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Abstract

Low-and middle-income countries are projected to experience a disproportionate burden of antimicrobial resistance (AMR), with significant impacts already evident in West Africa (WA). Active AMR surveillance in food-producing animals and the environment is essential to inform transmission pathways, detect emerging resistance trends, and assess risks to human health. Several WA countries have developed national AMR strategies, sampling plans, and standard operating procedures (SOPs) to support such surveillance. This review evaluates the

alignment of these documents across sectors and countries, and their capacity to support national monitoring, regional comparison, and One Health (OH) AMR analyses. AMR strategy documents, sampling plans, and SOPs were provided by Ghana, Nigeria, Senegal, and Sierra Leone for review. Data were extracted into a comparative framework to assess surveillance scope, livestock and environmental coverage, target bacterial species, and antimicrobial panels. Analysis focused on active AMR surveillance in animal health and environmental sectors, examining cross-sectoral and cross-country alignment from a OH perspective. All four countries prioritised poultry layers, tilapia, and catfish for active AMR surveillance. Across sectors and countries, *Escherichia coli* and *Salmonella* spp. were consistently included. Antimicrobial panels for *E. coli* showed convergence, particularly for carbapenems, cephalosporins, and quinolones, supporting the potential for cross-sectoral comparison. Environmental surveillance approaches were more heterogeneous, with differences in sampling sites and sample types that may limit comparability. Despite this, increasing alignment was observed in surveillance objectives, governance structures, and methodological approaches. The documents reviewed provide a coherent framework for generating high-quality AMR data across sectors in WA. Shared priorities in species, bacterial targets, and antimicrobial selection support the potential for regional trend analysis and strengthened OH surveillance. Further harmonisation of environmental sampling would enhance comparability. If implemented as outlined and data quality is maintained, these surveillance programmes will contribute to national monitoring, regional coordination, and evidence-informed AMR policy development.

Keywords: Antimicrobial resistance (AMR); Antimicrobial resistance surveillance; One Health; West Africa; AMR active surveillance

Introduction:

Antimicrobial Resistance (AMR) presents a profound threat to public, animal, and plant health, the environment, food security and to the global economy. The World Bank has estimated that by 2050 AMR could, if unchecked, cause the world to lose 3.8% of global gross domestic product each year and push 28 million people into poverty¹. In 2024, the Global Research on Antimicrobial Resistance (GRAM) project estimated that without intervention AMR will directly cause 39 million human deaths between 2025 and 2050². The World Organisation for Animal Health (WOAH) has estimated that by 2050, without interventions, the economic and public health impact of AMR in livestock could be substantial, including a significant cost associated with the spread of resistant pathogens from livestock to humans³. The burden of AMR has been predicted to fall most heavily on low-and middle-income countries, for several reasons including higher infectious disease burden and inadequate water, sanitation and hygiene (WASH) conditions; weaker regulation and health-system capacity; and extensive, often unregulated antimicrobial use in livestock that accelerates resistance across the One Health interface^{4,5}.

This global threat has triggered a global response, and the publication of the Global Action Plan (GAP) for AMR⁶. The GAP encouraged countries to establish National Action Plans (NAPs) on AMR, tailored to the needs of their nation, people, and economy, but following universal principles including a requirement for national AMR surveillance or monitoring. Surveillance contributes to an understanding of the AMR threat, informs interventions, and enables monitoring of progress in tackling AMR. Guidance for AMR surveillance in food-producing animals is provided by WOAH⁶ and the Codex Alimentarius Commission⁷. Surveillance (or monitoring) in food-producing animals can include AMR in veterinary pathogens obtained from clinical samples (clinical/passive surveillance) and AMR in commensals and/or zoonotic pathogens in healthy animals (active surveillance), that may serve as a risk to people, through for example, the food chain. Active AMR surveillance is defined as a core part of national surveillance by WOAH^{6,8}. The importance of AMR in the environment is highlighted by WOAH and the Codex and is an important component of the One Health approach, as recognised in the Quadripartite One Health Joint Plan of Action in which AMR has a dedicated Action Track⁹. Surveillance plans for this sector are relatively limited, with efforts being project-dependant in many countries around the globe.

Africa has one of the largest gaps in data on AMR prevalence, attributed to limited AMR surveillance networks across the continent¹⁰⁻¹². There is also a relatively low implementation of NAPs in Africa, with only 74% implemented due to a lack of financial commitment¹³. To address these issues, the Africa Centres for Disease Control and Prevention published guidance for the ‘Antimicrobial Resistance Surveillance Guidance for the African Region’¹⁴, which outlines how countries can establish governance structures, create robust AMR surveillance systems, and enable data sharing on the African continent. Similarly, efforts to address the data gaps through the UK Aid Fleming Fund programme has resulted in the production and implementation of NAPs, strategy documents, active sampling plans, and standardised Standard Operating Procedures (SOPs). Fleming

Fund supported countries in West Africa including Ghana, Nigeria, Senegal, and Sierra Leone and therefore the focus of this manuscript was on these countries. The burden of AMR in these four countries is recognised as substantial, with high AMR-associated age-standardised human mortality rates per 100,000 people: of 204 countries included Sierra Leone was 24th highest, Nigeria 30th, Ghana 35th, and Senegal placed 46th globally¹⁵. Each country produced the aforementioned documents outlining their active surveillance in humans, animals, and the environment. National active AMR surveillance programmes in food-producing animals are nascent and much of the current knowledge is based on project and pilot studies. To fill these data gaps each nation has developed detailed active AMR surveillance programmes for food-producing animals and the environment. Additionally, the Food and Agriculture Organization of the United Nations (FAO) developed the Assessment Tool for Laboratories and AMR Surveillance Systems (FAO-ATLASS) to support countries in assessing and strengthening AMR surveillance in the food and agriculture sectors¹⁶. The tool comprises complementary laboratory and surveillance modules that evaluate national systems across five domains: governance, data production networks, data collection and analysis, communication, and sustainability. FAO-ATLASS applies a Progressive Improvement Pathway (PIP) to identify gaps, prioritise system strengthening actions, and monitor incremental improvements in laboratory and surveillance capacity over time¹⁶. All four countries have participated in the ATLASS assessment with varying outcomes¹⁷.

