Food and Agriculture Organization of the United Nations

Animal & Plant Health Agency

Veterinary Medicines Directorate

Centre for Environment Fisheries and Aquaculture Science

FAO Reference Centre for AMR - Annual Report

Title of FAO Reference Centre for Antimicrobial Resistance	UK FAO Reference Centre for Antimicrobial Resistance
Name of the Institution and contact details	Department for Environment, Food and Rural Affairs (Defra) Woodham Lane Addlestone KT15 3LS
Head of the FAO Reference Centre	**Claire Gilbert and Elizabeth Marier**, Veterinary Medicines Directorate, Defra **David Verner-Jeffreys**, Centre for Environment, Fisheries and Aquaculture Science, Defra **Roderick M. Card**, Animal and Plant Health Agency, Defra
Reporting period	January 2023 – December 2023

Please report activities as specified in the paragraph 'areas of collaboration' in the designation letter – Where applicable, please always give details on beneficiary countries, project names, activities carried out, outcomes and recommendations.

Additionally, please provide information on:

1. Involvement in other non-FAO technical assistance projects or activity
2. Participation in international, regional scientific collaborative studies or projects (please mention partners and/or organisation; country, objectives and activities)
3. Organisation / participation in international / regional scientific meetings
4. Publication and dissemination of information relevant to the work of FAO including list of scientific publications, internet publishing activities, presentations at international, regional conferences
5. Any major change in staff or institution, including governmental institution(s), during the reporting period
6. Updates on accreditation or biosafety level (if applicable)
7. Comments or remarks on any general or technical matter/finding/trend

Note:
For country names, please refer to the Names of Countries system (NOCS):
https://www.fao.org/nocs/en

Contents

Glossary

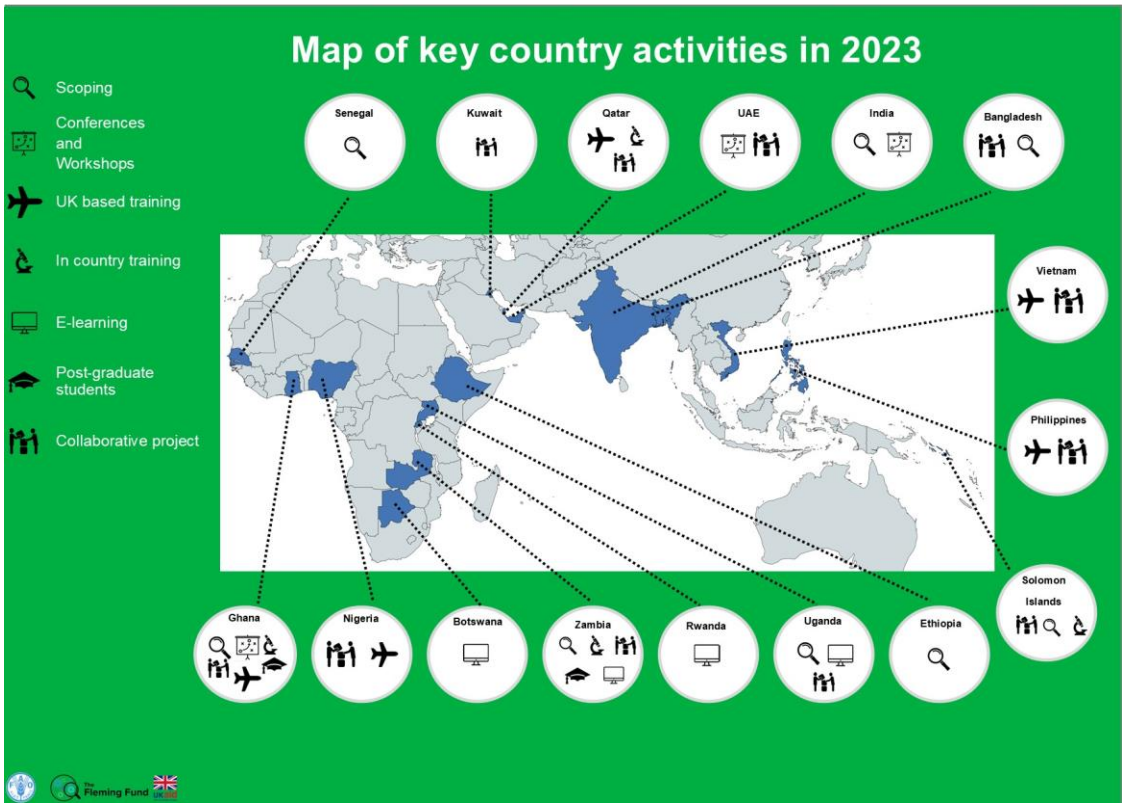
Abbreviation	Term
AMR	Antimicrobial Resistance
AMU	Antimicrobial Usage
APHA	Animal and Plant Health Agency
AST	Antimicrobial Susceptibility Testing
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CLSI	Clinical and Laboratory Standards Institute
CoP	Community of Practice
CVO	Chief Veterinary Officer
Defra	Department for Environment, Food and Rural Affairs
DHSC	Department for Health and Social Care
DIT	Department for International Trade
DTU	Danish Technical University
ECOFF	Epidemiological Cut Off Value (EUCAST)
ECV	Epidemiological Cut Off Value (CLSI)
EQA-PT	External Quality Assessment – Proficiency Testing
EUCAST	The European Committee on Antimicrobial Susceptibility Testing
ESBL	Extended Spectrum Beta Lactamase
FAO	Food and Agriculture Organisation of the United Nations
FAO – RAP	FAO – Regional office for Asia Pacific
FAO ECTAD	Emergency Centre for Transboundary Animal Diseases
FCDO	Foreign and Commonwealth Development Office
FOAO	Food products of animal origin
HLM	High Level Meeting
ICAR	Indian Council of Agricultural Research
InFARM	International FAO Antimicrobial Resistance Monitoring
LMIC	Low- or Middle-Income Country
MRL	Maximum Residue Limit
NAP	National Action Plan
NMIS	National Meat Inspection Services - Philippines
OCPP	Ocean Country Partnership Programme
ODA	Official Development Assistance
PT (Scheme)	Proficiency Testing (Scheme)
RAP	FAO Regional Office for Asia Pacific
TAG	Technical Advisory Group
UAE	United Arab Emirates
UK	United Kingdom
UKHSA	United Kingdom Health Security Agency
UNGA	United Nation General Assembly
USA	The United States of America
TATFAR	Transatlantic Trans-Atlantic Task Force
VMD	Veterinary Medicines Directorate
WHO	World Health Organisation
WOAH	World Organisation for Animal Health

Executive Summary

The UK FAO Reference Centre for AMR (Reference Centre) comprises a broad range of AMR expertise across three agencies of the UK's Department of Environment, Food and Rural Affairs (Defra): Animal and Plant Health Agency (APHA); Centre for Environment, Fisheries and Aquaculture Science (Cefas); and the Veterinary Medicines Directorate (VMD). In 2023 this designation was renewed by the FAO for a further four years until April 2027.

In March 2023, we hosted the inaugural Congress of FAO Reference Centres for AMR at our facilities in Weybridge, UK FAO colleagues from Rome and Regional Offices, together with the heads of the FAO Reference Centres for AMR from eight countries, attended in person or joined on-line. The Congress fostered stronger connections between network members, identified areas for future collaboration, and outputs included a list of prioritised activities aligned with FAO strategic objectives.

Over the last year we have delivered work to a high standard in all four of our main activity areas. The in-country activities delivered in 2023 are summarised in the map below.



Summary of activities undertaken by the AMR Reference Centre in countries 2023.

International Engagement

The Reference Centre has continued to provide **high quality expert advice** to our global partners, which include the FAO, the UK Government (Defra, DHSC, FCDO) and funding partners (Fleming Fund and Mott MacDonald). We have participated in and presented our work at **international conferences and workshops** in countries including Bangladesh,

Denmark, France, Ghana, India, Italy, Luxembourg, Serbia, Thailand, the United States of America, and the UK. Additionally, we attended or hosted numerous virtual meetings with our **international partners.** We had the opportunity to **visit FAO Reference Centre for AMR colleagues** at their home facilities in Denmark, Senegal, and Thailand to discuss potential collaborations, joint opportunities, identify current needs, and determine areas of common interest. We actively engaged with different countries to understand their processes and requirements. These **scoping visits** were conducted in Bangladesh, Senegal, Uganda, and Zambia. Notable highlights from 2023 include our participation in the FAO Regional AMR Technical Advisory Group Meeting for the animal health sector in Bangkok, Thailand; the development of joint projects in Zambia and Ghana; and the delivery of biosecurity training modules for finfish in Bangladesh.

Capacity Building

Helping countries build their capacity for long-term sustainability and resilience remains our focus, and a key deliverable of the reference laboratory. In particular, we directly supported a **vibrant AMR Community of Practice**, where over 90 AMR experts from 25 countries shared expertise, promoted good laboratory practices, and built professional networks. We helped deliver a **postgraduate programme** for AMR-related studies in Zambia. Capacity building has also included continuing delivering strong support to the **Fleming Fund Fellowship** Programme, including actively mentoring antimicrobial usage (AMU) and AMR fellows from Ghana and Nigeria. We have **hosted international visitors** at our UK facilities from ten countries who came for training, networking, and to strengthen our collaborations. We have provided **in-country microbiology laboratory training** for our partners in countries including Ghana and Zambia. We provided **residue surveillance** laboratory training in Zambia. Our experts rolled out **e-learning courses** to 20 specialists from Botswana, Uganda, and Zambia.

Surveillance and research

We engaged in **collaborative projects** in many of our partner countries, to support research **capacity development**. This partnership approach enables the generation of quality data and analyses addressing evidence gaps relevant to AMR and potential risks to veterinary or public health. Six **peer-reviewed publications** were generated in 2023 from our collective surveillance and research activities. Highlights include the first publication describing the prevalence, antimicrobial susceptibilities, and genomic diversity of *Salmonella* in commercial chicken table eggs in Ghana and an investigation of multidrug-resistant non-typhoidal *Salmonella* from migratory birds in Bangladesh. Further surveillance and research projects have been undertaken with partners in Kuwait, Qatar, the Solomon Islands, and Vietnam.

Guidance and standards

Our experts contributed to providing a range of key guidance and standards. These included the development of an e-learning course for pharmacovigilance training and the draft of **veterinary medicines residues guidelines**. We enrolled new laboratories from Africa into our antimicrobial susceptibility testing **proficiency testing scheme** for the 2024

distribution. We also sat on various **expert groups** including the CLSI Subcommittee on Veterinary Antimicrobial Susceptibility Testing Working Group on Aquatic Animals and FAO's AMR Subject Matter Experts forum. The Reference Centre has had a leading role in setting **susceptibility testing protocols** and the **development of interpretive criteria** for a range of aquaculture pathogens in collaboration with international laboratory partners.

In summary, we have a **strong track record** of delivery with FAO and other organisations in a range of countries to **tackle antimicrobial resistance**.

1.0 Introduction

The United Kingdom (UK) Food and Agriculture Organisation (FAO) Reference Centre for Antimicrobial Resistance (AMR) (hereafter referred to as the 'Reference Centre') works closely with the FAO Reference Centre secretariat and AMR focussed FAO staff for the delivery of its programmes. This is the Reference Centre's fourth report since our initial designation in 2019. This report covers the activities delivered in 2023 and demonstrates how we have built on our strong track record of delivery for FAO and other organisations in a range of countries to tackle AMR, strengthen surveillance, and improve capacity, with a focus on enabling long-term sustainability and resilience.

In 2023, a significant milestone achieved was the renewal of our designation as an FAO Reference Centre for Antimicrobial Resistance until April 2027. This was finalised by exchange of letters between the FAO Deputy Director-General, Maria Helena Semedo, and the Rt Hon Lord Benyon in his capacity as Minister of State at the UK Department for Environment, Food and Rural Affairs (Defra).

This redesignation recognises that the Reference Centre is now fully established. Our high-profile experts continued to engage widely with partners in many countries and, with the continued generous support of the Fleming Fund, Defra and other funders, we have been able to deliver significant programmes in several countries. In this report, we show how, by the forming of deep and enduring relationships with many of our partners since our initial designation, we have helped to ensure lasting impact in tackling the scourge of AMR. We intend to continue to build on these activities with our many engaged and supportive partners in the future.

1.1 Who we are

The FAO designation recognises the broad range of AMR expertise across three agencies of Defra: Animal and Plant Health Agency (APHA); Centre for Environment, Fisheries and Aquaculture Science (Cefas); and the Veterinary Medicines Directorate (VMD). Further information about each agency can be found in Appendix 1.

1.2 Our Vision

To safeguard animal and human health from the threat of antimicrobial resistance.

1.3 Our Mission

To provide leading **scientific and policy expertise** within the global community to tackle antimicrobial resistance in **terrestrial and aquatic animals** and their **environment** in a **One Health** context.

1.4. Our Objectives

1.5. Achieving our Objectives

To achieve our objectives, we seek to complement FAO's programme by supporting member countries in the implementation of their National Action Plans (NAP) on AMR. Our activities are aligned with the FAO Action Plan on AMR (2021-2025), the Quadripartite approach to One Health action on AMR, and the UK's AMR NAP (2019–2024). We contributed to the development of the next five-year UK AMR NAP (2024-2029), to make sure that our objectives were incorporated and aligned with the projected deliverables.

We place partnership at the core of our approach and seek to engage with a wide range of partners to deliver our activities under four broad categories: international engagement, surveillance and research, capacity building, and guidance and standards. Activities are underpinned by management and communication functions.

