculture AMU/AMR

Segment of the Value Chain	Risk for AMU and AMR to One Health sectors		
	Aquatic animals	Humans	Environment
<b>Production</b>			
Open systems (extensive ponds)	low	low	low
Semi-closed systems (semi-intensive ponds, tanks and cages)	high	high	high
Closed systems (RAS)	low	low	low
Integrated systems	High	High	High
<b>Post-harvest</b>			
Live fish	Medium to high	high	high
Fresh fish	medium	Low to medium	Low to medium
Frozen fillets	medium	Low to medium	Low to medium
Smoked fish	Low to medium	Low to medium	Low to medium

(Notes: **high** = AMU/AMR added directly by producer largely due to economic reasons; **medium** = AMU/AMR as a consequence of largely health management practices in earlier stage of production; **low** = AMU/AMR largely attributable to environmental sources)

The risk factor for AMU/AMR in the aquaculture value chain can be categorized as being attributable to the animal, production system, environmental factors, and segment in the value-chain. When transmission of AMR to humans and the environment is considered, the causative pathogens for fish disease can be an additional risk factor (Table 21).

**Table 21: Aquaculture AMU/AMR Risk factors categorized by production and AMU practices**

Risk Factor	Drivers for AMU/AMR
<b>Animal</b> <ul style="list-style-type: none"> <li>• Species farmed</li> <li>• Age of fish</li> </ul>	<ul style="list-style-type: none"> <li>• Increase production</li> <li>• Increase survival</li> <li>• Increase marketability</li> <li>• Increase profits/reduce production costs</li> </ul>
<b>Production system</b> <ul style="list-style-type: none"> <li>• Tanks vs ponds</li> <li>• Management practices</li> <li>• Nature of farm</li> <li>• Access to advisory services</li> </ul>	
<b>Value chain segment</b> <ul style="list-style-type: none"> <li>• Location in value chain</li> <li>• Market commodity</li> </ul>	
<b>Environmental</b> <ul style="list-style-type: none"> <li>• Location of farm</li> <li>• Season</li> </ul>	No direct drivers. Environment acted as recipient, pool from which AMU/AMR could be spread

The findings of the survey on AMU among fish farmers concurred with literature and the key stakeholder experiences (Okocha et al, 2021). Most farmers administered antibiotics (and other drugs) without professional advice or laboratory diagnosis. Antimicrobials were used in aquaculture primarily for economic gains. Farmers engaged in AMU to reduce mortality and enhance productivity. Fish traders and processors used antimicrobials to reduce fish stress, maintain fish vigor and prolong shelf-life enhance marketability and profitability from live fish sales. When signs of AMR were observed, the tendency was increase the dosage, or to change and/or use multiple antimicrobials simultaneously, including those not labeled for aquatic animal use.

### 8.2.1. Species

The species most exposed to aquaculture AMU was the catfish. Catfish were produced under more intensive conditions by virtue of their unique management requirements for reproduction, feeding and the market. Catfish were most marketable live, being sold as fingerlings for stocking and for table size for human consumption. Under such management conditions there were higher exposure of fish to stressors and high stocking densities in a drive to maximize productivity to offset high investment costs and risks of production and survival. Tilapia, on the other hand, were easier to reproduce even in ponds under semi-intensive management. Table size tilapia were sold fresh whole, filleted, fried or frozen.

### 8.2.2. Production systems

Findings from the survey, stakeholder consultations, national annual fish disease status reports, and literature indicated that catfish hatcheries, pond and tank production systems, and livestock-cum-integrated fish farming were predisposed to AMU, for the development and spread of AMR.

### 8.2.3. Hatcheries

Fish hatcheries, particularly catfish hatcheries, were run as more intensive operations. The age group reared in hatcheries (larvae to early juveniles) was less resilient to sub-optimal water quality, fluctuations in water and feed quality, stress and acquiring infections. The management requirements at this stage meant frequent handling, which exposed juveniles exposure to frequent

and high levels of stress during production and transportation. Consequently, the juveniles were more prone to infections (including from commensal organisms) and mortality. To avert the negative consequences of frequent handling on juvenile health, farmers resorted to administering AMU prophylactically. Consequently, antimicrobial treatments were administered based on anticipated exposure to stress rather than on the clinical expression of disease as a measure against high mortality rates and to safeguard returns. Antimicrobials were therefore administered during transportation, whenever seasonal changes affected the water quality of water sources and whenever juveniles were routinely handled such as during sorting and grading and transfer to new production units.

#### 8.2.4. Mixed farms and integrated fish farms

By virtue of the quality of inputs (animal by-products), mixed farms and integrated fish farms were more suited to and tend to focus on table fish production. The risks for aquatic species AMU/AMR on mixed farms or integrated animal-cum-fish aquaculture were:

- (a) **Mixed farms that reared both poultry and fish on the same premises tended to use the same medications for poultry to treat fish, and fed dead birds or poultry offals to catfish.** By-products were fed to fish that were either raised in ponds and/or tanks on such farms. Outdoor grow-out fish production tanks were more intensively managed. Fish raised in these tanks were more likely succumb to disease as a sequel to exposure to water quality and nutritional stressors. Medications were administered through the feed which was the common practice for catfish reared tanks for human consumption. Antibiotics were routinely added as additives to improve the performance of some the commercial feeds mixed farmers used as supplementary diets (see section 4.3 and 4.5 above).
- (b) **Poultry litter and manure (which may or may not have been composted first) was used to fertilize ponds.** In integrated production systems, by-products and waste from poultry houses (or other farm activity) were directly used as inputs for pond fish production. This was done to optimise nutrient cycling on-farm in order to increase overall farm productivity while reducing financial outlays and thus improve returns. Such farmers, used left-over poultry feed, un-composted manure, urine and other effluent to feed fish and/or fertilise the ponds. Ponds managed under integrated animal-fish systems were used to farm tilapia under monoculture or polyculture with catfish and other species.
- (c) **Farmers did not abide to withdrawal periods whenever they used by-products from animals under treatment as inputs for fish farming.** The development of resident resistant bacteria and genes on the farm establishment was more likely compared to the hatcheries, because of longer transient time for both fish and water within production units or on-farm.

#### 8.2.5. Location in value chain

Antimicrobials were added directly into water in holding units for live table fish destined to market. The transient time was comparatively short in holding units compared to production units. However, the fish harvested from these holding facilities, once sold was immediately used for human consumption and the water disposed of in public drainage or surrounding environments. The observance of withdrawal periods was not practiced at this end of the value chain. The risk for both AMU and consequently transmission of AMR to humans and environmental health was possibly higher at this point of the value chain as a result of direct fish consumption of fish and handling of water with the active agent.

### 8.2.6. Environmental sources

Findings from the National Annual Fish Disease Status Reports indicated that most cases of fish disease occurred during the rainy season, and in hatcheries with waters that had low pH, soft water, high levels of nitrite and ammonia. Respondent farmers also noted that the water quality at the water sources changed during the rainy season. Rainwater was ordinarily softer and colder. Consequently whenever there was run-off into a water body or water-way, the physical and chemical water quality characteristics of that water body changed. Additionally, the risk of contaminants being washed into such water bodies from surrounding farms or other land activities rose. Underground water quality also changed seasonally, depending on the type of well that had been constructed. Water in deep wells was less likely to become contaminated from surface seepage.

### 8.3. Transmission of Antibacterial Resistance through the Aquaculture Value chain to Humans and the Environment

Literature suggests that antibacterial resistance (AR) can easily enter the aquaculture food value chain undetected. This was because there was a wider range of microorganisms in the aquaculture environment and yet only a few indicator aquatic organisms could currently be cultured, unlike livestock. Other than through fish consumption, AR organisms could also be transferred to humans when workers with wounds came into direct contact with aquatic ecosystems. Bacterial populations in fish were also very similar to the populations in their growing environment. Furthermore, the movement of resistant genetic elements (mobilomes) was greater in aquatic ecosystems compared to the relatively static land environments. Thus, the transfer of mobilomes through contact with affected rearing water, fish and/or sediment to humans and the environment was a possibility, especially where aquaculture sanitary measures and biosecurity controls were weak (Anyanwu and Chah, 2016).

Studies have also indicated multiple antimicrobial resistance (MAR) in fish farm environments within Nigeria and antimicrobial residues in farmed catfish (Fakorede *et al.*, 2020; Olatoye and Basiru, 2013; Musefiu and Olasunkanmi, 2015; Anyanwu and Chah, 2016; Olatoye and Basiru, 2013; Igbinosa, 2016). Table 22 shows the bacterial pathogens for which antimicrobial resistance has been identified from these studies, against the antimicrobials used by farmers and traders who participated in the survey. The survey findings and literature show that the likelihood for the acquisition of AMR through the aquaculture value chain exists, and that can flow from farmed fish to humans and to the environment.

Table 22: Status of resistance to antimicrobials used by fish farmers

Antibacterial Use in Nigerian Aquaculture	Used by Respondent Fish Farmers	Bacterial Isolates Found with Drug Resistance in Nigerian Aquaculture	Remarks
<b>Penicillins</b>			
<b>Amoxicillin-clavulanic acid</b>	+	<i>Aeromonas, E. coli, Pseudomonas, Salmonella, Staphylococcus,</i>	Anyanwu and Chah, 2016; Masefiu and Olasunkanmi, 2015
<b>Ampicillin</b>	+	<i>Aeromonas, Alcaligenes, Citrobacter, Enterobacter, Escherichia, Proteus, Pseudomonas, Salmonella, Serratia, Micrococcus, Staphylococcus, Streptococcus, Bacillus, Vibrio</i>	Anyanwu and Chah, 2016; Masefiu and Olasunkanmi, 2015; Igbinosa, 2016
<b>Cloxacillin</b>	+	n/a	n/a
<b>Penicillin</b>	+	n/a	n/a
<b>Procaine penicillin</b>	+	n/a	n/a
<b>Ceftriaxone</b>	0	n/a	n/a
<b>Tetracyclines</b>			
<b>Tetracycline</b>	+	<i>E. coli, Pseudomonas, Salmonella, Staphylococcus, Streptococcus, Aeromonas, Vibrio</i>	Source of tetracycline resistance most likely from livestock manure, dead animals, and aquaculture workers (Anyanwu and Chah, 2016), Masefiu and Olasunkanmi, 2015; Igbinosa, 2016
<b>Oxytetracycline</b>	+	n/a	n/a
<b>Doxycycline</b>		n/a	n/a
<b>Cephalosporins</b>			

<b>Cephalexin</b>	+	n/a	There is need to have data on 2 <sup>nd</sup> , 3 <sup>rd</sup> and 4 <sup>th</sup> generation cephalosporins.
<b>Quinolones and fluoroquinolones</b>			
<b>Ciprofloxacin</b>	+	<i>Pseudomonas</i>	Anyanwu and Chah, 2016.
<b>Enrofloxacin™</b>	+	<i>Aeromonas</i>	Anyanwu and Chah, 2016.
<b>Nalidixic acid</b>	0	<i>E. coli, Salmonella, Pseudomonas, Staphylococcus, Streptococcus, Vibrio</i>	Anyanwu and Chah, 2016; Masefiu and Olasunkanmi, 2015; Igbinosa, 2016.
<b>Ofloxacin</b>	0	<i>Streptococcus, Staphylococcus</i>	Anyanwu and Chah, 2016; Masefiu and Olasunkanmi, 2015.
<b>Norfloxacin</b>	0	<i>Salmonella</i>	Anyanwu and Chah, 2016.
<b>Enrofloxacin</b>	0	<i>Aeromonas</i>	Anyanwu and Chah, 2016.
<b>Macrolides</b>			
<b>Tylosin</b>	+	n/a	n/a
<b>Erythromycin</b>	+	<i>E. coli, Pseudomonas, Salmonella, Staphylococcus, Edwardsiella, Vibrio</i>	Anyanwu and Chah, 2016; Igbinosa, 2016.
<b>Aminoglycosides</b>		n/a	n/a
<b>Neomycin</b>	+	n/a	n/a
<b>Streptomycin</b>	+	<i>E. coli, Pseudomonas, Staphylococcus, Salmonella, Aeromonas</i>	Anyanwu and Chah, 2016.
<b>Gentamicin</b>	0	<i>E. coli, Pseudomonas, Staphylococcus, Salmonella, Streptococcus</i>	Anyanwu and Chah, 2016. Masefiu and Olasunkanmi, 2015.
<b>Novobiocin</b>	0	<i>E. coli, Pseudomonas, Staphylococcus</i>	Anyanwu and Chah, 2016; Masefiu and Olasunkanmi, 2015.
<b>Nitrofurans</b>			
<b>Furaltadone</b>	+		

<b>Nitrofurantoin</b>	0	<i>Streptococci, Salmonella, E. coli, Pseudomonas, Staphylococcus</i>	Anyanwu and Chah, 2016.
<b>Nitrobenzenes/phenicols</b>			
<b>Chloramphenicol*</b>	+	<i>E. coli, Pseudomonas, Salmonella, Staphylococcus, Aeromonas, vibrio</i>	Anyanwu and Chah, 2016; Igbinosa, 2016.
<b>Florfenicol</b>	0	n/a	n/a
<b>Sulphonamide and diaminopyrimidine</b>	0	n/a	n/a
<b>Sulphamethoxazole</b>	0	<i>Pseudomonas, Salmonella, Staphylococcus, Vibrio</i>	Anyanwu and Chah, 2016; Masefiu and Olasunkanmi, 2015; Igbinosa, 2016.
<b>Sulphamethoxazole/ Trimethoprim</b>	0	<i>Staphylococcus, Streptococcus</i>	Anyanwu and Chah, 2016.
<b>Colistin (polymyxin E)</b>	+	n/a	n/a
<b>Aquaceryl™ (Trade name containing 2 classes of antibiotics)</b>	+	n/a	Trade name that contains neomycin, erythromycin and oxytetracycline.

