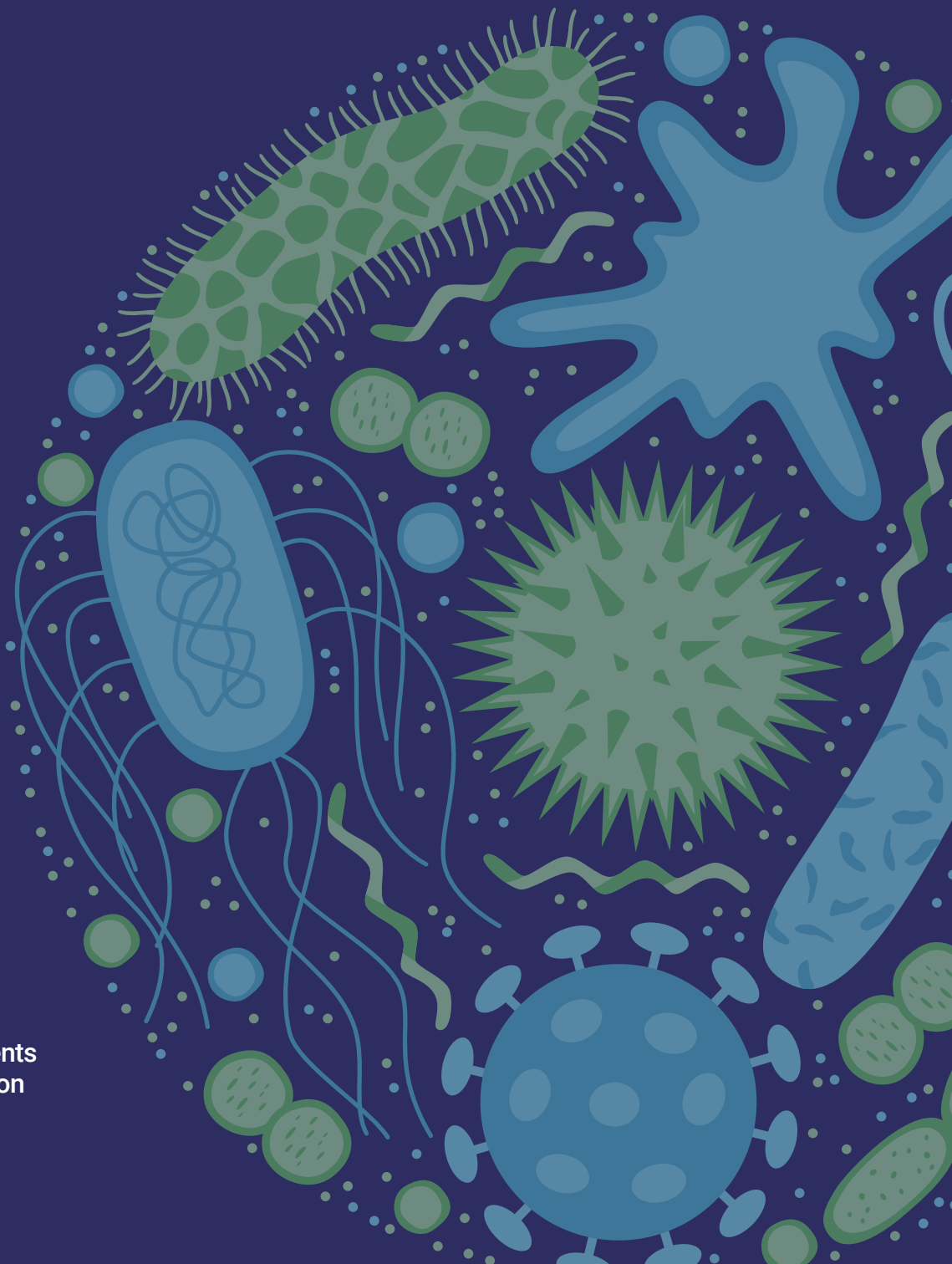
Biotechnology and Biological Sciences Research Council

Evaluation of the effectiveness and impact of BBSRC's investments in antimicrobial resistance research



This document represents the views and conclusion of a panel of experts

November 2022

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EXECUTIVE SUMMARY

Antimicrobial resistance (AMR) occurs when organisms that cause infection evolve ways to survive treatment. It is a growing problem in the UK and globally. In 2019, the UK Government published its 20-year vision[i] for tackling AMR alongside a five-year National Action Plan[ii]. There is a vital role for research and innovation to address the global challenge of AMR and this is highlighted within the 'tackling infections' theme of the recently published UKRI Strategy 2022 – 2027[iii].

Bioscience research has potential to make a critical contribution to addressing AMR. In 2014, "Combatting antimicrobial resistance" was introduced as a BBSRC responsive mode priority and approximately £30m per annum is currently invested in AMR research across a variety of investment mechanisms (such as responsive mode, initiatives, strategically supported institutes and fellowships). It is therefore timely to review the effectiveness of these investments and the extent to which they are delivering beneficial outcomes.

This document summarises the conclusions of an expert review panel which was established to conduct an independent evaluation of BBSRC's investments in AMR research. The evaluation covered four major areas:

- New knowledge and understanding
- Economic and societal impact
- Knowledge exchange and supporting stakeholder needs
- BBSRC's support for AMR research

Data for the evaluation were gathered from a number of sources including BBSRC's grants database, the Researchfish outcomes reporting system, bibliographic and bibliometric databases, grant holder surveys and semi-structured interviews. Outcomes data were obtained for 439 BBSRC AMR grants which had active spend between 2010 and 2020. Studentship investments were not included in the evaluation.

KEY CONCLUSIONS

1. **BBSRC's investments in AMR research have supported high-quality research that was internationally leading.**

   BBSRC's investments in AMR research have supported excellent research across its remit[iv]. AMR research projects have contributed to a variety of discoveries, producing new knowledge with the potential to underpin future advances addressing the challenges associated with AMR. Data on publication outputs demonstrated that the research was internationally leading with, for example 22% of BBSRC AMR research articles in the top 10% of related Web of Science publications. BBSRC's AMR investment had also contributed to a wide variety of other high-quality outputs and outcomes, including datasets/databases, new research tools/methods, and software. Grant holders were successful in obtaining further funding to continue or develop their research. Approximately £100m of further funding was reported.

2. **There was evidence of emerging economic and societal impact arising from the BBSRC AMR portfolio though, on balance, there was scope to deliver further impact and benefit from the investment.**

   There was clear potential for the high-quality research supported by BBSRC to address the challenge of AMR and deliver wider economic and societal impact. There was evidence of emerging impact arising from BBSRC's AMR portfolio and this covered the breadth of BBSRC's research priority in AMR. Progress in delivering economic and societal impact was demonstrated through a variety of reported outputs and outcomes, including new intellectual property (8% of grants), spin-outs (4%) and influence on policy and practice (11%). There were some very good individual examples of policy influence within the portfolio and, more broadly, approximately 3% of BBSRC-attributable AMR research publications (2016-2020) had been cited in policy-related documents. However, on balance, there could be scope to further maximise the potential to create economic and societal impact from BBSRC's investments in AMR research. For example, there were opportunities to increase the overall level of engagement between grant holders and stakeholders, increase the level of awareness of the wider government strategic drivers for tackling AMR, and improve the overall level of translation within the portfolio. Currently, the potential of BBSRC's research investments to deliver impact that addresses AMR is not being fully realised.

3. **Overall the level of collaboration across the AMR portfolio is good: the level of academic collaboration is a strength of the AMR portfolio, although there is scope for a greater level of engagement between BBSRC-supported researchers and non-academic stakeholders.**

   Collaboration and partnership are essential for delivering high-quality AMR research and subsequent economic and societal impact. The overall level of collaboration and partnership within the BBSRC AMR portfolio was good (for example 58% of grant holders reported a new

or improved collaboration or partnership as a result of their AMR research project). The level of academic collaboration was a strength of the AMR portfolio, both nationally and internationally (for example 67% of publication outputs had an international co-author). Moreover, international partnerships had provided significant added value to BBSRC AMR research, such as enabling the exploration of research questions that would not otherwise be possible. The overall level of partnership with non-academic stakeholders (for example industry, policy makers and end users/ practitioners) was more limited, though there were examples of effective partnerships between academic researchers and industry. As a major funder of AMR research in the UK, BBSRC has an important role in fostering a vibrant and effective AMR community. There are opportunities for BBSRC to work with other constituent components of UKRI to further strengthen the UK's AMR research community and help ensure that academic researchers have a common understanding of the motivations, needs and communication styles of stakeholders.

4. **The balance and coverage of BBSRC's AMR portfolio was very good, with BBSRC making a distinctive contribution to the wider UK AMR research and innovation landscape.**

   The overall balance and coverage[v] of the AMR research portfolio was very good, with excellent research supported across the breadth of BBSRC's remit. There was strong evidence that BBSRC had a distinctive and appropriate role in supporting the wider UK AMR research and innovation landscape, with a particular focus on underpinning biology that would enable subsequent investment by others. This was a notable achievement, particularly considering the breadth of BBSRC's remit which supports research at different scales from molecules to landscapes. There were some potential gaps in the portfolio, including:

   - supporting the development pipeline for new antimicrobial agents (for example antibiotics, antifungals and antiprotozoals),
   - the use of antimicrobial agents in the preservation of food and other products,
   - diagnostics to detect emerging AMR in plants and animals, and
   - addressing the changing AMR landscape in response to climate change.

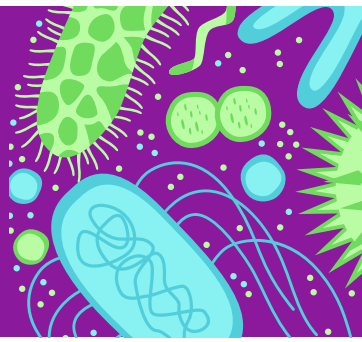
   There was a good level of multidisciplinary and interdisciplinary research within the BBSRC AMR portfolio. However, given the cross-cutting, multifactorial nature of the AMR and broader 'Tackling infections' global challenges, there are opportunities for BBSRC and other constituent components of UKRI to expand and coordinate support for multidisciplinary and interdisciplinary research in this area.

5. **There are opportunities for BBSRC to build on its effective support for AMR research to ensure that the UK can realise the ambition set out in the Government's 20-year vision of tackling AMR.**

   BBSRC has provided effective support for AMR research through a variety of different investment mechanisms and this investment track-record, alongside that of other key funders, will make a foundational contribution to the UK's 20-year vision for tackling AMR. Looking forward, BBSRC should seek to build on its successes and further strengthen its support for AMR research and innovation. There are opportunities for BBSRC to work more closely with other funders, including other constituent components of UKRI (for example MRC and Innovate UK), as well as with industry, to ensure the translation of BBSRC-funded AMR research into wider impacts and benefits. At present, although there are positive examples of emerging impact arising from BBSRC's AMR investments, the level of translation within the portfolio is unlikely to be sufficient to realise the full ambition set out in the UK's 20-year vision for tackling AMR. Future strategy will need to reflect on the need to accelerate effective translation and developing the mechanisms to achieve this.

1.

BBSRC'S INVESTMENT IN ANTIMICROBIAL RESISTANCE RESEARCH



1.1. UK policy drivers to address AMR

1. Antimicrobial resistance (AMR) occurs when organisms that cause infection evolve ways to survive treatment. AMR is a growing problem in the UK and globally, and is exacerbated by the inappropriate use of current antimicrobials. In 2019, the UK Government published its 20-year vision[vi] for containing and controlling AMR alongside a five-year National Action Plan[vii]. A POSTnote[viii] outlines how the UK is responding to the global challenge of AMR.