Here, we present a review of the strategy documents and sampling plans for active AMR surveillance in food-producing animals and the environment from Ghana, Nigeria, Senegal, and Sierra Leone. The three objectives of this review were to: i) assess data generation on animal health and the environment sectors from a One Health perspective and determine whether these data will help to inform in-country emerging AMR trends; ii) assess whether the data generated by the four countries within each sector can help to inform a regional comparison and perspective; and iii) offer recommendations to consider when creating AMR active surveillance and sampling plans

Methods

Data Collection

Documents included for review comprised the NAPs, AMR strategy documents, and sampling plans for each country and covered the active surveillance of AMR in livestock and the environment (Table 1). The NAPs of Ghana¹⁸, Nigeria¹⁹ and Sierra Leone²⁰ were downloaded from the WHO website. The second NAP for Senegal²¹ had been validated at the national level and, as it was not published on the WHO website at the time this review was undertaken, was provided to the authors in draft. Similarly, the AMR strategy documents and sampling plans are not publicly available, except for Nigeria (www.fmld.gov.ng), but consent was given and documents were shared by the countries to be used in this review for a high-level overview. Senegalese documentation was translated from French to English using DeepL²² for the purposes of this review. Key details and insights from Senegalese documents were validated by members of the authorship team with fluency in both languages. To provide a framework and benchmark for this review we consulted guidance publications, including the Fleming Fund protocol for active AMR surveillance in poultry²³ the WOAHA Aquatic Code²⁴ and the WHO Tricycle programme²⁵.

One Health Analysis of Strategy and Sampling Plans

Information from NAPs, strategy documents, and sampling plans was systematically extracted into an Excel spreadsheet to catalogue details in a harmonised format and assess alignment between strategy documents and sampling plans for within-country and between-country comparison. Extracted data included sampling areas, livestock species, environmental sample sites, target bacterial species, laboratory networks, and protocols (including antibiotic panels) (see supplementary file 1). Because first-level subnational administrative regions differ by country, we adopted the generic term “sampling area” to represent Ghana (regions), Nigeria (states), Sierra Leone (provinces), and Senegal (regions). In Nigeria, states can be grouped into geopolitical zones; this notation was retained when present in the source documents. Sampling strategies encompassed a range of animal types. We used the term “livestock species” as a generic descriptor, while recognising that poultry layers and poultry breeders belong to the same species; these were analysed separately due to substantial differences in production systems. Finally, the degree of One Health integration was assessed at both country and inter-country levels to evaluate robustness of strategies and facilitate comparability. This was achieved through comparing how bacterial species and antibiotic choices differed across animal health and the environment.

Visualisation of Sampling Locations

The Esri's World Hillshade standard basemap was used (ArcGIS inbuilt tool - World Hillshade - Overview) and each country's subnational administrative boundary shapefiles were downloaded from the Humanitarian Data Exchange Project database. A Polygon Merge tool (ArcGIS inbuilt tool) was used to group Nigerian states into the six geopolitical zones. A point layer was created to display laboratory locations, with labels applied using the labelling tool. Each map was extracted to a PDF using a 2000×1500-pixel resolution to ensure consistent sizes of figures.

Results

Situation Analysis in the Creation of NAPs and Strategy Documents

To inform their NAPs and AMR strategy documents all four countries conducted situation analyses, revealing differing stages of AMR surveillance development. Ghana was preparing its second NAP, building on the 2017–2021 plan, which fostered cross-sector collaboration and included a detailed budget. Ghana's situation analysis reported extensive antibiotic use in animal husbandry for disease prevention and growth promotion, with antibiotic residues present in the food chain and a likely driver of AMR¹⁸. Within the pig sector, antibiotics such as tetracycline, sulphadimidine, benzylpenicillin, and dihydrostreptomycin are commonly used for diarrhoea, rashes and coughs²⁶. At the time of writing the first NAP for Ghana, there was no department responsible for antibiotic usage, residues or surveillance within the aquaculture sector, the first NAP also states commonly used antibiotics in Ghanaian fisheries include tetracyclines, chloramphenicol, streptomycin and penicillin, although there was no reference supplied to this body of work. Nigeria's NAP outlined that, across the animal health sector, 10.9% of reported bacteria were multidrug resistant, and 2.3% were extremely drug resistant¹⁹. This also revealed a bias towards the poultry sector, with 49% of total submissions from poultry, highlighting the need for increased submissions from pigs, ruminants, and fish. Data was also limited in the environmental sector, with data generation reliant upon research rather than surveillance. The findings of what limited research there was suggests pathogenic bacteria, with high levels of drug resistance in ponds and wastewater, potentially influenced by hospital effluent, and human activities^{27,28}. Senegal's first NAP improved control and surveillance of infections caused by AMR pathogens and antimicrobial stewardship²¹. The second NAP outlined the need for further improvement, such as a national focal point for AMR, effective implementation of integrated AMR surveillance programs nationwide, and a digital platform for the collection and analysis of AMR surveillance data in a One Health manner. Similarly, a bias towards the poultry sector was highlighted, with the need for increased surveillance in aquaculture²¹. An initial pilot study identified molluscs to be an area of interest with low level presence of Extended-Spectrum Beta-Lactamase (ESBL) -producing *E. coli* (ESBL *E. coli*). Sierra Leone released its first NAP (2018-2022)²⁰ and identified key areas to address involving governance, awareness and education, laboratory surveillance, infection prevention and control, optimising antimicrobial usage and sustainable investment for AMR. Within the situation analysis Sierra Leone highlighted the lack of public awareness, with AMR not included as teaching content at schools and universities for veterinary, human health, or agriculture sectors, and no formally designated laboratory for AMR and subsequently limited data available in the animal health sector²⁰.