\*Use of chloramphenicol may be due to high cost of florfenicol in low income developing countries where African catfish is farmed (Anyanwu and Chah, 2016).

**Notes to the table:** (+) respondents in the survey conducted for the situation analysis mentioned they used this antimicrobial; (0) not among antimicrobials respondents used; (n/a) the AMR status of these antimicrobials in Nigerian aquaculture was not mentioned in the literature reviewed in the assignment. The fact that some antimicrobial were not mentioned by respondents in the survey, does not mean they were not used at all in Nigerian aquaculture.



## 8.4. Critical Control Points

Table 23 lists the critical points that would need to be monitored and control to minimize the development of AMU/AMR across the aquaculture value chain.

**Table 23: AMU/AMR monitoring and control points in the aquaculture value chain**

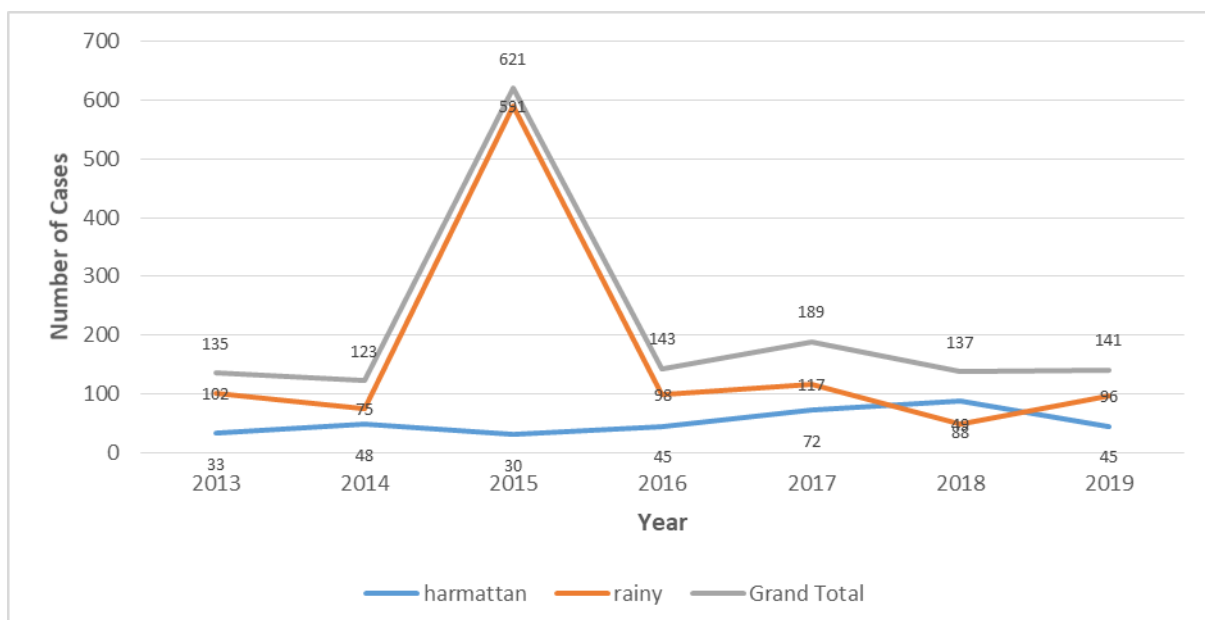
Elements in the Value Chain	AMU	AMR
<b>Water sources</b>	<ul style="list-style-type: none"> <li>• Use and disposal of antimicrobials upstream.</li> <li>• Antimicrobial residues</li> </ul>	<ul style="list-style-type: none"> <li>• Use and disposal of antimicrobials upstream.</li> <li>• Antimicrobial residues</li> </ul>
<b>Farms</b>	<ul style="list-style-type: none"> <li>• Sources of antimicrobials</li> <li>• Access to antimicrobials</li> <li>• Disease situation</li> <li>• Treatment recommendations</li> <li>• Administration of antimicrobials</li> <li>• Withdrawal periods</li> <li>• Sources of information on AMU</li> </ul>	<ul style="list-style-type: none"> <li>• Treatment recommendations</li> <li>• Administration of antimicrobials</li> <li>• Withdrawal periods</li> </ul>
<b>Feed</b>	<ul style="list-style-type: none"> <li>• Sources of antimicrobials</li> <li>• Treatment recommendations</li> <li>• Labelling</li> <li>• Distribution</li> <li>• Storage and milling</li> </ul>	<ul style="list-style-type: none"> <li>• Sources of antimicrobials</li> <li>• Treatment recommendations</li> <li>• Contaminated ingredients and water sources</li> </ul>
<b>Farm environment</b>	<ul style="list-style-type: none"> <li>• Disposal of unused drugs and medicated feeds</li> <li>• Effluent</li> <li>• pests</li> </ul>	<ul style="list-style-type: none"> <li>• Use and disposal of antimicrobials upstream</li> <li>• Disposal of unused drugs and medicated feeds</li> <li>• Effluent</li> </ul>
<b>Post-harvest handling, transportation and processing</b>	<ul style="list-style-type: none"> <li>• Fish condition and products</li> <li>• Sources of antimicrobials</li> <li>• Access to antimicrobials</li> <li>• Treatment recommendations</li> <li>• Administration of antimicrobials</li> <li>• Withdrawal periods</li> <li>• Fish holding facilities</li> <li>• Sources of Information on AMU</li> <li>• Antimicrobial residues</li> </ul>	<ul style="list-style-type: none"> <li>• Use and disposal of antimicrobials upstream</li> <li>• Antimicrobial residues</li> </ul>
<b>Market</b>	<ul style="list-style-type: none"> <li>• Fish holding facilities</li> <li>• Fish products</li> <li>• Antimicrobial residues</li> </ul>	<ul style="list-style-type: none"> <li>• Fish holding facilities</li> <li>• Antimicrobial residues</li> </ul>

## 8.5. Status of National Surveillance on Aquatic Animal Health

Aquatic animal health management programs in the Federal Department of Fisheries were instituted about ten years ago. The aquatic animal health unit has developed a checklist to guide its staff during monitoring of fish health status on fish farms. It was intended that fish farms in all states be regularly monitored. However, due to resource constraints, monitoring has so far been conducted in only a couple of states one of which is Lagos State. The following challenges have been a major hindrance for the implementation of fish health monitoring plans:

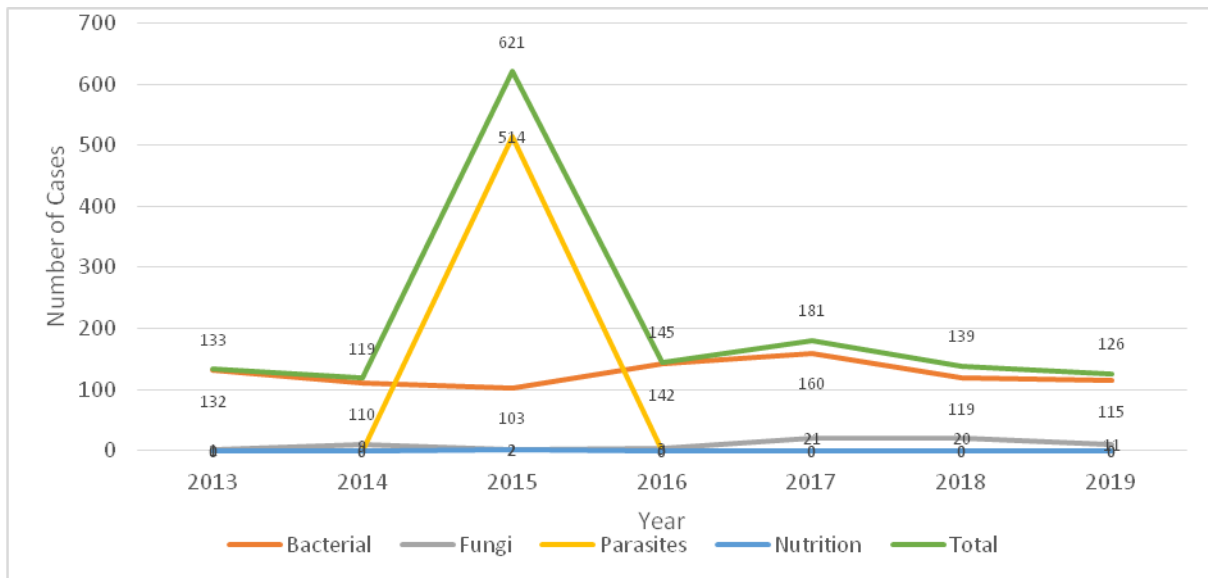
- i. The lack of laboratory and field diagnostic kits to support accurate diagnosis and prescription of treatments; and
- ii. Poor record keeping among producers, service providers and other stakeholders along the value chain.

Despite these challenges, the Fish Health Department has compiled annual reports of pathogens isolated from diseased fish since 2013. The data was compiled from cases handled by laboratories in Lagos, Abuja, Ogere, Asaba and Ibadan between 2013 to 2015. A total of 1,489 cases were handled by these laboratories during this time. Analysis of the data revealed that most disease cases occurred during the rainy season (76%, 1,128/1,489) and were associated with bacterial infections (59%, 881/1,489) (Figure , Figure ). Furthermore, incidences of disease tended to be from catfish hatcheries whose water quality had low pH, was soft with toxic levels of nitrite or ammonia, and high bacterial loads. Some cases were caused by multiple bacterial and/or protozoan infections. The most prevalent bacteria isolated from the cases handled by the laboratories were *Vibrio* spp, *Aeromonas* spp, *Staphylococcus* spp. and *Salmonella* spp (**Error! Reference source not found.**). The pathogens isolated from the fish disease report were commensal organisms, ordinarily found in aquatic ecosystems and animal production environments.



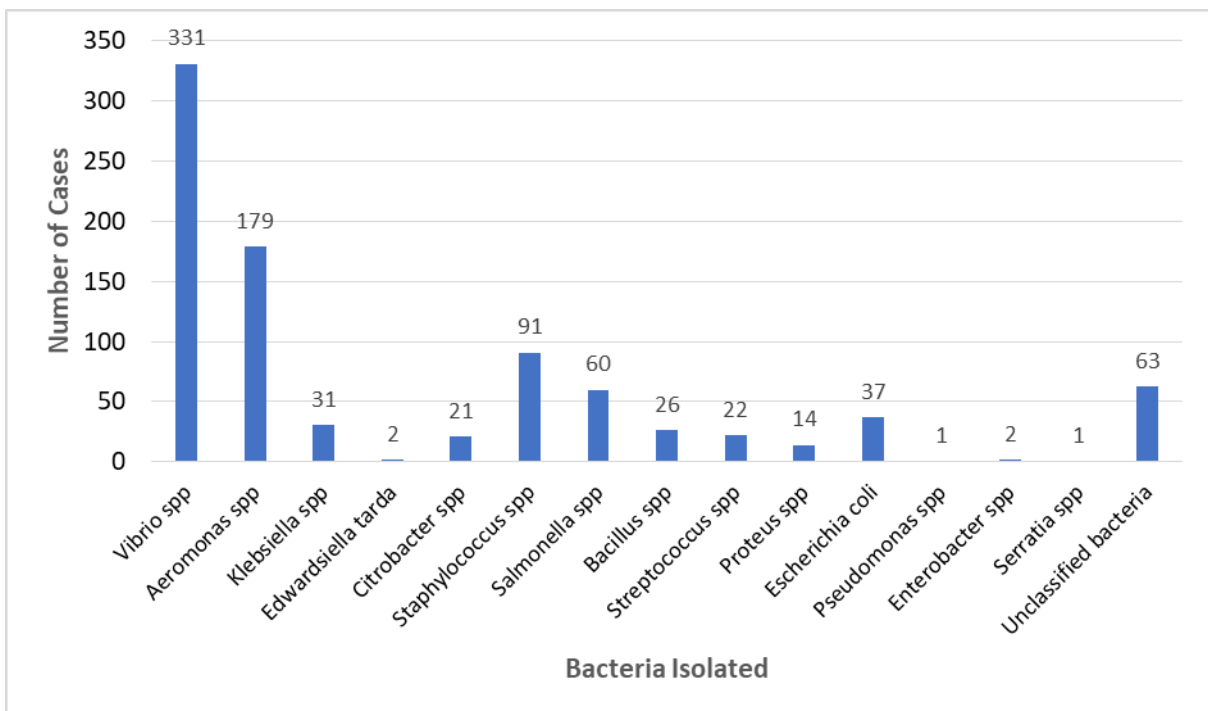
**Figure 3: Number of cases handled during the harmattan and rainy seasons**

The spike in 2015 was due to an unprecedented number of cases found to be affected with the parasite *Piscicola geometra*.