2. The UK's 20-year vision for AMR sets out the global challenge of AMR and highlights the strategic drivers for addressing the AMR threat. The 20-year vision states that the UK will contribute to the global effort through:
   - A lower burden of infection, better treatment of resistant infections, and minimised transmission in communities, the National Health Service (NHS), farms, the environment and all other settings.
   - Optimal use of antimicrobials and good stewardship across all sectors, including access to safe and effective medicines that have been manufactured responsibly for all who need them; achieving and maintaining usage levels by sector as good as the best countries in the world where comparable data are available.
   - New diagnostics, therapies, vaccines and interventions in use, and a full antimicrobial resistance research and development pipeline for antimicrobials, alternatives, diagnostics, vaccines and infection prevention across all sectors; with access to new and old technologies for all.

3. The UK's 20-year vision and 5-year National Action Plan recognise the critical role of research and innovation in addressing the challenge of AMR. This is highlighted in UKRI Strategy 2022 – 2027[ix] where 'Tackling infections' is included as a strategic theme for addressing major national and global challenges:

   Tackling Infections: protecting and enhancing health, our food supply and our natural capital by building knowledge and capabilities to detect and disrupt the emergence and spread of human, animal and plant diseases, accelerate new vaccines and therapeutics, and halt the 'slow motion pandemic' of antimicrobial resistance.

4. UKRI's research efforts aim to address the breadth of the challenges associated with AMR, recognising that resistant organisms are found in people, animals, food and the environment.

1.2. BBSRC investments in AMR research

5. Bioscience research has strong potential to make a critical contribution to addressing the challenge of AMR alongside research from other disciplines including multidisciplinary and interdisciplinary approaches.

6. BBSRC has invested in AMR research across a variety of different investment mechanisms, since its inception in 1994. Over the past three years, BBSRC expenditure on research relating to AMR has averaged over £30m million per year. Investment mechanisms include responsive mode[x], fellowships[xi], capital (such as mid-range equipment)[xii], Official Development Assistance (ODA) (Global Challenges Research Fund[xiii] and Newton Fund[xiv]) calls, International Partnership Awards[xv], Institute Strategic Programmes[xvi] and Industrial Partnerships Awards[xvii].

7. In 2014, "Combatting antimicrobial resistance" became a BBSRC responsive mode priority[xviii]. The priority includes research to:
   - Understand the fundamental microbiology of organisms with known resistance prevalence in order to understand how resistance develops and is maintained, and to develop mitigation strategies.
   - Investigate the selection pressures for antimicrobial resistance and the dynamics of transmission at the genetic, organism and host level impacting on the design of measures to control resistance.
   - Underpin the development of novel antimicrobials and alternatives to antimicrobials.

- Develop novel diagnostics to enable rapid identification of antimicrobial-resistant organisms or presence of resistance genes.

8. The priority covers AMR in microbes associated with animal, plant and soil systems plus relevant understanding of how such resistance could lead to the transfer of AMR to human pathogens or human commensal bacteria. It includes antibiotic resistance and antiviral resistance but excludes anthelmintics. It does not cover research focused solely on AMR in human-only pathogens, transfer of AMR between humans, or alternative strategies to combat AMR in human specific diseases as these are outside the remit of BBSRC.

9. The priority area aims to support research that delivers wider outcomes and impact. For example:
   - Research that demonstrates translational opportunities, such as by involving an industrial partner.
   - Research that might underpin future Government policy.
   - Impacts on training and the future UK skills base.

10. BBSRC has also supported AMR research through the Tackling AMR cross-Council Initiative[xix] and specific initiatives such as the Joint Programming Initiative on AMR (JPIAMR). It should be noted that projects supported through the Tackling AMR cross-Council Initiative or JPIAMR are not included within this evaluation.

1.3. Informing BBSRC's Future AMR Strategy

11. It is timely to review the extent to which BBSRC's investments in AMR have met their original research and innovation objectives and achieved beneficial outcomes. In 2019, BBSRC initiated a review of its investments in AMR research. This evaluation builds on this earlier review and is intended to help inform BBSRC's future AMR strategy.

1.4. Introduction to the evaluation of BBSRC investments in AMR research

12. This document summarises the views and conclusions of a Specialist Evaluation Panel, who conducted an independent evaluation of the effectiveness and impact of BBSRC's investments in AMR research. The panel membership is in Appendix 1.1.

13. Evidence for the evaluation was drawn from the following sources:
   - **BBSRC grants database**
   - **Research outcomes data**
   - **Bibliographic and bibliometrics databases** (that is Web of Science (WoS) and InCites, provided by Clarivate Analytics; Overton)
   - **Grant holder survey** of 62 grant holders
   - **Semi-structured interviews** with 10 grant holders

14. Outcomes data were obtained for 439 BBSRC AMR grants which had active spend between 2010 and 2020 (for example responsive mode, initiatives, strategically supported institutes and fellowships). Studentship investments were not included in the evaluation. Further details are provided in Appendix 1.2.

15. The role of the panel was to review and synthesise the evidence provided, using their expert knowledge to address the evaluation objectives as set out in Appendix 1.3.

16. The remainder of this report has been divided into four main areas:
   - New knowledge and understanding
   - Economic and societal impacts
   - Knowledge exchange and addressing stakeholder needs
   - BBSRC support for AMR research

2.

NEW KNOWLEDGE AND UNDERSTANDING

2.1. Summary

- BBSRC's investments in AMR research have supported high-quality research that is internationally leading.
- The research had contributed to a variety of discoveries, producing new knowledge with potential to underpin future advances addressing AMR.
- A majority (79%) of grant holders had been successful in delivering against their project's research objectives.
- The quantity and quality of publications arising from the AMR portfolio was very good (for example 22% of BBSRC AMR research articles were in the top 10% of related WoS publications).
- The AMR portfolio had also delivered a wider variety of other valuable research outputs and outcomes, including datasets/databases, new research tools/methods and software.
- The level of further funding obtained by grant holders was good (for example 53% of projects resulted in further funding; approximately £100m of further funding was reported).

The supporting data for this Chapter are provided in Appendix 2.

2.2. Grant performance

17. Overall, grant performance within BBSRC's AMR portfolio was very good. 79% of researchers surveyed indicated that their project had been successful or very successful in meeting its research objectives, and this self-assessment was supported by the wider evidence on project outputs and outcomes (for example see sections 2.3 to 2.8). Furthermore, 55% of researchers stated that their project had delivered unanticipated outcomes that were not envisaged at the outset of the project. This was positive and indicated that researchers were using BBSRC research funding to develop new knowledge and understanding of AMR.

2.3. New knowledge and understanding

18. BBSRC AMR research projects had contributed to a variety of discoveries, and there were numerous noteworthy examples within the portfolio. The investment had generated new knowledge and understanding of AMR across BBSRC's remit, and covered AMR in a variety of microorganisms (that is bacteria, viruses, fungi and protozoa) and host organisms/environments (such as humans, animals, plants, and soil systems). There was strong potential for the new knowledge generated to underpin future advances in addressing AMR.

2.4. Research quality

19. The overall quality of research within the BBSRC AMR portfolio was very high and internationally leading. This is most clearly evidenced by the excellent quality of the publication outputs (see section 2.5), but also by the other outputs arising from the investment (for example sections 2.6 and 2.7).

2.5. Publication outputs

20. The quantity and quality of publication outputs arising from the BBSRC AMR portfolio was very good; 88% of AMR grants with start dates between 2014 and 2018 resulted in a publication output. In total, 1,550 research articles were reported as arising from BBSRC's investment in AMR research between 2016 and 2020.

21. The quality of the publication outputs was demonstrated by a variety of bibliometric data as well as through 'publication highlights' identified by the surveyed grant holders. For example, 22% of the BBSRC AMR research articles were in the top 10% of related WoS publications, 41% were in the top 25%, and the category Normalised Citation Impact for the portfolio was 1.63 (note: the world average is 1). The 'performance' of BBSRC's AMR publication portfolio compared well to other major UK and international funders, and was higher than the UK average as well as the average for other G7 nations (Appendix 2.4). International co-authorship on BBSRC AMR publications was also very good, with 67% of research articles having an international co-author.

2.6. Other research outputs

22. BBSRC AMR research projects contributed to the delivery of a wide variety of other valuable outputs, as evidenced in data submitted through the Researchfish outcomes collection tool. For example, of AMR projects with start dates between 2014 and 2018:

- 22% resulted in a research dataset, database or model, with a total of 92 such outputs reported
- 22% contributed to the development of a new research tool or method, with a total of 76 such outputs reported
- 8% resulted in a software or technical product, with a total of 26 such outputs reported.

Overall, 31% of projects resulted in at least one output across these other output types.

23. The panel considered the quantity and quality of outputs arising from these investments to be good, noting the nature and variety of research being supported within BBSRC's AMR portfolio. These other outputs are as equally important as publications, providing valuable resources to the community that may have a long-lasting impact both within academia and more broadly. A good proportion of these resources appeared to be accessible through open access routes. However, there was scope for BBSRC and the research community to do more in ensuring such outputs are made widely accessible.

24. Four examples of other research outputs are presented below:

DESIGN, SYNTHESIS AND TESTING OF NOVEL PHYTOPATHOGENIC FUNGICIDES

"Originally we focussed on plant pathogens but this has now expanded to include human pathogens such as Candida and Aspergillus. We are in the process of forming a spin-out company, Alternox Scientific Ltd. to take these technologies to the market including a range of fungicides to treat both cereal and non-cereal pathogens. We have also made significant advances in the treatment of human pathogens which contain an AOX including those that cause candidiasis and cryptosporidiosis. Of particular importance is the finding that our compounds are effective at treating a new member of the candida family (*Candida auris*) which is an emerging multi-drug resistant human fungal pathogen resulting in a world-wide candidaemia epidemic of global concern."

EUROPEAN BREEDS DOMINATE CURRENT GENETIC RESOURCES

"Despite only 8% of cattle being found in Europe, European breeds dominate current genetic resources. This adversely impacts cattle research in other important global cattle breeds. To mitigate this issue, we have generated the first assemblies of African breeds, which have been integrated with genomic data for 294 diverse cattle into the first graph genome that incorporates global cattle diversity. We illustrate how this more representative reference assembly contains an extra 116.1Mb (4.2%) of sequence absent from the current Hereford sequence and consequently inaccessible to current studies. We further demonstrate how using this graph genome increases read mapping rates, reduces allelic biases and improves the agreement of structural variant calling with independent optical mapping data. Consequently, we present an improved, more representative, reference assembly that will improve global cattle research" This project helps to identify disease-resistant breeds to reduce antimicrobial usage in parts of the world outside Europe where AMR is more prevalent.

GCRF-BBR: BEYOND THE GENOME: ENABLING TROPICAL LIVESTOCK EPIGENOME-WIDE ASSOCIATION STUDY (EWAS) OF INFECTIOUS DISEASES

"We have successfully characterised DNA methylation profiles between cell types and how they have evolved between breeds. Leveraging this funding we have managed to supplement it with matching gene expression and chromatin datasets for the same samples, providing a more comprehensive cross-breed omic atlas. We have illustrated how these data can be successfully used to estimate cell type compositions in mixed cell datasets, the primary objective of the original grant. This will enable future studies to use this approach to correct for cell type composition biases in gene expression and epigenetic studies of mixed cell samples when, for example, studying changes linked to diseases. A web browser has been developed, Bovine OMic Atlas (BOMA), to make this data freely accessible and viewable across the cow genome alongside other related datasets. This is already being used by other groups to characterise chromatin and gene expression patterns in regions of interest and we expect to make the site live for all to access in the next few months. We are involved in discussions with Illumina to help develop a methylation array for cattle to enable large EWAS". This project aims to enable selection of cattle with natural disease tolerance to reduce the need and usage of antimicrobials.[1]

UNIVERSITY OF EDINBURGH CAMPYLOBACTER STUDY

Campylobacter is the leading cause of foodborne diarrhoeal illness in humans and is mostly acquired from consumption or handling of contaminated poultry meat. As effective vaccines and treatments for pre-slaughter control of Campylobacter in poultry are lacking, much interest exists in the potential for breeding chickens with improved resistance to intestinal colonisation by *Campylobacter jejuni*. Campylobacter intestinal colonisation levels are influenced by the host genetics of the chicken. In this study, two chicken populations were used to investigate the genetic architecture of avian resistance to colonisation. The level of colonisation with *C. jejuni* following experimental infection was found to be a quantitative trait. Finally, gene expression analyses were performed for some of the candidate resistance genes to support the results. Campylobacter resistance in chickens is a complex trait, possibly involving the Major Histocompatibility Complex, innate and adaptive immune responses, cadherins and other factors. Two of the QTLs for Campylobacter resistance are co-located with Salmonella resistance loci, indicating that it may be possible to breed simultaneously for enhanced resistance to both zoonoses.