2.0 Acknowledgements and Funding

We would like to thank our partners in the countries and organisations with whom we have worked for their ongoing support and engagement. We also wish to thank the FAO, its

AMR Reference Centre secretariat, and the FAO staff and teams for their continual support and collaborative approach.

We gratefully acknowledge our funding partners for their ongoing support:

- The Department for Environment, Food and Rural Affairs (Defra)
- The Fleming Fund, Department for Health and Social Care (DHSC)
- Defra Overseas Development Assistance (Defra ODA)
- The Fleming Fund Fellowship programme
- The Foreign, Commonwealth and Development Office (FCDO)
- Bill and Melinda Gates Foundation
- Food and Agriculture Organisation (FAO)

3.0 International Engagement

3.1 Engagement with the FAO Reference Centre for AMR secretariat, FAO AMR-focussed staff, and FAO Regional offices

3.1.1 FAO Reference Centre for AMR secretariat

The Reference Centre continued to work closely with the FAO Reference Centre secretariat and AMR-focussed FAO staff on the delivery of its programmes. Highlights from 2023 include: hosting the first congress of FAO AMR Reference Centres, continued planning and provision of proficiency testing schemes and further development of FAO e-learning Academy AMR courses. Each of these activities is described in greater detail within this report.

We continued to participate in **bimonthly FAO AMR Reference Centre meetings**, further strengthening our collaboration with representatives from the other FAO designated AMR Reference Centres and sharing knowledge, such as actions for the 2023 World AMR Awareness Week, with the global theme of ‘Preventing Antimicrobial Resistance Together’ and contributing to the FAO’s AMR Newsletter.

We are members of the **FAO’s AMR Subject Matter Experts forum** and provide an expert scientific resource for review and consideration of AMR matters for FAO.

With the AMR secretariat team at FAO, we discussed the opportunity to establish a **Joint Technical Secretariat** to contribute further to the operationalisation of the Reference Centres network with colleagues from the Danish AMR Reference Centre.

In October 2023, Rachel Dalton, the VMD focal point for the Reference Centre accreditation, commenced a secondment with the FAO in Rome. Her responsibilities were transferred to new team members at the VMD. The UK Reference Centre team thank our colleague for her tireless efforts in delivering the Reference Centre’s objectives through high-quality work.

3.1.2 Highlight 1: Annual congress of the FAO Reference Centres for AMR

ANNUAL CONGRESS OF THE FAO REFERENCE CENTRES FOR AMR

INTRODUCTION

The FAO and its Reference Centre for AMR in the UK* organised, on 15-16 March 2023, the inaugural congress for the current network of nine FAO AMR Reference Centres. The objectives of the congress were to foster stronger connections between the network members, share expertise, and identify areas for future collaboration. The congress adopted a hybrid format, allowing FAO delegates and representatives from each designated FAO Reference Centre the option to attend either in person in Weybridge (UK) or virtually.

AGENDA

- The International FAO Antimicrobial Resistance Monitoring (InFARM) System;
- AMR Multi-Stakeholder Partnership Platform (MSPP);
- Reducing the need for antimicrobials in agrifood systems (RENOFARM) initiative;
- AMR Laboratory Community of Practice;
- Collaboration areas under the five strategic objectives of FAO's action plan and engagement with decentralise offices.

DISCUSSION

The discussions focused on the important role of the FAO AMR Reference Centres and how they can contribute to the FAO initiatives.

Attendees discussed how countries can contribute to the InFARM platform currently under development. The FAO sought the attendees' input on linkage and synergies between the AMR MSPP platform and FAO's activities. The FAO mentioned that the attendees' participation and engagement in the RENOFARM initiative would be beneficial to support the launch.

The FAO asked the attendees, as technical experts, to express their interest to support the delivery of the AMR Laboratory CoP.

OUTCOMES

Each Reference Centre shared valuable insights and updates on their ongoing activities, areas of expertise and planned work programme. As a result, a 2023-2024 list of prioritised activities for each strategic objectives of the FAO Action Plan on AMR was developed. The summarised activities were published in the October 2023 FAO Newsletter.

The event contributed to strengthening the network of FAO AMR Reference Centres and was praised by many participants.

NEXT STEPS

During bimonthly meetings, the network will consider how to monitor delivery of the list of prioritised activities.

A joint technical secretariat will be established to enhance the coordination and provide technical guidance for the network's activities.

The next annual congress will be held in Denmark and co-hosted by the FAO and The Technical University of Denmark (DTU), the FAO Reference Centre for AMR in Denmark.

* The UK FAO Reference Centre for AMR is a joint designation across three Defra agencies: the VMD, APHA and CEFAS.

Antimicrobial Resistance Newsletter, October 2023 – Issue #14 (fao.org)

3.1.3 FAO regional office for Africa (FAO-RAF)

We have held discussions with FAO-RAF regarding the provision of a proficiency testing scheme for antimicrobial susceptibility testing (AST) for animal health and veterinary microbiology laboratories in Africa. We have met with FAO-RAF, FAO Ghana office and FAO Zambia office to discuss support for the FAO's Field Farmer School projects at poultry farms. Throughout 2023, multiple meetings were held with FAO-RAF colleagues to discuss the possibility of regional approaches to One Health AMR in West Africa. We met with FAO Zambia office to discuss the Official Development Assistance (ODA) programme as well as the options for a postgraduate programme with the University of Zambia and the support needed to implement surveillance of antimicrobial residues in food products of animal origin.

3.1.4 FAO regional office for Asia and the Pacific (FAO-RAP)

We are members of the FAO-RAP CoP on Prudent Antimicrobial Use in Animals (Section 6.5). We have provided comment and review of documents prepared by FAO-RAP colleagues, e.g. regional guidelines for monitoring and surveillance of AMR.

Reference Centre staff attended the **Regional AMR Technical Advisory Group Meeting (TAG)** for the animal health sector, organised by FAO-RAP (29-30 November, Bangkok, Thailand). The event was attended by 67 participants from Member Nations, FAO Reference Centres, and international experts. The meeting saw delegates from across South and South-East Asia gather to share updates on their ongoing work on AMR and identify gaps and new opportunities to work together to tackle AMR. We presented a poster, participated in the discussions, and one of our team was nominated to the Technical Working Group that will continue to develop AMR surveillance guidelines in bacterial pathogens from diseased livestock and poultry.

Reference centre staff during the Regional Antimicrobial Resistance Technical Advisory Group (TAG) Meeting for the animal health sector in Bangkok, Thailand.

3.1.5 Other FAO meetings and activities

- FAO announced in 2023 the designation of four FAO Reference Centres on AMR and Aquaculture Biosecurity to provide independent technical and scientific advice on related issues and to support FAO's mandate. The Reference Centres are the Pearl

River Fisheries Research Institute in China; the Yellow Sea Fisheries Research Institute in China; Nitte University in India; and Mississippi State University in the United States of America (USA). The launching of the AMR and Aquaculture Biosecurity Reference Centres took place at FAO Headquarters in Rome on 26 June 2023. Members of the UK Reference Centre also attended the inauguration, which was followed by a closed planning discussion and they gave presentations in the technical seminar 'Challenges in aquatic AMR mitigation and possible solutions'.

Reference centre staff attending the launching of AMR and Aquaculture Biosecurity Reference Centres at FAO, Rome.

Reference centre staff during the technical seminar 'Challenges in aquatic AMR mitigation and possible solutions' at FAO, Rome.

- The International FAO Antimicrobial Resistance Monitoring (InFARM) system and IT platform represents a global epidemiological information system which comprises the IT platform and related FAO activities that assist countries in generating, collecting, gathering, analysing, and effectively utilising their AMR data. FAO rolled out pilot testing of the InFARM beta version and during early 2023, staff of the Reference Centre

actively took part in the pilot phase and submitted feedback on the process and the visualisation of the data. In December 2023, we provided feedback on the FAO's InFARM draft framework for AMR surveillance, which aims to guide countries on how to participate in this initiative.

3.1.6 Engagement with other FAO Reference Centres for AMR

In 2023, we have been fortunate to visit FAO Reference Centre for AMR colleagues at their home facilities in Denmark, Senegal, and Thailand. We have been able to discuss potential collaborations, joint opportunities, identify current needs, and determine areas of common interest. For example, we visited the Danish Technical University (DTU) team in April 2023. Both parties made presentations on their respective activities and research interests and discussed possible research collaborations. These will build on our already strong collaborations with DTU, including mentoring Fleming Fund Fellows from Nigeria and Ghana (see Section 4.3) and other ongoing research collaborations, such as a project with SeqAfrica to sequence a range of bacterial isolates recovered from farmed fish in Ghana by our Ghana Fisheries Commission AMU Fleming fund Fellow. German FAO Reference Centre for AMR colleagues also provided valuable technical support and advice with helping to establish ecological cut off values (ECVs and ECOFF) for *Vibrio parahaemolyticus* and other aquatic pathogens (see Section 6.2).

3.2 Provision of consultancy to Fleming Fund and its partners

The Fleming Fund is a UK aid initiative aiming to tackle antimicrobial resistance in up to 25 countries in Africa and Asia. This programme is managed by the UK DHSC. The Reference Centre receives funding from the Fleming Fund, and works closely with its team and partners, such as the management agent Mott MacDonald and Country Grant holders, to provide expertise in animal health and policy. The Reference Centre has provided consultancy for the Fleming Fund on both ongoing and new initiatives as the Fleming Fund programme has advanced into Phase II.

Attendees at the Fleming Fund Delivery Partners event, Accra, Ghana

In September 2023, Reference Centre colleagues attended the Fleming Fund Delivery Partners event in Accra (Ghana) following an invitation from the Fleming Fund. At the workshop, we delivered the One Health session alongside colleagues from the University

of Exeter, FAO, and World Health Organisation (WHO). This event provided us with the opportunity to explore potential collaborations and engagement with colleagues from organisations such as the United Kingdom Health Security Agency (UKHSA), FAO, Mott MacDonald, the independent auditors (ITAD), and other international collaborators in the West Africa region.

We would like to take this opportunity to acknowledge the considerable support the Fleming Fund team at DHSC has given to the Reference Centre over the last year. They have provided valuable guidance and advice that has helped to focus our activities.

3.3 Provision of expertise to UK government

The Reference Centre agencies support the UK ambition to contain and control AMR by 2040, as set out in the UK 20-year vision for antimicrobial resistance (link) and the UK's five-year NAP for AMR 2019-2024 (link). Our activities contributed to the delivery of specific NAP commitments, including working with our global partners to strengthen and integrate AMR and AMU surveillance to identify common or emerging threats through a One Health approach, and to build research & regulatory capacity in Low- and Medium Income Countries' (LMICs') animal health sectors. We have contributed to the development of the next five-year UK AMR NAP (2024-29) to capture our objectives to work in partnership with various organisations to support international action on AMR; to support good laboratory practices and surveillance of AMR in LMICs; to share expertise; and to support capacity development and research activities in AMR. We continued to provide expert consultancy and input for Defra.

Reference Centre colleagues have been actively participating in the Pandemic Accord negotiations to ensure the concepts of AMR, One Health and animal health system strengthening are included in the treaty. We contributed to trade negotiations and G7 and G20 preparations. We have set up several bilateral meetings to establish relationships with counterparts in other member states, and we regularly meet with the Quads group (Australia, Canada, New Zealand, UK, and USA) to discuss ongoing issues related to AMR. We also provided representations on international committees such as the Trans-Atlantic Task Force on AMR (TATFAR).

Reference Centre colleagues are working in close alignment with DHSC, the UK Special Envoy on AMR, and the UK Chief Veterinary Officer (CVO), with support from the Defra One Health team, to prepare for the United Nations General Assembly (UNGA) AMR High Level Meeting (HLM). There will be a HLM on AMR at the UNGA in September 2024 which will be the centrepiece of a multi-year push for concrete international commitments and action on AMR. A paper approved by the Global Health Security Ministerial Group sets out a high level of ambition for the UNGA HLM, including engagement of ministers and prioritisation of resources, to enable global leadership in both human and animal health.

We worked with Defra colleagues in the delivery of ODA Technical Assistance and Research programmes being undertaken in Western and Southern Africa, such as the Animal Health Systems Strengthening and One Food projects. We also worked with the FCDO in Gulf Cooperation Council and other countries. We continued to work closely with

our human health colleagues at the WHO Collaborating Centre for Reference & Research on Antimicrobial Resistance and Healthcare Associated Infections based at the UKHSA. Our ongoing collaborative work with UKHSA and Nigerian Fleming fellows is described below (Section 4.3).

3.4 International conferences, workshops, and meetings

The Reference Centre contributed to a range of international meetings in 2023. A selection of these is highlighted below.

Codex Committee on Residues of Veterinary Drugs in Foods | 13-17 February | Oregon, USA

In February 2023, a colleague from the Reference Centre, representing the UK, participated in the 'Codex Committee on Residues of Veterinary Drugs in Foods' in Portland, Oregon (USA). Valuable contributions were made by attending expert working groups prior to the meeting, and by participating in discussions concerning the priority list of veterinary medicines, the establishment of Codex Maximum Residue Limits (MRLs), and the extrapolation of MRLs to additional species and commodities. These contributions supported the ambitions of Codex to establish global MRLs for veterinary drugs and antimicrobials, to ensure consumer safety, and support the trade of products of animal origin between Member States.

One Health Aquaculture workshop 20-22 February | Kochi, India

Delegates at the OCPP One Health Aquaculture workshop in Kochi, India

UK and Indian experts (including members of the Reference Centre) met in February 2023 in Kerala State, India, to discuss how new and emerging technologies could be applied to support safe and sustainable aquatic food supply chains in India (including surveillance and control of AMR in this sector). The workshop used the One Health Aquaculture framework to emphasize the role of diverse hazards in limiting current and future sustainability of aquaculture. The workshop was hosted by Cefas, in partnership with the Central Marine Fisheries Research Institute, a division of the Indian Council of Agricultural Research (ICAR). The workshop was funded by Defra's Ocean Country Partnership Programme (OCPP) through the UK's Blue Planet Fund.

