The Fleming Fund
Country Grants

# Establishing Aquatic Species AMR Surveillance in Nigeria

Recommendation Report

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## Abbreviations and Acronyms

| | |
|---|---|
| **AMU** | Antimicrobial Use |
| **AMR** | Antimicrobial Resistance |
| **AS** | Antimicrobial Stewardship |
| **GAP** | The tripartite Global Action Plan on AMR |
| **GLASS** | Global Antimicrobial Resistance Surveillance System |
| **FAO** | Food and Agriculture Organization of the United Nations |
| **FMARD** | Federal Ministry of Agriculture and Rural Development |
| **OH** | One Health |
| **OIE** | World Animal Health Organization |
| **MDAs** | Ministries, Departments and Agencies |
| **MDR** | Multiple Drug Resistance |
| **NAFDAC** | National Agency for Food and Drug Administration and Control |
| **NAP** | National Action Plan for Antimicrobial Resistance 2017-2022 |
| **NAS** | National Aquaculture Strategy |
| **NCDC** | Nigeria Centre for Disease Control |
| **NVMA** | Nigerian Medical Veterinary Association |
| **PEA** | Political Economic Analysis |
| **VCN** | Veterinary Council of Nigeria |
| **WHO** | World Health Organization of the United Nations |

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## EXECUTIVE SUMMARY

The growing prevalence of antimicrobial resistance (AMR) and its implications for food safety, human health, animal health and ecosystem health has become a global concern, including for Nigeria. A situation analysis on AMR conducted by the Nigeria Center for Disease Control (NCDC) found AMR to be broad and highly prevalent in humans, livestock, and the environment. Several challenges contributed towards this, among which were low level of public awareness on AMR and bottlenecks affecting the delivery of laboratory diagnostic and human and veterinary health services. Nigeria's rapidly expanding aquaculture sector was identified as among the priority animal food-value chain for AMR surveillance in view of the fact that there was little documented evidence on the status of aquaculture antimicrobial use (AMU), yet it was common knowledge that fish farmers used antimicrobials without professional supervision.

Support was consequently obtained from Fleming Fund by the NCDC to establish an aquaculture AMR surveillance system as a tool for generating evidence-based information to guide the development sector-specific One Health interventions for the control and monitoring of aquaculture AMU/AMR. This action was developed in collaboration with the Federal Ministry of Agriculture and Rural Development following the Political Economic Analysis (PEA) approach in recognition of the multiplicity of factors and stakeholders with a stake in aquaculture AMU and AMR that would affect the sustainability of any interventions to control aquaculture AMU/AMR.

A country situation analysis was subsequently undertaken to assess the aquaculture AMU status quo, map the stakeholders involved, identify the potential drivers, entry-points and hotspots for aquaculture AMU/AMR and recommend best-options for establishing a population-based aquaculture AMR surveillance system in Nigeria.

The key recommendations from the situation analysis centered on the need for strengthening One Health AMU/AMR control across the aquaculture value chain. There was a need for increasing public awareness, strengthening capacity for One Health AMR surveillance and research, strengthening capacity infection prevention and biosecurity control, improving access to diagnostic services and aquatic veterinary services, strengthening curricula in training institutions, policies and local human resource development for AMR across all levels, and streamlining access to antimicrobial agents to promote prudent use of AMU and antimicrobial stewardship. It identified where the surveillance could serve as a tool and stakeholders could potentially play a role in mitigating against exposure to AMR, preventing AMR exposure and control spread of AMR in the aquaculture value-chain.

## 1. Background and Introduction

The growing prevalence of antimicrobial resistance (AMR) and its implications for food safety, human health, animal health and ecosystem health have become a global concern. Animal food value chains have become important pathways for the transmission of 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. The progression of AMR has been demonstrated to exist between the human-animal-environment interfaces which increases the risk of transmission and acquisition for humans from secondary sources. The wide distribution of AMR has resulted a rise in cases of treatment failure, prolonged illness, increased treatment costs and mortality from treatable illnesses. The options for treating diseases caused by AMR microbes have as a result, been reduced across the world[27,41,].