One Health AMR Governance

A consistent strength across all four countries was the establishment of multisectoral governance bodies that facilitate collaboration between human and animal health, agriculture, environment, and fisheries sectors. These bodies have been pivotal in developing AMR strategies and sampling protocols. The strategy documents each reflect a One Health approach with contributions from Ministries across all sectors, with input from WHO, FAO, academia, civil service, private sector, donor partners, and regional laboratory experts. Although differing in detail, each nation has implemented a well-defined structure with clear responsibilities and reporting routes to facilitate a coordinated One Health AMR effort. These One Health governance structures will be pivotal in addressing AMR as they enable sectors to collaborate, supporting the development of surveillance mechanisms, evidence-based policy and coordinated responses to contain AMR. The governance structures are presented in Supplementary Figures S1A-S1D.

Surveillance Sampling Areas

The surveillance strategies defined the sampling areas and specified the locations for collection of samples from each livestock species and the environment. To illustrate the geographic distribution, Figures 1A–1D present the sampling sites for poultry (broilers and layers), aquaculture species (catfish and tilapia), and environmental sources, along with the locations of the laboratories performing the analyses. Ghana has introduced a phased approach to undertake the active surveillance. Initially, phase 1 involves surveillance sites close to the laboratories, and as each phase progresses samples will be transported from further afield. This approach enables protocol

adaptation and adjustment as laboratory capacity increases over time. In Nigeria, the laboratory network supporting the terrestrial animal health sector has been expanded to ensure representation across all six geopolitical zones and to enhance private sector participation. In addition to the six existing sentinel laboratories engaged in Nigeria's AMR surveillance, three new active sites were recently incorporated, and the inclusion of private laboratories marks an important step toward a maturity across countries

and sustainable national AMR laboratory network. Nigeria and Ghana both state samples will be transported in appropriate transport medium or swabs, maintained on ice and held at 4 °C. Senegal aims to sample poultry and the environment in three sampling areas and aquaculture in seven, reflecting the distribution of livestock production. The Senegalese laboratories are all based in Dakar, which is a substantial distance from some sampling areas and careful consideration of timely sample transport is important. The Sierra Leone strategy specifies five sampling areas for poultry, three for aquaculture, and one for environmental sources. Initially, all samples will be processed at the Central Veterinary Laboratory which is located some distance from certain sampling sites. However, both countries mitigate sampling transport issues by including detailed sampling transport direction. Senegal outlines that samples will be taken and either submerged in transport medium or AIMES swabs before transport in a cooler with dry ice to the laboratory. Similarly, Sierra Leone outlines the use of three-layer packaging for biosecurity, samples to be transported at 4 °C within 24 hours and processed within 72 hours. All these steps help to maintain sample integrity and generate high-quality data.

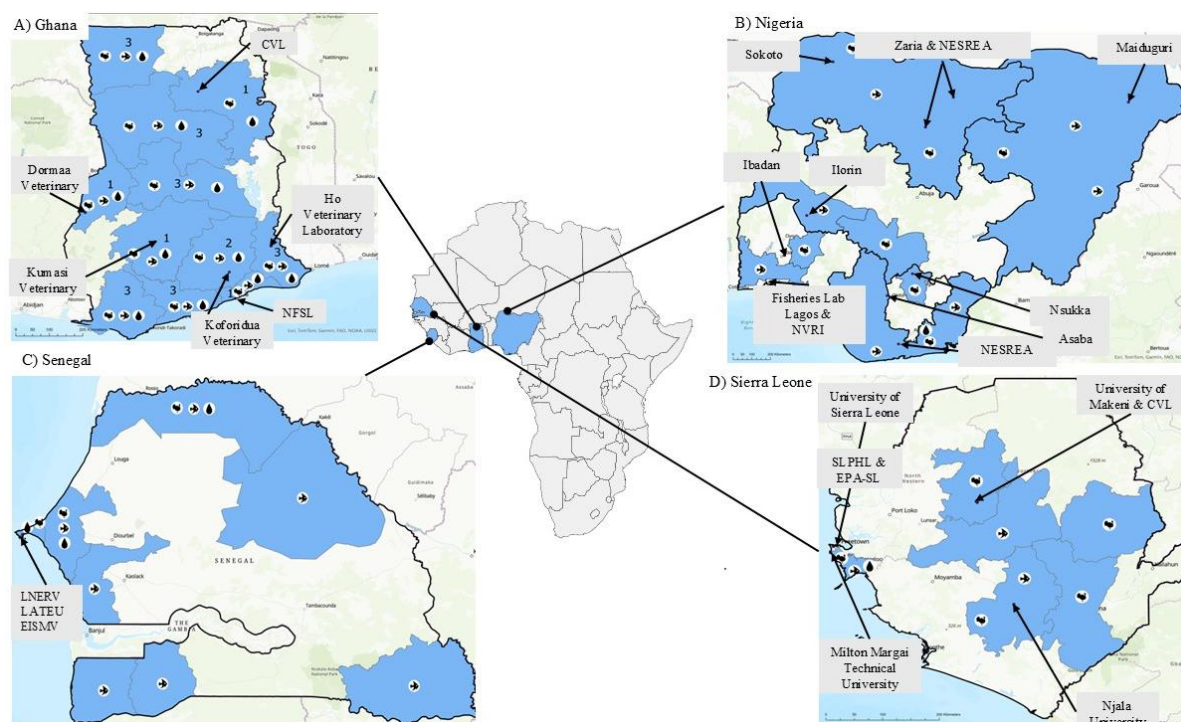


Figure 1: Sampling areas and laboratory locations for active antimicrobial resistance surveillance in livestock for A) Ghana, B) Nigeria, C) Senegal and D) Sierra Leone. Sampling areas highlighted in blue, with arrows indicating the locations of testing laboratories. Icon indicates sample type: chicken (layer or broiler chickens), fish (catfish and tilapia), and waterdrop (environment). A) Ghana sampling regions and the laboratory locations, with a number assigned to show the introduction of sampling regions using a phased approach (1-3). Laboratory acronym: NFSL, National Food Safety Laboratory; CVL, Central Veterinary Laboratory. B) Nigeria's six geopolitical zones each have a laboratory located in the zone. Zones are outlined in black. Laboratory acronyms: NVRI, National Veterinary Research Institute; NESREA, National Environmental Standards and Regulations Enforcement Agency. C) Senegal Laboratory acronyms: LNERVE, Laboratoire National de l'Elevage et de Recherches Vétérinaires; LATEU, Laboratoire de Traitement des Eaux Usées; EISMV, Ecole Inter-Etats des Sciences et Médecine Vétérinaires. D) Sierra Leone sampling locations in reference to the Central Veterinary Laboratory in Makeni, responsible for the aquaculture, poultry and pig AMR Surveillance. Laboratory acronyms: CVL, Central Veterinary Laboratory; SL PHL, Sierra Leone Public Health Laboratory; EPA-SL, Environment Protection Agency- Sierra Leone.