Based around hazards identified in the Seafood Risk Tool, the workshop introduced novel technologies that identify known and emergent chemical and microbial hazards, and the control options that may be applied to reduce risk in supply chains. Scientists at the

workshop identified 89 Challenges, 67 Technology and 60 Policy and Practice ideas proposed for future projects across 17 themes. During the workshop the 17 themes were ranked based on value to the One Health Aquaculture framework and ease of implementation, and the top four themes were citizen science, water quality, AMR and disease management.

Based on feedback received at the workshop, the future OCPP programme in India will be based on four research pillars:

1 **Water quality (including harmful algal blooms)**
2 **AMR**
3 **Aquatic disease**
4 **Climate change**

Technical/methodological capacities cut across most or all of these four themes, *e.g.* citizen science, GIS, in-field techniques, molecular biology/sequencing ('omics) and bioinformatics, and studentships.

Indian experts met with UK experts and Reference Centre colleagues in a follow up meeting in Koch, to discuss taking forward work under the Sustainable Seafood pillar of OCPP and developing a range of master's scholarships being run by the Association of Commonwealth Universities (ACU) with the universities in India. These included potential projects on AMR. Information about Reference Centre activities was shared with the aquaculture lead for the Indian Network for Fisheries and Animal Antimicrobial Resistance program.

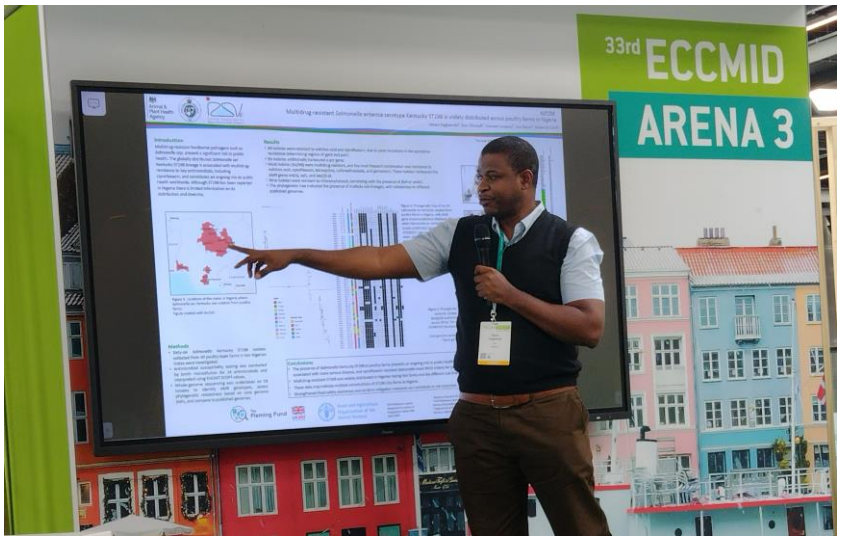
Expert Dialogue on Working in Partnership to Tackle Emerging AMR issues in Agri-food Systems | 17 March | Weybridge, UK

The Reference Centre hosted this Expert Dialogue to promote discussion on One Health approaches to identifying and tackling AMR in terrestrial and aquatic farmed animals. The meeting also addressed new and emerging AMR in pathogens of terrestrial and aquatic farmed animals. Participants included representatives from FAO, the FAO Reference Centres for AMR (Denmark, France, Germany, Thailand, UK, and USA), the UK government (including DHSC, UKHSA, and Food Standards Agency) and academia (Universities of Liverpool, Oxford, Bath, and Mississippi State).

33rd European Congress of Clinical Microbiology and Infectious Diseases (ECCMID 2023) | 15-18 April | Copenhagen, Denmark

Reference Centre staff attended and presented two posters on collaborative projects with partners from Bangladesh: 'Migratory birds in Bangladesh harbour multidrug resistant nontyphoidal *Salmonella* spp. of public health significance' and 'Investigation into multidrug resistant *Escherichia coli* taken from live bird markets in Dhaka, Bangladesh'. We sponsored the attendance of a colleague from the National Veterinary Research Institute (Vom, Nigeria), who gave an oral presentation on 'Multidrug resistant *Salmonella enterica* serotype Kentucky ST198 is widely distributed across poultry farms in Nigeria', a

collaborative study investigating AMR and genomic diversity in *Salmonella* Kentucky isolates from poultry farms in Nigeria.



A colleague from the National Veterinary Research Institute in Nigeria presenting the results of his study at ECCMID 2023.

International Conference on One Health Antimicrobial Resistance (ICOHAR) | 18-20 April | Copenhagen, Denmark

Reference Centre staff presented two posters entitled ‘Establishing a One Health Antimicrobial Resistance Community of Practice: The UK FAO Reference Centre for AMR Experience’ and ‘Understanding the use of sex pilus specific bacteriophages to reduce conjugative dissemination of antibiotic resistance’. We also sponsored the attendance of a colleague from the National Veterinary Research Institute (Vom, Nigeria).

9th Applied Bioinformatics and Public Health Microbiology | 3-5 May | Cambridge, UK

Reference Centre staff attended this meeting and gave an oral presentation on ‘Multidrug resistant *E. coli* in poultry from live bird markets in Bangladesh’.

Gates Cambridge Alumni Weekend | 3-4 June | Cambridge, UK

A Reference Centre colleague is a Gates Cambridge Alumnus who attended this event. They gave an oral presentation detailing the current activities and research projects of the Reference Centre. Details of the event and the talk were published on the Gates Cambridge website.

Annual CoVetLab Meeting | 21-22 June | Weybridge, UK

CoVetLab is a partnership of national veterinary public health institutes from Denmark, France, The Netherlands, Sweden, and the UK. Reference Centre staff attended the

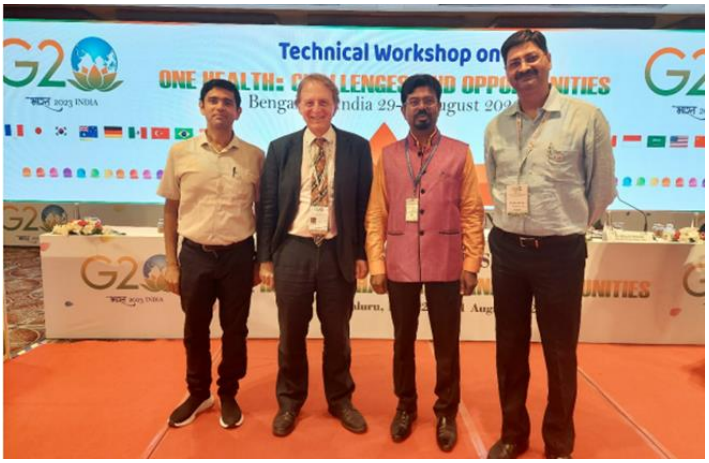
annual CoVetLab meeting and presented an overview of the activities and impact of the UK FAO Reference Centre for Antimicrobial Resistance.

9th Symposium on Antimicrobial Resistance in Animals and the Environment | 3-5 July | Tours, France

Attended by Reference Centre staff who gave an oral presentation on 'Prevalence of Extended-Spectrum Beta-Lactam (ESBL) and colistin resistance in *Escherichia coli* isolated from broiler chickens in dressing plants in the Philippines' and presented a poster on 'Mobile tigecycline resistance gene found in live bird markets in Dhaka, Bangladesh'. We also sponsored the attendance of two colleagues from the National Meat Inspection Service (Quezon City, Philippines).

Member of the Reference Centre delivering an oral presentation at ARAE 2023 in Tours, France

G20 Technical Workshop on One Health: Opportunities and Challenges | 29-31 August | Bangalore, India



Member of the Reference Centre with delegates from Indian Council for Agricultural Research at the G20 Technical Workshop on One Health

A Reference Centre colleague attended the G20 Technical Workshop on One Health in Bangalore on behalf of Defra. This workshop was organised by the ICAR. It was attended by more than 50 representatives from across the ICAR network). G20 delegates from countries including USA, Canada, Australia, France, Italy, and Saudi Arabia were in attendance, as well as Oman (as an observer). The delegates and invited speakers delivered a range of presentations on their visions of One Health and how these can be implemented. The Reference Centre colleague provided a presentation entitled 'Health partnerships: an effective response to the global health agenda' that detailed the range of One Health activities, including AMR, championed by the UK.

European Association of Fish Pathologists 21st International Conference on Diseases of Fish and Shellfish | 11-14 September | Aberdeen, UK

Reference centre staff attended this important aquatic animal health conference and delivered presentations and posters. They also helped organise and lead a **workshop on AMR surveillance in aquaculture on 14 September**. This was attended by more than 50 international aquaculture health experts. Among the topics discussed and shared was the potential to further extend laboratory networks to develop and implement interpretative criteria for aquatic health.

Seed meeting on Working Together to Fight Antimicrobial Resistance in Aquaculture | 26-27 September | French Embassy | London, UK

Attendees at the antimicrobial resistance in aquaculture seed meeting at the French Embassy in London

Under the theme of 'Working together to fight antimicrobial resistance in aquaculture', researchers from France and the UK gathered at the French Embassy in London in September 2023. This Seed Meeting, funded by the Higher Education, Research and Innovation Department at the French Embassy in the UK, enabled fourteen scientists to meet, present their research projects and discuss future collaborations and opportunities. Participants originated from the French academic and research institution Oniris/INRAE ('École nationale vétérinaire, agroalimentaire et de l'alimentation de Nantes-Atlantique' as partner of 'Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement'), as well as from French (Agence Nationale de Sécurité Sanitaire de l'Alimentation, de l'Environnement et du Travail) and UK Government agencies (Cefas, VMD and APHA). After institutional presentations, a session focused on Early Career Researchers to foster links and exchanges between countries and institutions in the future. Specific topics discussed in the later sessions included epidemiology, molecular techniques to detect antimicrobial resistance, and the potential shared use of experimental aquarium facilities at Oniris/INRAE and Cefas. There was also a discussion on the possibility for students to be shared between different institutes. In addition, the participants explored the possibilities of common teaching activities to train the next generations of veterinarians in the fight against antimicrobial resistance and the implementation of the One Health concept.

Finally, the researchers agreed on common research interests with significance for both animal and human health and defined a plan to obtain competitive funding during the year 2024. This Seed Meeting created a very promising grouping of international aquaculture

research collaborators, with a real determination to make progress in the fight against antimicrobial resistance, whilst keeping aquaculture products safe and healthy.

WOAH European and Central regional ANIMUSE training and workshop | 6-10 November | Serbia

Reference Centre colleagues attended a 3-day WOAH workshop for the European and Central Asian region. There were over 50 countries from across Europe and Central Asia We had the opportunity to share UK AMU data to the globally accessible antimicrobial use database and contribute to the discussion about the importance of AMU data transparency and the different countries' animal health systems. We learned from our international counterparts about their AMU data collection processes.

Transatlantic Taskforce on Antimicrobial Resistance (TATFAR) | 14-15 November | Luxembourg

A UK delegation, including Reference Centre colleagues, attended the TATFAR meeting in Luxembourg. TATFAR brought together government agency representatives from Canada, the European Union, Norway, the UK, and the USA along with leading experts on AMR, to address the shared challenges in tackling AMR. The aim of the meeting was to share best practices and to strengthen domestic and global efforts to develop tactics to help reduce this global public health threat, with particular focus on the lead up to the United Nation's High-Level Meeting on AMR in 2024.

Multi-Stakeholder Partnership Platform | 16 November | Rome, Italy

In November 2023, the UK Chief Veterinary Officer led a UK Government delegation, which included colleagues from the Reference Centre, to attend the inaugural meeting of the newly established AMR Partnership Platform led by the Quadripartite (WHO, World Organisation for Animal Health, United Nation Environment Programme, FAO). The aim of the Platform is to catalyse a global movement for action against AMR by fostering cooperation between a diverse range of stakeholders at all levels across the One Health spectrum. A highlight of the visit was the appointment of the UK CVO to the Steering Committee for the Platform which is a great opportunity for long-term impact at an international level to strengthen the joined-up response to AMR.

3.5 Country Engagement

3.5.1 Zambia: Scoping visit

In July 2023, a team from Defra, the Reference Centre, and APHA's WOAH Reference Laboratory for Salmonellosis undertook a scoping visit to Zambia. Meetings were held with partners at FAO, the Zambian government's Central Veterinary Research Institute and the School of Veterinary Medicine at the University of Zambia to define areas for collaboration and the support that can be provided by the Reference Centre. Areas of training needs were identified and detailed further after the visit, with a delivery plan developed for implementation in 2024.

3.5.2 Uganda: Scoping and training visit

In August 2023, colleagues from the Reference Centre were hosted by the National Agricultural Research Organisation (NARO) to engage with the responsible authorities including the Ministry of Agriculture Animal Industry and Fisheries (MAAIF) and academic colleagues at the College of Veterinary Medicine Animal Resource and Biosecurity (COVAB) at Makerere University. Various meetings were held, including with the Chief Veterinary Officer, to discuss collaborative action to tailor support for the development and implementation of improved disease investigation, diagnostics, and AMR surveillance in the Ugandan aquaculture industry.