**Figure 4: Trends in Nature of Infections**

*The spike in 2015 was due to an unprecedented number of cases found to be affected with the parasite *Pisciola geometra*.*



**Figure 5. Number of fish cases from which bacteria were isolated between 2013 - 2015**

## 8.6. Legal and Policy Frameworks

Broadly speaking, the current aquaculture, animal health and environmental management policies and regulations promoted the control of aquaculture AMU/AMR. However, there were weaknesses which if addressed, could provide a robust foundation for aquaculture AMU/AMR stewardship and surveillance (table 24).

**Table 24: SWOT analysis of current polices, regulations and institutional capacity for aquaculture AMU/AMR control**

<p><b>Strengths</b></p> <ul style="list-style-type: none"> <li>• In line with current government policies</li> <li>• Involvement of producers</li> <li>• The One Health approach has been adopted by all the health sectors, including the Fish Health Department</li> <li>• Participation of farmers</li> </ul>	<p><b>Weaknesses</b></p> <ul style="list-style-type: none"> <li>• Currently fish health monitoring plan does not comprehensively cover entire country</li> <li>• Strengthen functional linkages between the different departments</li> <li>• Current status of diagnostic facilities and other resources limits the ability to comprehensively and routinely undertake surveillance</li> <li>• Current policies do not directly address AMU/AMR needs in aquaculture</li> </ul>
<p><b>Opportunities</b></p> <ul style="list-style-type: none"> <li>• Existence of diagnostic capacity (laboratories, personnel)</li> <li>• Collaboration between different departments</li> <li>• Existence of both public and private sector laboratories that diagnose aquatic animal diseases which creates opportunity for establishing PPPs</li> <li>• Policies and regulations can be updated to reflect the AMU/AMR concerns of the aquaculture sector</li> </ul>	<p><b>Threats</b></p> <ul style="list-style-type: none"> <li>• Inadequate number of available trained field staff in both public and private sector</li> <li>• Currently no comprehensive National Strategy for Aquatic Animal Health which makes it difficult to ensure adequate resources are secured for biosecurity control and AMU/AMR – likely to affect sustainability</li> <li>• Currently no LIMS, i.e. National Reference Laboratories for Aquatic Animal Diseases in the country.</li> </ul>

## 8.7. Stakeholder engagement on AMU/AMR control

The sectors stakeholders contribute to the risks associated with aquaculture AMU/AMR. The sectors stakeholders must therefore be fully involved for the successful implementation of any initiatives instituted for the control of aquaculture AMR (Table 25).

**Table 25: Factors likely to cause antimicrobial resistance in aquaculture production and marketing**

Risk Factors for AMU/Aspects to monitor	Issue	Key Stakeholders
<b>Horizontal transfer</b>	<ul style="list-style-type: none"> <li>- Indiscriminate use</li> <li>- Current disposal practices</li> </ul>	<ul style="list-style-type: none"> <li>- Fish farmers</li> <li>- Fish processors and traders</li> <li>- Livestock and poultry farmers</li> </ul>
<b>Sub-therapeutic doses or overuse of antibacterial agents</b>	<ul style="list-style-type: none"> <li>- Prophylaxis</li> <li>- Self-diagnosis by farmers</li> <li>- Non-prescribed treatments</li> <li>- Targeted species for formulations used</li> </ul>	<ul style="list-style-type: none"> <li>- Fish farmers</li> <li>- Fish processors and traders</li> <li>- Feed manufacturers</li> <li>- Advisors (veterinarians and extension agents)</li> </ul>
<b>Sub-standard therapeutics</b>	<ul style="list-style-type: none"> <li>- Drug quality control</li> <li>- Recommended drugs and feed additives</li> <li>- Targeted species for formulations in market</li> </ul>	<ul style="list-style-type: none"> <li>- Veterinary input suppliers</li> <li>- NAFDAC</li> <li>- FMARD</li> </ul>
<b>Manufacture and use of medicated feed</b>	<ul style="list-style-type: none"> <li>- Leeching of antimicrobial agent from feed</li> <li>- Dosage rates used</li> <li>- Methods used for feeding medicated feeds*</li> </ul>	<ul style="list-style-type: none"> <li>- Farmers</li> <li>- Feed manufacturers</li> <li>- NAFDAC</li> <li>- Advisors (veterinarians and extension agents)</li> </ul>
<b>Acquisition and spread on antimicrobial resistant bacteria through the environment</b>	<ul style="list-style-type: none"> <li>- AMU practices in poultry and livestock</li> <li>- Disposal of unused antimicrobials</li> <li>- Effluent management</li> <li>- Environmental management (land use patterns and climate change)</li> <li>- Residues – influent and effluent water, fish products, feeds</li> </ul>	<ul style="list-style-type: none"> <li>- Animal producers</li> <li>- Veterinarians</li> <li>- Feed manufacturers</li> <li>- FMARD</li> <li>- NAFDAC</li> <li>- Environment management authority</li> </ul>

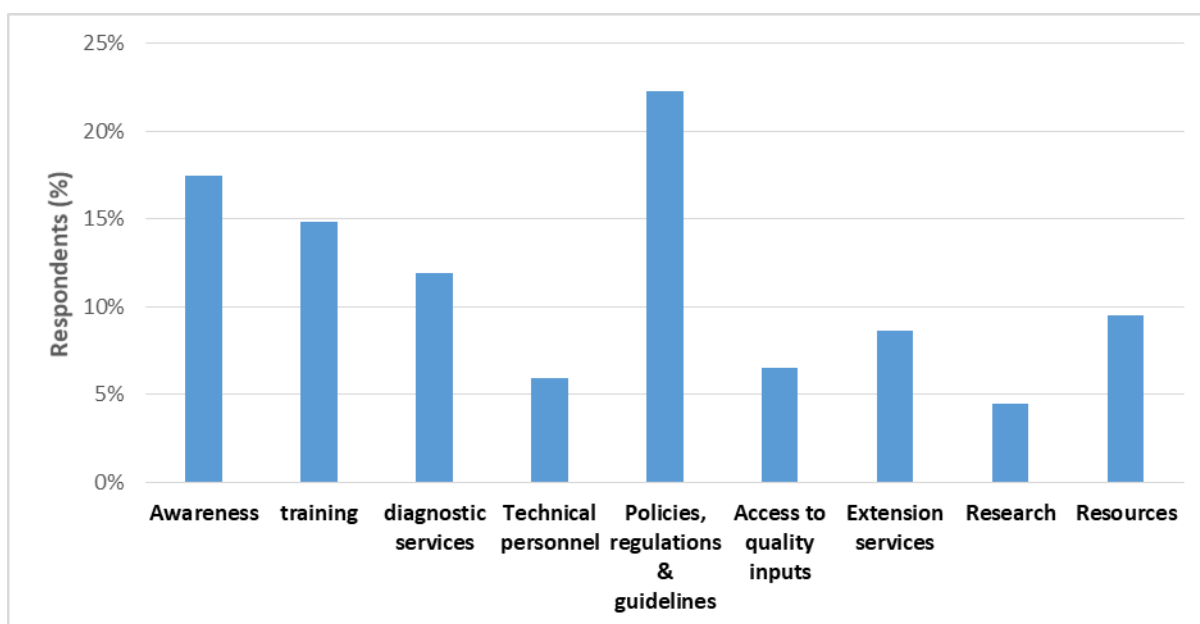
*\*Infected fish often have poor appetite and poor digestibility. Uneaten feeds would go straight into the environment. Undigested drugs associate with the feed and approximately 70-80% of undigested drug pass into environment in unabsorbed form in feces or after absorption, in secreted forms in urine and other secretions, then deposit in the pond sediment (Anyanwu and Chah, 2016).*

## 9. Recommendations: Options for Strengthening AMU/AMR Control in the Aquaculture Value Chain

Strengthening One Health AMU/AMR control across the aquaculture value chain requires:

- Building the capacity of the Veterinary and Aquaculture and Fisheries Departments at Federal and State level, VCN and NAFDAC to create public awareness on aquaculture AMR.
- Strengthening capacity for undertaking One Health aquaculture AMR surveillance and research in the Veterinary Departments at Federal and State level, Faculties of Veterinary Medicine, National Veterinary Research Institute and Institutes of Fresh Water Fisheries
- Strengthening capacity infection prevention and biosecurity control among Veterinary Departments at Federal and State level
- Improving access to diagnostic services and aquatic veterinary services by strengthening the capacity of the Veterinary Departments at Federal and State level, VCN and NVMA to provide these services.
- Strengthening curricula in training institutions, policies and local human resource development for AMR across all levels. This includes building the capacity of the Veterinary Departments at Federal and State level and VCN to develop and supervise standards for the delivery of professional aquatic veterinary services and for aquatic animal health and welfare.
- Strengthening the capacity Veterinary Departments at Federal and State level, VCN and NAFDAC to supervise, monitor and control the distribution and use of veterinary drugs in aquaculture in order to promote the prudent antimicrobial use, responsible disposal of antimicrobials used in aquaculture and develop and implement an aquaculture Residual Monitoring Plan. The latter will be implemented in collaboration with the Federal and State Fisheries and Environmental Departments.

Stakeholders were asked to give their views on what interventions should be made to control of aquaculture AMU/AMR. **Error! Reference source not found.** shows below shows what the sectors stakeholders viewed as priority actions.



**Figure 6: Respondents' recommendations for the control of AMU/AMR**

The specific recommendations for strengthening AMU/AMR control in the aquaculture value chain:

1. **Monitoring and control of antimicrobials used in the aquaculture value chain is key.** A legal and policy framework that support the monitoring and control of AMU in aquaculture fortunately already exists. The implementation of the current policies, regulations and government programs for aquaculture biosecurity and phyto-sanitation should be strengthened by strengthening the capacity for passive and active AMU/AMR surveillance of across the aquaculture value chain and the environment.

The key components to implement this are:

- a. **Registration of fish farmers and maintaining the national database on fish farmers, aquaculture practices, fish diseases and antimicrobial use on farms.** It would be important to include the location of aquaculture establishments to permit spatial analyses of fish disease and aquaculture AMU/AMR prevalence and AMU/AMR risk.
  - b. **Monitoring and controlling access to and the use of antimicrobials.**
  - c. **Improving disease detection and laboratory diagnostic capacity, record keeping and reporting across all levels.** From farm, practitioners, feed manufacturers, input suppliers, laboratories, veterinary drug suppliers and pharmacies, farmed fish processors and traders, and channeled to the FMARD.
  - d. **Improve stakeholder engagement, stewardship and public awareness.**
2. **Review and strengthen the current aquaculture policies and regulations to ensure that they specifically address the needs for AMU/AMR in aquaculture.** Government should be more committed to regulations, standardization, and exposing Nigeria's farmed products to achieve industry benchmarks set by countries that have

successfully implemented AMU/AMR controls in aquaculture. Access to, control of, and use of antimicrobials needs to be restricted and closely monitored.