Livestock species selected

We compiled the livestock species included in active surveillance and summarise these in Table 2. A total of ten livestock species were identified. Ghana included the most diversity of livestock species (nine) and Sierra Leone the least (four). Only three livestock species were included for sampling by all four countries: poultry layers, tilapia, and catfish (Table 2). Cattle, poultry broilers and pigs were selected by three countries, and sheep and goat were selected by Ghana and Nigeria only. Pigs were not included for sampling in Senegal because the national herd is small. Sierra Leone did not include poultry broilers because prior sampling profiles identified that in-country poultry broiler production accounts for only 20% of the total poultry consumption, mainly as village/backyard chickens (FAO classification Sector 4; Supplementary Table 2), and the remainder are imported. Oysters were included in the surveillance in Senegal, and Ghana included crustaceans due to their industrial growth and contribution to food security, nutrition, and employment. A core guidance document used for design of poultry and aquaculture sampling was the Fleming Fund active surveillance document²³. WHO recommendations and a previous global review on AMR in the aquaculture sector²⁹ also informed the aquaculture sampling plans. The potential explanation for using a poultry protocol to develop an aquaculture sampling plan could be due to the lack of a similar protocol in the aquaculture sector at the time of preparation of the strategy documents reviewed here. Across all four countries there was an established exclusion criteria for sampling, unanimously stating that animals (terrestrial and aquaculture) exhibiting signs of disease were not included.

Poultry are a major protein source, widely consumed, associated with foodborne infections, and antimicrobials, including those critical for human health, are commonly used in poultry production. Consequently, poultry were included in all four surveillance plans. The FAO Classification system for poultry production defines four sectors, and all four countries included industrial integrated farms (sector 1; high biosecurity), commercial poultry farms (sector 2; high biosecurity), and smaller commercial poultry farms (sector 3; low biosecurity) (Supplementary Table 2). Across all countries Sectors 1, 2 and 3 were selected for sampling due to their traceability (farms to markets) for broilers and layers. In Sierra Leone however, only layers were selected for sampling due to broilers mostly being backyard (Sector 4) raising traceability issues or imported from neighbouring countries. Backyard poultry (sector 4) were only included in Ghana. This approach mirrors recommendations in the Fleming Fund poultry protocol²³. Sample size calculations were similarly based on this protocol, which employs Cochran's formula, to yield 384 samples per round of active sampling. However, in Sierra Leone, this calculation was undertaken and then adjusted with consideration to the laboratory capacity (reduced to 200 samples).

Tilapia and catfish are included in the AMR active surveillance strategies of all four countries, because they are widely farmed and consumed, involve frequent antimicrobial use, and constitute potential source and/or reservoirs of AMR with implications for human, animal, and environmental health. Different approaches on the targeted organ(s) and whether dissection will occur onsite or at the laboratory were evident between strategies. For example, samples in Nigeria were whole fish and kidney samples, in Ghana soft tissues and skin were targeted, and in Sierra Leone skin and gills swabs, and internal organs are sampled. Senegal will transport live fish to the laboratory, with no direct information regarding sample collection or transport, outlined in the strategy or sampling plans. Sampling at fish farms across the four countries was integrated with additional sampling types including fish feed, pond water and sediment samples. Sierra Leone additionally described the swabbing of farmers hands. The sampling strategy for Nigeria included details on sample transport at a controlled temperature to laboratories for processing.

Environmental sample types

There was considerable diversity with environmental sample types included in surveillance protocols, with 21 different types in total (Table 3). This may reflect a lack of standardised nomenclature in the environmental sector. The number of sample types per country ranged from 19 in Nigeria to five in Senegal. Hospital wastewater was the only sample type included by all four countries. Most sample matrices were water collected from different environmental sources, although Ghana included air samples at hospitals. Ghanaian sampling included wastewater from farms, factories, healthcare settings, rivers, lakes, schools, and markets, with 20 sites per phase and sample numbers increasing from 400 in Phase 1 to over 600 by Phase 3. Nigeria's program integrates passive (routine surveillance) and active (*e.g.* event based or periodic surveillance) sampling, targeting four river points to assess anthropogenic impacts on AMR, particularly ESBL *E. coli*. Senegal described pilot sampling in three regions: Dakar, Thiès, and Saint Louis (Table 3), including animal and hospital wastewater, urban and treated wastewater, and surface water. Sierra Leonean plans targeted wastewater, human faecal sludge, drinking water, informal settlements, hospitals, livestock farms, rivers, lakes, coastal waters, and tailing storage facilities at mines.

Environmental surveillance, while still the least developed element of the One Health framework, was nonetheless incorporated into all four NAPs, with each country demonstrating significant efforts to include environmental AMR surveillance. However, guidelines and protocols for environmental AMR surveillance remain limited. The World Health Organization Tricycle Programme represents an example of an initiative that incorporates an environmental component, aiming to harmonise AMR surveillance across the human, animal, and environmental sectors. Environmental sampling focuses on AMR ‘hotspots’, such as rivers receiving wastewater, animal slaughter wastewater, and human communal wastewater³⁰. The Tricycle programme focuses solely on ESBL *E. coli* as a sentinel species and provides a strong starting base for environmental surveillance. Nigeria, Senegal and Sierra Leone used the WHO Tricycle Programme to inform environmental surveillance site selection. Nigeria will focus on ESBL *E. coli* and leaving scope in the future to expand bacterial species. In contrast, Senegal and Sierra Leone will also include carbapenem-producing *E. coli*, vancomycin-resistant Enterococci and *Salmonella* spp. (Table 4). Ghana seeks to implement an extensive but staged environmental surveillance approach including carbapenem-producing *E. coli*, methicillin resistant *Staphylococcus aureus*, vancomycin resistant Enterococci and additional targeted bacterial species (Table 4).