Three fish farms were visited and in-field fish dissection training for viral and bacterial disease diagnostics was provided to student veterinarians and NARO delegates. Furthermore, training in bacterial isolation, identification and antimicrobial sensitivity testing was conducted at COVAB teaching laboratories. The Reference Centre is currently working with NARO, COVAB, and the National Animal Disease Diagnostics and Epidemiological Centre (NADDEC-MAAIF) on *Edwardsiella* infections in fish as well as to generate genotypic and phenotypic AMR data to develop epidemiological cut off values. This work has been sponsored by the WOAH Collaborating Centre for Emerging Aquatic Animal Diseases designation at Cefas and the Reference Centre, supported by the Fleming Fund.

Social media outputs: https://covab.mak.ac.ug/uk-based-centre-for-environment-fisheries-and-aquaculture-science-cefas-seeks-collaboration-with-covab-in-aquatic-health/

Meeting with NARO-Aquaculture Research and Development Centre in Kajjansi.

Meeting with COVAB at Makerere University in Kampala

3.5.3 Senegal: Scoping visit

Colleagues from the Reference Centre visited Dakar, Senegal between 20-24 November 2023. The visit was hosted and facilitated by the FAO-ECTAD lead in Senegal. Meetings were held with a range of stakeholders to discuss how the Reference Centre could support implementation of AMU and AMR surveillance in the agri-environmental sectors in Senegal. The delegation took the opportunity to visit the 'Fondation Institut Pasteur de Dakar' (FAO Reference Centre for AMR for Senegal). Relevant government departments and laboratories were also visited, including: the 'Laboratoire national de l'Élevage et de Recherches Vétérinaires' (LNERV), (the national reference laboratory for AMR in animal health in Senegal), 'Laboratoire national d'analyse et de contrôle' (LANAC), 'Laboratoire de phytopathologie et malherbologie de la direction de la protection des végétaux' (DPV), and the 'Direction des Services Vétérinaires' (DVS). The group also visited the 'Laboratoire de Control des Médicaments Vétérinaires' (LACOMEV) part of the 'École Inter-État des Sciences et Médecines Vétérinaires' (EISMV) to discuss surveillance of veterinary medicine residues and Brooke West Africa to talk about their training related to animal health and responsible use of veterinary medicines. Valuable time was spent with the subregional FAO office for West Africa and FAO Senegal ECTAD team to discuss how the Reference Centre and the FAO can work together in West Africa.

Institut Pasteur, FAO Reference Centre for AMR in Dakar, Senegal.

3.5.4 Bangladesh: Highlight 2: Biosecurity training modules for finfish

BIOSECURITY TRAINING IN FINFISH IN BANGLADESH

INTRODUCTION

Building on the success of the Bangladesh FAO Emergency Centre for Transboundary Animal Diseases (ECTAD) team to develop and implement a very successful biosecurity training module for poultry in the country. Members of the Reference Centre visited Bangladesh to develop similar training modules for the Bangladesh finfish aquaculture sector. The UK FAO Reference Centre for AMR experts worked together with project partners, the Department of Fisheries (DoF), FAO ECTAD team and WorldFish.

METHOD

The working group visited fish farms in Mymensingh region to understand the current farming practises and undertake a gap analysis working together with farmers.

1) DoF officials identified sites for delivery
2) Collaborators modified current Participatory Disease Search and developed pilot gap analysis for finfish for delivery in the field
3) Planned schedule for delivery and review and adjustments of pilot PBGA
4) Recognise 12 key pathogen pathways
5) Identify potential biosecurity measures to reduce pathogen pathways
6) Discuss biosecurity measures identified and share knowledge
7) Produce 10 point biosecurity measures plan for finfish aquaculture sector

NEXT STEPS

Short term – 3 months

- Visit additional aquaculture hubs for information collection.
- Develop draft Biosecurity Guidelines for FAPS in Bangladesh.

Medium term – 6 months

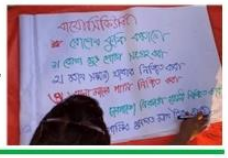
- Finalisation of Biosecurity guideline and identification of associated resources such as information advice and guidance.
- Development of piloting training modules and initial delivery at selected areas.

Long term – 12 months

- Review and finalise the training module.
- Validation workshop for the sharing of the findings of the piloting training module.
- Expand the training module at other aquaculture hubs.

NATIONAL BIOSECURITY FRAMEWORK

- National delivery biosecurity training module to assist with the implementation of site-specific biosecurity plans
- Strengthen disease surveillance and AMR in aquaculture through participatory approach, a reporting service and disease diagnosis
- Investigation into a potential regulatory national biosecurity regulatory framework



Papadopoulou, A., Worswick, J., Rahman, M.H, Naher, K., Rheman, S., Hossain, S., Bhuiyan, M.M., Nowsher, A. and Alam, B.

4.0 Capacity Building

4.1 Highlight 3: Postgraduate programme in Zambia

POSTGRADUATE PROGRAMME IN ZAMBIA

OVERVIEW

A new postgraduate programme of antimicrobial resistance-related studentships has been established through a partnership between the Veterinary Medicines Directorate (VMD) and the University of Zambia (UNZA).

This collaboration, funded by the Fleming Fund, will enable local students to gain scientific experience and academic qualifications, while conducting AMR-relevant research. The projects will contribute to improving the understanding of antimicrobial use in the Zambian livestock sector, thereby providing valuable information to help tackle antimicrobial resistance.

OBJECTIVES

- Develop capacity and capability of local postgraduate students by providing them with training and development opportunities.
- Improve the understanding and knowledge of AMR/AMU within the Zambian context and strengthen in-country capacity to address AMR.
- Support research on AMR and veterinary medicinal products in low- and middle-income countries (LMICs) and generate high-quality field-based data.
- Build collaborative supervisory teams comprising academic institution experts, VMD technical specialists, and researchers involved in AMR/AMU projects.

RESEARCH TITLES

PhD

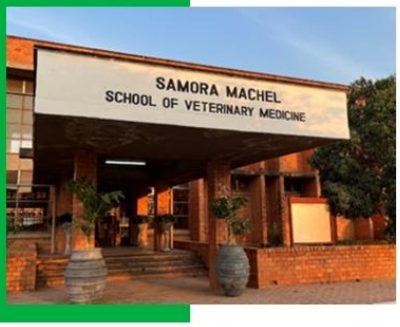
- An 'mHealth' intervention for promotion of antimicrobial stewardship among smallholder dairy farmers in Zambia: A Precede-Proceed Model analysis.

MSc

- Assessing knowledge and understanding of AMR by veterinary and paraveterinary professionals in Zambia
- Assessing responsible use of veterinary medicines through analysis of prescribing behaviours by non-veterinary qualified suppliers

COLLABORATION

Student supervisory teams are led by UNZA academic colleagues. Each team also includes a VMD Technical Advisor with relevant specialist expertise. These Technical Advisors will provide expert support, when required, and facilitate networking with teams at the VMD and in other UK organisations.



Students will visit the UK to participate in a knowledge exchange and training programme. This will include delivering presentations to the VMD Research Group to share their research findings.

PROGRESS

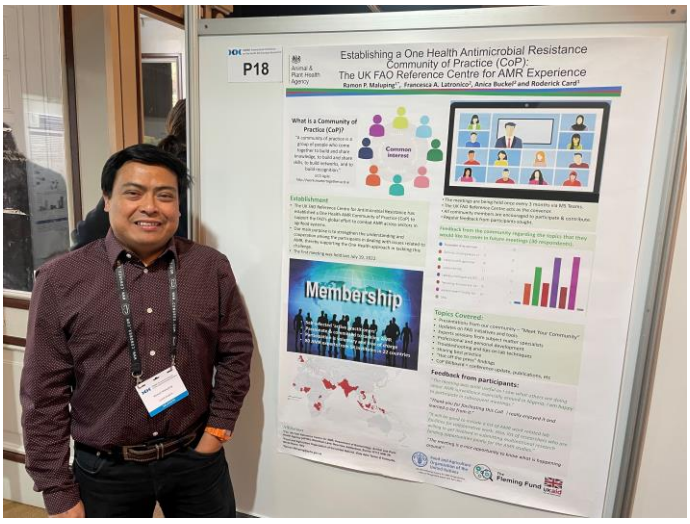
Scholarships have been awarded to one PhD student and two MSc students, based at the School of Veterinary Medicine, UNZA.

The PhD student commenced his studies in October 2023, and the MSc scholars are preparing to start their courses in February 2024.

The VMD is currently establishing a framework to strengthen the programme by supporting additional AMR-related postgraduate research projects at UNZA.

4.2 AMR Community of Practice (CoP)

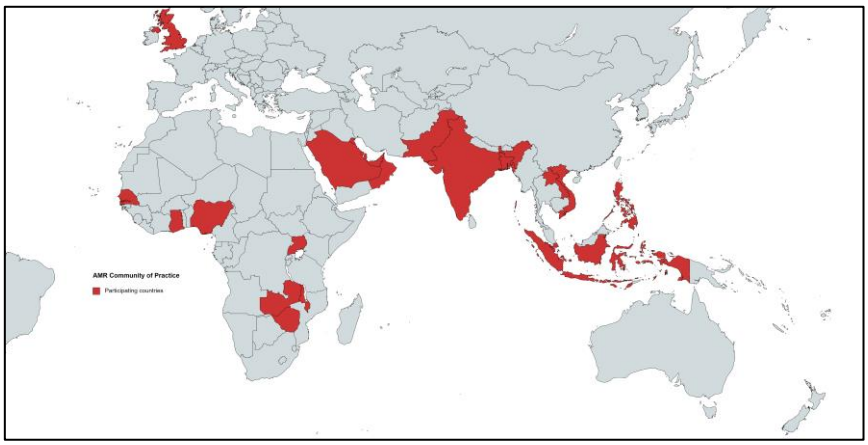
The Reference Centre established an AMR CoP in 2022, which brings together current and prospective laboratory collaborators and other groups or individuals who are involved and interested in topics related to AMR. The main missions of the CoP are to increase awareness and engagement among our partners and other key stakeholders, and to assist in improving laboratory capacity and promote good laboratory practices among its participants. The CoP provides opportunities to share new ideas and to network and collaborate with other participants.



Reference Centre staff presenting the AMR Community of Practice poster at ICOHAR in Copenhagen, Denmark.

The CoP supports FAO work to combat AMR across sectors in food and agriculture around the world. We have worked closely with FAO colleagues regarding the establishment and implementation of this CoP, and supported FAO initiatives to launch its broader umbrella Community of Practice on Antimicrobial Resistance Laboratory (link), of which our CoP is a component. To share our experiences, Reference Centre staff gave an oral presentation regarding the UK FAO Reference Centre's experience in establishing the CoP during the Congress of FAO Reference Centres for Antimicrobial Resistance. The Reference Centre and FAO shared authorship of a poster titled 'Establishing a One Health Antimicrobial Resistance Community of Practice: The UK FAO Reference Centre for AMR Experience', which was accepted for presentation at the International Conference on One Health Antimicrobial Resistance in Copenhagen, Denmark (April 2023).

In 2023, the Reference Centre's AMR CoP saw its membership grow to over 90 AMR experts representing over 70 institutes/universities/laboratories from 25 countries.



Members of the AMR Community of Practice come from institutions across Africa and Asia.

The CoP meets virtually once every three months, and the content and format of these meetings is based on the feedback gathered from surveys of members. A summary of the four meetings held in 2023 follows below.

- The first meeting of the year was held in January and was attended by more than 30 participants. Presentations were given by scientists from Malawi and the Philippines. During the talks, speakers introduced their home institutions and outlined some of their AMR-related activities and research. There was an interactive quiz on AST, which was a popular session with the participants. A session called the 'CoP Billboard' was also launched. For this meeting, a member of the Reference Centre presented highlights of the 7th World One Health Congress held in Singapore in November 2022.

- The second meeting was held in May with 35 attendees. A talk on 'Curbing AMR triggering contaminants in foods - the Indian Perspective' was delivered by the Director of National Food Laboratory (NFL) - Chennai, Food Safety and Standards Authority of India (FSSAI). A second presentation was delivered by a Reference Centre team member on 'Mobile tigecycline resistance gene *tet*X4 found in live bird markets in Dhaka, Bangladesh'. A distinguished professor from the Department of Veterinary Public Health and Preventive Medicine, University of Ibadan, Nigeria was the speaker of the 'Meet Your Community' session and presented on the department's past and on-going research projects on AMR.

- The third meeting was held in July with 36 attendees. This was a significant meeting as it was the first-year anniversary of the CoPs inaugural meeting. A Reference Centre team delivered a well-received talk on AMR and whole genome sequencing. There was also a presentation regarding the Bangladesh AMR Response Alliance Initiative in Bangladesh and Indonesia under the One Health Approach. Representatives from FAO-Bangladesh discussed the creation and implementation of Antibiotic Treatment Guidelines in Bangladesh and Indonesia. CoP members from Nigeria and Bangladesh spoke about their institutions and their AMR-related research and activities as part of the 'Meet Your Community' session. There was a lively and interactive discussion about the presentations towards the end of the meeting.

- The final meeting of the year was held in October with 25 people in attendance. An Associate Professor from the University of the Philippines and a member of the Quadripartite Technical Group on the Economics of AMR talked about machine learning and how it can be used in addressing questions regarding the epidemiology of AMR. The talk entitled 'Unveiling antimicrobial resistance puzzles: machine learning meets genomic epidemiology' was well-received by the participants. There was also a talk from a veterinarian at the Ebonyi State University (Nigeria) on the role of disinfectant resistance genes in *E. coli* isolated from livestock and in-contact with humans in treatment and infection control. Recent publications and conference presentations from community members from Nigeria and Qatar were recognised during the 'CoP Billboard' session.