A concerted effort by the global community to reduce the spread of AMR and maintain the efficacy of the world's essential antimicrobial treatments has therefore been instituted by the World Health Assembly and is articulated in the Global Action Plan on AMR (GAP). The GAP seeks to raise awareness and build capacity for reducing incidences of infection and optimizing the use of antimicrobial medicines in human and animal health holistically, through One Health[41]. Among the tools established by the GAP, is the Global Antimicrobial Resistance Surveillance System (GLASS). The purpose of the GLASS is to generate the much-needed evidence and knowledge for developing and monitoring impacts of interventions to control AMR and global trends[42].

In compliance with the GAP's recommendations, the Nigerian government conducted a situation analysis on the status of AMR in the country[24]. The situation analysis found Nigeria's AMR status to be very similar to the global situation. AMR was found to broad and highly prevalent in humans, livestock, and the environment. Chronic and community-acquired diseases in humans were caused and treated by similar pathogens and antibiotics as domestic animals. The potential risk of AMR occurrence and spread through the country's animal food value chains raised concern. The findings of the country's AMR situation analysis prompted the development of Nigeria's National Action Plan for Antimicrobial Resistance 2017–2022 (NAP) that provides a roadmap for reducing, preventing, and slowing the evolution of antimicrobial resistant organisms and their impact on health care[25].

Fish is a major component in the diet of Nigeria's 186 million citizens. Currently, National fish production does not meet the domestic demand of 3.32 million tons of fish per annum. About one million ton of fish per annum, comprising 750,000 tons from capture fisheries and 300,000 tons from aquaculture are produced within the country. Thus 600,000 metric tons of fish are imported annually to offset the deficit. Household fish consumption is estimated to be 13.3 kg/capita/year, lower than the world's average of 20.3 kg/capita/year[5,19,32,44]. Commercial aquaculture has therefore been promoted as the most sustainable option for expanding domestic production to address this deficit[16,19,32]. Since this intervention, Nigeria has become Africa's second largest aquaculture producer after Egypt[11]. Unfortunately, the progressive aquaculture development and growth has seen with it the increased antimicrobials use(AMU) by fish farmers[17,30,]. Concern on the safety of aquaculture food products within Nigeria (and globally) has subsequently been raised especially because AMU in the sector is not well regulated, documented nor understood[2,3,4,6,7,8,9,36].

## 2. Purpose of the Assignment

The Nigeria National Aquaculture Strategy (NAS) projects that the aquaculture value chain will expand to a production capacity of two million tons of fish per annum to become the country's major source of safe and quality assured food fish and fish products destined for domestic and external markets[16]. In light of this, it becomes pertinent to address the AMR risks associated with aquaculture to safeguard human and fish health. The Nigeria Center for Disease Control (NCDC) consequently prioritized aquaculture as among the animal food value-chains for AMR surveillance[38]. A Fleming Fund Country Grant was thus obtained by NCDC to support the establishment of a population-based AMR aquatic species surveillance system in the country.

## 3. Methodology Used

The Political Economy Analysis (PEA) was used as the framework to identify options and draw recommendations for establishing a population-based aquatic species AMR surveillance system. The PEA was opted for to identify the options for addressing aquaculture AMU/AMR given its strengths that holistically support the integrated analysis of varying technical, social, political, and economic factors which as an approach, has been found to result sustainable development outcomes. The aquaculture PEA permitted a holistic multi-stakeholder and multi-disciplinary analytical approach that enabled intersectoral stakeholder and institutional analyses within the context of the NAP, GAP, and other relevant national and international guidelines for the control of AMR in agriculture[14,15]. Notable among these were Nigeria's *National Aquaculture Strategy*[16], the *Codex Texts on Foodborne Antimicrobial Resistance*[12], *OIE Standards, Guidelines and Resolution on Antimicrobial Resistance*[27], the *Guidelines for Risk Analysis of Foodborne Antimicrobial Resistance CAC/GL 77- 2011*[10] and *Recommendations for the Prudent and Responsible Use of Veterinary Medicines in Aquaculture*[13].