Bacterial Species Selected for AMR Active Surveillance

Focussing on the poultry, tilapia, and environment sample types a total 16 different bacterial species were named in the four strategies. Of these only *E. coli* and *Salmonella* spp. were included by all four nations (Table 4). *E. coli* is often used as an indicator organism for drug resistance, as this commensal bacterium is ubiquitous and present in different hosts and environments and it can transfer plasmids and subsequently resistance genes to other microbes. Additional bacterial species included *Enterococcus* spp. for poultry and environmental sampling and *Aeromonas* spp. for aquaculture sampling. Each country has selected additional bacterial species based on national priorities and surveillance objectives (Table 4). The WOAHA Aquatic Code provides guidance to competent authorities on the development of monitoring and surveillance systems for AMR in aquaculture²⁴. This document was used as guidance for the active AMR surveillance in the aquaculture sector for Ghana. The Aquatic Code recommends *Vibrio parahaemolyticus*, *Salmonella* spp., and *Listeria monocytogenes* to be included in active surveillance for products entering the retail chain. *Vibrio parahaemolyticus* is relevant for shellfish screening but not in tilapia and catfish production. However, inclusion of *Listeria monocytogenes* could be considered, taking into consideration farming practices *i.e.* terrestrial animals farmed near aquatic animals and the isolation of the bacteria from meat products in West Africa³¹.

Antibiotic Selection for *E. coli* and *Salmonella* spp., for a One Health Approach

To enable an assessment between sample types and countries we examined the antibiotics selected for *E. coli* and *Salmonella* and present these in Table 5 and Table S4, respectively. Sierra Leone used an identical panel of 13 antibiotics for *E. coli* from poultry, tilapia and environmental sampling. This enables resistance profiles to be readily compared across species and sectors (*e.g.* between animals and environment samples), simplifying training, implementation, and supply chain management. Ghana has nine antibiotics shared across poultry, tilapia and environmental sampling, Senegal eight and Nigeria seven (Table 5). All four countries included those antibiotics authorised for use in humans only for active surveillance, as well as those classified by the WHO as Highest Priority Critically Important Antimicrobials (HPCIA), Critically Important Antimicrobials (CIAs), and Highly Important Antimicrobials (HIAs) for human use³².

ESBL *E. coli* are an indicator organism included in many AMR surveillance programmes and are often employed as key metrics for AMR monitoring³³⁻³⁵. Indeed, the Tricycle programme focuses exclusively on ESBL *E. coli* as the sentinel organism³⁰. Given this importance, detection of ESBL *E. coli* was included in the animal and environmental AMR surveillance plans for all four nations. For environmental surveillance, each country intends to follow the Tricycle protocols for the isolation, identification and confirmation of ESBL *E. coli*. The Tricycle methods are standardised and include selective culture for ESBL *E. coli* on culture media supplemented with 4 mg/L cefotaxime, follow by confirmation through demonstrating synergy with clavulanic acid. Tricycle has selected two cost effective ESBL confirmatory methods that are recommended by CLSI and/or EUCAST: the combination disk diffusion test (CDD) and double disk synergy test (DDST)³⁰.

For other samples originating from animal and aquaculture settings, however, we observed differences in procedures for ESBL *E. coli* isolation and confirmation. Where specified in the documentation provided, ESBL isolation would be undertaken on culture media supplemented with 1 mg/L cefotaxime, which is the screening concentration recommended by EUCAST³⁶. Nigeria details confirmation of the ESBL phenotype by CDD or DDST, whereas Senegal and Sierra Leone described the use of Etest ESBL strips or the CDD method. The relevant

surveillance protocols in Ghana had not been finalised at the time this review. These differences present an opportunity to consider harmonisation at national, or even regional, level to standardise laboratory SOPs, simplify procurement, and streamline staff training and competency, potentially leading to more readily comparable data.

Quality Assurance

The importance of quality assurance and control is recognised and highlighted in the documentation from each country. This includes the need for laboratory training, ISO accreditation, development of internal quality schemes, and participation in external quality control assurance programmes to ensure reliable and reproducible results. Internal controls are required at every stage of the laboratory workflow from media preparation to antimicrobial susceptibility testing to ensure the results generated are accurate and reliable. All four countries strategy documents and sampling plans outline a theme of quality control throughout the strategy and sampling plans, from sample collection and metadata to data storage and management. Ghana outlines that the national reference laboratory (NRL) will provide quality assurance and relevant revisions for improvement. Similarly, Nigeria, Senegal and Sierra Leone state the incorporation of external quality assurance (EQA) and internal quality assurance (IQA) led by the NRL creating IQA for the sentinel laboratories, and in turn the NRL is included in EQA. Senegal also states key stakeholders in their strategy documents to include quality management experts to oversee all stages of the surveillance process to ensure high quality data is generated.