4.3 Fleming Fund professional fellowship scheme

The Reference Centre continues to engage strongly with the Fleming Fund Fellowship scheme. As part of this scheme, we mentored an AMR Laboratory Fellow and veterinarian from the Department of Veterinary and Pest Control Services, Lagos State, Nigeria. They completed training in a range of activities, including aquaculture disease, bacterial diagnostics, and AST. They also successfully undertook a survey of AMU in more than 50 Nigerian fish farms in Oyu State, Nigeria. We also mentored a microbiologist from the Ghana Fisheries Commission who graduated successfully as an AMU Fleming Fund Fellow. They undertook a similar range of training and activities in Ghana during their Fellowship, including completing a parallel survey of AMU and AMR in Ghana catfish and tilapia farms. Both Fellows successfully completed the Fellowship programme and graduated in 2023.

We have published findings from the collaborative One Health projects we have undertaken with Fellows in Nigeria (see Communications). We have also supported the attendance of Fellows we have mentored at International Conferences (see International Engagement). A significant achievement in 2023 was the publication of the manuscript 'Establishing a One Health AMR Community of Practice in Nigeria' in CABI One Health Cases. This work was undertaken in partnership with Nigerian Fleming Fellows and their mentors at APHA, Cefas, UKHSA, and the Danish FAO Reference Centre for AMR, which together make up a multidisciplinary team dedicated to addressing AMR in the human and animal health sectors in Nigeria. The case study follows this team, sharing how their work has contributed to meeting the objectives outlined in the Nigerian National Action Plan for AMR, as summarised in the table below.

Table 1. Community of Practice activities mapped against Focus Areas in the Nigerian National Action Plan for AMR 2017–2022.

Nigerian National Action Plan for Antimicrobial Resistance (2017–2022) Focus Areas	Community of Practice example activities
Focus Area 1: Increasing Awareness and Knowledge of AMR and Related Topics	• Advocacy to policy makers via TAG • Stakeholder engagement • Training of laboratory professionals • WAAW activities
Focus Area 2: Building a 'One Health' AMR Surveillance System	• Advocacy at TAG • Collaborative projects piloted multi-sectoral AMR surveillance and addressed evidence gaps • Secured new project funding • Training of laboratory professionals
Focus Area 3: Intensifying Infection Prevention and Control in the Tripartite Sectors	• Stakeholder engagement with livestock farmers and abattoir workers
Focus Area 4: Promoting Rational Access to Antibiotics and Antimicrobial Stewardship	• Advocacy at TAG • Projects piloted inter-sectoral AMR collaboration • Stakeholder engagement with livestock farmers
Focus Area 5: Investing in AMR Research and Development	• Projects supported AMR researchers and provided technical expertise for genome analysis

TAG: Technical Advisory Group; and WAAW: World AMR Awareness Week.

A second manuscript ‘Determination of Antimicrobial Use in Commercial Poultry Farms in Plateau and Oyo States’, Nigeria was also published by this team in 2023. This study, led by a Fellow at Nigeria’s Federal Ministry of Agriculture and Rural Development (mentored at the Danish FAO Reference Centre for AMR), trialled and validated an approach for AMU surveillance in the animal health sector that can now be applied across Nigeria. It also provided insight into farmers’ knowledge and practices with regards to the use of antimicrobials and identified areas to target behaviour change initiatives.

Community of Practice Fleming Fellows raising awareness of antimicrobial resistance and biosecurity with farmers in Oyo State, Nigeria

We continued to provide representation on the Alumni Network Steering Committee, established to provide support to Fellows after graduation from the programme. Through this representation we work with other mentors, fellows, and the management teams at Mott MacDonald and the Fleming Fund to support to the Alumni.

Following on from the success of the Third Fleming Fellows’ Symposium held in October 2022, we continued to provide representation on the Symposium Steering Committee and are actively planning the Fourth meeting alongside other mentors, fellows, and colleagues at Mott MacDonald and the Fleming Fund.

4.4 Hosting visitors at our UK facilities

The Reference Centre supports capacity building and training by hosting and funding short-term visits by scientists, veterinarians, and other experts from partner laboratories and institutes at our UK facilities. Through these visits we provide high-quality tailored 1:1 training that addresses needs that have been defined by our visitors. We always seek to employ a ‘train-the-trainer’ approach to maximise value and facilitate follow-on training delivery in their home country by the visitor. Visits are often undertaken in the broader context of collaborative project work we are undertaking together (see Section 5.1), to leverage the investments made by us and our partners.

In 2023, our visitors had the opportunity to network widely within our organisations and meet recognised experts, such as the heads of our other Reference Centre designations, Quality Managers, and Health & Safety leads. Visitors were invited to present their institutes and work to colleagues from across APHA, Cefas, and VMD, allowing them to share their expertise and insight with a wide audience. We have also sponsored our collaborator's attendances at International Conferences, to support their professional development, broaden networking opportunities, and the dissemination of findings from our collaborative projects. The types of training provided included, for example, bacterial diagnostics, AST, bacterial genomics, and laboratory quality management.

In 2023 we hosted visitors from:

- Brooke, Addis Ababa, Ethiopia
- Department of Veterinary and Pest Control Services, Lagos, Nigeria
- Fisheries Commission, Accra, Ghana
- Khalifa University, Abu Dhabi, United Arab Emirates
- Kuwait Environmental Public Authority, Kuwait
- Ministry of Agriculture, Food Security and Enterprise and Belize Agricultural Health Authority, Belize.
- Ministry of Marine Affairs and Fisheries and the Ministry of Agrarian Affairs and Spatial Planning, Jakarta, Indonesia
- National Institute of Veterinary Research; Hanoi, Vietnam
- National Food Safety Laboratory, Accra, Ghana
- National Meat Inspection Service, Quezon City, Philippines
- National Veterinary Research Institute, Vom, Nigeria
- Qatar University, Doha, Qatar
- University of Ghana, Accra, Ghana

Ethiopian and British guests from Brooke, July 2023

4.4.1 Highlight 4: AMR in poultry in the Philippines

Assessing AMR in poultry at slaughter in the Philippines

In partnership with the National Meat Inspection Service (NMIS) of the Philippines, the U.K. FAO Reference Centre for AMR has undertaken a collaborative project assessing the antibiotic resistance in E. coli *from poultry at slaughter in the Philippines.*

Our Aims

Research

- To achieve insight into AMR in *E. coli* isolated from broiler chickens at slaughter using whole genome sequencing (WGS) & antibiotic susceptibility testing.

Engagement

- To strengthen partnership and engagement between institutes.

Capacity Building

- To train staff and share best practices.

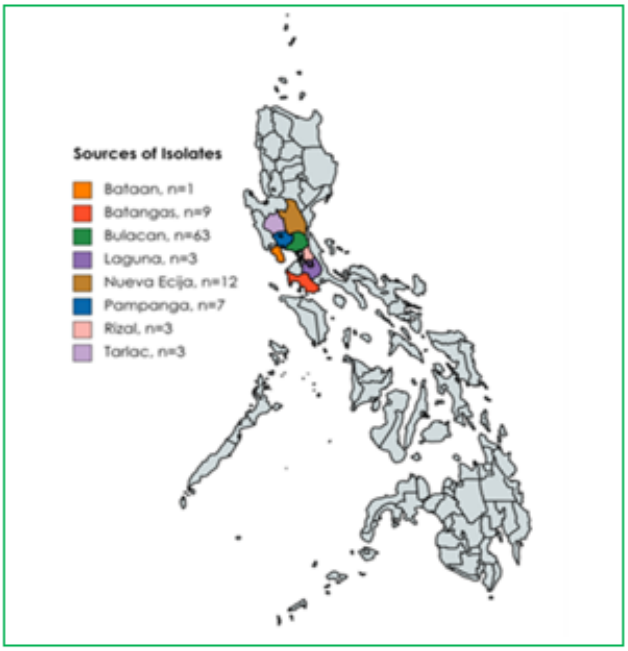
Capacity Building: Hosting NMIS Staff in UK

We hosted two visiting scientists from NMIS at our UK facilities for:

- Training on antimicrobial susceptibility testing, MALDI-TOF, and WGS analysis
- Laboratory tours and discussions with APHA scientists and visit to APHA's Central Sequencing Unit
- NMIS staff delivered a site-wide presentation on "Who we are and what we do"
- Visit to Veterinary Medicines Directorate for discussion on monitoring programmes and National Residues Control Plan

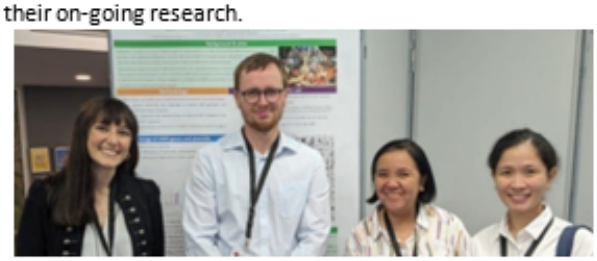
Research: Findings of Collaborative Project

- 101 *E. coli* from poultry at slaughter tested
- Excellent correspondence between AMR phenotype and genotype for all antimicrobials
- 91/101 isolates were multidrug resistant
- No carbapenem resistance detected
- Colistin resistance was detected in 10 isolates, associated with *mcr-1* gene
- Resistance to 3rd generation cephalosporins was detected in 23 isolates associated with bla_{DHA-1}, bla_{CMY-2}, $bla_{CTX-M-15}$, $bla_{CTX-M-55}$ or $bla_{CTX-M-123}$ genes



Engagement: Attendance at an International Conference

With the support from the UK FAO Reference Centre, NMIS staff attended an international conference in France, together with APHA colleagues to present outcomes of their on-going research.



Outcomes

- The research has filled important evidence gaps by providing data on AMR resistances and genomic diversity of *E. coli* in poultry entering the food chain.
- The visit provided an opportunity to network widely, and training can be used to help improve laboratory and research capacity in the Philippines.

4.5 Ecological health assessments in Ghana with Council for Scientific and Industrial Research and Fisheries Commission

Through the UK ODA funded Ocean Country Partnership Programme, scientists from the Reference Centre and more widely across Cefas collaborated with the Fisheries Commission and the Council for Scientific and Industrial Research Ghana to develop and implement a toolbox approach to strengthening ecological health assessment of shellfish aquaculture sites in coastal regions of Ghana. Aquaculture scientists and fish veterinarians were trained in conducting biopsies for molluscan and crustacean diseases, e.g. haemolymph extractions for isolation of bacterial pathogens. They were also trained in collection of water and sediment samples for eDNA to assess biodiversity at the microbiome and AMR resistome level.

Fish biopsy training with CSIR and Fisheries Commission in Western and Central region, Ghana.

4.6 Bacterial fish disease diagnostics and antimicrobial sensitivity test training programme for Ghanaian and Nigerian aquaculture Fleming Fellowship

The Reference Centre hosted a two-week visit to the Cefas Weymouth Laboratory by Dr Suliat Adeleke, a veterinarian at the Department of Veterinary and Pest Control Services under the Federal Ministry of Agriculture and Rural Development, Nigeria. While in the UK, she obtained training in AST and bacterial diagnostics of aquatic pathogens. She also visited the APHA and VMD in Weybridge where she met with key staff and delivered a talk on AMR surveillance activities in agri-food systems in Nigeria. Dr Adeleke has undertaken One Health AMR research in Nigeria that has been supported by Cefas and APHA through the AMR Reference Centre and she recently graduated from the Fleming Fund Fellowship programme having been mentored by colleagues at Cefas.

Fleming Fund Aquaculture Laboratory Fellow from Nigeria obtaining training in AST at the Cefas laboratories in Weymouth, UK.

Cefas also hosted a Senior Lecturer from the University of Ghana, their PhD student, and an alumnus Fleming fellow (from the Fisheries Commission) for three weeks for meetings to network and obtain technical training in virology, bacterial diagnostics and AST. They also spent two days with the Cefas Fish Health inspectorate visiting farms and learning how to undertake disease inspections and investigations. They also visited APHA and VMD at Weybridge where they were given a laboratory tour and an opportunity to present their work through the Fleming Fellowship programme.

Visitors from University of Ghana and Ghana Fisheries Commission obtaining training in bacterial diagnostics and AST at the Cefas laboratories in Weymouth, UK.

4.7 Sub-Saharan Africa Project: Self-Assessment tool for veterinary medicines regulatory agencies

Colleagues from the Reference Centre have worked with Rwanda (Food and Drug Authority) and Botswana (Botswana Medicines Regulatory Authority Veterinary Medicines), under Bill and Melinda Gates Foundation funding, to examine their veterinary medicine legislation, regulatory processes, and documentation using a beta version of a newly created self-assessment tool for National Regulatory Agencies. The tool was recognised as highly useful and helpful to promote a structured approach to evaluating the performance of veterinary medicine regulation. Additionally, the tool was presented at the Quadripartite Summit for human and veterinary medicines regulators in May 2023, where it garnered significant interest and support. Work has also been ongoing in developing a prototype for an electronic veterinary medicine dossier submission and application management system suitable for regulatory agencies in Sub-Saharan Africa.

4.8 Residue surveillance laboratory training in Zambia

Colleagues at the CVRI, Lusaka, Zambia

The Reference Centre and consultant John Points visited the Central Veterinary Research Institute (CVRI) in Lusaka (Zambia) in June 2023. The purpose of the visit was to provide a two-week laboratory training session on conducting residue testing using instruments recently acquired by the laboratory. Alongside the laboratory training, presentations were delivered to staff from different departments, including the Department of Veterinary Services, on the importance of implementing surveillance of residues. Following the visit, regular virtual follow-ups were delivered to offer ongoing support in implementing the taught methodology, addressing any queries and assisting with troubleshooting.