3. **Strengthen the implementation of policies and regulations to address stakeholder concerns on the high prevalence of poor quality fish feeds, feed ingredients, and drugs on the market.** This was found to be among the drivers for the extra-label use of antimicrobials among farmers and feed manufacturers. The extra-label use of antimicrobials was done as a mitigation measure against poor performance arising from the use sub-standard inputs and drugs. The effective implementation of existing regulations governing the production, distribution and use of these key inputs was necessary for preventing routine prophylaxis.
4. **Address the major drivers for current AMU malpractices by farmers, notably the economic benefits and challenges associated with access to drugs, veterinary and laboratory services.** Addressing this would entail:
  - a. **Undertaking cost-benefit analysis of current production practices and recommended disease control measures.**
  - b. **Building capacity among farmers and support services to improve fish disease diagnosis and reduce incidences of disease on-farm.** The latter requires a holistic approach that addresses biosecurity on-farm, environmental concerns, fish feeds and marketing options to reduce fish stress and provide alternatives to the use antimicrobials for the prevention of diseases (e.g. probiotics, vaccination). In addition to developing and disseminating guidelines, appropriate research to establish determinants of disease, risk factors and develop the most appropriate cost-effective biosecurity control and treatments options for the sector should be prioritised.
  - c. **Implementing multi-disciplinary national surveillance on fish disease status, AMU and AMR** following a one-health approach.
5. **Build awareness of AMU/AMR in the aquaculture sector among all stakeholders and the public.** Stakeholders need be made aware of and equipped with the skills and resources (institutional, financial, information) they need to play their roles effectively for AMR stewardship. Of key concern is limited involvement of veterinary and animal diagnostic laboratories in aquaculture health management and biosecurity control. Curricula at both National Diploma and undergraduate degree level on fisheries and aquaculture, animal health, and veterinary medicine need be strengthened to address this gap.
6. **Provide financial and operational resources.** Systematic and sustained investment is needed for effective monitoring, control, surveillance and AMU/AMR information sharing. Public guidelines and standard operating procedures need be developed and disseminated; technical personnel need equipping with the necessary diagnostic tools; laboratories need to be well equipped; and government extension or veterinary personnel better enumerated. Providing these resources will reduce stakeholder costs and make standardized diagnostic and other AMU services more accessible to producers.

7. **Expand the fish disease diagnostic laboratory capacity and network to increase coverage.** This is essential if services are to be accessible and responsive to local fish health and food-safety challenges. To scale up rapidly, consideration should be given to upscaling and integrating private sector and other public sector animal diagnostic laboratories (in tertiary and research institutions) to provide basic (level I and II) diagnostic services. A business model within which diagnostic services can be provided sustainably at an affordable cost by such laboratories would have to be considered.
  
8. **The creation of an Aquatic Animal Health Department within The Department of Veterinary and Pest Control Services in the Federal Ministry of Agriculture and Rural Development.** The purpose of this is to streamline operations, and standardize best practices in AMR surveillance and control across all the different animal food production value-chains in Nigeria. The approach will also serve to strengthen the implementation of One Health comprehensively across all the facets of Nigeria's animal production sector.

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## Appendices

### Appendix 1. Checklist for Key Informant Interviews

#### A3.11 SECTOR MANAGERS/REGULATORS (fisheries/aquaculture, environment, veterinary, human health and markets/trade)

The information sought from these includes:

- (i) Current policies and regulations affecting aquaculture production and marketing, aquatic animal health, drugs, foods safety and environmental management. Status reports if any.
- (ii) Templates or protocols of data collected and how frequently monitoring may be done
- (iii) Fish health and fish farm certification protocols
- (iv) Lab records and protocols (e.g. fisheries laboratory Lagos, Ibadan University, etc)
- (v) Observations of trends
- (vi) Suggestions for establishing and operating an aquatic species AMR surveillance

### Appendix 2: Report of Online Aquatic Stakeholder Meeting 5th August 2020

#### Executive Summary

There is growing concern globally, over the increased prevalence of Antimicrobial Resistance (AMR) associated with animal food value chains. The global framework for addressing this, hinges on the One Health approach and is set out in the tripartite Global Action Plan (GAP). The Government of Nigeria, under the auspices of the Nigeria Centre for Disease Control (NCDC) has also embarked upon addressing AMR in Nigeria's animal food value chains. A Country Grant was subsequently obtained from the Fleming Fund, to strengthen national capacity for AMR surveillance and control. Aquatic species were among the identified priority animal food value chains for this support.

It is a prerogative, that any established AMR surveillance system be robust in compliance to international standards and should also address the objectives of Nigeria's AMR National Action Plan and the GAP. Effective implementation and sustainability are additional key parameters. Hence, the Political Economic Analysis (PEA) was adopted as the preferred approach for establishing a foundation for aquatic species AMR surveillance in Nigeria. The approach was adapted to suit Nigeria's local context and an aquatic species PEA framework drawn. Given the rapid growth of the aquaculture sector where scanty information is available on antimicrobial use (AMU), it was agreed initially aquatic species surveillance should focus on aquaculture.

The PEA advocates stakeholder involvement and ownership in all steps of any action. A stakeholder consultative meeting to share stakeholder experiences and thus review the draft aquatic species PEA framework was set-up. A total of 23 stakeholders representing the Federal Department of Fisheries, Livestock Management Services, the private sector, academia, and DAI participated in this meeting.

The major outcomes of this meeting were:

- (i) The adoption of the PEA approach for establishing the foundation for an aquatic species AMR surveillance system in Nigeria was supported.

(ii) In view of their likely impact for the establishment, effective implementation and sustainability of an aquatic species AMR surveillance system, the status of the following were identified as key areas for evaluation during the PEA:

- *Public awareness and sensitization of stakeholders* (also being a priority initial action)
- *Surveillance of farm aquatic animal health status*
- *Status of reporting on aquaculture*
- *Access to and use of antimicrobials*
- *Certification of aquaculture establishments*
- *Residue Monitoring and Control*
- *Quality of and access to aquatic veterinary services*
- *Diagnostic laboratory Services*
- *Food-safety -*
- *Training of personnel and producers in best practices*
- *Policy and Legislation Appropriate legislation.*
- *Establishing networks*

It was also agreed that the presentation and draft PEA framework be shared with participants for their final input.

### **Background and Introduction**

There is growing concern globally on the rising prevalence of Antimicrobial Resistance (AMR) and its implications for food-safety, human health, animal health and ecosystem health. An important pathway for AMR is through food value chains. Antimicrobials used in animal production, for example, largely belong to the same families as those used in humans. Residues often find their way into the environment and over time become part of the AMR cycle. In order to abate the development and prevalence of AMR globally, the Global Action Plan (GAP) against AMR was jointly developed by the World Health Organization (WHO), Food and Agriculture Organization (FAO) and the World Animal Health Organization (OIE) as a One Health initiative. To this end, the Global Antimicrobial Resistance Surveillance System (GLASS) was developed as a harmonized tool to support countries monitor and control AMR and to facilitate comparative analyses of global status.

In compliance to the GAP, the Government of Nigeria conducted a situation analysis of the country AMR status under the auspices of the Nigeria Centre for Disease Control (NCDC). The situation analysis found that Nigeria's AMR status was broad, highly prevalent in humans, livestock, and the environment. In addition, chronic and community acquired diseases in humans were caused and treated by similar pathogens and antibiotics as domestic animals. Consequently, the National Action Plan for Antimicrobial Resistance (2017 – 2022) (NAP) was developed to reduce, prevent, and slow the evolution of antimicrobial resistant organisms and their impact on health care. The NAP recommended the establishment of an AMR surveillance system that integrates all One Health sectors if the objectives of the NAP and GAP are to be achieved.

Aquatic species play an important role in Nigeria's food value chain. However, domestic supply is inadequate. Imports of fish to supplement domestic supply are on the increase. Despite this, supply is still not adequate to cover the country's growing deficit for fish that is estimated at 2.2 million metric tons. Aquaculture is consequently being promoted to offset the deficit in domestic supply. Aquaculture production contributes 30% of domestic fish supply but the Nigeria National Aquaculture Strategy envisages that this contribution can be doubled if the sector's full potential of 2.5 million tons is fully realized. The prevailing environment has propelled commercial aquaculture

development whereby more intensive production systems have been adopted and antimicrobial use (AMU) by farmers is on the rise. While there are some reports, the true extent and scope of AMU and AMR in Nigeria's aquaculture sector is not known. This makes it a risk for AMR especially if appropriate control measures in line with the NAP are not instituted for the sector. Aquaculture was therefore identified as among the priority animal food value chains for which an AMR surveillance system need be established by the NCDC and respective line ministries.

A Country Grant was subsequently obtained from the Fleming Fund to strengthen national capacity for AMR control in prioritized animal food value chains. The specific objective of the grant for aquatic species was to establish a foundation for AMR surveillance in aquaculture species. The expected outputs are:

- (i) A situation analysis of AMR diagnostic capacity, and
- (ii) A population-based AMR aquatic species surveillance system to generate data on resistance in aquatic species and pathogens relevant to human health.

In view of the fact that, the amount and quality of information available to support such an action was limited for aquaculture, the Mott MacDonald tool whose basis is the Political Economic Analysis (PEA) was adopted to guide the process. A framework to guide the process of establishing the proposed aquatic species AMR surveillance system for Nigeria using the PEA was developed as among the first steps for this assignment. This analytical tool has been adopted to develop a similar aquaculture AMR surveillance mechanism in Bangladesh.

The PEA uses methods from economics, sociology, and political science to understand how economic processes, political policies, and social institutions influence and affect the management and performance of policy, programs, and practice within sectors. They were not meant to be exhaustive nor prescriptive; but rather flexible and simple. The major objective a PEA framework was to facilitate a deeper understanding of local sectors and of how policy arenas function in order to identify entry points for development action. A deep sector analysis is consequently achieved whereby stakeholders themselves are empowered to identify the opportunities, issues and drivers for change and therefore develop comprehensive strategic actions to institute the desired changes. PEA normally follows a three-stage process:

- (i) A country analysis that establishes the status and foundations of the sector and issues at hand.
- (ii) A sectoral analysis to obtain an understanding of the organizations, institutions, and actors within the sector and how their structural features, power roles and ideologies drive and influence change in the sector.
- (iii) Definition the entry points for action, the objectives, and expectations of proposed actions as well as modes of implementation and support for the recommended actions.

### **Purpose of the Meeting**

The purpose of the meeting was to review the draft AMR aquatic species PEA framework with sector stakeholders to ensure it is well adapted to Nigeria's local context, and that the envisaged outcomes for the NAP and ultimately GAP could be achieved in a manner that also advanced the objectives of Nigeria's National Aquaculture Strategy.

### **Specific Objectives of the Meeting**

The specific objectives of the meeting were to:

- (i) Obtain stakeholder input into the proposed PEA framework for establishing a foundation for aquatic species AMR surveillance in Nigeria.
- (ii) Share stakeholder experiences and lessons learnt on AMU and AMR within the sector.

## **Methodology**

Twenty-three participants attended the meeting from government departments, the private sector and academia. The meeting was conducted online.

The meeting was opened with remarks given by officials from the donor DAI, Livestock Management Services (LMS) and the Federal Departments of Fisheries and Animal Health. Ms. Blessing Stephen on behalf of DAI gave an overview of the Fleming Fund Country Grant to Nigeria whose overall objective was to strengthen capacity for AMR. Dr. Bala Mohammed, the Animal Health Leader from LMS provided a general overview of the overall status of animal health and AMU and AMR within the animal production sector. He also facilitated the meeting.

Dr. Pwapso, the Director of Aquaculture from the Federal Department of Fisheries and Dr Dupe Ogunnoiki the National OIE Aquatic Animal Health Focal Point provided an overview of the national status of aquaculture development and aquatic animal health management, respectively. Dr. Dupe mentioned that Nigeria had embarked on efforts to address AMR in aquaculture about 10 years ago for which there had been some gains (see Annex 1 for the meeting agenda).

A power-point presentation that provided an overview of the proposed AMR aquatic species PEA framework was then delivered by the consultant after which the plenary was opened for discussion.

## **Outcomes of the Meeting**

The participants appreciated and supported the proposed PEA framework as the approach to be used for establishing a foundation for AMR surveillance within the aquaculture sector. They however noted that since the level of public awareness was extremely low on AMR in aquaculture, it would be important that sensitization of producers and the public be brought to the fore front in the proposed aquatic species PEA framework. The benefit of this would be that when field work and stakeholder consultations commenced, the public would be aware and more co-operative.

The following is a summary of what participants viewed as being the status, opportunities, and envisaged challenges for establishing an aquaculture AMR surveillance system based on their experiences working with aquaculture policy, producers, and aquatic animal health:

- *Surveillance of farm aquatic animal health status* – Programs on aquatic health in the Federal Department of Fisheries were instituted about ten years ago. The aquatic animal health unit has developed a checklist that is used guide its staff when monitoring fish health status on fish farms. It was intended the fish farms in all states be regularly monitored. However, due to resource constraints, monitoring has so far been done in a couple of states, of which Lagos State was among. The major technical challenges they faced for the effective implementation of the monitoring plan were:
  - (i) The lack of laboratory and field diagnostic kits to support accurate diagnosis and prescription of treatments, and
  - (ii) Poor record keeping among producers, service providers and other stakeholders along the value-chain.
- *Status of reporting on aquaculture* - There was under-reporting in the sector. It would therefore be important to conduct in-country stakeholder consultations and a survey to

ascertain more comprehensively the status of the industry in terms of aquaculture production and fish health during the PEA.