2.7. Further funding

25. Further funding to continue or develop the research can be an indicator of a project's success. The sources of further funding may also demonstrate that researchers are seeking to translate their research into practical application.

26. Overall, the level of further funding obtained within the BBSRC AMR portfolio was good. For example, 53% of AMR projects resulted in further funding, and 493 unique instances of further funding were reported. Funding was received to support research, training, equipment, translation and travel.

27. Further funding was obtained from over 110 different sources. The majority of further funding was obtained from public sector sources (56% of further funding awards). The remainder was from charity/non-profit (22%), private sector (11%), academic/university (9%) and other (3%). The main source of further funding was BBSRC (33% of further funding awards), with other major sources including: Wellcome Trust (7%), MRC (6%), European Commission (4%), EPSRC (4%), Royal Society (3%), UKRI (3%) and Innovate UK (2%). The sources of further funding demonstrate that many grant holders were seeking support to translate their research to deliver wider benefit. However, overall, the panel considered there was scope for grant holders to achieve further outcomes in this area (such as increasing the level of further funding support from medical funders, increasing the level of support from industry/private sector).

28. In total, £167.2m further funding was reported. This included a small number of very high-value further funding awards (>£2.5m), which were often large consortia awards where the grant holder had not provided details on the specific component they had received as further funding. If these awards are excluded, the total value of further funding reported was £99.9m. Of the £99.9m, at least £12m was obtained from non-UK funding sources.

2.8. Staff next destinations, training and skills

29. There was limited data on training and skills development presented as part of the evaluation evidence, and investments in AMR-related postgraduate studentships were not included in the evaluation. One source of evidence that was available to the panel were data on the next destinations of staff employed on AMR projects. These can provide some insight into the contribution of BBSRC AMR investment in building capacity and capability within this research area.

30. Overall, the panel considered the next destination data for BBSRC AMR projects to be positive. For the 140 postdoctoral researchers where data were available, 90% were reported as remaining 'research active' in their next employment. 76% remained in academia, 13% entered the private sector, and the other 11% enter other sectors (such as the public sector, charitable sector, etc.) or their destination was unknown. It was the panel's view that the proportion of postdoctoral researchers pursuing a career in the private sector or within a policy setting was lower than anticipated.

2.9. Factors enabling academic impact

31. As part of the grant holder survey and interviews, researchers were asked about what factors had enabled their research project to deliver academic impact. The three main factors reported as enabling academic impact were international academic collaboration (18% of grant holders), collaboration with other UK academic institutions (17%) and access to further research funding (16%). Other strong factors were access to academic facilities outside of grant holders' institutions (11%), capital equipment funding (9%), and involvement of academic disciplines outside of bioscience (8%).

3.

ECONOMIC AND SOCIETAL IMPACT

3.1. Summary

- Current BBSRC AMR investments are likely to be critical in enabling the UK to realise its 20-year vision for tackling AMR.
- There is clear potential for the high-quality AMR research supported by BBSRC to deliver wider economic and societal impact.
- There was evidence of emerging impact and wider impact arising from BBSRC's AMR portfolio, and this covered the breadth of BBSRC's research priority in AMR.
- Approximately half (46%) of researchers indicated that their project had been successful or very successful in meeting its impact objectives.
- A good proportion (52%) of grant holders indicated that they had made a successful or very successful contribution to at least one strategy objective from the UK National AMR Action Plan.
- Progress in delivering economic and societal impact was demonstrated through a variety of reported research outputs and outcomes, including new intellectual property (8% of grants), spin-outs (4%) and influence on policy and practice (11%).
- On balance, there was scope to improve the delivery of economic and societal impact from BBSRC's AMR portfolio, for example increasing the overall level of engagement with stakeholders, increasing the level of awareness of the wider government strategic drivers in addressing AMR (that is 20-year vision), and improving the level of translation.

The supporting data for this Chapter are provided in Appendix 3.

3.2. Background context

32. Research has an important role in addressing the national and international challenge of AMR. It is critical that BBSRC's AMR research investments contribute to realising the UK's 20-year vision for AMR through the delivery of wider economic and societal impact. Given the nature of BBSRC's AMR research portfolio, such impacts are more likely to arise in the longer-term (such as 10 to 20 years). As AMR was introduced as a responsive mode priority in 2014, it will likely take more time for the impact of associated investments to become fully evident.

33. The panel also noted that there were wider structural issues within the UK research and innovation system that may act as barriers to achieving economic impact, and that these ware outside the control of researchers and BBSRC. For example, at this time within the UK, there are very few companies that are actively commercialising AMR research and there are few major pharmaceutical companies active in this area. The panel noted that the sector is characterised by SMEs and that these companies may face additional barriers to interacting (and co-funding research) with the academic community. It can also be difficult for SMEs to access appropriate finance and incubation space. Since government largely depends on large pharmaceutical companies to provide industry 'pulls' to close gaps in the health-related innovation landscape, the absence of these large companies from the AMR space compounds the difficulty of getting focus for translation. Furthermore, there is a need for novel and effective reimbursement models to tackle market failures in the development and commercialisation of new antimicrobials, as well as regulatory barriers that may inhibit progress.

3.3. Delivery of economic and societal impact

34. There is clear potential for the high-quality AMR research supported by BBSRC to deliver wider economic and societal impact. There was evidence of emerging impact and wider benefit arising from BBSRC AMR research investments. Examples are presented at the end of the chapter and cover the breadth of BBSRC's research priority in AMR (see Chapter 1). However, on balance, the evidence suggested that there was scope to improve the delivery of impact from within the portfolio (for example see Sections 2.7, 3.3 to 3.7, 4.2 to 4.6). There were also opportunities to improve grant holders' knowledge of wider government strategic objectives in addressing the challenge of AMR.

35. In grant holder surveys, 46% of researchers indicated that their project had been successful or very successful in meetings its impact objectives, with a further 21% indicating that it was too soon to know if their impact objectives would be met. This is notably

lower than the proportion of researchers surveyed (79%) who indicated that their project had been successful or very successful in meeting its research objectives. This self-assessment on delivery of impact objectives was supported by the wider evidence on project outputs and outcomes.

36. A good proportion (52%) of grant holders surveyed indicated that they had made a successful or very successful contribution to at least one strategy objective from the UK's National AMR Action Plan. However, the survey responses indicated that many grant holders did not appear to be aware of the priorities within the UK's 20-year vision for tackling AMR or the five-year National Action Plan, nor how their research was contributing to these. The panel considered that this may have limited opportunities to deliver future impact, as if researchers are unaware of these priorities, they may not seek to address these within their research project/proposals.

3.4. Intellectual property and spin-outs

37. The AMR research portfolio had delivered a variety of new intellectual property (that is patent applications). For example, 8% of AMR grants with start dates between 2014 and 2018 had contributed to new intellectual property. In total, 23 instances of intellectual property were reported as arising from the BBSRC's investment in AMR research between 2016 and 2020. Some of the patents had contributed to the future development of spin-out companies (such as Smart Biofilms and Amprologix). Overall, the panel considered this a positive achievement. However, as the evaluation only captured limited evidence on the use and licensing of any intellectual property, it was difficult for the panel to assess any subsequent impact.

38. BBSRC's investments in AMR research also contributed to the establishment of spin-out companies. For example, 4% of AMR grants with start dates between 2014 and 2018 had contributed to the establishment of a spin-out company. In total, 14 spin-outs were reported, twelve of which are still active. The establishment of spin-out companies demonstrated that BBSRC-funded researchers were seeking to translate and commercialise their research outputs, which was positive. However, the panel noted that it was too early to determine whether these spin-out companies would achieve commercial success in developing new products to address the challenges associated with AMR and subsequently deliver wider economic and societal benefit.

3.5. Influence on Policy and Practice

39. The use of research findings to inform policy and practice is an important route to impact for BBSRC AMR research investments and there were positive achievements in this area. 11% of AMR grants with start dates between 2014 and 2018 had contributed to an influence on policy and practice, and in total 70 instances of influence on policy and practice were reported as arising from the portfolio. The majority (63%) of reported influences were described as having a national (UK) reach with a further 13% having a multinational reach. The remainder were local/regional (8%), Europe (7%), Africa (4%), South America (3%), Asia (1%), North America (1%).

UNIVERSITY OF BIRMINGHAM AND TRICLOSAN RESISTANCE

The research provided insight into how biocide exposure can select antibiotic resistance, proved that common mechanisms of resistance are relevant to both biocides and antibiotics and that mutants selected after biocide exposure are fit in animal models. The research also identified significant gaps in the current knowledge base regarding the mechanisms by which bacteria respond to biocides and commonalities with response to antibiotics, as well as a dearth of data on biocide tolerance in clinical and environmental isolates of pathogenic species. Their report gave a series of recommendations including instigation of research programmes to develop surveillance programmes to identify levels of biocide tolerance, develop standards for testing of the propensity of biocides to select for resistance and to monitor biocide production and environmental accumulation levels. The new rules now require demonstration that a product will not select for cross-resistance to antibiotics in in-use conditions.

The research has not only helped to shape EU opinion but also influenced changes to the law governing the use of biocides. The new 'EU biocides regulation (No 528/2012)' became legally binding across the EU from 2013. In the UK alone 652 biocidal products are currently licensed under the previous directive, as detailed on the Health and Safety Executive website of licensed biocides. The new regulations influenced by this work will apply to at least this number of products in a growing market.

40. In addition, an analysis of the 1,550 BBSRC-attributable AMR publications (2016-2020) indicated that 53 (3.4%) had been cited in policy-related documents. This included 99 individual documents from 38 organisations, including the UK Government, World Health Organisation, European Centre for Disease Prevention and Control, Publications Office of the European Union, and Food and Agriculture Organisation of the United Nations.

41. There were some very good individual examples of policy influence within the portfolio. For example, research at the University of Birmingham which showed the common mechanistic links between antibiotic and triclosan (a commonly used biocide) which has impacted on policy at the international level[xx].

3.6. Factors enabling economic and societal impact

42. As part of the grant holder survey and interviews, researchers were asked about what factors had enabled their research project to deliver wider economic and societal impact. The four main factors reported as enabling economic impact were: engagement with industry after the grant was awarded (20% of grant holders); engagement with the university technology transfer office (18%); designing research with industry at the application stage (17%); and engagement with end users and practitioners (15%). The three main factors reported as enabling societal impact were: engagement with policy makers after the grant was awarded (18% of grant holders); engagement with industry after the grant was awarded (18%); and engagement with end users/practitioners (13%). These areas are discussed in more detail below, as well as in Chapter 4.

3.7 The role of collaboration and partnership in facilitating impact

43. Collaborations and partnerships are critical to delivering high-quality research and subsequent economic and societal impact. This includes collaboration with other national and international academics, as well as interactions with industry, policy makers and other stakeholders.

44. Collaboration and partnership with industry plays a significant role in enabling the commercialisation of research and in delivering wider economic impact. There was a variety of evidence that indicated that BBSRC AMR grant holders were collaborating with industry. For example, researchers reported collaborations with more than 50 different companies with a range of sizes (SMEs to FTSE 100 companies) and from a variety of industry sectors. Co-authorship analysis indicated that 3% of publications arising from the BBSRC AMR portfolio had a non-academic co-author, and researchers had obtained £4.7m further funding from the private sector. This was a positive achievement, but the panel considered that there was scope for greater interaction with industry within the portfolio in order to maximise opportunities to deliver future impact.