Following this methodology, a comprehensive situation analysis on the status of AMU and AMR within the aquaculture sector was achieved and an aquaculture stakeholder analysis undertaken to explore the options for effectively engaging the sectors' stakeholders in antimicrobial stewardship. The tools used to collect data included literature review, online multi-stakeholder workshops, direct key stakeholder interviews: a sentinel survey that comprised the administration of non-structured questionnaires and checklists to the value-chains' primary stakeholders[1a]. A total of 536 respondents were interviewed in the survey (table 1). Sector managers and policy makers from the Federal Ministry of Agriculture and Rural Development (FMARD) were also interviewed. A value-chain analysis and stakeholder analysis on AMU/AMR were among the analytical tools used that contributed to the overall situation analysis.

[a] ***Primary stakeholders*** were those who directly advised, manufactured, distributed, used and/or disposed antimicrobials for the production of fish or fish products at any segment in the aquaculture value chain. As such, primary actors were found to be fish farmers, aquaculture extension workers, veterinarians, chemists and pharmacists, veterinary input manufacturers and suppliers, feed manufacturers, fish processors, transporters and traders, and livestock farmers. ***Secondary stakeholders*** were those who influenced and/or controlled the access and use of antimicrobials for producers by virtue of their institutional roles or influenced acquisition through environmental sources. They include policy managers, government agencies and regulators, training and research institutions, consumers, producer and professional associations, the media, and public. ***Observers*** were those who had no direct influence or control, except by expressing their views in the form of public opinion.

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

| Stakeholder Category and List of Tools | Population Size[a] | | | 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[b] | | | 14 | 8 | 22 |
| **Fish farmers associations** | n/a[b] | | | 3 | 3 | 6 |
| **Fish Market administrators** | n/a[b] | | | 3 | 2 | 5 |
| **TOTAL NUMBER RESPONDENTS INTERVIEWED** | | | | | | **536** |

[a] *Population size was based on estimates given by the respective State Departments. This could not be authenticated due to inadequate data available at the departments.*

[b] *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.*

The situation analysis brought to light the entry points, pathways, and potential hotspots for AMR in Nigeria's aquaculture value chain (Figure 1). The stakeholder analysis mapped the sector's stakeholders and identified options for establishing an Aquaculture Stakeholder Antimicrobial Stewardship and Surveillance Network.