Training on residues testing methods and discussion on how to draft a residues sampling plan, at the CVRI, Zambia

4.9 Provision of online training

Between April and June, the Reference Centre rolled out a hybrid format – facilitated virtual sessions in between periods of individual self-learning – of its e-learning course on surveillance of veterinary medicines residues in food products of animal origin (FOAO) in Zambia to a mixed group of twelve laboratory-based staff and managers from the Central Veterinary Research Institute. A group of 20 experts from Botswana and Uganda started the course at the end of 2023, to be completed in 2024.

The 'Understanding Bioequivalence in Veterinary Medicinal Products' e-learning was delivered to nine experts from the Rwanda Food and Drugs Authority (FDA) in June-July, and to six experts from the Uganda National Drug Authority (NDA) in September-November. Feedback was very positive, and we have continued to improve the live sessions by introducing interactivity and encouraging audience engagement.

5.0 Surveillance and Research

5.1 Collaborative projects

We undertook joint collaborative projects with scientists and laboratories in several countries to support their work addressing evidence gaps relevant to AMR and potential risks to veterinary or public health. Through this approach, we can provide research capacity development including, confirmatory testing, AST, whole genome sequencing and bioinformatics capability. This partnership approach enables the generation of quality data and analyses that can provide new insights which will help inform the design of future surveillance or research protocols and contribute towards the assessment of risk to humans via, for example, the food chain. We work closely with colleagues at APHA's WOAH Collaborating Centre for Risk Analysis & Modelling to provide epidemiological support, including sample size calculations for study design, risk factor analysis, and modelling of results. We also engage the expertise of staff and resources from the other national and international designations held by our home Agencies, such as the FAO Reference Centre for Bivalve Mollusc Sanitation, WOAH Collaborating Centre for Emerging Aquatic Animal Diseases (Cefas), the *Campylobacter* National Reference Laboratory (APHA), and the WOAH Reference Laboratory for Salmonellosis (APHA). In 2023, we have undertaken collaborative projects with partners in Bangladesh, Ghana, Nigeria, Philippines, Qatar, and Vietnam.

5.1.1 Highlight 5: *Salmonella* surveillance at live bird markets in Bangladesh

AMR Surveillance at Live Bird Markets in Bangladesh

Background

Bangladesh has implemented an AMR National Action Plan (NAP) incorporating a 'One Health' approach, with substantial coordination between the human health and livestock sectors.

Bangladesh has a large livestock sector, with 403 million terrestrial animals, accounting for 1.5% of the GDP for the national economy.

The Central Disease Investigation Laboratory (Dhaka, Bangladesh) has been undertaking AMR surveillance in *E. coli* from poultry at live bird markets in Dhaka. Surveillance of AMR at a point near to consumption allows assessment of the risk that AMR from livestock may present to people.

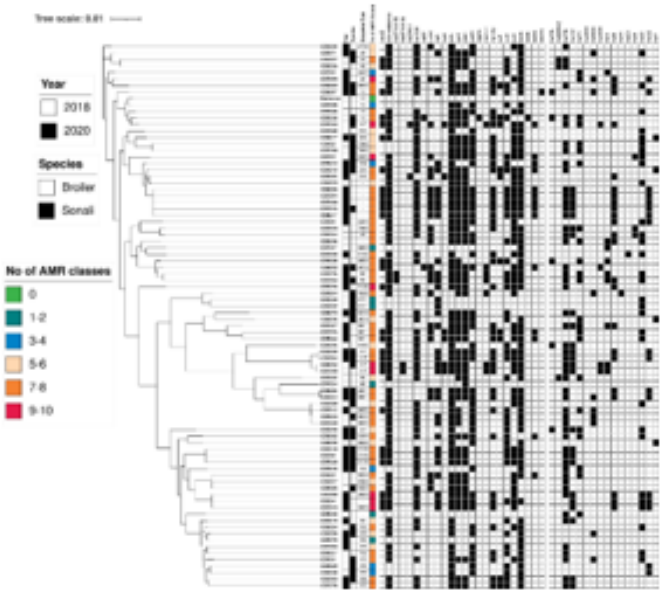
The purpose of this collaborative project was to build on this work by characterising the genomic diversity and establishing the AMR gene identity & location.

Methods

- Eighty-three *E. coli* isolates were analysed by broth microdilution (14 antimicrobials)
- Whole Genome Sequencing (WGS) was undertaken to identify AMR genotypes and compare with phenotypic resistance
- Phylogenetic relatedness was assessed using core genome SNPs
- The carriage of AMR genes on plasmids was assessed for three isolates using Nanopore sequencing

Results

- High diversity of AMR *E. coli* found in live bird markets, as shown in phylogenetic tree
- High multidrug resistance prevalence
- High prevalence of resistance to ciprofloxacin
- No carbapenem resistance detected
- Mobile tigecycline resistance gene *tet*(X4) identified on an IncHI1A/B-IncFIA mosaic plasmid
- Seven isolates found with colistin resistance *mcr1* gene
- *mcr1* resided on an IncH plasmid in two isolates



Summary and Impact

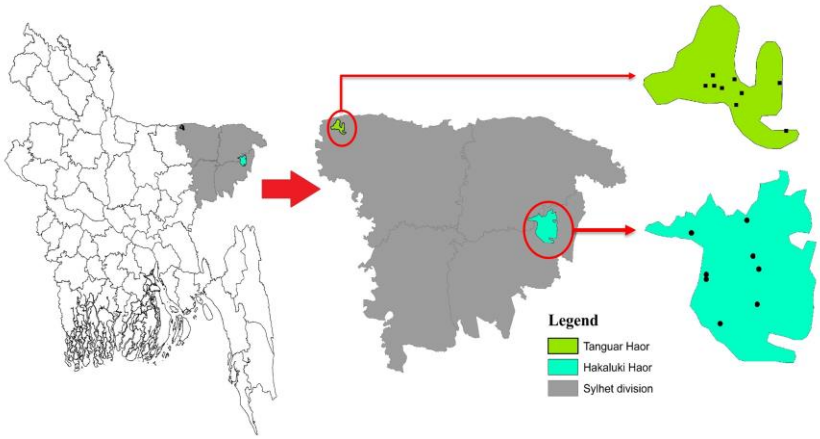
This study has

- demonstrated the value of using phenotypic and genomic approaches in a surveillance programme to define antimicrobial susceptibilities and describe in detail the genetic diversity of isolates
- highlighted important linkages between AMR in public and animal health in Bangladesh
- provided new insights into the potential for transmission between the two sectors in Bangladesh

This work has been presented as oral and poster presentations at International Conferences.

5.1.2 Bangladesh: Investigating multidrug-resistant non-typhoidal *Salmonella* from migratory birds

In 2023 we published a collaborative project undertaken with colleagues at the Bangladesh Livestock Research Institute investigating multidrug-resistant non-typhoidal *Salmonella* of public health significance recovered from migratory birds in Bangladesh. Birds were sampled in the years 2018-2022 at Tanguar and Hakaluki Haors, important wetland ecosystems in Northeastern Bangladesh. The prevalence of *Salmonella* was 13.5% and six serovars were identified: *Salmonella* serovars Perth, Kentucky, Albany, Infantis, Weltevreden, and Brancaster. The Perth and Weltevreden isolates were susceptible and harbored no acquired AMR genes. Isolates from the remaining serovars were multidrug resistant, commonly possessing resistance to tetracycline, ampicillin, chloramphenicol, sulfamethoxazole, trimethoprim, and ciprofloxacin. There was excellent concordance between resistance phenotype and the presence of corresponding AMR genes, as established by whole genome sequencing. The Kentucky isolates had high-level ciprofloxacin resistance, which correlated with the presence of mutations in the chromosomal *gyrB* and/or *parC* genes, which met WHO criteria as a priority pathogen. They were of Sequence Type 198, a widely distributed multidrug-resistant lineage reported in humans and animals and constituting an ongoing risk to public health worldwide. By demonstrating the presence of multidrug-resistant *Salmonella* in migratory birds we provide evidence that there is a potential for their long-range dissemination between countries, as has been previously observed for highly pathogenic avian influenza.

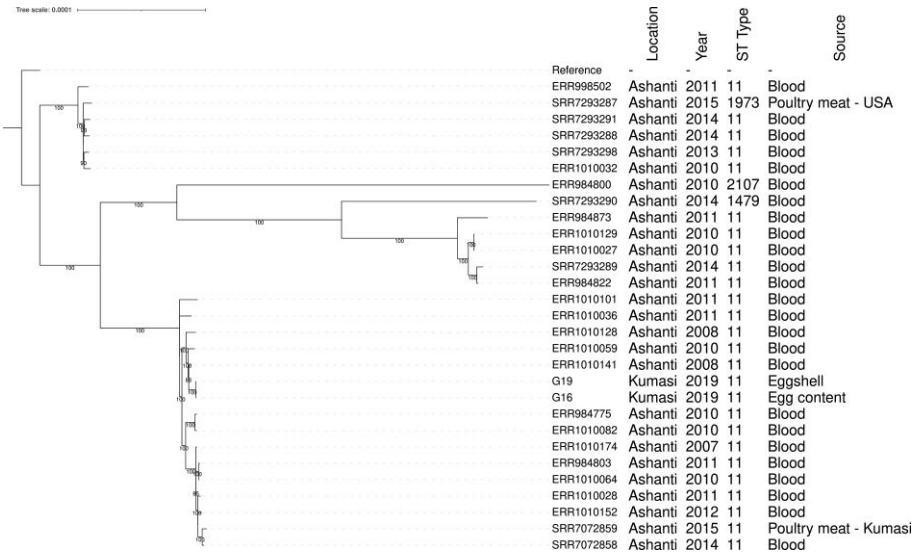


Migratory bird sampling area of Tanguar Haor and Hakaluki Haor in Bangladesh.

5.1.3 Ghana: Investigation of *Salmonella* prevalence in commercial chicken table eggs

In 2023 we completed a collaborative project undertaken in partnership with colleagues at the University of Ghana, which provided the first investigation of *Salmonella* prevalence in commercial chicken table eggs retailed in traditional markets in Ghana. This study defined the antimicrobial susceptibilities and genomic diversity, including serovars, of *Salmonella* which were found in the eggs, as described in the publication arising from this work. We provided evidence for multidrug resistance and the virulence potentials of these isolates. For example, using whole genome sequencing, we demonstrated that two multidrug *Salmonella* serovar Enteritidis isolates from eggs were closely related to the genome of a

Ghanaian Enteritidis isolate from a human blood infection described in 2008. These data provided critical baseline information in Ghana that can be used for *Salmonella* risk assessment in the egg food chain to mitigate potential future outbreaks and to inform ongoing One Health genomic approaches.

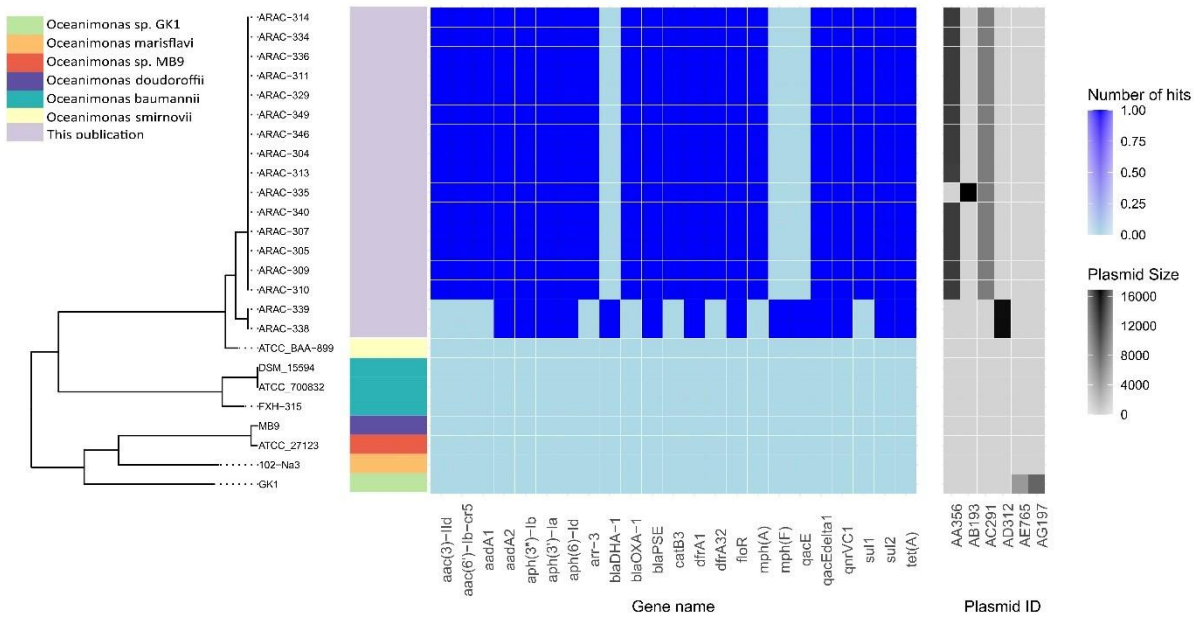


Phylogenetic tree showing the relationship between Salmonella serovar Enteritidis isolates from eggs and previously published human clinical samples from the Ashanti region, Ghana.