3.8 The role of BBSRC and other constituent components of UKRI in facilitating the delivery of impact

45. It is clear that facilitating early engagement between academics, industry, policy makers and other stakeholders helps to support the delivery of impact from BBSRC's AMR investment. Working with other constituent components of UKRI to ensure funding opportunities are available to support the translation of BBSRC science is welcomed. There are opportunities to learn lessons from investment mechanisms (both from BBSRC and other funders) that have been effective in fostering engagement between academics and other stakeholders. These are covered in more detail in Chapter 5.

46. Overall, the panel considered that there was scope to improve the delivery of economic and societal impact from BBSRC's investments in AMR research. Although there was evidence of progress in the delivery of wider benefit from AMR research projects, the panel noted that there were also clear opportunities where more could be achieved. For example, increasing the overall level of engagement between academics, industry, policy makers and practitioners, increasing the level of awareness of the wider government strategic drivers in addressing AMR, and improving the level of translation within the portfolio. This is particularly important given the scale of the global challenge of AMR, the consequences of not addressing this challenge, and the strong potential of research to deliver practical solutions to AMR. There are opportunities for closer working across UKRI to maximise the potential to deliver economic and societal benefit from BBSRC investment in AMR research.

3.9 Examples of economic and societal impact arising from BBSRC's investments in AMR research

PHAGE-BASED DIAGNOSTICS

A Fellowship led to the successful engineering of a fluorescent bacteriophage and an understanding of the mechanism by which the bacteriophage is able to clear infection in human cells. This led to a collaboration with DSV Imperial and the formation of Lucidix Biolabs, a University of Warwick spin-out.

While diagnostics are currently complex and take longer than a standard 10 minute GP appointment, the team's phage-based diagnostic could discern bacterial and viral infections in under a minute, allowing prescriptions to take place during GP consultations. However, it is so simple that doctors are not even needed to administer it. Further proof of concept is underway.

DURHAM UNIVERSITY IN PARTNERSHIP WITH PROCTER & GAMBLE

Work performed by Durham University bioscientists and chemists in collaboration with Procter & Gamble's microbiology division (P&G) has altered the formulations of their products for improved antibacterial efficacy. Work with P&G on developing combinations of chelants with improved efficacy aims to reduce quantities of preservatives and additives in products with supplementary benefits for the environment and life-span. Biodegradable chelant alternatives are being evaluated for further benefits. The researcher stated "Industry collaboration with P&G (including a BBSRC DTP PhD student) has been invaluable in generating data on the antibacterial mode of action of chelating agents that has just been submitted for publication."

FARMS-SAFE

The FARMS-SAFE project (Future-proofing Antibacterial resistance Risk Management Surveillance and Stewardship in the Argentinian Farming Environment) provides information to better characterise antibacterial resistance and antibacterial drug usage on livestock farms. It has provided policy insights into better ways to manage and measure antibacterial use as well as to prevent AMR. In providing a Vade Mecum (handbook of medicines) detailing the antibiotics used in the cattle and pig sectors in Argentina, it is anticipated that management of their use will be improved.

"Our work very much informs collaborations and work with a number of industry and UK government partners, various veterinary practices and the general public as well as international partners in Thailand and Argentina. I often use data from our work to inform these partners about the most updated information regarding opportunities for surveillance and a focus on reduction of AMU/AMR on livestock farms, both in the UK and in LMICs."

NOVEL ANTIBACTERIAL TREATMENTS

The grant outputs increased the visibility of a Newcastle University group's to antibacterial drug discovery companies. A project with VenatoRx used assays from the grant to test their new antibacterial compounds. It initiated collaboration with AiCuris, on novel inhibitors of Penicillin-binding proteins, and we have co-supervised a PhD student. Collaboration with Demuris intensified, on screening for novel cell wall inhibitors.

UNDERSTANDING OF AZOLE RESISTANCE EVOLUTION

Better understanding of azole resistance evolution and interaction with Defra (CRD) together with other research partners led to a change of labelling of azole products to control Septoria leaf blotch. Change of fungicide use labels and recommendations to UK cereal growers through FRAG-UK and AHDB have avoided unnecessary use of fungicides and improved their yields. The latest data on fungicide resistance monitoring is provided regularly to FRAG-UK

https://ahdb.org.uk/frag

NATIONAL BIOFILMS INNOVATION CENTRE

The National Biofilm Centre is in part funded by BBSRC.

"A key element of NBIC's (National Biofilm Innovation Centre) impact requires its engagement with industry partners. We are developing a knowledge-exchange platform and have created an integrated and interdisciplinary consortium that now includes >300 companies. NBIC have held over 750 business engagement meetings and 100 public engagement and outreach events. We have awarded 89 Proof of Concept (PoC) and seed projects (£4.7m, including £388k that has supported SMEs). The PoCs include 80 different industry partners across all sectors, leveraging £2.4m in additional industry contributions (cash and in-kind)."

"My research has benefited most significantly from the award of a BBSRC David Phillips Fellowship which allowed me to establish an independent research career, and the BBSRC NBIC award which is enabling and facilitating translation and impact from the basic research base."

AMPROLOGIX

Launched in 2018, Amprologix will develop and commercialise work from an antibiotic discovery programme at Plymouth University. The company has a partnership with Ingenza, and initially developed the technology with UMI3 Ltd at the University of Manchester. The first product from the company is expected to be a cream containing epidermicin, which can rapidly kill harmful bacteria including MRSA (methicillin-resistant *Staphylococcus aureus*), *Streptococcus* and *Enterococcus* at very low doses, even if they are resistant to other antibiotics.

Awarded £1.2m (via the Innovate UK/SBRI fund), the lead compound (epidermicin) NI01 will be progressed through a full pre-clinical ADMET work-up. Amprologix will seek investment to support completion of Phase-I and Phase-II human clinical trials to determine efficacy. Involvement with Ingenza for development of a production system for epidermicin, has been critical (made possible following the grant BB/J021474/1).

SUSTAINABLE CONTROL OF DIGITAL DERMATITIS IN LIVESTOCK

Digital Dermatitis (DD) is a bacterial infection which produces severe foot lesions in infected animals causing substantial suffering and significant economic loss, estimated at £80m/year in the UK. With no vaccines, disease management has substantially relied on large scale inappropriate antibiotic use.

Research at the University of Liverpool into DD has led to a commercial PCR diagnostic test and significant changes in national and international veterinary and livestock industry policies and practice for DD control. The team have developed treatment and prevention protocols that reduce reliance on antibiotics and encourage their responsible use.

Researchers identified significant benefits of vaccinating sheep with a repurposed vaccine (Footvax MSD) for DD control and their advice on its use has been widely taken up by farmers and vets.

THE DYNAMICS OF ANTIBACTERIAL RESISTANCE GENES IN THE PIG AND HUMAN GUT MICROBIOME IN UGANDA

A BBSRC Fellowship has examined whether people in contact with pigs in peri-urban settings are at higher risk of acquiring AMR genes than people in rural settings and found that the risk is associated to the level of antibiotic use for both farmers and their pigs. The specific antibiotics used are detectable as resistance at phenotypic and genotypic level. Using statistical models, they found the use of antibiotics has a direct impact on the microbiomes of farmers and their pigs, both at taxonomic level and the resistome they carry. They observed direct transmission of resistance genes from farmers and pigs to each other.

The research provided a blue-print for One-health AMR surveillance in Uganda. It led to £1.5m from the Fleming Fund, and a further £470k from NIHR, MRC and GECO awards, to support the implementation of National AMR Action Plans in Uganda, Kenya and Malawi.

IMPROVED APPROACH TO MASTITIS CONTROL

Bovine mastitis is an inflammatory disease of the udder and is a major barrier to the sustainability of dairy farming worldwide. Mastitis treatment and control accounts for over 30% of all antibiotic use in dairy cattle. Annual losses exceed £170m in the UK; 38% of the total direct costs of disease.

Streptococcus uberis is the most common pathogen associated with bovine mastitis. It is now known that different strains of *S. uberis* have different transmission and infection characteristics with different disease outcomes. Researchers at the University of Nottingham can differentiate them using mass spectrometry. Their software makes predictions about the behaviour of mastitis pathogens and thereby improves clinical decision-making on-farm. The results are being used by SME industrial partner, Quality Milk Management Services Ltd, to provide a service to dairy farmers for *S. uberis* strain typing.

TACKLING RESISTANCE TO FOOD PRESERVATIVES: HETEROGENEITY IN FUNGAL SPORE POPULATIONS

Results from the University of Nottingham established that key food preservatives selectively target spoilage yeasts when they are growing by respiration rather than by fermentation. As the industry and consumers have been migrating to low-sugar foods and drinks, this is important because our research showed that sugar concentration is a major determinant of whether spoilage yeasts metabolise by respiration or by fermentation. Consequent changes in preservative practice contributed to an overall reduction of approximately 10% in beverage spoilage and an estimated £1.2m savings with a reduced product recall risk over 5 years.

4.

KNOWLEDGE EXCHANGE AND SUPPORTING STAKEHOLDER NEEDS

4.1. Summary

- The overall level of collaboration and partnership within the BBSRC AMR portfolio was good (for example 58% of grant holders reported a new or improved collaboration partnership as a result of their AMR research project).
- There was good evidence that grant holders were co-designing their research proposals with other academics, including with researchers from non-biological disciplines. However, the level of co-design with non-academics was more limited.
- The level of academic collaboration was a strength of the BBSRC AMR portfolio, both nationally and internationally (for example 67% of publication outputs had an international co-author).
- International partnerships have provided significant added value to the BBSRC AMR research portfolio and have enabled the exploration of research questions that would not otherwise be possible.
- Early engagement with industry, policy makers and end users at the outset is likely to make an important contribution to ensuring that research is aligned to addressing stakeholder needs and the delivery of future impact.
- BBSRC AMR research had benefited from collaboration and partnership with industry, policy makers and other stakeholders.
- There are opportunities for a greater level of interaction and connection between BBSRC-funded AMR researchers and stakeholders within the AMR portfolio.

The supporting data for this Chapter are provided in Appendix 4.

4.2. Researchers' motivations for conducting AMR research

47. The grant holder survey examined researchers' motivation for conducting AMR research, asking about the drivers for a specific grant proposal. Researchers identified a wider variety of motivations for conducting their AMR research (see Appendix 4.1) and, in general, these were aligned to wider government priorities for addressing AMR (such as the 20-year vision and the five-year National Action Plan). The top four motivations reported were:
    - Understanding the fundamental microbiology of organisms to understand how resistance is developed or is maintained (34% of grant holders)
    - Development of novel antimicrobials (26%)
    - Improvements to human health (28%)
    - Improvements to animal health (17%)

4.3. Collaboration and partnership

48. Collaboration and partnership are essential for delivering high-quality AMR research and subsequent economic impact. The overall level of collaboration and partnership within the BBSRC AMR portfolio was good. For example, 58% of BBSRC AMR grants with start dates between 2014 and 2018 had contributed to a new or improved collaboration or partnership. In total, 363 instances of new and improved collaborations and partnerships were reported as arising from the AMR portfolio between 2016 and 2020. The level of academic-academic partnership was generally very good, with some strong examples of international academic partnerships (see section 4.4; Appendix 2.7).

49. There were also several examples of effective partnerships between academic researchers and industry, although overall the level of non-academic partnership was more limited (for example see section 3.7; Appendix 4.2). Grant holders' views on the effectiveness of non-academic partnerships in enhancing the delivery of outcomes and impact from their AMR research were varied. Partnerships with industry and end users/practitioners were rated more highly than those with policy makers, charitable organisations and not-for-profit/social enterprises (see Appendix 4.2).

4.4. Co-design of research proposals at the outset

50. There was good evidence that grant holders were co-designing their research proposals with other academics. For example, 97% of grant holders surveyed reported that they had co-designed their research with other bioscience researchers.