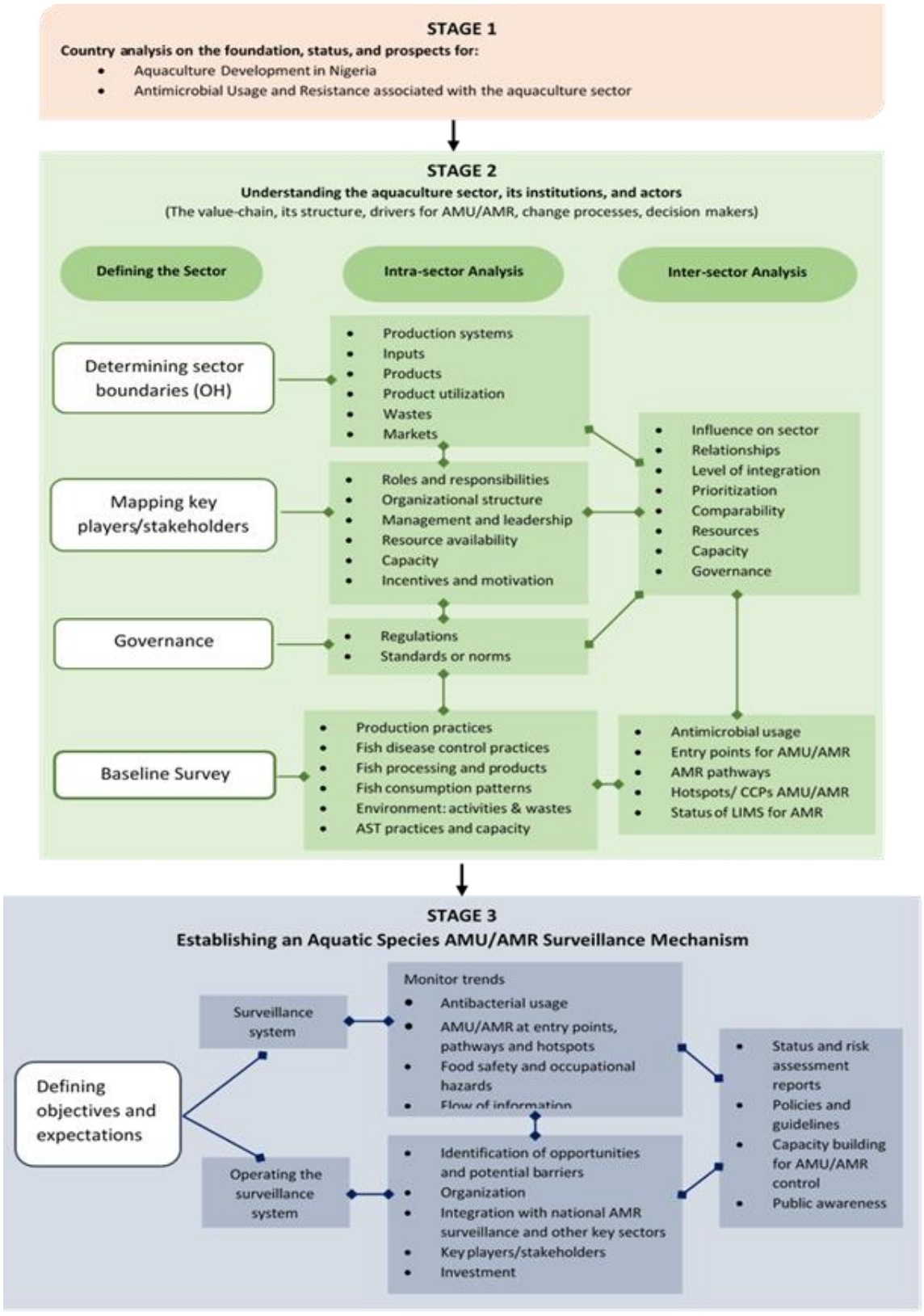


**Figure 1:** PEA framework integrated with the One Health Approach for establishing an Aquatic Animal Species *(adapted from Moncrieffe and Luttrell, 2005, and Brunton et al., 2019)*

## 4. Key Findings of the Assignment

The following were the key findings of the assignment:

1. The use of antimicrobials in Nigerian aquaculture was indiscriminate and characterized by overuse. Sixty-one percent (25/41) of veterinary input suppliers noted that farmers purchased antimicrobials from them without prescriptions. All (79/79) the fish processors and traders interviewed obtained antibiotics from veterinary input suppliers or human pharmacies without a prescription. The choice and route administration of antimicrobials used by farmers and producers in such cases was based on recommendations from other farmers or fish processors and traders or their own experience. Extra-label use of drugs whereby livestock and human antimicrobial products were used by farmers and traders occurred. Withdrawal times were not complied with by 27% (51/186) of farmers and 100% (79/79) of fish traders or processors. Fish were also fed by-products from poultry production even when birds were under treatment. These included unused medicated feeds, dead birds and manure.