5.1.4 Analysis of bacteria recovered from wet fish markets in Bangladesh

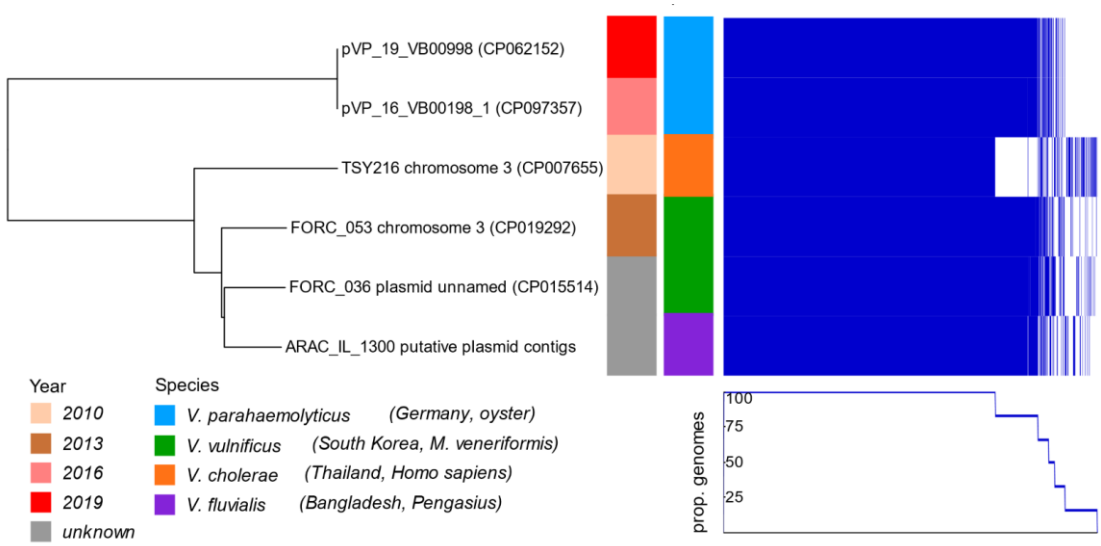
In collaboration with Bangladesh Livestock Research Institute, we are in the process of drafting two manuscripts based on sampling and whole genome sequencing of bacteria isolated in and around wet fish marketplaces and from seabirds in Bangladesh.

In one of these studies, we have uncovered the potential for an environmental bacterial genus *Oceanimonas* to act as a reservoir for AMR. We sequenced 17 isolates of *Oceanimonas* from seabirds and discovered 23 antimicrobial resistance genes conferring resistance to 12 different antibiotic classes across these genomes. Previously sequenced genomes in this genus do not appear to carry any AMR genes, indicating that these genes have been gained in the isolates recovered in this study. Many of the genes found were harboured on plasmids. We are currently undertaking long read sequencing to investigate the possibility that one of these plasmids, AB356, has recently gained two more AMR genes *(floR* and *tet*(A) found in plasmid AB193). This study highlights the ability of understudied environmental bacteria with flexible genomes to harbour AMR genes which could be redistributed to other bacteria of importance to human and animal health.



Phylogenetic tree of Oceanimonas genomes from seabirds found in markets in Bangladesh compared to publicly available genomes from the Oceanimonas genus. AMR genes and putative plasmids found in each isolate are shown.

Another study conducted in the same markets at the same time uncovered two strains of *Vibrio fluvialis* present in Pangasius fish. Within one of these strains, for which we have thirteen genomes, we consistently recovered a megaplasmid approximately 900-kb in length. Variants of this megaplasmid have previously been sequenced in full in three other *Vibrio* species and was first described in *Vibrio cholerae* in 2010. The function of the plasmid is still unknown, although the presence of huge numbers of distinct tRNA genes, which increase in numbers in the plasmid over time is notable. This paper will be the first description of a megaplasmid family in *Vibrio*. Its discovery and study will help us to understand the ecology and evolution of megaplasmids, which have been shown to play a role in antimicrobial resistance in other bacterial groups.



Pangenome and SNP tree of five complete and one draft (ARAC_IL_1300) plasmid genomes. The plasmid appears in four Vibrio species across five countries and sample types. Gene content varies within and between species, and the plasmid has gained many genes since it was found in Vibrio cholerae in 2010.

5.2 One Health programme in United Arab Emirates

Khalifa University (Abu Dhabi, United Arab Emirates (UAE)) and Cefas have established a UAE-UK One Health Biosecurity AMR Consortium in partnership with Khalifa University in the UAE. The Consortium will foster bilateral cooperation between Emirati and UK institutions to improve the One Health understanding of AMR in the combined human-agricultural-environmental system and support identification of mitigation actions for AMR. During the past year, Reference Centre members attended two planning meetings for the consortium in February 2023 and November 2023 in Abu Dhabi. Stakeholders from UAE Government departments (Abu Dhabi Agriculture and Food Safety, Abu Dhabi Health Centre, and Dubai Police) and academia (Khalifa University, Zayed University, Mohammed Bin Rashid University of Medicine and Health) and partners from UK (Cefas, APHA, University of Bath, University of Oxford, and University of Birmingham) attended the workshops. This brought together government and academic experts from both countries to design approaches to improve our understanding of the development and spread of AMR in animals, humans and the environment using phenotypic and genomic approaches. This international collaboration will help us develop combined expertise in AMR to support future surveillance practices and policies.

Attending the second planning meeting for UAE-UK One Health Biosecurity AMR Consortium in Abu Dhabi, UAE.

Reference Centre staff attending the first planning meeting for UAE-UK One Health Biosecurity AMR Consortium in Abu Dhabi, UAE.

5.3 Kuwait

AMR Reference Centre staff visited Kuwait in January and May 2023 to undertake collaborative work with the Kuwait Institute of Scientific Research and Kuwait Environmental Public Authority. This project is a component of a wider baseline survey in Kuwait City for the understanding of the AMR prevalence in water and marine sediments and its change over time.

Collaborators sampling effluent treated water from wastewater treatment plants (left image) in Kuwait and marine grab samples collection from Kuwait bay, Kuwait (right image).

5.4 Qatar

The Reference Centre has established a collaboration with the University of Qatar to support capacity development for the detection and characterisation of *Campylobacter* from food at retail. A visiting scientist from the University was hosted in the UK by the Reference Centre and APHA's National Reference Laboratory for *Campylobacter* for training. A training visit by the APHA *Campylobacter* team to the University of Qatar swiftly followed to help embed the learning and establish laboratory procedures. This project continues to support *Campylobacter* surveillance and research in Qatar.

5.5 Solomon Islands

During August 2023, Reference Centre staff were involved in two environmental microbiology assessments around Honiara, Guadalcanal, Solomon Islands. The overarching aim was to strengthen microbiology skills in Solomon Islands. Cefas worked closely with the Ministry of Environment, Climate Change, Disaster Management and Meteorology (MECDM). Training was given for techniques in water quality and microbiology. Focus was specifically aimed at faecal indicators, *Vibrio* spp., and ESBL-producing bacteria as an introduction to AMR.

Discussions are underway with WOAH, Fiji, to understand what is happening from a veterinary AMR perspective in the Pacific region, and how the Reference Centre could add value to existing programmes or gain funding for an aquatic AMR surveillance from a regional grant.

MCDM team receiving hands on water quality training in the field.

6.0 Guidance and standards

6.1 Proficiency Testing schemes

The Reference Centre supports good laboratory practice and the generation of quality assured AMR data in LMICs through the provision of a Proficiency Testing scheme for the AST of *Escherichia coli*. The scheme was developed and validated in-house for disc diffusion and broth microdilution according to EUCAST and CLSI interpretative criteria. This scheme is delivered by VETQAS, APHA's independent and ISO/IEC 17043 accredited PT service. The scheme operates by providing participating laboratories with test samples for analysis. Laboratories analyse these, preferably as part of their normal routine, and report the results to the scheme organisers. They are then provided with a report showing how closely their results agreed with the accepted values. Regular participation in PT schemes supported external quality assessment and provided evidence for regulators and accreditation bodies of competent performance.

The report for the PT scheme distribution of Winter 2022 was provided to participants in early 2023. To support laboratories which participated in that distribution and to strengthen their testing capability, the Reference Centre provided bespoke support by discussing potential sources of error and suggestions for improving laboratory performance as requested. The distribution of the PT scheme in 2023 was paused as we recruited additional laboratories from sub-Saharan Africa into the scheme, following consultation with FAO and VETQAS. The PT scheme distribution is now scheduled for January 2024.

6.2 Setting susceptibility testing standards and interpretive criteria

The Reference Centre has been involved with **setting ECVs for a range of aquaculture pathogens** with other laboratories around the world. This includes leading a project to develop ECVs for the zoonotic pathogen *Vibrio parahaemolyticus*. Standardised susceptibility testing panels and other materials were sent out to participants at five international laboratories. Results are presently being collated with a view for recommending ECVs for this pathogen to at least five antimicrobials 2025. A key part of this programme is the links we have established with the CLSI to ensure efficient uptake of results by standard setting bodies.

6.3 Developing a warm water aquaculture pathogen proficiency scheme

The Reference Centre has been in communication with VETQAS and other laboratories internationally to develop a bacterial disease of warmwater fish PT scheme. VETQAS already have a similar scheme for bacterial diseases of cold water fish (Proficiency Testing at APHA Quality Assurance Unit (QAU)- PT0008 - Bacterial diseases in cold water fish (defra.gov.uk). This additional scheme would be particularly useful for laboratories undertaking diagnostics and AST of fish and shellfish reared in warm water regions. More than 10 laboratories in Africa and Asia have already expressed an interest in joining such a scheme, once established.

6.4 Development of e-learning course

The Reference Centre is developing a new e-learning on pharmacovigilance for veterinary medicines, to complement its current learning portfolio. The Fleming Fund-supported project started in March 2023 and is scheduled for completion in March 2024. The training is intended for regulators in LMICs who are developing or strengthening veterinary pharmacovigilance systems. Four out of six modules have been developed, with the package including animations and video segments to support learning.

6.5 Monitoring and surveillance of antimicrobial residues in food products of animal origin (FOAO)

In support of strengthening AMR surveillance and research in the Asia-Pacific Region, FAO RAP identified a priority need for a written regional guideline addressing monitoring and surveillance of antimicrobial residues in FOAO to support countries in developing their policy, their surveillance and research. The Reference Centre was commissioned to provide technical support to develop the Guideline collaboratively with FAO RAP. The draft Guideline developed was discussed during a regional consultation with over 50 national experts, FAO Reference Centre for AMR leading laboratories and other key partners. The draft Guideline describes recommendations in six chapters to assist national competent authorities across FAO RAP countries in Asia-Pacific region, in establishing veterinary medicine (mainly antibiotics) residues surveillance programmes for major food animal species and in strengthening effective measures for food safety in line with international guidance and standard principles. The next steps include refining the content and scope of the draft Guideline, taking into consideration the feedback and comments received from

stakeholders. A poster was developed to describe the process and was presented during the FAO-RAP meeting in November.

6.6 Antimicrobial usage guidelines

- FAO-RAP has established a CoP on Prudent Antimicrobial Use in Animals. This community aims to provide a space where individuals interested in promoting responsible antimicrobial use in animals can come together to create a supportive professional environment. Ultimately, the group aims to produce a guidance document outlining the process for developing national antimicrobial treatment guidelines in Southeast Asia and LMICs. The Reference Centre is a member of this CoP and participates in regular virtual meetings with other nominated members and recognised experts to discuss topics related to responsible prescribing, animal health, and welfare.

- In May 2023, a colleague from the Reference Centre co-chaired the TATFAR subgroup, which focuses on antimicrobial usage. The key discussion contributed to finalising a review paper on the reporting of antimicrobial sales and usage data by member countries (the UK, the EU, the USA and Canada), which was published in October 2023. Reporting of sales and use of antimicrobials per animal species by TATFAR members (cdc.gov)

7.0 Communications and publications

7.1 Peer reviewed publications

Caputo A, Bondad-Reantaso MG, Karunasagar I, Hao B, Gaunt P, **Verner-Jeffreys D**, Fridman S, Dorado-Garcia A. 2023. Antimicrobial resistance in aquaculture: A global analysis of literature and national action plans. Reviews in Aquaculture 15, 568-578.

Archer EW, **Chisnall T,** Tano-Debrah K, **Card RM**, Duodu S, Kunadu AP. 2023. Prevalence and genomic characterization of *Salmonella* isolates from commercial chicken eggs retailed in traditional markets in Ghana. Front Microbiol. 1;14:1283835. doi: 10.3389/fmicb.2023.1283835. PMID: 38029182; PMCID: PMC10646427.

Card RM, **Chisnall T**, Begum R, Sarker MS, Hossain MS, Sagor MS, Mahmud MA, Uddin ASMA, Karim MR, Lindahl JF, Samad MA. 2023. Multidrug-resistant non-typhoidal *Salmonella* of public health significance recovered from migratory birds in Bangladesh. Front Microbiol. May 15;14:1162657. doi: 10.3389/fmicb.1162657. PMID: 37256054; PMCID: PMC10226424.

Ndahi MD, Hendriksen R, Helwigh B, **Card RM**, Fagbamila IO, Abiodun-Adewusi OO, Ekeng E, Adetunji V, Adebiyi I, Andersen JK. 2023. Determination of antimicrobial use in commercial poultry farms in Plateau and Oyo States, Nigeria. Antimicrob Resist Infect Control. 10;12(1):30. doi: 10.1186/s13756-023-01235-x. PMID: 37038206; PMCID: PMC10084607.

Ndahi M, Fagbamila IO, Adebiyi I, Ekeng E, Adeleke S, Adetunji V, Hendriksen R, Ryan C, Patel H, **Verner-Jeffreys D, Chisnall T**, **Card RM**. 2023. Establishing a One Health AMR Community of Practice in Nigeria. One Health Cases. https://doi.org/10.1079/onehealthcases.2023.0030

Smith P, Le Devendec L, Jouy E, Larvor E, **Verner-Jeffreys D**, **Joseph AW, Light, E.**, et al. 2023. Epidemiological cut-off values for *Vibrio anguillarum* MIC and disc diffusion data generated by standardised methods. Dis Aquat Organ, 155:109-123. https://doi.org/10.3354/dao03745

7.2 Oral presentations

*Key: Reference Centre staff underlined and presenting author indicated with an asterisk **

- David Verner-Jeffreys* UK FAO Reference Centre for antimicrobial resistance. Ocean Country Partnership Programme (OCPP) India workshop on One Health aquaculture, Kochi, India, **20-22 February 2023**.