There was also evidence of co-design with researchers from non-biological disciplines including clinical/veterinary science (19%), social sciences (5%) and other disciplines (19%), and this was helping to enable multi- and interdisciplinary research within the BBSRC AMR portfolio. A good proportion of grant holders also reported co-design of their research with international academics, including researchers from developed countries (15%) and Low and Middle Income Countries (LMICs) (15%).

51. Co-design of research proposals with non-academics was more limited within the BBSRC AMR portfolio. For example, researchers reported that they had co-designed their research proposal with industry (31%), policy makers (6%), and end user/practitioners (16%).

52. The panel noted that early engagement with industry, policy makers and end users at the outset is likely to make an important contribution to ensuring that the research is aligned to addressing stakeholder needs. Co-design can also help establish effective and trusted partnerships with stakeholders that may help deliver future outcomes and impact. Although the evidence on co-design from grant holder surveys was generally positive, this was not necessarily always supported by other evidence reviewed by the panel (such as data on researcher motivations, the content and co-authorship of publication outputs). On balance, the panel considered that there were opportunities for greater alignment of the AMR research portfolio with government strategic drivers and stakeholder needs, and there are likely to be benefits in facilitating increased early engagement between the BBSRC AMR research community and non-academics.

4.5. International collaboration

53. AMR is a global problem and international collaboration is key to addressing many of the challenges in this area. The level of international collaboration within the BBSRC AMR portfolio was very good, with evidence that BBSRC has fostered effective partnership working between UK researchers and international academics. For example, 67% of publications arising from the BBSRC AMR publication had an international co-author. In total, 99 countries were listed as co-author locations within the publication portfolio (Appendix 2.6). While some researchers had used BBSRC joint investment mechanisms to establish and develop international partnerships, many appeared to have been developed without specific BBSRC funding, which was very encouraging.

54. International collaboration with researchers had enabled BBSRC AMR investments to explore research questions that would not be possible with a UK-only team, and have enhanced our understanding of the mechanisms of AMR emergence and spread. BBSRC/UKRI ODA investment mechanisms such as the Newton Fund and Global Challenges Research Fund (GCRF) have been relatively successful in addressing the challenge of AMR for stakeholders in LMICs. Moreover, such partnerships help reduce duplication of effort, enable multi-scale investigations, and generate baseline data to support national action plans. There were some good examples of engaging with practitioners on the ground in an international setting, which may ultimately deliver wider impact through influence on policy and practice. International partnership working was also increasing the level of multidisciplinary and interdisciplinary research within the portfolio.

4.6. Collaboration with policy makers and other stakeholders

55. There was limited evidence that BBSRC AMR researchers were actively engaging with policy makers, particularly prior to the start of their research project. For example, 6% of researchers surveyed indicated that they had co-designed their research with policy makers at the outset. Nevertheless, there were some positive examples of engagement within the portfolio and researchers reported working with a variety of government departments and other policy makers (such as Animal and Plant Health Agency, Department for Environment Food & Rural Affairs (Defra), Department of Health and Social Care, European Food Safety Authority, Food and Agriculture Organisation of the United Nations, Foreign and Commonwealth Office, Food Standards Agency, Public Health England, United Nations Environment Programme, Veterinary Medicines Directorate, World Health Organisation, World Organisation for Animal Health, and the European Union).

56. In general, researchers surveyed and interviewed indicated that they did not know how to engage with policy makers or how their research outputs might subsequently be used to inform policy. For those researchers who had engaged with policy makers, many indicated that this had been fortuitous rather than planned. Researchers who had established partnerships with policy makers had mixed views on the effectiveness of these partnerships; 53% of these researchers indicated that their partnerships with policy makers were effective or very effective.

57. There is significant expertise within the BBSRC AMR research community that could help inform future policy and practice relating to AMR, and this is demonstrated by the internationally leading nature of research supported within the BBSRC AMR research portfolio (see Chapter 2). The panel noted that there were opportunities for a greater level of interaction and connection between BBSRC-funded AMR researchers and policy makers, which would help facilitate the use of research findings in informing future policy and practice. This could include a greater level of co-design of proposals at the outset, attendance at professional (rather than academic) conferences, membership of professional groups (for example the British Cattle Veterinary Association), and engagement with government departments and organisations that are actively involved in policy making (such as Defra, the Agriculture and Horticulture Development Board (AHDB) and the Responsible Use of Medicines in Agriculture Alliance (RUMA)).

4.7. Benefits arising from non-academic partnerships

58. BBSRC AMR research had benefited from collaboration and partnership with industry, policy makers and other stakeholders. Such partnerships had enabled researchers to access materials, resources, equipment, facilities and expertise that are not readily available within the academic community, as well as access to additional funding. Interaction and two-way knowledge exchange with stakeholders on the ground has also enhanced BBSRC researchers' understanding of the challenges faced by stakeholders and how research might best address these.

5.

BBSRC SUPPORT FOR AMR RESEARCH

5.1. Summary

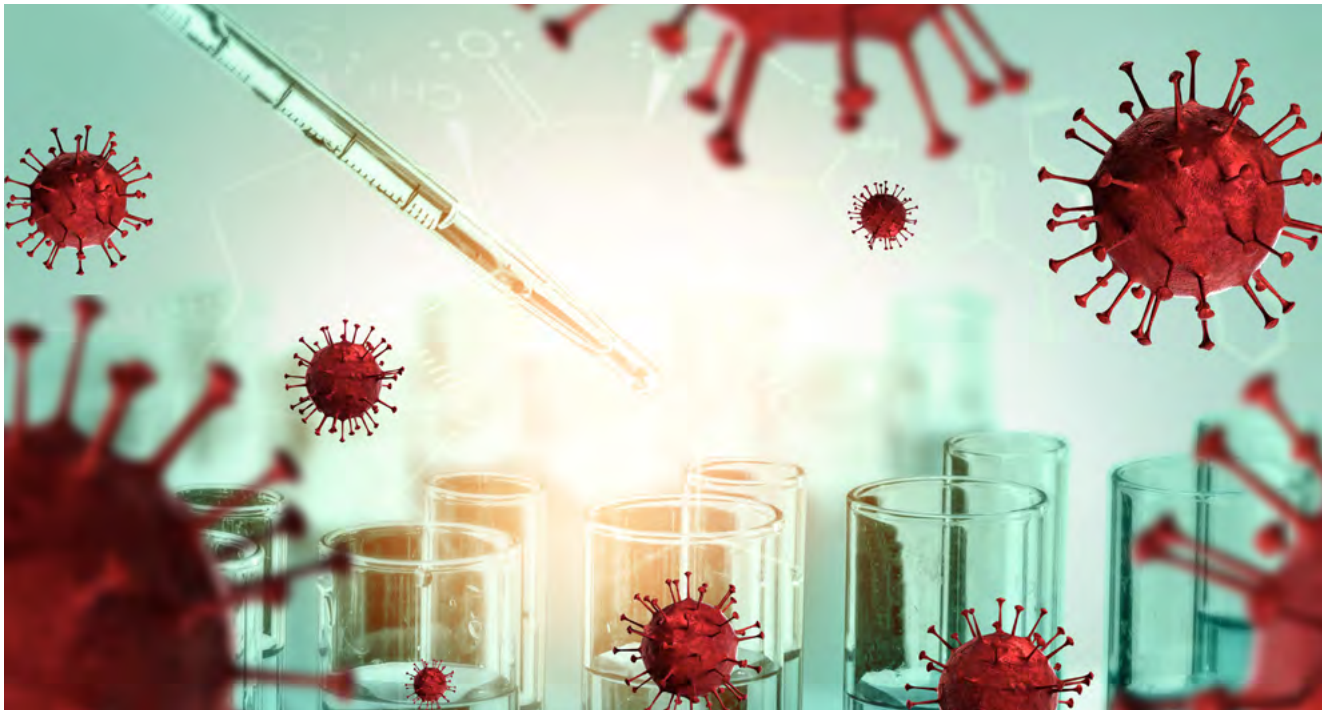
- The balance and coverage of BBSRC's AMR research portfolio was very good, with excellent research supported across BBSRC's remit.
- BBSRC is making a distinctive and appropriate contribution to the wider UK AMR research and innovation landscape.
- There was a good level of multidisciplinary and interdisciplinary research within the BBSRC AMR portfolio, but there are opportunities for BBSRC and other constituent components of UKRI to expand this further.
- BBSRC's overall support for AMR research was effective.
- There are opportunities for BBSRC to strengthen its work with others (including other constituent components of UKRI) to help ensure that there are effective routes for the translation of its AMR research.
- There are opportunities for BBSRC, working with other parts of UKRI, to strengthen the UK AMR research community and build connections between academics and other stakeholders.

The supporting data for this Chapter are provided in Appendix 5.

5.2. Balance and coverage of the portfolio

59. Between 2016 and 2020, BBSRC invested c. £132m in AMR research through a variety of investment mechanisms (that is responsive mode, initiatives, strategic institutes, and fellowships). BBSRC's current annual spend for AMR research is £30m. This spend is supplemented by other investments such as the Tackling AMR cross-Council initiative[xxi] and the Joint Programming Initiative on AMR (JPIAMR)[xxii]. BBSRC's investments demonstrate the Council's positive commitment to supporting AMR research. These figures exclude support for postgraduate training, which was not included as part of the evaluation.

60. The balance and coverage of BBSRC's AMR research portfolio was very good. BBSRC AMR investments are supporting excellent research across BBSRC remit. There was strong evidence that BBSRC had a distinctive and appropriate role in supporting the UK AMR research landscape alongside other UK funders, with a particular focus on fundamental underpinning



biology that would enable subsequent investment by others (for example Appendix 5.3). This was a notable achievement, especially given the breadth of the BBSRC remit which supports research at a variety of different scales, from molecules to landscapes. However, the panel questioned whether the balance between curiosity-driven research and strategic/applied research within the portfolio was currently optimal. This was difficult to assess from the evidence provided, but the panel noted that it is important for BBSRC to ensure an appropriate balance to maximise opportunities for its AMR investment to deliver its intended impact.

61. There was clear commitment from BBSRC to support AMR research aligned to the UK's five-year National Action Plan for AMR and the UK's 20-year vision for tackling AMR. However, the panel noted that there were some potential gaps in the portfolio, particularly with regards to supporting the development pipeline for new antimicrobial agents (for example antibiotics, antivirals, antifungals, and antiprotozoals). The panel considered that the need for new antifungals is especially urgent. Other areas that would benefit from additional investment included the use of antimicrobial agents in the preservation of food and other products, diagnostics to detect emerging antimicrobial resistance in plants and animals, and addressing the changing AMR landscape as a result of climate change. More broadly, the panel noted that there is some scope for a greater 'risk appetite' within the AMR research portfolio to support the development of novel approaches. Addressing the challenge of AMR also requires long-term, sustained investment.

5.3. Support for multidisciplinary and interdisciplinary research

62. Support for multidisciplinary and interdisciplinary research is critical for addressing the complex challenges associated with AMR and for maximising opportunities to address stakeholder needs and deliver wider impact. Furthermore, it can be an important mechanism for driving the wider One Health agenda[xxiii], by bringing together researchers from different disciplines. The panel noted that BBSRC and other constituent components of UKRI have played an important role in recognising the One Health nature of AMR and supporting research in this key area (for example through the AMR cross-Council initiative).

63. The panel noted that there was a good level of multidisciplinary and interdisciplinary research within the BBSRC AMR portfolio. This was demonstrated by the analysis of publication outputs arising from BBSRC's AMR investments (for example details of the research in WoS publication abstracts, data on WoS publication outputs that have been supported by more than one UKRI research council, and coverage of WoS subject categories; see Appendix 2.7, 5.2, 5.3). Analysis of the BBSRC AMR grant portfolio (Appendix 5.3) and data on co-design of research proposals with academics from non-bioscience disciplines (Appendix 4.2) also provide an indication of BBSRC support for multidisciplinary and interdisciplinary research. Given the cross-cutting, multifactorial nature of the AMR problem and the broader 'Tackling infections' challenge as identified in the UKRI Strategy, there is scope for BBSRC and other constituent components of UKRI to expand support for multidisciplinary and interdisciplinary research in this area.