- *Access to and use of antimicrobials* - The country did not have its own approved drug list. It relied on the drug list recommended by FAO for aquatic species. Most of the drugs officially approved were already captured in the aquaculture regulations. This notwithstanding, it was common knowledge that farmers had access to and used unapproved drugs. The sources and distribution channels of these were not officially known. Furthermore, there were 'home grown' treatment regimens used by farmers for disease control. Hence, the situation analysis and survey need generate data and information on:

- (i) The sources, distribution and administration of all drugs used by farmers in the aquaculture value-chain
- (ii) Procedures used by service providers and farmers to diagnose diseases as well as the treatment regimens used for conditions described.
- (iii) Assess how drugs are used or misused

The data generated on the access to and use of drugs should help address the following for AMU/AMR surveillance:

- (i) The harmonization and standardization of valid 'home grown' treatments (as well as all others) against national and international standards
- (ii) Nationally standardization and approved protocols for the diagnosis and control of aquatic animal diseases and biosecurity
- (iii) Up-dated information and a database of sources, distribution channels and service providers in this aspect of the value-chain. This would help streamline and monitor service provision in accordance with official guidelines and requirements of the NAP.

- *Certification of aquaculture establishments* – A certification policy was put in place in 2009. Standards and guidelines for all fish farmers willing to certify their farms were already in place. These guidelines were being used for inspection. However, there was need for building the capacity of inspectors. The guidelines would also need to be up-dated based on the NAP and outcomes of the PEA.
- *Residue Monitoring and Control* - A program on residue control in the animal sector had been developed. During the process of its development, several of lessons learnt were captured in the progressive reports submitted in 2016 and 2018. These lessons would be useful for the aquatic species AMR situation analysis. There was now a residue monitoring plan in place however the drawback was no fixed separate budget line to ensure regular residue monitoring. This has affected implementation. The aspect of securing resources for aquatic species AMR surveillance should not be ignored during the situation analysis.
- *Quality of and access to aquatic veterinary services* - A major concern for the provision of aquatic veterinary services to farmers was 'Who are professionals being engaged by producers in the sector?'. Farmers faced difficulties in getting profession help and so resorted to 'self-help' to diagnose and treat fish diseases. Often, they got advice from the wrong experts and thus several farmers had had their 'fingers burnt'. The need for standardizing certification, disease diagnoses and treatment protocols were raised as key concerns.

- *Diagnostic laboratory Services* – The status of aquatic animal diagnostic and food-safety laboratories needed improvement if they were to get accreditation and become ISO certified. Currently samples had to be sent for testing overseas whenever fish was destined for export. This was costly and time consuming. It would be more beneficial for the sector and for the implementation of biosecurity and AMR measures, if fish health and food quality laboratory services were locally available.
- *Food-safety* - The issue of food-safety was very pertinent when one considered farm practices which prompted the question ‘*What are fish farmers actually giving Nigerians to eat?*’. The capacity for fish-safety control along the entire spectrum of the aquaculture value-chain was necessary.
- *Training sector personnel, service providers and producers* - to build their capacity to adopt and implement best practices, including for AMR surveillance was key. The status of skills/needs assessment needed to be integrated into the PEA.
- *Policy and Legislation Appropriate legislation.* It was recommended that all fish farming activities be aligned with the NAP, LMS and aquaculture guidelines. In practice, this was yet to be fully the case. Another challenge affecting the comprehensive implementation on AMR was the lack of a national aquatic animal health structure. The information generated from the PEA should help inform policy on how best such gaps could be addressed for the benefit of fish health and AMR control.
- *Establishing networks* – It was apparent that there was a gap in the knowledge of stakeholder roles within the sector. Without this knowledge and stakeholder networking, it would practically be impossible to implement AMR surveillance. The outcomes from the stakeholder analysis should enable the development of a stakeholder database.
- *Public awareness and sensitization of stakeholders* - Sensitization and awareness should be brought forward. They were considered critical for the establishment and sustainability of the aquaculture AMR surveillance.

### **Next steps**

1. The presentation and draft PEA framework be shared with participants to receive comments. Comments from this meeting and review of the draft shall be used to finalize the PEA framework as well as input into the situation analysis and design of survey tools.
2. Stakeholder consultation is important.
3. The date for an ensuing stakeholder consultative meeting to review the up-dated draft situation analysis will be set and communicated by DAI.

## Appendix 3: Survey Tools Used

### 3.1. FARMERS QUESTIONNAIRE

Date and Time:

Enumerators Name:

This survey is aimed at improving fish and human health and establishing surveillance system on antimicrobial use/ antimicrobial resistance in aquatic species in Nigeria. It will take about 30 minutes of your time to fill. Thank you for your cooperation.

I .....agree that purposes for which this survey is being undertaken, has been duly explained to me in a language that I understand, and assured of confidentiality of any information passed on to the research team. Based on this, I agree to take part in the survey and understand that the data collected will only be used for the purpose stated therein.

Phone number:

Farmers Signature:

Date:

\*\*\*\*\*

1. Questionnaire No.

2. Location of Farm (*GPS, physical address, town and state*)

#### Farmers Profile

1. Age (years) of farm owner \_\_\_\_\_
2. Gender of farm owner: **Male** [  ] **Female** [  ]
3. Highest Level of education achieved? **None** [  ] **Primary** [  ], **secondary** [  ] **tertiary** [  ] **Other** [  ]
4. What is the name of your farm? \_\_\_\_\_
5. When did you start farming fish? \_\_\_\_\_
6. Is the farm run as a family business or registered enterprise? **Family** [  ] **Registered Business** [  ]
7. Do you employ or rely on family labor? (*full time, part-time or both*). Tick the box in the table below

Source of Labour	Full-time	Part-Time
Family		
Hired		

\*Describe tasks done in each category

8. Is it you who runs the farm? **Yes** [  ] **No** [  ]
9. If not run the farm, who does? **Manager** [  ] **family member** [  ] **other** [  ]
10. Has the manager/person running the farm received any specific skills training in fish farming? **Yes** [  ] **No** [  ]
11. If yes, in which topics have you obtained skills/information and who provided it to you? **Please tick the appropriate box**

Source of Skills/Information	Yes/No	Internet	Fisheries extension/vet	Other farmer(s)	Training Center/Univ	Did you have to pay (Yes/No)	Amount Paid (Naira)
Feeding fish							
Water quality management							
General fish farm maintenance							

Record keeping							
Fish health management							
Treatment of fish (administering drugs)							
Post-harvest handling/processing							
Marketing							

Additional comments if any: \_\_\_\_\_

12. Are you a member of any association/network? **Yes** [ ] **No** [ ]

13. If you are a member of an association, please mention the name and type of organization you belong to?

**Name of Association:** \_\_\_\_\_

**Type of organization:** Fish farmers [ ] mixed farmers [ ] traders/market [ ], professional [ ]

**Production System**

1. What is the production focus of your fish farm and which species do you raise? *Please tick appropriate box.*

Species raised	hatchery	Grow-out	Both
Tilapia			
African Catfish			
Other catfishes/hybrids			
Shrimp			
Other species _____			

2. Do you also raise other and crops on the farm? **Yes** [ ] **No** [ ]

*Please name them* \_\_\_\_\_

3. Which culture and production methods do you use? *You may tick more than one*

Ponds		Tanks		Cages
Static water		Static water		
Flow through		Flow through		
extensive		RAS		
Semi-intensive		hapas		
monoculture				
polyculture				
Integrated aquaculture				
hapas				

4. Which inputs do you use?

Inputs	Source	Average cost
broodstock		
fingerlings/fry		
feeds		
drugs		
disinfectants		
Inorganic fertilizers		
manures		

5. What is your average annual production? \_\_\_\_\_

6. Where do you source your water for farm use? **River** [ ] **Borehole** [ ] **Spring** [ ] **Lake** [ ] **Dam** [ ] **roof-top** [ ] **Swamp/wetland** [ ] **Tap water** [ ] **Deep well** [ ] **Stream** [ ] **Others** \_\_\_\_\_

7. Mention and describe other activities found upstream or around your farm?

8. Does effluent/water from these places drain into your farm water source(s)?

**Yes** [ ] **No** [ ] **Do not know** [ ] .

*If yes, please explain* \_\_\_\_\_

**Biosecurity Measures on Farm**

1. What measures do you take to:

(i) ensure diseases or pests do not enter or leave your farm \_\_\_\_\_

(ii) affect the fish or your water sources \_\_\_\_\_

(iii) spread on the farm? \_\_\_\_\_

(e.g./also mention/note diseases, treatments, disinfection regimes, vaccinations, pre and probiotics, diets/feed additives, etc.)

2. What investments have you had to make for this(these) (e.g. fencing, screens, the costs, isolation units, etc.)?
3. How do you dispose of dead or sick fish/animals? **Bury** [  ] **Burnt** [  ] **Thrown into drainage** [  ] **Fed to other animals/fish** [  ] **Thrown into bush** [  ] **Open rubbish pit** [  ] **Nothing** [  ] **Other** [  ]
4. How do you handle *predators and other non-targeted/wild animals/fish inclusive*?
5. Do you keep farm records on production, fish health, treatments used, their costs? If so, what is contained in the respective records?

Records kept	Frequency ( <i>daily, weekly, monthly, irregular, never</i> )	Content ( <i>circle/tick as appropriate or add an extra</i> )
Production (unit)		<i>Species stocked, age, Fertilization, aeration, stocking, harvest, sampling - growth, etc.</i>
Feeding		<i>Feed type, quantity consumed, feeding response</i>
Water quality		<i>e.g. O<sub>2</sub>, NH<sub>3</sub>, Temperature, flow rate, etc.</i>
Fish health, diseases, treatments		<i>Species, symptoms, number affected, mortality, diagnosis/disease, treatment given, etc.</i>
Financial		<i>Expenses and income</i>

### Antimicrobial Use on Fish

1. Do you give antimicrobials to fish on farm? **Yes** [  ] **Sometimes** [  ] **Never** [  ]
2. When do you use them? \_\_\_\_\_
3. What makes you decide whether to use antimicrobials? \_\_\_\_\_  
**Disease/sick** [  ] **Cost of medication** [  ] **reduce mortality** [  ] **reduce spread** [  ] **improve growth rate** [  ]
4. Do you engage the services of laboratories before using antimicrobials? **Yes** [  ] **No** [  ]
5. Can you please provide a record of your use of antimicrobials (which (brand), when, how much, why, how did you use or give them to the fish, where did you get information on how to use the antimicrobials)?
6. Where did you get the recommendation and/or information on how to use the antimicrobials you have mentioned?
7. How do you administer antimicrobial treatments? (*fish, water, feed, post-harvest handling, processing, market*)
8. Do you sell or distribute fish you have treated? **Yes** [  ] **No** [  ]
9. Do you observe withdrawal periods? **Yes** [  ] **No** [  ]
10. How do you dispose of the water/medium through which you administered the anti-microbials?
11. How do you dispose of antimicrobials you no longer need or have expired?
12. How to you store antimicrobials on the farm? **Yes** [  ] **No** [  ]
13. Who has access to the antimicrobials? \_\_\_\_\_
14. Who is responsible for administering antimicrobials or can any of the personnel do it? *Please explain.*
15. What benefits have you obtained by occasionally or regularly using antimicrobials in your production and marketing (*e.g. yields, survival, profits, shelf-life, appearance of product, taste, reduction of disease spread or severity, etc.*)

### Antimicrobial Resistance

1. Have you ever experienced situations where your antimicrobial of first choice did not work? **Yes** [  ] **No** [  ]
2. *Please explain what happened and how you overcame the challenge. Also mention the antimicrobials or any other pharmaceutical or management measures you took to address this challenge.*
3. How many times/how often have you experienced treatment failure?
4. Whom did you approach for advice on how to overcome treatment failure?
5. Please describe the production, cost and other consequences you have experienced as a result of the treatment failure(s)?

### Post-Harvest Handling and Marketing

1. Describe how you handle fish after harvest? \_\_\_\_\_
2. What facilities/equipment do you use for harvesting, post-harvest handling and transportation of products?
3. Are there sanitary or other measures you employ during this process? **Yes** [  ] **No** [  ]  
*Please describe (e.g. where you source water, is it filtered/screened, disinfect nets between use, etc.).*
4. Do you add antimicrobials to fish water during transportation or marketing? **Yes** [  ] **No** [  ]
5. If you yes in (4) above, why? \_\_\_\_\_

6. Where do you sell your fish? \_\_\_\_\_
7. Which farmed fish products do you produce for sale? (e.g. live fingerlings, live table fish, fresh whole, fillets, chilled on ice, smoked, etc.). which inputs and ingredients go into their processing or storage for market?