2. The drivers for AMU in aquaculture were largely economic. Farmers (56%, 186/336) used antimicrobials to abate production and economic losses as a result of the poor quality of feeds on the market (10%, 19/186), occurrence and spread of disease (84%, 156/186) and to reduce mortality (47%, 89/186). Fish processors and traders (27%, 21/79) added antimicrobials to live fish holding vats prior to processing or delivery to market in order to reduce fish stress, mortality and prolong the water's dissolved oxygen retention time. Some fish feed manufacturers (44%, 8/18) routinely added antimicrobials as a safeguard against poor feed performance arising from the use poor quality of feed ingredients. Feed manufacturers complained about the poor quality of feed ingredients dominated the market and was a great challenge for them. Occasionally batches of medicated feed were produced upon request. Thus, AMU was done for prophylaxis, to promote growth and disease treatment. It should be noted that just prior to the publication of this report, the AMU in feeds as growth stimulants and for prophylaxis was banned in Nigeria.

3. Eighty-four percent of farmers (156/186) who reportedly had treated fish with antimicrobials, self-diagnosed the disease. Antimicrobial treatment failure had been experienced by 27% (51/186) of these farmers. Only 15% (27/186) of the farmers that they had engaged the services of a diagnostic laboratory prior; and this was after experiencing treatment failure. The veterinarians (7/17) and local animal diagnostic laboratories (4/4) that had handled samples for fish diseases diagnosis had obtained results of antimicrobial resistance against antimicrobials commonly used by fish farmers. Studies conducted on aquaculture AMR within the country, confirmed the findings of the assignment and indicated that Multiple Drug Resistance (MDR) also existed in some cases[18,23],. The antimicrobials used in the aquaculture value chain for which AMR had also been identified for humans and livestock included amoxicillin, ampicillin, cloxacillin, penicillin, procaine penicillin, tetracycline, oxytetracycline, cephalexin, ciproflaxcin, enroflaxcin, tylosin, erythromycin, neomycin, streptomycin, furaltadone, chloramphenicol, colistin and Aquaceryl[3,17,29,30]. Some of these drugs were available as combination products for veterinary use.

4. The factors found to have a significant influence on for AMU/AMR were the farmers age ($p<0.001$) and level of education ($p<0.008$), production system ($p<0.04$), membership to associations ($p<0.01$), access to the internet ($p<0.04$), trained manager running the farm ($p<0.01$) and live fish products ($p<0.001$). Commercial catfish farmers or managers with post-

secondary education had better access to internet from which they obtained information on fish disease control and treatment. Similarly members of fish farmer associations and/or sold live fish producers/traders exchanged fish health management information through these accessible networks. Thus, catfish hatcheries, intensive catfish grow-out farms and live catfish outlets were more predisposed to non-judicious AMU and consequently AMR. Integrated fish-poultry/livestock farms and semi-intensive ponds were predisposed to acquiring AMR from the feeding of sick or dead birds to fish, use of manure and feeding, throwing or releasing effluent with medicated feeds and/or drugs into fish ponds. The long water resident time and natural biological process in ponds favored an environment for the horizontal evolution and transfer of resistant microbes and genes[28]. Veterinarians, however, were found to positively associate with the prudent AMU; in that according to the laboratories surveyed (75%, 3/4), it was they who submitted samples for confirmatory disease diagnosis and AST prior to recommending treatments. Farmers also found laboratory and veterinary services to be costly and to locate out of reach and hence, only sought their services after experiencing a series of treatment failures.

5. The potential entry-points for AMU/AMR into aquaculture production systems and from aquaculture establishments into the environment were through the disposal unused medicated feeds, animals that may have died during treatment and unwanted drugs directly into drainage or water channels, vegetation around farms or by burying. Fish farms located downstream that extracted water from such sources were predisposed to acquiring AMR from contaminated surface or ground water sources. When it rained, run-off from the affected environs sometime entered fish farms. Similarly, fish farms that discharged effluent with antimicrobial residues became a possible pathway for AMU/AMR entering the environment. Transmission to humans was also possible through direct contact with water containing resistant microbes of genes where farm workers worked with open wounds. This constituted a potential occupation hazards for aquaculture practitioners. Environmental risks associated with aquaculture have also been cited in literature[7,18,26,28,31,43].