5.4. Effectiveness of BBSRC investment mechanisms

64. BBSRC has supported AMR research through a variety of investment mechanisms (see section 1.2). Grant holder survey responses indicated that, in general, researchers were satisfied with the support and investment mechanisms provided, although many also noted potential areas for improvement. Although the panel did not examine the effectiveness of individual investment mechanisms in detail, BBSRC's overall support for AMR research was effective (that is based on the outcomes and achievements reported).

65. The panel welcomed the inclusion of 'combatting antimicrobial resistance' as a BBSRC responsive mode research priority (introduced in 2014). This helps to signal BBSRC's commitment to this area of research to the community. It was difficult to assess the effectiveness of this approach in influencing the balance and coverage of the AMR portfolio with the data available, although the panel noted that there was scope for greater alignment of AMR research grants to stakeholder needs and wider government strategic drivers for tackling AMR (see also Chapters 3 and 4). The panel noted that there would be value in BBSRC providing additional clarity on this priority area including, for example, BBSRC's expectations for research to address the UK National Action Plan and the delivery of impact. There are also opportunities for BBSRC to do more to communicate the breadth of the AMR agenda and the role of bioscience research in addressing the associated challenges. For example, emphasising that AMR is not limited to human and animal pathogens, but also includes a wide variety of other areas (such as plant disease, food spoilage, and degradation of commercial materials etc.).

66. AMR is a global problem and BBSRC cannot expect to maximise the impact from its research investments by working alone. There are significant structural issues in the AMR sector which limit the ability to progress research into practical application and deliver wider benefit (see section 3.2). There are opportunities for BBSRC to strengthen its approach to working with others to help ensure that there are effective routes for the translation of its AMR research. Working more closely with other parts of UKRI to stimulate progress in this area, particularly with MRC and most especially with Innovate UK, which would also fill a gap in translation of research - would be beneficial.

5.5. Supporting the development of an AMR research community

67. A healthy AMR research community is critical for ensuring the delivery of excellent science and the subsequent delivery of wider benefit and impact. There were extensive national and international collaborations between academic researchers within the BBSRC AMR portfolio (for example section 4.2), which demonstrate the good linkages between academic bioscience researchers within the AMR community. More broadly, however, there was scope to enhance connections between academics and other stakeholders (such as industry, policy makers, end users/practitioners), as well as researchers from other disciplines (for example sections 3.7, 4.5 and 5.3). Grant holders also reported in surveys that they would welcome further support to help them engage with stakeholders.

68. As a major funder of AMR research in the UK, BBSRC has an important role in fostering an AMR research community. The panel considered that there are opportunities for BBSRC to work with other constituent components of UKRI to further strengthen the UK's AMR research community and help ensure that academic researchers have a common understanding of the motivations, needs and communication styles of stakeholders. Bringing together academic researchers from different disciplines as well as academics, industry, policy makers and end users/practitioners is likely to have numerous benefits. For example, it could help encourage a broader variety of partnerships than those currently observed within the BBSRC AMR portfolio.

69. The panel noted that there are existing private sector bodies and AMR networks that could help stimulate engagement and provide direction regarding the AMR problems that need solving. For example, the Beam Alliance[xxiv] is an industrial network of UK and European based SME's providing a single voice in the

AMR space. Globally, the World Health Organisation is an important source of information on real-world AMR issues[xxv]. There is also scope for greater engagement between BBSRC and policy makers to drive forward the AMR agenda. For example, there are opportunities for BBSRC to work with other funders and organisations (such as learned societies) to help highlight the value of AMR research to policy makers including, the All-Party Parliamentary Group on Antibiotics[xxvi].

5.6. Additional reflections

70. The panel reflected on further ways that BBSRC might improve its support for AMR research. In doing so, the panel drew on direct evidence presented as part of the evaluation, as well as their own knowledge and experience of the UK AMR research and innovation landscape.

Training and skills development

71. There was limited evidence presented on training and skills development within the evaluation, and investments in AMR-related postgraduate studentships were not included. The panel noted that investment in effective postgraduate training is critical in ensuring that the next generation of researchers have the appropriate skills to conduct high-quality research that will address current and emerging challenges associated with AMR. Training that supports the development of multidisciplinary skills and the translation of research into wider

impact is very valuable in this context. The panel also commented that CASE studentships are a valuable mechanism for establishing effective partnerships between academic and industry. These can be particularly effective for SMEs, given the relatively low risk and financial input for the industry partner.

Learning from other investment mechanisms

72. There would be value in BBSRC providing more support to enable two-way knowledge exchange between academics and other stakeholders, including industry (see Chapters 3 and 4). Drawing on their own knowledge and experience, the panel noted examples of investment mechanisms that were particularly useful in this regard. The Networks in Industrial Biotechnology and Bioenergy (NIBB)[xxvii] programme is a successful model for promoting engagement between academia and industry, and the Natural products discovery and bioengineering network (NPRONET NIBB)[xxviii] is a useful example covering work within the AMR space. The National Biofilms Innovation Centre[xxix] is also a good model that has promoted engagement with industry. BBSRC's Industrial Partnership Award scheme is valuable, but the specific requirements for industry financial contributions may limit SME participation. BBSRC's Follow-on Fund has also been successful in supporting the translation of research into practical application.

73. In addition to facilitating greater engagement with industry, there are opportunities for BBSRC to consider how its investment mechanisms could better support engagement with policy makers and practitioners (Chapter 4). The panel noted that the cross-funder Zoonoses and Emerging Livestock Systems (ZELS) [xxx] programme facilitated good interactions with international researchers, and had a strong focus on ensuring research was of relevance to informing future policy and practice. More recently the UK Government's PATH-SAFE [xxxi] initiative is bringing together government departments to develop a programme for pathogen surveillance and may offer an effective model for linking policy to basic research.

74. The UKRI's COVID-19 rapid response call may also offer opportunities for future learning. For example, this call included an expectation that the research should deliver wider impact within a defined timeframe. BBSRC could also consider expanding support for short-duration grants, as these are likely to be more appealing to SMEs for establishing new academic-industry partnerships.

Funding barriers that may limit opportunities for translation

75. Industry requires low risk mechanisms of engaging with academia, with short-timescales, low costs and specific objectives. To date, industrial translation of more developed ideas has been limited by a lack of appropriate investment mechanisms across UKRI. For example, the panel noted that it can be difficult for industry to access Innovate UK funding in this area and there are barriers to entry for the AMR sector for specific schemes (such as Innovate UK's Smart Grants do not provide long-term support to enable effective commercialisation of AMR research; the Biomedical Catalyst did not support AMR-specific calls).

76. Within the UK, there is also relatively limited public funding to support early-stage clinical trials for new antimicrobials. There is a need for UKRI to work with other partners such as NIHR to address this issue.

5.7. Conclusions

77. BBSRC has provided effective support for AMR research and has invested in a wide variety of excellent science within its remit. Looking forward, BBSRC should seek to build on its successes and further strengthen its support for AMR research. For example, there are opportunities for BBSRC to foster an AMR research community that has a deeper understanding of the challenges of AMR faced by stakeholders and which can help improve the delivery of impact from within its AMR portfolio. Early engagement between academic researchers and industry, policy makers, and end users/practitioners will be critical to achieving this aim. Moreover, there are opportunities for BBSRC to strengthen partnership working with other funders, including other constituent components of UKRI, to ensure that there is effective support to enable the translation of outputs from BBSRC AMR research into wider benefit. At present, although there are positive examples of emerging impact arising from BBSRC's AMR investments, the level of translation within the portfolio is unlikely to be sufficient to realise the ambition set out in the UK's 20-year vision for tackling AMR. Future strategy will need to reflect on the need to accelerate effective translation and developing the mechanisms to achieve this.

APPENDICES

Appendix 1

1.1 Membership of the Review Panel

Professor Paul Hoskisson	University of Strathclyde (Chair)
Dr Lucy Coyne	RCVS Knowledge
Dr Pete Jackson	Infex Therapeutics Ltd
Professor Eshwar Mahenthiralingam	Cardiff University
Professor Kristen Reyher	University of Bristol – Bristol Veterinary School
Dr Holly Shelton	Pirbright Institute
Professor Jonathan Statham	Professor (Chair in Sustainable Livestock Health & Welfare at Harper and Keele Veterinary School) and Chief Executive of RAFT Solutions Ltd
Professor Mark Woolhouse	Usher Institute, University of Edinburgh

1.2 Methodology

Methodology – the results and evidence in the paper presented to the panel were drawn from the following sources:

- **BBSRC grants database:** relevant data were obtained from the BBSRC grants database.
- **Research outcomes data:** data from 439 BBSRC AMR grants which had active spend between 2010 and 2020 were obtained. The outcomes data were last updated in March 2021. The total value of these awards was £229.7m.
- **Bibliographic and bibliometrics databases:** additional data on publications arising from the BBSRC AMR portfolio were obtained from Web of Science (WoS) and InCites, provided by Clarivate Analytics.
- **Grant holder survey:** 62 grant holders completed the survey between 22 June and 2 August 2021 – a response rate of 55%.
- **Semi-structured interviews:** 10 grant holder interviews were conducted between 24 August and 17 September 2021.

Two distinct approaches are used to analyse the outputs and outcomes data:

- **Outcomes-focused analyses:** Such analyses are based on outcomes that have arisen between 2016 and 2020. The data include outputs from 439 grants with active spend between 2010 and 2021, totalling £229.7m.
- **Grant-focused analyses:** Such analyses are based on 212 AMR grants with start dates between 2014 and 2018 (total value = £114.5m). This approach is intended to provide sufficient time for the grants to realise and report outputs and outcomes, noting that there can be a significant lag time between the research activity and the realisation of outputs.

The word grant and projects are used interchangeably.

1.3 Evaluation Objectives

The aim of the evaluation is to provide an independent assessment of the effectiveness and impact of BBSRC's investment in AMR research. Specifically, the objectives of the evaluation are to:

i. To examine the development and effectiveness of BBSRC's approaches and strategies relevant to supporting AMR research.
ii. To assess the outputs, outcomes and achievements of BBSRC's major investments in AMR research.
iii. To assess the extent to which BBSRC's research in tackling AMR addresses broader national and international stakeholder strategies.
iv. To consider how BBSRC have met the expectations of users, stakeholders and policy makers.
v. To assess the economic and societal impacts of BBSRC-supported AMR research and training.
vi. To examine the level of interaction with industry and other potential users of AMR research.
vii. To examine the balance and coverage of the AMR portfolio.
viii. To examine the extent to which our investments have built capacity and capability in UK AMR research, and contributed to strong research communities.

Appendix 2

2.1 Grant performance data from Researchfish

The two sources of grant performance data are shown in Table 2.1 and 2.2:

- **Table 2.1.** Researchers were asked "How successful has the project been in meeting the objectives set in your original application?" 79% indicated that their project had been successful or very successful in meeting its research objectives. 46% indicated that their project had been successful or very successful in meeting its impact objectives.

- **Table 2.2.** A Researchfish 'Key Findings' PI self-assessment where researchers were asked "Have you met your original objectives?" 70% of grant holders with completed AMR grants reported that their project had met its objectives.

Table 2.1. Project performance data from grant holder surveys

	Proportion of survey respondents (%)				
	Not at all successful	Somewhat successful	Successful	Very successful	Too soon to know
Research objectives (n=57)	0	10	37	42	11
Impact objectives (n=55)	2	31	31	15	21

Table 2.2. Project performance data from Researchfish

	Proportion of grant holders (%)			
	No	Partially	Yes	Too early to say
Completed grants (n=151)[1]	1	22	70	7

[1] Data are for AMR grants with start dates between 2014 and 2018 that were complete at the time of the most recent Researchfish Submission Period (1 February 2021).