Product	Species	Input/ingredient post-harvest
Live fingerlings		
Live table fish		
Fresh whole		
fillet		
chilled		
smoked		
other		
other		

8. Are there standards your client or the state demands of your produce or products?  
Yes [ ] No [ ]
9. If so, please mention them \_\_\_\_\_
10. How do you meet these standards? \_\_\_\_\_
11. Do you process fish on your farm? Yes [ ] No [ ]
12. If so, where do you source the water used in handling, processing, and packaging fish for sale after harvest?
13. What are the costs of these (i.e. items in your enterprise budget – inputs, sales, etc.).

#### Disposal of Effluent/Wastes and Environmental Management

1. How do you dispose of the waste or water from your production, post-harvest handling and marketing units/activities? \_\_\_\_\_
2. Are you aware of any government guidelines on these? Yes [ ] No [ ]  
Mention them and the ones you implement?
3. What investments have you had to make to implement these guidelines?
4. How has implementing/following these guidelines benefited your operations, access to markets, community, etc.?

#### Sources of information and service delivery

1. Where do you get information, specific skills training, and/or technical support on the different specific aspects (production, marketing and market information, fish health control, government regulations and standards, etc.)? (e.g. other farmers, newspapers, internet, social media, feed manufactures, agro-input dealers, extension workers, veterinarians, consultants, radio, associations, institutions, etc)

Please tick.

Source of Information	production	Marketing/market information	Fish Health and Biosecurity control	antimicrobial use	Environmental issues	Government regulations /standards
Other farmers						
News papers						
internet						
Social media						
Feed manufacturers						
Agro-input dealers						
Extension workers						
Veterinarians						
Consultants						
Radio						
Associations						
Institutions (training colleges, universities)						
NGO's						

Other						
-------	--	--	--	--	--	--

2. How much does it cost you to get information or training from the sources you mention?
3. Is the information readily accessible? **Yes** [  ] **No** [  ]
4. What are your comments on the status of information and availability of information and technical support? (*include suggested recommendations for challenges met*)

**General Comments**

1. In your own words, what is your understanding of AMU/AMR and its relevance to your business? and to society?
2. What do you think you can do? Or the community can do to control it?
3. Do you have any other questions/comments?

### A3.2. FEED MANUFACTURERS

Date and Time: \_\_\_\_\_

Enumerators Name: \_\_\_\_\_

This survey is aimed at improving fish and human health and establishing surveillance system on antimicrobial use/ antimicrobial resistance in aquatic species in Nigeria. It will take about 20 minutes of your time to fill. Thank you for your cooperation.

I .....agree that purposes for which this survey is being undertaken, has been duly explained to me in a language that I understand, and assured of confidentiality of any information passed on to the research team. Based on this, I agree to take part in the survey and understand that the data collected will only be used for the purpose stated therein.

Company's Name: \_\_\_\_\_

Respondent's phone no.: \_\_\_\_\_

Signature of Company Representative: \_\_\_\_\_

\*\*\*\*\*

1. Questionnaire No.
2. Location of Farm (*GPS, physical address, town and state*)

#### General Information

1. Which year did you start manufacturing fish feed for producers? \_\_\_\_\_
2. How would you categorize the nature of animal feed producer are you?  
**On-farm feeds** [  ] **small-scale unmechanized** [  ] **medium-scale manufacturing** [  ] **large-scale manufacturing** [  ]
3. Which animal feed products do you produce? *Please list*
4. What is the average annual production (in tons) of each of the feed types you produce? Including overall total?

Type of Feed	Average tonnage produced/year

#### Feed Manufacturing Processes and Products

1. What ingredients do you use and where do you source them from?
2. Do you have a quality control/recording system to track the ingredients used, their source and quality? **Yes** [  ] **No** [  ] *If yes, may we have a look at the records?*
3. Do you add feed additives to the feed? **Yes** [  ] **No** [  ]
4. If yes, which additives do you add, when and why? \_\_\_\_\_
5. Have you ever produced medicated feed for farmers? **Yes** [  ] **No** [  ]
6. If so, for which specific feed products has this been done, when and why?
7. Who gives you the recommendations on the dosing/mixture rates and on how medications should be incorporated into the feed? \_\_\_\_\_
8. Do you have records of medicated feed that has been produced and to whom it has been dispatched/requested for it? **Yes** [  ] **No** [  ] *If yes, may we have a look at the records?*
9. What is typically on your feed labels?
10. Do you label your medicated feeds to show which medication (feed additive) has been added along with specific recommendations for handling, storage and use on farm? **Yes** [  ] **No** [  ]. *Or is this left to the person who gave the specific request to follow-up?*
11. How do you dispose of unrequired ingredients or unused/expired feed additives or medications?
12. Have you ever experienced a situation whereby the ingredients, feed additives or medications you procured for manufacturing feed have been sub-standard? **Yes** [  ] **No** [  ]

13. If so, briefly explain under what circumstances this occurred/or situations under which it most frequently occurs and how you disposed of the respective undesirable ingredients, feed additives, or medications.

#### **Distribution, Marketing and Sales**

1. Who are your major clients that purchase directly from your establishment?
2. Based on your knowledge, what is the geographical reach of the various feed products? (*i.e. states where it is sold/used*) \_\_\_\_\_
3. Typically, how is the distribution done of your feeds to the end-user?
4. Are there any differences in how distribution is done for the different feed-types and clients?
5. Do you have a system of calling-back and disposing of products that may have gone bad/found to be substandard from the market? (*i.e. do you have a traceability system for your feed products?*) **Yes** [  ] **No** [  ]
6. What means are used to bring in ingredients? *Please describe e.g. smallholders may use open bicycles, uncovered pickups, etc.* \_\_\_\_\_
7. What means are used to distribute your products to your clients? *Please describe e.g. smallholders may use open bicycles, uncovered pickups, etc.*

#### **Advisory services given to fish and other farmers**

1. Do you provide advisory services to transporters, agro-input dealers, and farmers on how to handle, store and use the feed? **Yes** [  ] **No** [  ]
2. What feedback have you obtained on your feeds? (*be it positive or negative*)

#### **General Remarks**

1. Do you have additional comments or questions to ask?
2. Based on your experience, what suggestions would you give to abate the misuse of antimicrobials and AMR arising from feed manufacture and use?

**A3.3. VETERINARY INPUT SUPPLIERS (FEEDS, FEED ADDITIVES, DRUGS)**

**Date and Time:**

**Enumerators Name:**

This survey is aimed at improving fish and human health and establishing surveillance system on antimicrobial use/ antimicrobial resistance in aquatic species in Nigeria. It will take about 15 minutes of your time to fill. Thank you for your cooperation.

I .....agree that purposes for which this survey is being undertaken, has been duly explained to me in a language that I understand, and assured of confidentiality of any information passed on to the research team. Based on this, I agree to take part in the survey and understand that the data collected will only be used for the purpose stated therein.

**Company's Name:**

**Respondent's phone no.:**

**Signature of Company Representative:**

**Date:**

\*\*\*\*\*

1. Questionnaire No.
2. Location of Farm (*GPS, physical address, town and state*)

**General Information**

1. What are your qualifications/qualifications of the person who runs the business daily? (*and their name and contact if different from above*) \_\_\_\_\_
2. Describe your clients. (*i.e. are they farmers, which type of farmers, smallholder, large scale, rural/urban, etc.*)
3. What products and services do you provide clients?
4. Are any of these tailored to meet the needs of fish farmers, processors, or traders?  
**Yes [ ] No [ ]**
5. How do you tailor your services to meet the needs of your clients? (*e.g. re-packaging, accessibility to and for clients, use of phones, structure of consultation fees/payments, etc.?*).

**Veterinary Inputs Stocked for Aquaculture**

1. What products do you stock for fish farming and where do you source them from?

Product Sold to Fish Farmers	Source

2. How do you store these items?
3. Of these commodities, which has the highest turnover?
4. Do you have an idea of which type fish farmers use the various commodities and how they use them on-farm?
5. Do you give them advice on the use of these items (including medications)?  
**Yes [ ] No [ ]**.
6. If yes, what sort of advice do you give them?
7. Other than yourself, based upon your knowledge, who else gives advice to fish farmers on which inputs (including medications) to purchase and on their use?

**Veterinary Medicines**

1. In you view/based on your records, what are the most common fish health problems farmers describe to you?
2. How are diseases diagnosed before treatments are recommended?
3. Do farmers come to purchase medications with prescriptions?  
**Yes [ ] No [ ] Sometimes [ ]**
4. May you provide the details of medications prescribed or those fish farmers use when they have fish health problems? \_\_\_\_\_
5. Do you have records on what quantities of medications mentioned above have been purchased to treat fish? **Yes [ ] No [ ]** *If yes, can you please share the information.*

**General Remarks**

1. Do you have additional comments or questions to ask?
2. Based on your experience, what suggestions would you give to abate the misuse of antimicrobials and AMR arising in fish farming in the country?

#### A3.4. FISHERIES/AQUACULTURE EXTENSION OFFICERS

**Date and Time:**

**Enumerators Name:**

This survey is aimed at improving fish and human health and establishing surveillance system on antimicrobial use/ antimicrobial resistance in aquatic species in Nigeria. It will take about 20 minutes of your time to fill. Thank you for your cooperation.

I .....agree that purposes for which this survey is being undertaken, has been duly explained to me in a language that I understand, and assured of confidentiality of any information passed on to the research team. Based on this, I agree to take part in the survey and understand that the data collected will only be used for the purpose stated therein.

**Phone number:**

**Signature:**

**Date:**

\*\*\*\*\*

1. Questionnaire No.

2. Location

#### **Production Practices**

1. What different fish farming systems are practiced in your area of operation?
2. What specific management practices accrue to each of the production systems?
3. Are the fish farmers, processors and traders aware of AMU?  
**Yes** [  ] **No** [  ] **Not sure** [  ]
4. What are the common fish diseases in the area/production system?
5. What diseases control measures are used for each of the disease conditions you have mentioned?
6. Who provides guidance? \_\_\_\_\_
7. In the event that antimicrobials are used, are laboratory diagnostic tests done prior?  
**Yes** [  ] **No** [  ] **Not always** [  ] **Not sure** [  ]
8. Where samples are taken to the lab prior, who collects and takes the samples? **Farmer** [  ] **Extension agent** [  ]  
**Veterinarian/Fish disease specialist** [  ] **Other** \_\_\_\_\_
9. Name the diagnostic laboratories are commonly used by producers in your area?
10. Where do fish farmers tend to source antimicrobials when they use them?
11. Do you know whether or not fish farmers comply with withdrawal periods after treating fish? **They do** [  ]  
**Some do** [  ] **Never do** [  ] **Do not know** [  ] *Explain* \_\_\_\_\_
12. Do you know how fish farmers store and dispose of unused antimicrobials on farm?
13. Are fish farm water sources and effluent routinely monitored for microbial loads or AMR? **Yes** [  ] **Rarely** [  ]  
**No** [  ] **Do not know** [  ] *If monitored, what are the common findings?*
14. Do farmers sometimes need to have their fish tested for bacteria or other residues prior to marketing? **Yes** [  ]  
**No** [  ] *Explain* \_\_\_\_\_

#### **General Comments**

**A3.5. FIELD VETERINARIANS**

**Date and Time:**

**Enumerators Name:**

This survey is aimed at improving fish and human health and establishing surveillance system on antimicrobial use/ antimicrobial resistance in aquatic species in Nigeria. It will take about 20 minutes of your time to fill. Thank you for your cooperation.

I .....agree that purposes for which this survey is being undertaken, has been duly explained to me in a language that I understand, and assured of confidentiality of any information passed on to the research team. Based on this, I agree to take part in the survey and understand that the data collected will only be used for the purpose stated therein.