Data Reporting

Across the four countries, active AMR surveillance data generated at national level are intended for reporting both nationally and to international platforms, for example WOA's ANIMUSE and the FAO International Antimicrobial Resistance Monitoring system (InFARM)³⁷, although reporting structures and platforms vary. Ghana, Nigeria and Sierra Leone used WHONET platform for data analysis before submitting data to national and international platforms. Laboratories in all countries are operating a paper-based system with some also using Microsoft Excel. LIMS and WHONET were introduced or re-enforced in Ghana, Senegal and Sierra Leone during Fleming Fund phase 2. In Ghana, sentinel laboratories will generate AMR data, NRLs will collate the data, and submit to the National Central Data Repository. The National Coordinating Centre will produce annual cross-sectoral reports and disseminate them through the Ghana AMR Secretariat, while also reporting data internationally to WHO GLASS³⁸ and WOA's ANIMUSE³⁹. Ghana will also seek to develop an integrated, real-time system linking AMR, AMU, and antimicrobial consumption data across human, animal, and environmental sectors. This system was developed after the strategy document, and it is called the Ghana AMR Surveillance System (GASS) which is a fully automated One Health system with a functional dashboard located at the AMR secretariat. In Nigeria, sentinel laboratories will report AMR data to NRLs, which will submit the data to the National Animal Diseases Information and Surveillance (NADIS) system for epidemiological analysis. NADIS will submit outputs to the Chief Veterinary Officer who in turn will share the information with the National AMR Steering Committee and will also report data to the Antimicrobial Resistance Information System for secure national storage and international submission to InFARM. Additionally, a multi-sectorial platform integrating human, animal and environmental health sectors for AMR data has been developed, named Antimicrobial Resistance Information System (AMRIS) and is hosted by Nigeria Centre for Disease Control and Prevention. National Environmental Reference Laboratories will collate environmental AMR data and report them to the Federal Ministry of Environment and to GLASS. Nigeria will additionally produce surveillance reports, policy briefs, and technical documents to support in-government dialogue and improvements in active surveillance, while government platforms will share findings periodically online. Nigeria will also produce newsletters and educational materials to increase wider public awareness. In Senegal, the NRL will collate and analyse AMR data generated by sentinel laboratories, while the National Livestock and Veterinary Research Institution (LNERV) will manage animal sector surveillance through the national epidemiological surveillance system. LNERV will report outputs to the Directorate of Veterinary Services and the Ministry of Livestock and Animal Production, and the Directorate of Veterinary Services will share official reports with the Ministry of Health and report animal sector data to InFARM. The environmental sector will produce annual reports; however, the reviewed documents did not specify data dissemination pathways. In Sierra Leone, the Central Veterinary Laboratory will generate AMR data and submit them to the national epidemiological unit within the Ministry of Agriculture and Food Security for analysis and dissemination to national stakeholders, including the Chief Veterinary Officer and the One Health Inter-Ministerial Committee. The Chief Veterinary Officer is responsible for reporting data to international platforms such as InFARM. In Sierra Leone, the environmental sector plans to establish a centralized national database for AMR data collection, storage, and analysis.

Discussion and Conclusion

This review assessed the documents for active AMR surveillance in animals, aquaculture and the environment from four West African countries: Ghana, Nigeria, Senegal, and Sierra Leone. This review provides the first comparative analysis of their alignment, completeness, and One Health integration. Overall, the documents reveal strong multisectoral coordination and a shared commitment to generating AMR data across terrestrial animals, aquaculture, and environmental sources. The presence of established governance structures and cross-ministerial planning highlights strong recognition of AMR as a national, regional and global multisectoral threat, consistent with the GAP⁶. This review also highlights essential components of effective strategy documents and sampling plans for countries developing or refining their AMR surveillance systems.

The four countries have demonstrated their commitment to AMR surveillance, throughout their NAPs, National AMR Strategy documents, and sampling plans. All countries have clear governance structures and mechanisms for AMR surveillance, data reporting to national and international platforms, and AMR surveillance inclusive to all three sectors: humans, animals including aquaculture, and the environment. AMR is a true One Health problem, and surveillance is required to enable the early detection of resistance, monitor trends, and inform coordinated interventions across human, animal, and environmental health⁴⁰. As mentioned by Chen and colleagues¹³ to ensure documents remain up to date and relevant to the situation, countries in the early stages should focus on robust One Health governance structures, strengthen AMR surveillance systems, and improve data collection in a step wise manner. Therefore, periodic updates to all provided documents is a necessary step to continue implementation and high-quality data generation.

A key strength across all countries is their convergence on priority livestock species particularly poultry, tilapia, catfish, and bacterial targets including *E. coli*, and *Salmonella* spp. which will facilitate important steps towards regional AMR trend analyses. Similarly, the adoption of the Fleming Fund poultry protocol and alignment with WHO Tricycle principles helped shape comparable approaches to sample collection, laboratory workflows, and antimicrobial panel selection. Most importantly, linkage with the human health sector is achieved through the focus on zoonotic bacterial species and the prioritisation of antimicrobials of HPCIA, CIA, and HIA, strengthening the One Health relevance and cross-sector comparability of data produced. Proposed AMR surveillance priorities align closely with those identified in other regions including in Eastern Africa³⁵. South East Asia³³, the European Union⁴¹ and the UK³⁴. These have a focus on key zoonotic bacteria (*e.g. Salmonella* spp., *E. coli*, *Enterococcus* and *Campylobacter* spp.) in food-producing animals and include ESBL *E. coli* and AmpC -producing *E. coli*⁴²⁻⁴⁴. In contrast, West Africa lacks harmonised regional AMR surveillance guidance beyond limited country- and species-specific studies, positioning this manuscript as a potential framework for neighbouring countries seeking to establish active AMR surveillance systems^{45,46}.

Despite these commonalities, important divergences remain. Environmental surveillance shows the greatest variability, with countries selecting different sampling sites and sample types, which may limit cross-country comparability. This reflects the early stage of environmental AMR surveillance worldwide, where protocols remain limited and a lack of agreed naming conventions for sampling matrices adds further uncertainty^{47,48}. Differences in sample types and antibiotic selection in the aquaculture sector also indicate areas where additional harmonisation would be beneficial³³. In the absence of sector-specific protocols, countries have relied heavily on the Fleming Fund poultry and WHO Tricycle protocols, two of the few detailed guidance documents available at the time the countries were developing their strategies and sampling plan protocols. While this approach has supported initial development, there is an opportunity to enhance consistency by establishing dedicated sampling protocols for the aquaculture and environmental sectors. In many cases aquaculture and environmental surveillance plans are either not publicly available or are research-driven^{49,50}. Within the European Union, Member – States will undertake active AMR surveillance in the aquaculture sector by 2028, while environmental surveillance was initiated on a small scale, voluntary basis between 2023 – 2025, with the need for a Member – State-wide surveillance subsequently proposed but not yet undertaken^{42,44}. Nevertheless, we observed many similarities between the West African plans and proposed European Union active surveillance plans for aquaculture and environmental sectors, specifically on the targeted bacterial species and antibiotics^{42,44}.