- Athina Papadopoulou* Cefas research on AMR in aquatic environments and wastewater in GCC and wider. One Health AMR Research Collaboration Planning Workshop. **27-28 February 2023**.

- Roderick Card* APHA research on AMR in agricultural contexts. One Health AMR Research Collaboration Planning Workshop, Khalifa University, United Arab Emirates. **27-28 February 2023**.

- Ramon P. Maluping* and Roderick Card* AMR Community of Practice: The UK FAO Reference Centre Experience. Congress of FAO Reference Centres for AMR. APHA, Weybridge, UK. **15 March 2023**.

- Athina Papadopoulou* Developing a Participatory Biosecurity Training module for finfish aquaculture production systems in Bangladesh. 8th coordination meeting of Fleming Fund grantees and partners. Virtual Event. **30 March 2023**.

- Thomas Chisnall* Multidrug resistant *E. coli* in poultry from live bird markets in Bangladesh. Applied Bioinformatics and Public Health Microbiology, Cambridge, UK. **3-5 May 2023.**

- Ramon P. Maluping* How my experience as a Gates Cambridge Scholar has motivated and inspired me to achieve both my personal and professional goals? Gates Cambridge Alumni Weekend, University of Cambridge, U.K. **3-4 June 2023**.

- Roderick Card* UK FAO Reference Centre for Antimicrobial Resistance. CoVetLab Annual Meeting, APHA Weybridge, UK, **21 June 2023**.

- Elizabeth Marier* Surveillance of veterinary medicines in food products of animal origin. Central Veterinary Research Institute, Lusaka, Zambia, **22 June 2023**.

- Athina Papadopoulou* Introduction to UK' FAO RC for AMR. Launch of the FAO Reference Centers for Antimicrobial Resistance (AMR) and Aquaculture Biosecurity. Rome, Italy, **26 June 2023**.

- Athina Papadopoulou* AMR in the aquatic environment. Launch of the FAO Reference Centres for Antimicrobial Resistance (AMR) and Aquaculture Biosecurity. Rome, Italy, **26 June 2023**.

- Rachel Hartnell*. One Health – unlocking safe, sustainable global approaches to aquatic food production. Launch of the FAO Reference Centres for Antimicrobial Resistance (AMR) and Aquaculture Biosecurity. Rome, Italy, **26 June 2023**.

- Roderick Card*. AMR surveillance and research at APHA. National Institute of Animal Biotechnology (India) visit to APHA. UK, APHA Weybridge, UK, **26 June 2023**.

- Ramon P. Maluping*, Remedios F. Micu, Thomas Chisnall, Alistair Davies, Evelyn E. Embestro, Mary Ann Escoto, Mildred A. Padilla and Roderick Card. Prevalence of Extended-Spectrum Beta-Lactam (ESBL) and Colistin Resistance in *Escherichia coli* Isolated from Broiler Chickens in Dressing Plants in the Philippines. 9th Symposium on Antimicrobial Resistance in Animals and the Environment (ARAE), Tours, France. **3-5 July, 2023**.

- Roderick Card* AMR surveillance and research at APHA. Central Veterinary Research Institute, Zambia and University of Zambia **12-14 July 2023**.

- Thomas Chisnall* Multidrug-resistant *Salmonella enterica* serotype Kentucky ST198 is widely distributed across poultry farms in Nigeria. Central Veterinary Research Institute, Zambia and University of Zambia, **12-14 July 2023.**

- David Verner-Jeffreys* Health partnerships: an effective response to the global health agenda. G20 Technical Workshop on One Health: Opportunities and Challenges (UK Delegate and Invited Speaker). Bangalore, India, **29-31 August 2023.**

- Roderick Card* One Health AMR including the Environment. Fleming Fund Delivery Partners Event. Accra, Ghana, **25-27 September 2023**.

- Athina Papadopoulou*, Craig Baker-Austin* Research interests on AMR. Seed Meeting 'Fighting together AMR in Aquaculture'. **26-27 September 2023**.

- Roderick Card*, Marier Elizabeth*, Verner-Jeffreys David* UK FAO Reference Centre for Antimicrobial Resistance. Government laboratories and ministries and Brooke and the veterinary school**. 21-24 November 2023**.

- Athina Papadopoulou* Implementation of antimicrobial resistance surveillance in farmed aquatic animals. Avoiding AMR together: Ensuring healthy and safe aquatic foods. Virtual Event. **27 November 2023**.

7.3 Poster presentations

*Key: Reference Centre staff underlined and presenting author indicated with an asterisk **

- Alistair Davies*, Thomas Chisnall, Shamima Akter, Mohammad Golam Azam Chowdhury, Md. Mohibul Hassan Afrad, Zakiul Hasan, Mohammad Habibur Rahman, Eric Brum, Roderick Card. Investigation into multidrug resistant *Escherichia coli* taken from live bird markets in Dhaka, Bangladesh. 33rd European Congress of Clinical Microbiology & Infectious Diseases, Copenhagen, Denmark, **15-18 April 2023**.

- Ramon P. Maluping*, Robert Atterbury, Paul Barrow, Janis Rumnieks and Michael A. Jones. Understanding the use of sex pilus specific bacteriophages to reduce conjugative dissemination of antibiotic resistance. ICOHAR International Conference on One Health Antimicrobial Resistance, Copenhagen, Denmark, **18-20 April 2023**.

- Ramon P. Maluping*, Francesca A. Latronico and Roderick M. Card. Establishing a One Health Antimicrobial Resistance Community of Practice: The UK FAO Reference Centre for AMR Experience. ICOHAR International Conference on One Health Antimicrobial Resistance, Copenhagen, Denmark, **18-20 April 2023**.

- Alistair Davies*, Thomas Chisnall, Shamima Akter, Mohammad Golam Azam Chowdhury, Md. Mohibul Hassan Afrad, Zakiul Hasan, Mohammad Habibur Rahman, Eric Brum, Roderick Card. Mobile tigecycline resistance gene found in live bird markets in Dhaka, Bangladesh. 9th Symposium on Antimicrobial Resistance in Animals and the Environment, Tours, France, **3-5 July 2023**

- Athina Papadopoulou, Nicola Coyle*, Isobel Smith., Niamh Langford, Ben Maskrey, Mickael Teixeira, Edel Light. Antimicrobial resistance surveillance in imported ornamental fish. Poster and flash oral presentation. 21st EAFP Conference, **11-14 September 2023**.

- Athina Papadopoulou, Nicola Coyle, Niamh Langford, Eliot Stanton, David Ryder, Andy Joseph, Oliver Robinson, Edel Light, David Verner-Jeffreys*. Implementation of a UK farmed trout passive antimicrobial resistance surveillance programme. 21st EAFP Conference, **11-14 September 2023**.

- Elizabeth Marier, Callum Harris, Ruth Barnes, Rachel Dalton*. Volume 6: Regional Guideline for the Monitoring and Surveillance of Antimicrobial Residues in Foods of Animal Origin. The Regional AMR Technical Advisory Group Meeting (TAG) for the animal health sector, Bangkok, Thailand, **29-30 November 2023**.

- Ramon P. Maluping*, David Verner-Jeffreys, Claire Gilbert and Roderick M. Card. The UK's FAO Reference Centre for Antimicrobial Resistance. The Regional AMR Technical Advisory Group Meeting (TAG) for the animal health sector, Bangkok, Thailand, **29-30 November 2023**.

7.4 Blogs and online reports

VMD News story | Rachel Dalton | 29 March 2023
First Annual Congress of FAO Reference Centres for Antimicrobial Resistance (AMR) - GOV.UK (www.gov.uk)

APHA Science Blog | Rod Card | 3 August 2023
APHA and partners in the battle against a growing global health crisis - APHA Science Blog

APHA Science Blog | Jane Tennant | 3 November 2023
APHA's One Health approach is critical - APHA Science Blog

Defra blog | Dr Christine Middlemiss, CVO | 3 November 2023
Celebrating the 8th Annual 'One Health' Day – Working Across Boundaries - Government Vets (blog.gov.uk)

APHA Science Blog | Sarah Stewart | 10 November 2023
Generating new scientists and biosecurity champions! - APHA Science Blog

APHA Science Blog | Tom Chisnall | 16 November 2023
World Antimicrobial Resistance (AMR) Awareness Week - APHA Science Blog

APHA Science Blog | Rod Card, Manal AbuOun, Ramon Maluping | 22 November 2023
Raising AMR awareness globally - APHA Science Blog

APHA Press Release | 24 November 2023
APHA and VMD buildings 'go blue' for World AMR Awareness Week - GOV.UK (www.gov.uk)

APHA Science Blog | Remedios F. Micu and Mary Ann R. Escoto | 8 December 2023
A visit of a lifetime: Our experience with APHA's UK FAO Reference Centre for AMR - APHA Science Blog

VMD Blog | Sannah Malik | 21 December 2023
VMD AMR team International Engagement - Veterinary Medicines Directorate (blog.gov.uk)

Appendix 1

Description of the three Defra agencies which together hold the UK FAO Reference Centre for AMR designation.

Animal and Plant Health Agency (APHA)

APHA works to safeguard animal and plant health for the benefit of people, the environment, and the economy. Its responsibilities include identifying and controlling endemic and exotic diseases and pests in animals, plants, and bees; surveillance of new and emerging pests and diseases; scientific research in areas such as bacterial, viral, prion and parasitic diseases and vaccines, and food safety; and to act as an international reference laboratory for many farm animal diseases. The APHA science strategy outlines how science is embedded across APHA and is the foundation for the evidence and expert advice provided to policy customers, industry and stakeholders in delivering threat awareness, definition and mitigation.

APHA has a long-standing reputation as a world leading centre of veterinary science expertise and this is acknowledged by its status as a National and International Reference Laboratory for a wide range of infectious and non-infectious diseases in animals. The agency provides veterinary and scientific consultancy to countries throughout the world offering: confirmatory testing; technical training and expert consultancy; and development and standardisation of diagnostic methods to ensure they are fit for purpose to detect new strains of pathogens.

APHA is globally recognised for its AMR expertise, has been a reference laboratory on AMR for the World Organisation for Animal Health (WOAH) since 2003, and is the UK's national reference laboratory for AMR in veterinary bacteria. The APHA undertakes passive and active AMR surveillance in UK livestock and food sectors and provides AMR data and expert analysis for the UK's annual report on sales of antibiotics and surveillance of AMR. It has significant laboratory capability in its network of diagnostic laboratories and at its central facility at Weybridge, Surrey. APHA's capability includes development of phenotypic and genotypic diagnostic tests; molecular typing utilising dedicated sequencing units (*e.g.* whole genome sequencing); research with extensive collaborative networks and complex modelling techniques.

APHA website: Animal and Plant Health Agency - GOV.UK (www.gov.uk)

Centre for Environment, Fisheries and Aquaculture Science (Cefas)

Cefas is the UK government's marine and freshwater science agency, working for healthy and productive oceans, seas and rivers and safe and sustainable seafood. Innovative, world-class science is central to the mission, working to safeguard human and animal health, enable food security and support marine economies. Cefas is a global leader in aquatic animal health and is positioned to provide services in identifying AMR risks to aquatic animals and to help develop and assess the effectiveness of alternatives to use of

antibiotics for control of diseases of farmed aquatic animals (particularly in finfish and shrimp).

For this, Cefas can draw on its extensive expertise in disease investigation, diagnosis, and control, including experience of AMR characterisation of aquatic pathogens. As well as state of the art equipment for measuring AMR, it also has access to a range of advanced pathology and molecular technologies, including high throughput sequencing for pathogen genomics. Cefas epidemiology and risk teams also have experience in designing and interpreting surveys to help quantify and reduce antibiotic usage on farms.

Cefas website: https://www.cefas.co.uk/

Veterinary Medicines Directorate (VMD)

The Veterinary Medicines Directorate (VMD) is the UK regulator of veterinary medicines. VMD facilitates the availability of safe and effective veterinary medicines for prevention and treatment of disease and to protect animal health and welfare, human health, and the environment. We have built a reputation as a leading centre for regulation, encompassing all aspects of Veterinary Medicinal Products authorisation and post authorisation management, including legislation, scientific data assessment, pharmacovigilance, surveillance of antimicrobial use, resistance and residues, and compliance with good manufacturing and distribution practices.

The VMD is the UK policy lead on AMR in regard to animal health and is responsible for overseeing implementation of the animal health aspects of the UK 5 Year AMR NAP and 20-year vision, working closely with human health colleagues, and taking a One Health approach. The VMD publishes an annual report on sales of antibiotics and surveillance of AMR (UK Veterinary Antimicrobial Resistance and Sales Surveillance) and chair Defra's cross-government AMR Coordination group which brings together expertise from across the UK government and devolved administrations to review and respond to emerging AMR threats.

The VMD works with LMICs to provide technical and policy expertise across all aspects of veterinary medicines regulation. The VMD is a member of VICH, participates in expert advisory groups for the British Pharmacopoeia and the European Pharmacopoeia, is a committee member for the Pharmaceutical Inspection Co-operation Scheme (PICs) and provides subject specific expertise on aspects of veterinary medicines to Codex Alimentarius, FAO and WOAH.

VMD website: Veterinary Medicines Directorate - GOV.UK (www.gov.uk)