**Phone number:**

**Signature:**

**Date:**

\*\*\*\*\*

1. Questionnaire No.
2. Location (*GPS, physical address, town and state*)

**Veterinary Medicines**

1. In you view/based on your records, what are the commonest fish health problems farmers describe to you?
2. How are diseases diagnosed before treatments are recommended?
3. What is the likelihood that laboratory tests are done prior to antimicrobial prescriptions being given?
4. Are prescriptions given? *Explain* \_
5. May you provide the details of medications you have prescribed or that fish farmers use when they have fish health problems?
6. Do you have records of what quantities of these have been purchased to treat fish?  
**Yes [ ] No [ ]** *If yes, can you please share the information.* \_\_\_\_\_
7. Have you ever done/recommended microbial testing of any of the following: farm water sources, production water, feed, fish and/products and farm effluent water?  
**Yes [ ] No [ ]**

*Explain what was done and what the findings and recommendations were?*

Item Tested	Tests Done	Findings/action recommended

8. Based on your experience with stocking and supplying inputs for fish production, are there any specific feed additives, drugs that in your view, the market needs or is lacking? *Explain*
9. Do you have basic field diagnostic tools needed for fish diseases? (*e.g. water quality kit, light microscope, etc*)

**General Remarks**

1. Do you have additional comments or questions to ask?
2. Based on your experience, what suggestions would you give to abate the misuse of antimicrobials and AMR arising in fish farming in the country?

### A3.6. LOCAL ANIMAL DIAGNOSTIC/FISHERIES LABORATORIES

**Date and Time:**

**Enumerators Name:**

This survey is aimed at improving fish and human health and establishing surveillance system on antimicrobial use/ antimicrobial resistance in aquatic species in Nigeria. It will take about 10 minutes of your time to fill. Thank you for your cooperation.

I .....agree that purposes for which this survey is being undertaken, has been duly explained to me in a language that I understand, and assured of confidentiality of any information passed on to the research team. Based on this, I agree to take part in the survey and understand that the data collected will only be used for the purpose stated therein.

**Company's Name:**

**Respondent's phone no.:**

**Signature of Company Representative:**

**Date:**

\*\*\*\*\*

1. Questionnaire No.
2. Location (*GPS, physical address, town and state*)

#### Laboratory Samples and Tests

1. Which are the commonest tests requested for fish? *Please list in increasing order of importance*
2. Who requests for these? **Farmers** [  ] **Fisheries extension** [  ] **Veterinarians** [  ]  
**Fish food safety inspectors** [  ] **Others** \_\_\_\_\_
3. Which samples are brought in most for testing?
4. How are samples brought to the laboratory?
5. What is the status of the samples? Explain (*e.g. if good or bad, status labelling, etc.*)
6. Which protocols do you use for the tests required?
7. How do you give feedbacks to your client?
8. Do you have records of recent tests? **Yes** [  ] **No** [  ]
9. What are the common antimicrobial resistance patterns you have observed?

#### General Remarks

1. What is the status of your ability to undertake required diagnostic and anti-sensitivity tests, traceability and give feedback to clients
2. Any other remarks and suggestions for improving the monitoring and control of AMR in fish.

**A3.7. FARMED FISH/FISH PROCESSORS AND TRADERS**

**Date and Time:**

**Enumerators Name:**

This survey is aimed at improving fish and human health and establishing surveillance system on antimicrobial use/ antimicrobial resistance in aquatic species in Nigeria. It will take about 10 minutes of your time to fill. Thank you for your cooperation.

I .....agree that purposes for which this survey is being undertaken, has been duly explained to me in a language that I understand, and assured of confidentiality of any information passed on to the research team. Based on this, I agree to take part in the survey and understand that the data collected will only be used for the purpose stated therein.

**Phone number:**

**Signature:**

**Date:**

\*\*\*\*\*

- 1. Questionnaire No.
- 2. Location (*GPS, physical address, town and state*)

**Post-harvest Handling and Food-safety**

- 1. How is the fish from farms handled after harvest and enroute to the processing plants or markets?
- 2. Where do you source the water you use for handling and processing fish?
- 3. Have you ever taken this water for microbial testing? **Yes [ ] No [ ]**
- 4. Are there chemicals/drugs you use to improve water quality during handling, processing, or marketing? **Yes [ ] No [ ]**
- 5. If yes, please name and state the circumstances under which such chemicals/drugs have been used.
- 6. Where do you source the chemicals/ drugs?
- 7. Who give you recommendations for their use?
- 8. Are there government guidelines you follow in your business? **Yes [ ] No [ ]**

**Marketing and Consumer Preferences**

- 1. How do you sell your fish/products on the market?
- 2. Which are the most popular products? And why? *Please rank in order of increasing importance*
- 3. How do your consumers prepare these at home?

**General Remarks**

- 1. What would you suggest for controlling the use of antimicrobial in fish production?
- 2. Any other comment?

**A3.8. LIVESTOCK AND POULTRY FARMERS IN THE VICINITY**

**Date and Time:**

**Enumerators Name:**

This survey is aimed at improving fish and human health and establishing surveillance system on antimicrobial use/ antimicrobial resistance in aquatic species in Nigeria. It will take about 10 minutes of your time to fill. Thank you for your cooperation.

I .....agree that purposes for which this survey is being undertaken, has been duly explained to me in a language that I understand, and assured of confidentiality of any information passed on to the research team. Based on this, I agree to take part in the survey and understand that the data collected will only be used for the purpose stated therein.

**Phone number:**

**Signature of Company Representative:**

**Date:**

\*\*\*\*\*

1. Questionnaire No.
2. Location of Farm (*GPS, physical address, town and state*)

**Production and Water**

1. Which livestock/poultry do you rear?
2. Do you also raise fish on your farm? **Yes** [  ] **No** [  ]
3. If yes, which production system do you use to raise the fish? *Also mention the fish species raised*
4. Are there fish farms in the vicinity of your farm? **Yes** [  ] **No** [  ]
5. Do you use antimicrobials to treat animals on the farm? **Yes** [  ] **No** [  ]
6. Please list the antimicrobials you used against the diseases they are used to treat/control?

Antimicrobial	Disease (s)

7. Are any of the farm’s by-products used to rear fish on your farm or on other farms? **Yes** [  ] **No** [  ]
8. If yes, please mention them \_\_\_\_\_
9. Describe how you handle water effluent from your farm?
10. Where does the farm effluent drain into?
11. Are there fish farms downstream that use the surface water into which you discharge your effluent as their source of water for production? **Yes** [  ] **No** [  ]

**A3.9. FARMERS ASSOCIATIONS**

**Date and Time:**

**Enumerators Name:**

This survey is aimed at improving fish and human health and establishing surveillance system on antimicrobial use/ antimicrobial resistance in aquatic species in Nigeria. It will take about 10 minutes of your time to fill. Thank you for your cooperation.

I .....agree that purposes for which this survey is being undertaken, has been duly explained to me in a language that I understand, and assured of confidentiality of any information passed on to the research team. Based on this, I agree to take part in the survey and understand that the data collected will only be used for the purpose stated therein.

**Phone number:**

**Signature:**

**Date:**

\*\*\*\*\*

1. Questionnaire No.

**General Questions on Farmers Practices**

1. How many farmers are in the association? \_\_\_\_\_
2. Which systems of production do your members use? *Please list starting with the commonest.*
3. Are you aware of any farmers who use antimicrobials? **Yes** [  ] **No** [  ]
4. Under what circumstances are antimicrobials commonly used by farmers?
5. Who normally provides advice and guidelines to farmers and traders on the use of antimicrobials?
6. Have members of the association received any training on drug use in aquaculture?

**General Remarks**

**A3.10. FISH MARKET ADMINISTRATORS**

**Date and Time:**

**Enumerators Name:**

This survey is aimed at improving fish and human health and establishing surveillance system on antimicrobial use/ antimicrobial resistance in aquatic species in Nigeria. It will take about 10 minutes of your time to fill. Thank you for your cooperation.

I .....agree that purposes for which this survey is being undertaken, has been duly explained to me in a language that I understand, and assured of confidentiality of any information passed on to the research team. Based on this, I agree to take part in the survey and understand that the data collected will only be used for the purpose stated therein.

**Phone number:**

**Signature:**

**Date:**

\*\*\*\*\*

1. Questionnaire No.

**General**

- 1. How many stalls sell farmed fish in the market? \_\_\_\_\_
- 2. Are farmers required to obtain permits permitting them to transport and bring farmed fish to market for sale? **Yes [ ] No [ ]**
- 3. If so, please mention the permits and the agency responsible for giving these permits
- 4. What are the basic standards farmed fish need to meet to be sold for human consumption?
- 5. Are farmers and/or traders generally compliant to these? **Yes [ ] No [ ] Sometimes [ ]**
- 6. If not, what challenges do traders or the farmers face with regard to meeting standards?
- 7. Are there cases of addition of chemicals and drugs to fish?
- 8. Is microbial testing ever done of the water used at fish stalls or tanks for holding live fish? *Explain including results*
- 9. What is done when products are found to be substandard?
- 10. Are there government guidelines shared with producers and traders? If so which ones?

**General Comments**

#### Appendix 4. Elements within the Aquaculture Value Chain Likely to Influence/Drive AMU/AMR

	Hatchery	Grow-out	Post-harvest handling and processing	Marketing and distribution	Consumption
<b>Animal Interface (Production System)</b>					
Species	<ul style="list-style-type: none"> <li>• Tilapia, catfish, shrimp</li> <li>• Mixed</li> <li>• other</li> </ul>	<ul style="list-style-type: none"> <li>• Tilapia, catfish, shrimp</li> <li>• Mixed</li> <li>• other</li> </ul>	<ul style="list-style-type: none"> <li>• Tilapia, catfish, shrimp</li> <li>• Mixed</li> <li>• Other, e.g. imported, inland fisheries</li> </ul>	<ul style="list-style-type: none"> <li>• Tilapia, catfish, shrimp</li> <li>• Mixed</li> <li>• Other, e.g. imported, inland fisheries</li> </ul>	<ul style="list-style-type: none"> <li>• Tilapia, catfish, shrimp</li> <li>• Other species</li> </ul>
Water source	<ul style="list-style-type: none"> <li>• Surface: river, stream, dam, lake</li> <li>• Underground: protected/unprotected well</li> </ul>	<ul style="list-style-type: none"> <li>• Surface: river, stream, dam, lake</li> <li>• Underground: protected/unprotected well</li> <li>• Effluent from livestock/crop farms</li> </ul>	<ul style="list-style-type: none"> <li>• Surface: river, stream, lake</li> <li>• Underground: protected/unprotected well</li> <li>• Portable water</li> <li>• Rainwater</li> <li>• other</li> </ul>	<ul style="list-style-type: none"> <li>• Surface: river, stream, lake</li> <li>• Underground: protected/unprotected well</li> <li>• Portable water</li> <li>• Rainwater</li> <li>• other</li> </ul>	<ul style="list-style-type: none"> <li>• Surface: river, stream, lake</li> <li>• Underground: protected/unprotected well</li> <li>• Portable water</li> <li>• Rainwater</li> <li>• other</li> </ul>
System design	<ul style="list-style-type: none"> <li>• open, closed or semi-closed system</li> <li>• mono or polyculture</li> <li>• flow-through or water reuse</li> <li>• level of intensity</li> </ul>	<ul style="list-style-type: none"> <li>• open, closed or semi-closed system</li> <li>• mono or polyculture</li> <li>• flow-through or water reuse</li> <li>• integrated systems</li> <li>• level of intensity</li> </ul>	<ul style="list-style-type: none"> <li>• commercial</li> <li>• artisanal</li> <li>• does it enable implementation of phytosanitation and sanitation requirements?</li> </ul>	<ul style="list-style-type: none"> <li>• existence and use of cold chains</li> <li>• status of market(ing) infrastructure and storage facilities</li> </ul>	<ul style="list-style-type: none"> <li>•</li> </ul>
Inputs	<ul style="list-style-type: none"> <li>• Source of feeds</li> <li>• Type of feeds</li> <li>• Veterinary inputs</li> </ul>	<ul style="list-style-type: none"> <li>• Source of feeds</li> <li>• Type of feeds</li> <li>• Veterinary inputs</li> </ul>	<ul style="list-style-type: none"> <li>• Type</li> <li>• Sources</li> <li>• Packaging materials</li> <li>• Cleaning agents</li> </ul>	<ul style="list-style-type: none"> <li>•</li> </ul>	<ul style="list-style-type: none"> <li>•</li> </ul>
Management protocols	<ul style="list-style-type: none"> <li>• Feeding</li> <li>• Stocking</li> <li>• Handling</li> <li>• Harvesting</li> </ul>	<ul style="list-style-type: none"> <li>• Feeding</li> <li>• Stocking</li> <li>• Handling</li> <li>• Harvesting</li> </ul>	<ul style="list-style-type: none"> <li>• Availability and implementation of Food safety and hygiene practices and</li> </ul>	<ul style="list-style-type: none"> <li>• Availability and implementation of Food safety and hygiene standards?</li> </ul>	<ul style="list-style-type: none"> <li>•</li> </ul>