Differences in sampling distances and laboratory locations can pose potential challenges for sample integrity and sustainability. Addressing these through feasible transport logistics and by enhancing capacity in peripheral laboratories, or considering the development of closer laboratories, may help support more robust procedures. Senegal and Sierra Leone either outlined their sample collection and transportation in the sampling plans provided or stated they were included in the SOPs to maintain sample integrity when transporting over long distances.

Additionally, a pilot phase could be introduced, using smaller scalable sample numbers or sample site of closer proximity, to establish a baseline data and benchmark the AMR situation in all sectors. Such an approach may also allow adjustments to the surveillance strategy if sample integrity issues affect the data. A staged approach, like the phased expansion planned by Ghana across all sectors, may further support implementation by allowing laboratory staff time to become familiar with procedures, build competence, and develop operational resilience. Extensive surveillance may increase the workload in countries with minimal laboratory availability and therefore assessment of the laboratory space, equipment, laboratory personnel and workload should be considered to enable full implementation of AMR surveillance. To reduce cost and effort, countries could focus active surveillance for aquatic animal products intended for human consumption at slaughter before they enter retail market, similar to EU plans⁴⁴.

Participation in Proficiency Testing (PT) schemes provides a laboratory with EQA for key laboratory activities, such as antimicrobial susceptibility testing. PT schemes operate by providing participating laboratories with test samples for analysis. Laboratories analyse the PT samples, ideally as part of their normal routine, and report the results to the scheme organiser. They are then provided with a report showing how closely their results agree with the expected values and participants can take action to address any areas of concern. Participation also enables laboratories to provide evidence to regulators and accreditation bodies of their commitment to monitoring and improving performance. Participation in PT schemes has shown to overall increase laboratory performance overtime, generating high quality and reliable data, and therefore this should be prioritised in active AMR surveillance^{51,52}.

Data reporting pathways to national platforms were detailed, ensuring that AMR surveillance information is passed to competent authorities to support informed decision making and monitoring. Submission of data to international platforms was explicitly included in strategies in all four countries, demonstrating a national commitment to support global action on AMR. To facilitate efficient and compliant data sharing it would be helpful to prepare guidance documentation detailing procedures and responsibilities, although some countries have developed such procedures while this manuscript was under preparation, they were not in-scope for this review. For laboratories, access to IT facilities, suitably competent data-handling staff, and reliable electricity and internet connections will also be important considerations to allow timely reporting.

It is important to highlight the limitations to this study. The review was based on the strategy documents and sampling plans provided by each country and therefore reflects planned, not necessarily implemented surveillance activities. In some cases, documents lacked operational detail, particularly regarding laboratory workflows, and on some occasions strategies and sampling plans had not been finalised, meaning the information reviewed may not fully represent future practice. Finally, this review did not assess field implementation, laboratory performance, or data outputs, which limits the extent to which we can assess the feasibility or effectiveness of the planned surveillance activities. Despite these constraints, the review provides a valuable snapshot of the current landscape and highlights key opportunities for comparability between the targeted bacteria (such as *E. coli* and *Salmonella* spp.) and the selected antibiotics in the three sectors poultry, aquaculture and environment. Various recent studies have shown measurable improvements in AMR outcomes to typically emerge several years after implementation of national action plans, highlighting that the strategies reviewed here represent early stages of a longer policy-to-impact trajectory¹³. We also recognise that changing funding and policy priorities can lead to change in the implementation of AMR surveillance. Ensuring financial sustainability is essential for the long-term success of these surveillance systems. Countries will need to consider prioritising domestic funding for AMR surveillance, as reliance on external support limits sustainability and long-term impact. Investment prioritisation for AMR surveillance generates critical baseline data on resistance prevalence, dissemination pathways, and potential risks to public health. AMR surveillance remains an important and essential endeavour to generate information for action to contain and control AMR. Strengthening coordinated One Health AMR surveillance will support evidence-based policies, improve regional preparedness, and contribute to global efforts to reduce the burden of antimicrobial resistance⁴³.

Taken together, the active surveillance strategies and sampling plans developed by the four countries demonstrate significant progress toward establishing robust One Health AMR surveillance systems in West Africa. If implemented as designed, these plans will generate high-quality, comparable AMR data across poultry, aquaculture, and environmental sectors. Shared priority species, similar methodological foundations, and multisectoral collaboration all provide a foundation for regional AMR trend analysis. However, sustained investment in laboratory capacity, harmonisation of sampling methodologies particularly for aquaculture and

498 environmental surveillance and practical considerations such as sample transport and workflow demand will be
499 essential to ensure data reliability.

500

501 **Author contributions**

502 Conceptualisation: ATN, RMC, JC, AP, Methodology and investigation: JC, AP, MB Supervision: SO, KA, NEA,
503 CFD, HOA, MN, ED, KD, JL, MB, MS, CBA, RMC, ATG, MB, BKS, EAC Data curation and formal analysis:
504 JC, AP, Resources: SO, KA, NEA, HOA, MN, ND, ED, RB, KD, JL, CBA, RMC, ATN. Writing original draft
505 preparation: JC, AP, RMC. All authors read and approved the final manuscript.

506 During the preparation of this work, the authors used DeepL for the translation of Senegalese documents into
507 English, these translations were then checked by an author fluent in both French and English, to ensure
508 consistency. The authors reviewed and edited the output as needed and take full responsibility for the content of
509 the published article.

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Table 1: Documentation used to inform this review provided for Ghana, Senegal, Sierra Leone and Nigeria.