6. The use of antimicrobials in the aquaculture sector was influenced by different institutions within the public and private sector. The Federal Ministry of Agriculture and Rural Development within which the Fisheries (also the Competent Authority for aquaculture) and Veterinary Departments were, was the line ministry. The National Agency for Food and Drug Administration and Control (NAFDAC) was the regulator for the importation, manufacture and distribution and quality of pharmaceutical products and feeds in the country. The Federal Ministry of Environment ensures manages and ensures sustainable use of the environmental. The NCDC ensured public health aspects from all activities. Between these institutions, a comprehensive legal framework existed upon which the control of AMU/AMR in aquaculture could effectively be built. The current institutional gaps for establishing a population-based aquaculture AMR surveillance systems centered largely on the poor implementation of currently and limitation in scope of the current guidelines specifically addressing AMU and AMR in aquaculture. The low levels of awareness on aquaculture AMU/AMR within the public and among the sectors stakeholders was a bottleneck for mobilizing them and resources for Antimicrobial Stewardship (AS). The capacity of all the sectors stakeholders needed to be built for implementing Antimicrobial Stewardship (AS) including of producer and professional associations that were found to have a strong influence on the adoption of field practices by their members. Similarly, there was untapped potential that should similarly be harnessed within the Country's training and research institutions to build the capacity of the work-force, undertake research to develop best practices and provide outreach services to the sector.

However, the challenge lies with the status of implementation and limitations associated with their current scope for addressing emerging AMR issues raised by the aquaculture situation analysis. The capacity of all the sectors stakeholders needs to be built for implementing Antimicrobial Stewardship (AS). Producer and professional associations have a strong influence on the adoption of field practices among their members. Similarly, an untapped potential lies within the training and research institutions that nurture human resources, undertake research to develop best practices and provide outreach services to the sector. The low levels of awareness on AMU/AMR in aquaculture were a bottleneck to harnessing these assets, mobilizing resources for implementation, and obtaining stakeholder buy-in for antimicrobial stewardship.

## 5. Key Recommendations

Given the outcomes of the situation analysis and stakeholder analysis whereby the drivers, potential entry-points and hotspots for aquaculture were identified as swell as options for establishing a population-based aquaculture AMR surveillance system to monitor and control the spread of aquaculture AMR (figure 2).

Strengthening One Health AMU/AMR control across the aquaculture value chain was found to be key and required:

- 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.

| Key Concerns | Areas of Risk in Value Chain | Strategic Actions | Options for Control | Areas to Monitor (Data Sources) |
|---|---|---|---|---|
| **Antimicrobial Exposure** | • Production system<br>• Post-harvest handling and processing<br>• Medicated feeds<br>• Agricultural by-products<br>• Water sources | **Mitigation** | • Biosecurity control<br>• Animal welfare<br>• Diagnostic services<br>• Aquatic animal health services<br>• Food-safety and market standards<br>• Disposal of agricultural waste, effluent, and unused drugs | • Aquatic animal health and welfare<br>• Food-safety<br>• Water sources<br>• Environs receiving effluent/waste from farms<br>• Laboratories (disease diagnostic, food-safety, drug residues in environment)<br>• Feeds |
| **AMR acquisition** | • Non-guided and Indiscriminate use of antimicrobials<br>• Feed manufacturers<br>• Sources of antimicrobials notably veterinary input suppliers, chemists, and other farmers (fish and livestock)<br>• By-products from animal production | **Prevention** | • Policy: define and govern stakeholder roles in AMU<br>• Laboratory diagnostic services<br>• Veterinary services<br>• Control trade, distribution, and disposal of antimicrobials<br>• Aquatic environmental management<br>• Use of agricultural by-products<br>• AMR stewardship and capacity building | • Veterinary input suppliers (and chemists)<br>• Laboratory reports (AST, resistant genes in value chain)<br>• prescriptions given<br>• adoption of guidelines<br>• information disseminated<br>• food-safety |
| **AMR transmission** | • Feeding products and by-products to other animals and humans<br>• Disposal of waste, effluent, drugs<br>• Effluent from farms<br>• Treated feeds<br>• Indiscriminate AMU<br>• Environment – sediment and water | **Control** | • AMU/AMR regulations and guidelines<br>• Public awareness<br>• AMR stewardship and capacity building | • application of standards and guidelines (food-safety, environmental and production)<br>• monitoring for resistomes in fish products and environments |