For the grants that had not met or partially met their research objectives, the reasons for this included:

- Experimental, methodological or technical issues (77%; 17% of all grants)
- Staffing matters (e.g. skills shortage, recruitment delays, unexpected extended leave or departure of staff) (27%; 6% of all grants)
- The changing landscape of the research programme (24%; 5% of all grants)
- Other resourcing issues (e.g. difficult/delay in securing key equipment) (21%; 5% of all grants)
- Difficulties with collaborative partners (15%; 3% of all grants).

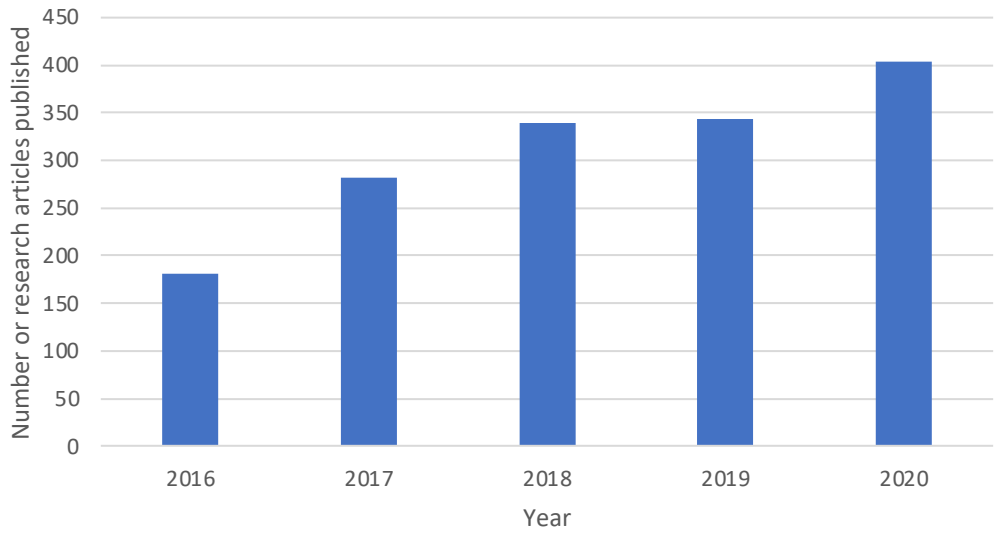
2.2 Published outputs arising from AMR grants

Researchers are able to report a variety of publication types within Researchfish including original research articles, review articles, books, book chapters and conference proceedings.

88% of AMR grants with start dates between 2014 and 2018 resulted in a publication output (of any type).

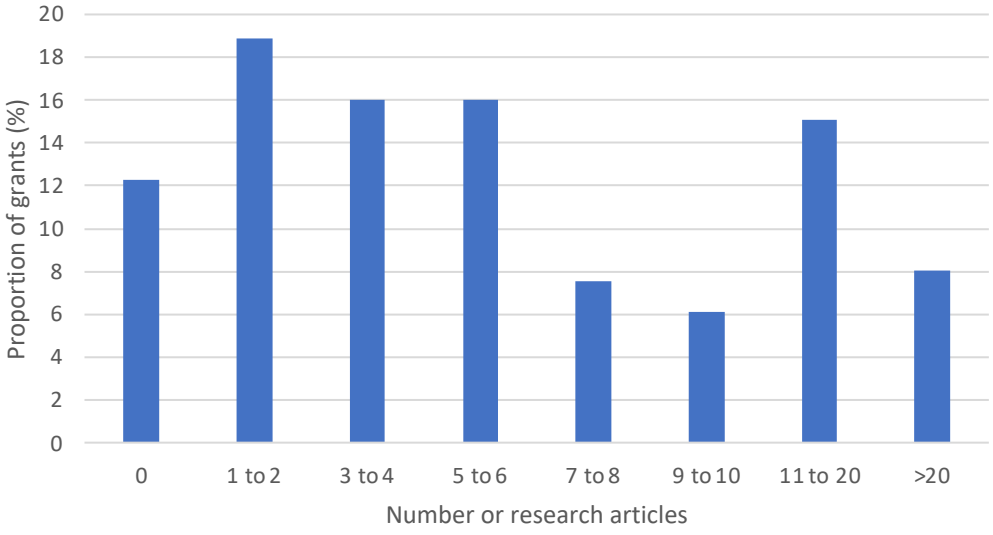
Between 2016 and 2020, a total of 1,550 research articles were reported as arising from the AMR portfolio. Figure 2.1 shows a breakdown on research articles by publication year.

Figure 2.1. BBSRC AMR research articles by publication year



When only research articles are considered, 88% of AMR grants with start dates between 2014 and 2018 had resulted in a publication. The mean number of research articles per grant was 9.4; the median was 5 with a range of 0 to 197. The number of research articles reported for each grant is shown in Figure 2.2.

Figure 2.2. Number of original research articles per grant

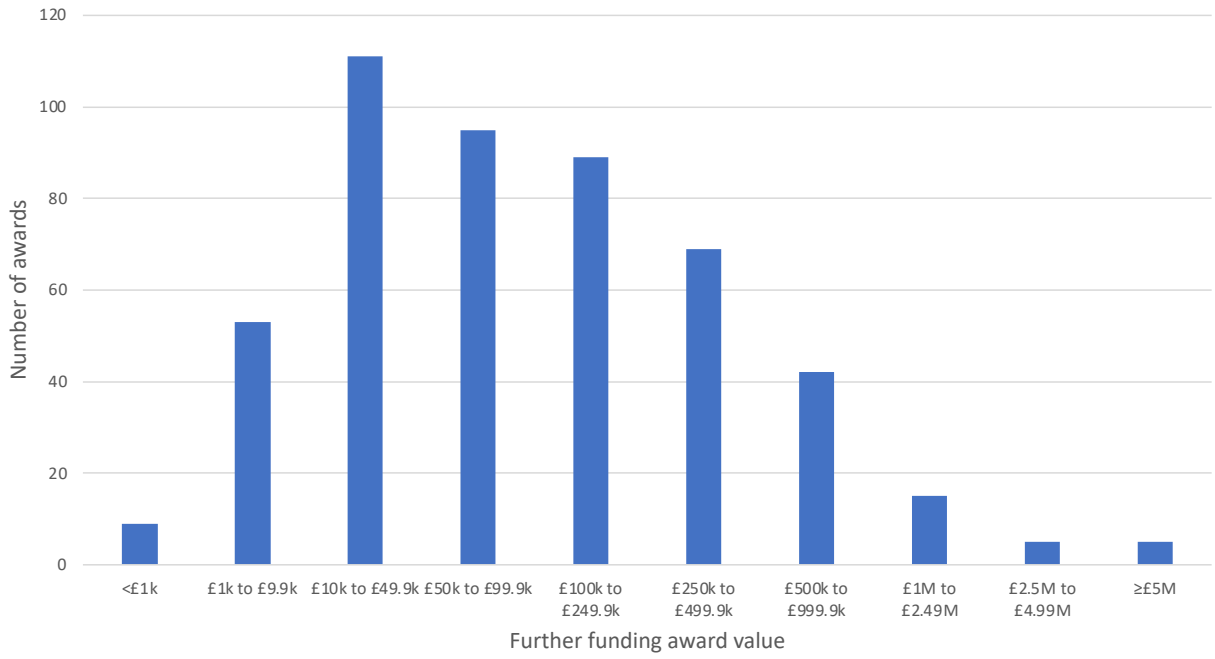


Between 2016 and 2020, a total of 1,550 research articles were reported as arising from the AMR portfolio.

2.3 Distribution of further funding awards

Between 2016 and 2020, 493 instances[1] of further funding were reported as arising from the AMR portfolio. Funding was received for a variety of activities including research, training, equipment, translation and travel. A breakdown of further funding awards by value is shown in Figure 2.3.

Figure 2.3. Distribution of further funding awards by value



The total value of the 493 further funding awards was £167.2m.

Further funding was obtained from over 110 different sources. The main sources of further funding were:

BBSRC	33%	(148 awards)
Wellcome Trust	7%	(30 awards)
MRC	6%	(26 awards)
European Commission/EU	4%	(17 awards)
EPSRC	4%	(16 awards)
Royal Society	3%	(13 awards)
UKRI	3%	(11 awards)
Innovate UK	2%	(10 awards)

All other funding sources were reported less than 10 times.

The breakdown of further funding sources by sector was:

Public Sector	56%	(275 awards)
Charity/Non-profit	22%	(106 awards)
Private Sector	11%	(52 awards)
Academic/University	9%	(45 awards)
Other	3%	(15 awards)

[1] A best attempt was made to deduplicate further funding records, so that each further funding award was only included once within the analysis. This was achieved by examining unique IDs where available (grant references, Researchfish record IDs) as well as other characteristics of the further funding award records (e.g. description, value, start and end dates).

2.4. BBSRC AMR portfolio compared against the UK and international funders

To provide additional context on the BBSRC AMR publication portfolio, equivalent citation data were obtained for AMR publications supported by other UK and international funders.

Table 2.3 shows the cNCI[1] values and best percentile values for the BBSRC AMR portfolio compared with other major UK and international funders.

Table 2.4 shows the cNCI values and best percentile values for the BBSRC AMR portfolio compared against the UK and other G7 countries.

Table 2.3. Comparison of BBSRC AMR publication portfolio bibliometric indicators with other UK and international funders (2016-2020)

Funder	Manual search strategy			'Antibiotic and Antimicrobial' citation topic		
	Number of documents	cNCI	% documents in top 10%	Number of documents	cNCI	% documents in top 10%
UK funders						
BBSRC	251	2.04	29.1	291	2.07	26.5
Wellcome Trust	387	2.06	28.2	684	1.89	24.3
MRC	339	2.53	25.4	726	2.44	25.1
EPSRC	162	1.86	22.8	111	2.18	27.9
NIHR	149	1.95	28.9	456	1.95	25.4
NERC	59	2.09	35.6	51	2.28	39.2
International funders						
NIH (USA)	1791	1.90	23.3	4326	1.64	18.7
European Commission	1444	2.04	24.9	2441	1.89	21.4
NSF (USA)	472	1.60	21.4	372	1.80	21.5
DFG (Germany)	226	1.59	19.0	472	1.54	21.2
ANR (France)	139	1.49	18.0	284	1.59	18.3
ERC	138	2.93	34.8	158	2.23	27.2
BMGF	136	2.66	30.1	234	2.61	24.4

Table 2.4. Comparison of BBSRC AMR publication portfolio bibliometric indicators with the UK and other countries (2016 to 2020)

Funder	Manual search strategy			'Antibiotic and Antimicrobial' citation topic		
	Number of documents	cNCI	% documents in top 10%	Number of documents	cNCI	% documents in top 10%
BBSRC	251	2.04	29.1	291	2.07	26.5
UK	2372	1.93	23.9	7238	1.66	17.4
USA	5604	1.68	19.9	22961	1.28	12.9
Germany	1324	1.83	21.2	4892	1.36	14.0
France	1029	1.82	22.2	4452	1.36	14.2
Japan	654	1.43	13.6	3356	0.79	6.0
Italy	1071	1.73	20.9	3574	1.50	13.6
Canada	992	1.86	20.5	2769	1.52	13.9

[1] Category Normalised Citation Impact (cNCI): calculated by dividing an actual citation count by an expected citation rate for documents with the same document type, year of publication, and subject area. A cNCI value of one represents performance at par with world average, values above one are considered above average, and values below one are considered below average.

2.5. Table 2.5 is a sample of publications for the whole AMR portfolio.

Researchers who responded to the survey were asked to provide one paper to highlight to the panel that best represented their research. Below is a list of those full 49 papers including the Normalised Citation Index and the Number of Citations. Panel members were invited to note the research quality of AMR grants and their publications.