Country	Documents
Ghana	NAP version 1.0 (2017-2021) Integrated Antimicrobial Resistance Surveillance Framework (2024-2034) (in draft)
Nigeria	NAP version 2.0 (2024-2028) National strategy, framework and protocol for antimicrobial resistance surveillance, data sharing and reporting in the animal health sector of Nigeria (2024-2028) Antimicrobial Resistance Surveillance Strategy and Protocol for the Environmental Health Sector (2024)
Sierra Leone	NAP version 1.0 (2018-2022) National Antimicrobial Resistance Surveillance and Antimicrobial Use Monitoring Strategy for Animal Health (2022) Protocol for Active Surveillance AMR in the Pigs Sector in Sierra Leone (2023) Protocol for Active Surveillance AMR in the Poultry Sector in Sierra Leone (2022) Protocol for Active AMR Surveillance in Aquaculture in Sierra Leone (2025) Protocol for Active AMR Surveillance in the Environmental Sector in Sierra Leone (2025)
Senegal	Senegal version 2.0 (2024-2028) Integrated antimicrobial resistance surveillance manual Monitoring AMR in effluents in Senegal Active Surveillance Protocol in Poultry Sector Senegal (2025) Active Antimicrobial Resistance Surveillance Protocol in Environment in Senegal (2025) Animal health is used to encompass the health of both terrestrial and aquatic animals (2025)

Table 2: Overview of the animals selected for active antimicrobial resistance sampling in Ghana, Nigeria, Senegal and Sierra Leone.

Country	 Layers	 Broilers	 Cattle	 Pig	 Goat	 Sheep	 Catfish	 Tilapia	 Oysters	 Crustaceans
Ghana	✓	✓	✓	✓	✓	✓	✓	✓		✓
Nigeria	✓	✓	✓	✓	✓	✓	✓	✓		
Senegal	✓	✓	✓				✓	✓	✓	
Sierra Leone	✓			✓			✓	✓		

518

519 **Table 3: Environmental sample types selected for active antimicrobial resistance surveillance in Ghana, Nigeria, Senegal and Sierra Leone.**

	Air samples	Upstream ambient river	Midstream	Upstream prior to discharge	Downstream ambient river	Slaughterhouses	Hospital wastewater	Urban wastewater	Treated wastewater	Surface wastewater	Faecal sludge	Wastewater treatment plants	Household drinking water	Waste dump sites	Informal settlements	Livestock farms	Rivers	Lakes	Coastal waters	Informal mining areas	Effluents from pharmaceuticals
Ghana	✓	✓	✓	✓	✓		✓			✓			✓			✓	✓	✓			✓
Nigeria		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Senegal						✓	✓	✓	✓	✓											
Sierra Leone							✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

520

Table 4: Bacterial species selected for active antimicrobial resistance surveillance in poultry, aquaculture and environmental sectors in Ghana, Nigeria, Senegal and Sierra Leone. Data is presented by country and sector: poultry (chicken icon), tilapia (fish icon), and environment (waterdrop icon). Note, for Sierra Leone broilers are not included in the active surveillance and the tick represents active surveillance carried out in layers.

	Sector	<i>Escherichia coli</i>	<i>Salmonella</i> spp.	<i>Enterococcus</i> spp.	<i>Vibrio</i> spp.	<i>Aeromonas</i> spp.	<i>Pseudomonas</i> spp.	<i>Streptococcus</i> spp.	<i>Klebsiella</i> spp.	<i>Campylobacter</i> spp.	<i>Staphylococcus</i> spp.	<i>Acinetobacter</i> spp.	<i>Clostridium</i> spp.	<i>Edwardsiella</i> spp.	<i>Shigella</i> spp.
Ghana		✓	✓	✓			✓		✓	✓	✓	✓	✓		
		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Nigeria		✓	✓	✓											
		✓	✓	✓	✓	✓		✓		✓					
		✓													
Senegal		✓	✓	✓											
		✓	✓		✓	✓		✓							
		✓	✓	✓					✓						
Sierra Leone		✓	✓												
		✓	✓	✓	✓	✓	✓								
		✓	✓	✓	✓		✓								

527 **Table 5 Continued: Comparison of antibiotic panels employed for antimicrobial susceptible testing of *E.***
528 ***coli*.** Data is presented by country and sector: poultry (chicken icon), tilapia (fish icon), and environment
529 (waterdrop icon). Antibiotics are grouped by class and priority indicated, according to WHO List of Medically
530 Important Antimicrobials. Colour key: Blue, Only for human health; Red, Critically Important Antibiotic; Orange,
531 Highly Important Antibiotic; Yellow, Important Antibiotic.

Antibiotic Class	Antibiotic	Priority	Ghana			Nigeria			Senegal			Sierra Leone		
Sector			🐔	🐟	💧	🐔	🐟	💧	🐔	🐟	💧	🐔	🐟	💧
Aminoglycoside	Gentamicin			✓		✓	✓		✓	✓	✓	✓	✓	✓
	Amikacin										✓			
Amphenicol	Chloramphenicol					✓	✓		✓	✓	✓	✓	✓	✓
Carbapenem	Meropenem/Imipenem		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Ertapenem		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cephalosporins	Cefepime		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Cefotaxime		✓	✓	✓			✓			✓			
	Ceftazidime		✓	✓	✓			✓						
	Cefoxitin										✓			
	Cefalexin										✓			
	Ceftriaxone		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Penicillin	Ampicillin					✓	✓	✓	✓	✓	✓	✓	✓	✓
	Amoxicillin-Clavulanic Acid								✓	✓	✓			
	Piperacillin-Tazobactam										✓			
	Temocillin										✓			
	Ticarcillin										✓			
	Ticarcillin-Clavulanic Acid										✓			
Quinolone	Ciprofloxacin		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Nalidixic Acid					✓	✓		✓	✓		✓	✓	✓
	Pefloxacin									✓		✓	✓	✓
	Levofloxacin		✓	✓				✓			✓			
	Enrofloxacin													
	Oxolinic Acid													
Lipopeptide	Colistin		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Sulphonamide	Co-trimoxazole		✓	✓	✓			✓	✓	✓		✓	✓	✓
Tetracycline	Tetracycline					✓	✓		✓	✓		✓	✓	✓
Macrolide	Erythromycin									✓				
Folate	Trimethoprim										✓			
Phenicol	Florfenicol									✓				
Fosfomycin	Fosfomycin										✓			
Nitrofurantoin	Nitrofurantoin										✓			

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