**Figure 2.** Overall Outcomes expected from Aquaculture AMR Surveillance

The sectors stakeholders further reiterated the following as being key for strengthening their participation in AMU/AMR control across the aquaculture value chain:

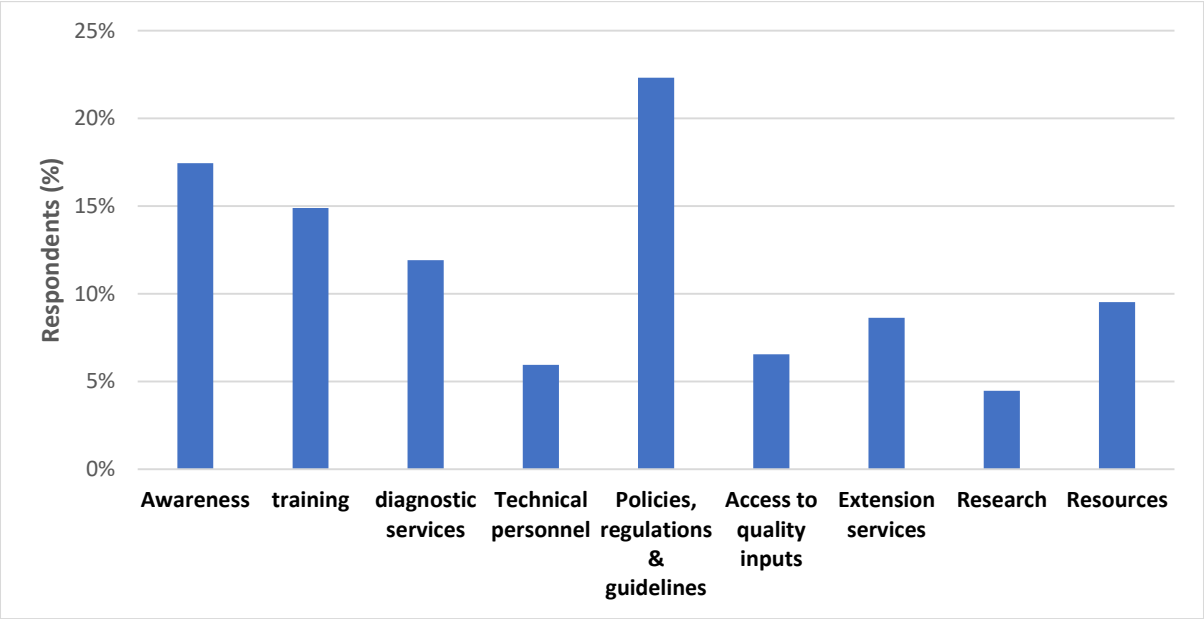


**Figure 3: Respondents' recommendations for the control of AMU/AMR**

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 was needed for effective monitoring, control, surveillance and AMU/AMR information sharing. Public guidelines and standard operating procedures needed to be developed and disseminated; technical personnel need to be equipped with the necessary diagnostic tools; laboratories needed to be well equipped; and government extension or veterinary personnel better enumerated. Providing these resources would reduce fish disease diagnostic costs for producers' costs and make standardized diagnostic and other AMU services more accessible to aquaculture 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 was 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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