	<ul style="list-style-type: none"> <li>Treatments</li> <li>Biosecurity</li> <li>Water quality management</li> </ul>	<ul style="list-style-type: none"> <li>Treatments</li> <li>Biosecurity</li> <li>Water quality management</li> </ul>	<ul style="list-style-type: none"> <li>standards?</li> <li>Formal or informal standards</li> <li>Market driven?</li> <li>HACCP??</li> </ul>	<ul style="list-style-type: none"> <li>Formal or informal standards</li> <li>Market driven?</li> </ul>	
Products	<ul style="list-style-type: none"> <li>Fish seed</li> </ul>	<ul style="list-style-type: none"> <li>Table fish</li> <li>stockers</li> </ul>	<ul style="list-style-type: none"> <li>Smoked</li> <li>Live</li> <li>Whole</li> <li>Frozen</li> <li>packaging</li> </ul>	<ul style="list-style-type: none"> <li>live</li> <li>cold-chain or not?</li> </ul>	<ul style="list-style-type: none"> <li>Cooking methods</li> <li>Storage at home</li> </ul>
<b>Environmental Interface</b>					
Disposal and handling of waste	<ul style="list-style-type: none"> <li>Methods used</li> </ul>	<ul style="list-style-type: none"> <li>Methods used</li> </ul>	<ul style="list-style-type: none"> <li>Methods used</li> <li>How long before fish/other waste removed</li> <li>Likelihood of waste and other potential contaminants building up on premises</li> </ul>	<ul style="list-style-type: none"> <li>Methods used</li> </ul>	<ul style="list-style-type: none"> <li>Methods used</li> </ul>
Human activities around establishments	<ul style="list-style-type: none"> <li>Industrial area</li> <li>Other agricultural activities in neighborhood</li> <li>Residential area</li> <li>Waste dump?</li> </ul>	<ul style="list-style-type: none"> <li>Industrial area</li> <li>Other agricultural activities in neighborhood</li> <li>Residential area</li> <li>Waste dump?</li> </ul>	<ul style="list-style-type: none"> <li>Activities in environment result into contamination of fish during handling and processing</li> </ul>	<ul style="list-style-type: none"> <li>Activities in environment result into contamination of fish during handling and processing</li> </ul>	<ul style="list-style-type: none"> <li>Activities in environment result into contamination of fish during handling and processing</li> </ul>
Geographical location and other attributes	<ul style="list-style-type: none"> <li>Urban/peri-urban setting</li> <li>Ecotone or swamp?</li> <li>Likelihood of runoff/flooding?</li> </ul>	<ul style="list-style-type: none"> <li>Urban/peri-urban setting</li> <li>Ecotone or swamp?</li> <li>Likelihood of runoff/flooding?</li> </ul>	<ul style="list-style-type: none"> <li>Location of premises</li> </ul>	<ul style="list-style-type: none"> <li>Location of premises</li> </ul>	<ul style="list-style-type: none"> <li>location</li> </ul>
<b>Socio-Economic Interface</b>					
Enterprise performance	<ul style="list-style-type: none"> <li>Productivity</li> <li>Profitability</li> </ul>	<ul style="list-style-type: none"> <li>Productivity</li> <li>Profitability</li> </ul>	<ul style="list-style-type: none"> <li>Productivity</li> <li>Profitability</li> </ul>	<ul style="list-style-type: none"> <li>Productivity</li> <li>Profitability</li> </ul>	<ul style="list-style-type: none"> <li>Productivity</li> <li>Profitability</li> </ul>
Markets	<ul style="list-style-type: none"> <li>Location</li> <li>requirements</li> </ul>	<ul style="list-style-type: none"> <li>Location</li> <li>requirements</li> </ul>	<ul style="list-style-type: none"> <li>Location</li> <li>requirements</li> </ul>	<ul style="list-style-type: none"> <li>Location</li> <li>requirements</li> </ul>	<ul style="list-style-type: none"> <li>requirements</li> </ul>
Product utilization	<ul style="list-style-type: none"> <li>fish stock</li> </ul>	<ul style="list-style-type: none"> <li>human consumption</li> <li>processing</li> </ul>	<ul style="list-style-type: none"> <li>use of by-products</li> <li>products</li> </ul>		<ul style="list-style-type: none"> <li>Cooking</li> <li>Eaten raw</li> </ul>
Formal and informal	<ul style="list-style-type: none"> <li>Government</li> </ul>	<ul style="list-style-type: none"> <li>Government</li> </ul>	<ul style="list-style-type: none"> <li>Government</li> </ul>	<ul style="list-style-type: none"> <li>Government</li> </ul>	<ul style="list-style-type: none"> <li>Consumer associations</li> </ul>

governance	<ul style="list-style-type: none"> <li>guidelines</li> <li>• Producer associations</li> </ul>	<ul style="list-style-type: none"> <li>guidelines</li> <li>• Producer associations</li> </ul>	<ul style="list-style-type: none"> <li>guidelines</li> <li>• Producer associations</li> </ul>	<ul style="list-style-type: none"> <li>guidelines</li> <li>• Producer associations</li> </ul>	<ul style="list-style-type: none"> <li>• Government guidelines</li> </ul>
Key players	<ul style="list-style-type: none"> <li>• Farmers</li> <li>• Extension agents</li> <li>• Animal health providers</li> </ul>	<ul style="list-style-type: none"> <li>• Farmers</li> <li>• Extension agents</li> <li>• Animal health providers</li> </ul>	<ul style="list-style-type: none"> <li>• Farmers</li> <li>• Extension agents</li> <li>• Quality control inspectors</li> </ul>	<ul style="list-style-type: none"> <li>• Farmers</li> <li>• Extension agents</li> <li>• Quality control inspectors</li> <li>• Market inspectors</li> </ul>	<ul style="list-style-type: none"> <li>• Consumer</li> <li>• Health workers and/or nutritional adv</li> </ul>
<b>Health Aspects</b>					
Occupational hazards	<ul style="list-style-type: none"> <li>• Handling antibiotics</li> <li>• Exposure to contaminated water (i.e. residues, resistant pathogens, etc.)</li> <li>• Conditions and control/treatments</li> </ul>	<ul style="list-style-type: none"> <li>• Handling antibiotics</li> <li>• Exposure to contaminated water (i.e. residues, resistant pathogens, etc.)</li> <li>• Conditions and control/treatments</li> </ul>	<ul style="list-style-type: none"> <li>• Handling affected fish/fish parts</li> <li>• Exposure to contaminated water (i.e. residues, resistant pathogens, etc.)</li> <li>• Conditions and control/treatments</li> </ul>	<ul style="list-style-type: none"> <li>• Handling contaminated fish products</li> <li>• Exposure to contaminated water (i.e. residues, resistant pathogens, etc.)</li> <li>• Conditions and control/treatments</li> </ul>	<ul style="list-style-type: none"> <li>• Handling contaminated products</li> <li>• Conditions and control/treatments</li> <li>• Diagnostic capacity used in human health facilities</li> </ul>
Animal diseases	<ul style="list-style-type: none"> <li>• Diseases</li> <li>• Zoonotic conditions</li> <li>• Diagnostic methods</li> <li>• Control methods used</li> <li>• pharmaceuticals</li> </ul>	<ul style="list-style-type: none"> <li>• Diseases</li> <li>• Zoonotic conditions</li> <li>• Diagnostic methods</li> <li>• Control methods used</li> <li>• pharmaceuticals</li> </ul>	<ul style="list-style-type: none"> <li>• Affected tissues</li> <li>• Quality control tests used</li> </ul>	<ul style="list-style-type: none"> <li>• Affected tissues</li> <li>• Quality control tests used</li> </ul>	<ul style="list-style-type: none"> <li>• Zoonotic conditions</li> <li>• Control methods used</li> </ul>
Environmental health practices	<ul style="list-style-type: none"> <li>• Environment management practices</li> <li>• Residue levels</li> <li>• Resistant pathogens</li> <li>• Environmental indicators and testing methods</li> </ul>	<ul style="list-style-type: none"> <li>• Environment management practices</li> <li>• Residue levels</li> <li>• Resistant pathogens</li> <li>• Environmental indicators and testing methods</li> </ul>	<ul style="list-style-type: none"> <li>• Environment management practices</li> <li>• Residue levels</li> <li>• Resistant pathogens</li> <li>• Environmental indicators and testing methods</li> </ul>	<ul style="list-style-type: none"> <li>• Environment management practices</li> <li>• Residue levels</li> <li>• Resistant pathogens</li> <li>• Environmental indicators and testing methods</li> </ul>	<ul style="list-style-type: none"> <li>• Environment management practices</li> <li>• Residue levels</li> <li>• Resistant pathogens</li> <li>• Environmental indicators and testing methods</li> </ul>

## Appendix 5. Factors associated with antimicrobial use among fish farmers in Lagos and Oyo States, Nigeria

Variables	Categories	AMU in fish positive n = 186 (%)	AMU in fish Negative n = 150 (%)	Odds ratios (95% confidence interval)	P value
Location	Lagos	163 (87.6)	132 (88.0)	0.97 (0.50 – 1.87)	1.00
	Oyo	23	11		
Age (years)	≤ 39	84 (45.2)	41 (27.3)	2.19 (1.38 – 3.47)	0.001*
	40 >	102	109		
Gender	Female	34 (18.3)	34 (22.7)	0.76 (0.45 – 1.30)	0.39
	Male	152	116		
Education	≤ Secondary	65 (35.0)	32 (21.3)	1.98 (1.21 – 3.24)	0.008*
	Tertiary	121	118	Ref.	
Years in fish rearing	≤ 2	20 (10.8)	17 (11.3)	0.96 (0.46 – 2.00)	1.00
	3 - 5	45 (24.2)	39 (26.0)	0.94 (0.54 – 1.64)	0.95
	6 - 9	50 (26.9)	36 (24.0)	1.13 (0.65 – 1.97)	0.76
	10 >	71	58	Ref.	
Who runs the farm?	Farm Manager	17 (9.1)	20 (13.3)	0.65 (0.33 – 1.30)	0.30
	Self/ family member	169	130		
Trained personnel runs the farm	Yes	152 (81.7)	138 (92.0)	0.39 (0.19 – 0.78)	0.01*
	No	34	12		
Association member	Yes	108 (58.1)	105 (70.0)	0.59 (0.38 – 0.94)	0.03*
	No	78	45		
Pond Production	Yes	166 (89.3)	121 (80.7)	2.00 (1.07 – )	0.04*

				3.68)	
	No	20	29		
Tank Production	Yes	45 (24.2)	49 (32.7)	0.66 (0.41 – 1.06)	0.11
	No	141	101		
Effluent into Environment	Yes	42 (22.6)	12 (8.0)	3.35 (1.69 – 6.64)	<0.001*
	No	144	138		
Effluent into Field	Yes	22 (11.8)	7 (4.7)	2.74 (1.14 – 6.60)	0.03*
	No	164	143		
Effluent into Drainage	Yes	145 (78.0)	128 (85.3)	0.61 (0.34 – 1.07)	0.11
	No	41	22		
Client Standards	Yes	99 (53.2)	99 (66.0)	0.59 (0.38 – 0.91)	0.02*
	No	87	51		
Aware of Govt. guidelines on effluent	Yes	21 (11.3)	29 (19.3)	0.53 (0.29 – 0.98)	0.06
	No	165	121		
Source Production info. from other farmers	Yes	147 (79.0)	101 (67.3)	1.83 (1.12 – 2.99)	0.02*
	No	39	49		
#SPI from Association	Yes	68 (36.6)	76 (50.7)	0.56 (0.36 – 0.87)	0.01*
	No	118	74		
#SPI from Internet	Yes	78 (41.9)	46 (30.7)	1.63 (1.04 – 2.57)	0.04*
	No	108	104		
Source of AMU from other farmers	Yes	130 (69.9)	73 (48.7)	2.45 (1.56 – 3.83)	<0.001*
	No	56	77		
#S_AMU Veterinarian	Yes	38 (20.4)	16 (10.7)	2.15 (1.15 – 4.03)	0.02*
	No	148	134		
Source_Env. Other farmers	Yes	121 (65.1)	81 (54.0)	1.59 (1.02 – 2.46)	0.05

	No	65	69		
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## Appendix 6. Ingredients used by feed manufacturers

- Fish meal
- Soya
- Maize
- Additives - amino acids, multivitamins, minerals, GNC, lysine, methionine, toxin binders
- Groundnut cake
- soyabean meal
- millet flour
- Noodles waste
- Fish meal (72%)
- Spaghetti waste
- Maize
- Blood meal
- Pkc
- Rice bran
- Wheat bran
- Corn bran
- Poultry meal
- Feather meal
- Oxytetracycline
- Biscuit waste
- Groundnut cake
- Fish premix
- Salt
- Vitamin C
- Toxin binder
- Cassava
- Wheat – locally grown in Nigeria