Ref No	NCI Citations Year published	Title and Digital Object Identifier (DOI)
1	NCI – 5.6996 Citations – 25 2019	**Rapid MinION profiling of preterm microbiota and antimicrobial-resistant pathogens** https://doi.org/10.1038/s41564-019-0626-z
2	NCI – 5.4476 Citations – 62 2017	**Klebsiella pneumoniae antibiotic resistance mechanism that subdues host defences and promotes virulence** https://doi.org/10.15252/emmm.201607336
3	NCI – 5.8692 Citations – 83 2017	**SERS Detection of Multiple Antimicrobial-Resistant Pathogens Using Nanosensors** https://doi.org/10.1021/acs.analchem.7b02653
4	NCI – 4.7735 Citations – 42 2019	**Bacterial sensors define intracellular free energies for correct enzyme metalation** https://doi.org/10.1038/s41589-018-0211-4
5	NCI – 4.4185 Citations – 31 2019	**Genome mining identifies cepacin as a plant-protective metabolite of the biopesticidal bacterium Burkholderia ambifaria** https://doi.org/10.1038/s41564-019-0383-z
6	NCI – 3.6947 Citations – 157 2011	**A widespread family of bacterial cell wall assembly proteins** https://10.1038/emboj.2011.358
7	NCI – 3.6368 Citations – 65 2015	**Parallel evolutionary pathways to antibiotic resistance selected by biocide exposure** https://doi.org/10.1093/jac/dkv109
8	NCI – 2.9825 Citations – 12 2019	**Cephalosporin nitric oxide-donor prodrug DEA-C3D disperses biofilms formed by clinical cystic fibrosis isolates of Pseudomonas aeruginosa** https://doi.org/10.1093/jac/dkz378
9	NCI – 3.1729 Citations – 131 2010	**Structural Basis of Gate-DNA Breakage and Resealing by Type II Topoisomerases** https://doi.org/10.1371/journal.pone.0011338
10	NCI – 3.0866 Citations – 94 2010	**A 96-well plate fluorescence assay for assessment of cellular permeability and active efflux in Salmonella enterica serovar Typhimurium and Escherichia coli** https://doi.org/10.1093/jac/dkq169
11	NCI – 2.2438 Citations – 60 2014	**Outer-membrane lipoprotein LpoB spans the periplasm to stimulate the peptidoglycan synthase PBP1B** https://doi.org/10.1073/pnas.1400376111
12	NCI – 4.5653 Citations – 17 2019	**Assessing evolutionary risks of resistance for new antimicrobial therapies** https://doi.org/10.1038/s41559-019-0854-x
13	NCI – 1.6799 Citations – 28 2017	**Thiophene antibacterials that allosterically stabilize DNA-cleavage complexes with DNA gyrase** https://doi.org/10.1073/pnas.1700721114
14	NCI – 1.9315 Citations – 49 2013	**Methylglyoxal resistance in Bacillus subtilis: Contributions of bacillithiol-dependent and independent pathways** https://doi.org/10.1111/mmi.12489
15	NCI – 2.1541 Citations – 6 2009	**Topoisomerase Inhibitors Addressing Fluoroquinolone Resistance in Gram-Negative Bacteria** https://doi.org/10.1021/acs.jmedchem.0c00347
16	NCI – 1.6166 Citations – 29 2016	**Adaptive Remodeling of the Bacterial Proteome by Specific Ribosomal Modification Regulates Pseudomonas Infection and Niche Colonisation** https://doi.org/10.1371/journal.pgen.1005837

Ref No	NCI Citations Year published	Title and Digital Object Identifier (DOI)
17	NCI – 1.7152 Citations – 22 2015	**Antimicrobial use in animals, how to assess the trade offs** https://doi.org/10.1111/zph.12193
18	NCI – 1.6828 Citations – 45 2014	**Structural basis for hijacking siderophore receptors by antimicrobial lasso peptides** https://doi.org/10.1038/nchembio.1499
19	NCI – 1.1399 Citations – 5 2020	**Resistance to change: AMR gene dynamics on a commercial pig farm with high antimicrobial usage** https://doi.org/10.1038/s41598-020-58659-3
20	NCI – 0.9129 Citations – 29 2013	**Hfq binding changes the structure of Escherichia coli small noncoding RNAs OxyS and RprA, which are involved in the riboregulation of rpoS** https://doi.org/10.1261/rna.034595.112
21	NCI – 1.1331 Citations – 5 2019	**Ubiquitin activation is essential for schizont maturation in Plasmodium falciparum blood-stage development** https://doi.org/10.1038/s42004-019-0211-7
22	NCI – 0.4376 Citations – 2 2020	**Flowering Poration—A Synergistic Multi-Mode Antibacterial Mechanism by a Bacteriocin Fold** https://doi.org/10.1016/j.isci.2020.101423
23	NCI – 0.8033 Citations – 14 2016	**Multilocus Sequence Typing of Pathogenic Treponemes Isolated from Cloven-Hoofed Animals and Comparison to Treponemes Isolated from Humans** https://doi.org/10.1128/AEM.00025-16
24	NCI – 0.5418 Citations – 5 2018	**Predictive modelling of a novel anti-adhesion therapy to combat bacterial colonisation of burn wounds** https://doi.org/10.1371/journal.pcbi.1006071
25	NCI – 0.456 Citations – 2 2020	**Modifying bacterial flagellin to evade Nod-like Receptor CARD 4 recognition enhances protective immunity against Salmonell**a https://doi.org/10.1038/s41564-020-00801-y
26	NCI – 0.9119 Citations – 4 2020	**Bacteriophage K1F targets Escherichia coli K1 in cerebral endothelial cells and influences the barrier function** https://doi.org/10.1038/s41598-020-65867-4
27	NCI – 0.2851 Citations – 2 2019	**Characterization of the Streptomyces coelicolor Glycoproteome Reveals Glycoproteins Important for Cell Wall Biogenesis** https://doi.org/10.1128/mBio.01092-19
28	NCI – 0.1758 Citations – 1 2020	**Inhibition of Indole Production Increases the Activity of Quinolone Antibiotics against E. coli Persisters** https://doi.org/10.1038/s41598-020-68693-w
29	NCI – 0.2716 Citations – 4 2017	***Development of a new fluorescent reporter:operator system: location of AraC regulated genes in Escherichia coli K-12.*** https://doi.org/10.1186/s12866-017-1079-2
30	NCI – 0.4686 Citations – 2 2020	**An assessment of the use of Hepatitis B Virus core protein virus-like particles to display heterologous antigens from Neisseria meningitidis** https://doi.org/10.1016/j.vaccine.2020.03.001
31	NCI – 0.4476 Citations – 5 2018	**Discrimination of contagious and environmental strains of Streptococcus uberis in dairy herds by means of mass spectrometry and machine-learning** https://doi.org/10.1038/s41598-018-35867-6
32	NCI – 0.121 Citations – 2 2018	**On the antibacterial activity of azacarboxylate ligands: lowered metal ion affinities for some bis-amide derivatives of EDTA do not necessarily mean reduced activity.** https://doi.org/10.1002/chem.201800026
33	NCI – 0 Citations - 0 2021	**Re-wiring the regulation of the formicamycin biosynthetic gene cluster to enable the development of promising antibacterial compounds**. https://doi.org/10.1016/j.chembiol.2020.12.011
34	NCI – 0.8835 Citations – 3 2020	**An untargeted metabolomics strategy to measure differences in metabolite uptake and excretion by mammalian cell lines.** https://doi.org/10.1007/s11306-020-01725-8

Ref No	NCI Citations Year published	Title and Digital Object Identifier (DOI)
35	NCI – 0.5761 Citations – 3 2019	**Novel Minor Groove Binders Cure Animal African Trypanosomiasis in an in Vivo Mouse Model** https://doi.org/10.1021/acs.jmedchem.8b01847
36	NCI – 0 Citations – 0 2021	**A retrospective analysis of antimicrobial resistance in pathogenic Escherichia coli and Salmonella spp. isolates from poultry in Uganda** https://doi.org/10.1080/23144599.2021.1926056
37	NCI – N/a Citations – N/a 2021	**A cattle graph genome incorporating global breed diversity** https://doi.org/10.1101/2021.06.23.449389
38	NCI – 0.228 Citations – 1 2020	**Regulation of Antimycin Biosynthesis Is Controlled by the ClpXP Protease** https://doi.org/10.1128/mSphere.00144-20
39	NCI – 1.6907 Citations – 18 2018	**Bovine Staphylococcus aureus Superantigens Stimulate the Entire T Cell Repertoire of Cattle** https://doi.org/10.1128/IAI.00505-18
40	NCI – 0.228 Citations – 1 2020	**Phenotypic traits of Burkholderia spp. associated with ecological adaptation and plant-host interaction** https://doi.org/10.1016/j.micres.2020.126451
41	NCI – 0 Citations – 0 2021	**Impact of research on contagious ovine digital dermatitis on the knowledge and practices of UK sheep farmers and veterinarians** https://doi.org/10.1002/vetr.674)
42	NCI – 0.228 Citations – 1 2020	**The Preservative Sorbic Acid Targets Respiration, Explaining the Resistance of Fermentative Spoilage Yeast Species** https://doi.org/10.1128/mSphere.00273-20
43	NCI – 0.8851 Citations – 30 2012	**Ribosome clearance by FusB-type proteins mediates resistance to the antibiotic fusidic acid** https://doi.org/10.1073/pnas.1117275109
44	NCI – 1.6391 Citations – 1 2021	**Cotranscriptional R-loop formation by Mfd involves topological partitioning of DNA** https://doi.org/10.1073/pnas.2019630118
45	NCI – 1.7567 Citations – 49 2011	**Abyssomicin biosynthesis: formation of an unusual polyketide, antibiotic-feeding studies and genetic analysis** htpps://doi.org/10.3389/fmicb.2020.00645
46	NCI – 1.3581 Citations – 1 2021	**Pharma to farmer: field challenges of optimizing trypanocide use in African animal trypanosomiasis, Trends in Parasitology** https://doi.org/10.1016/j.pt.2021.04.007
47	NCI – 0.1865 Citations – 9 2008	**Clerocidin selectively modifies the gyrase-DNA gate to induce irreversible and reversible DNA damage** https://doi.org/10.1093/nar/gkn539
48	NCI – 0.9421 Citations – 4 2020	**Substrate and stereochemical control of peptidoglycan crosslinking by transpeptidation 12.** https://doi.org/10.1021/jacs.9b08822
49	NCI – 0 Citations – 0 2020	**Widespread distribution of resistance to triazole fungicides in Brazilian populations of the wheat blast pathogen in Plant Pathology** https://doi.org/10.1111/ppa.13288

Table 2.6. Most frequently used journals for the AMR research article portfolio

Journal Title	Number of publications
Scientific Reports	94
Nature Communications	68
Frontiers in Microbiology	47
Proceedings of the National Academy of Sciences of the USA	40
PLoS ONE	32
Nucleic Acids Research	31
PLoS Pathogens	31
MBIO	29
Journal of Biological Chemistry	24
Nature Microbiology	22
Molecular Microbiology	21
Microbiology Resource Announcements	20
Microbiology	19
Journal of Antimicrobial Chemotherapy	17
BMC Genomics	15
Frontiers in Genetics	15
eLIFE	14
Angewandte Chemie – International Edition	13
Infection and Immunity	13
Applied and Environmental Microbiology	12
Environmental Microbiology	12

Table 2.7. Distribution of BBSRC AMR research article portfolio by WoS subject category

Web of Science subject category[1]	Proportion of publications (%)
MICROBIOLOGY	29.6
BIOCHEMISTRY & MOLECULAR BIOLOGY	24.0
GENETICS & HEREDITY	6.8
IMMUNOLOGY	5.7
CELL BIOLOGY	5.6
INFECTIOUS DISEASES	5.6
VETERINARY SCIENCES	5.2
BIOTECHNOLOGY & APPLIED MICROBIOLOGY	5.1
VIROLOGY	4.6
CHEMISTRY, MULTIDISCIPLINARY	4.3
BIOLOGY	3.8
PHARMACOLOGY & PHARMACY	3.6
PARASITOLOGY	3.4
PLANT SCIENCES	3.4
BIOCHEMICAL RESEARCH METHODS	3.2
BIOPHYSICS	2.6

[1] Only the top 40 subject categories are shown. In total, the BSBRC AMR publication portfolio covers 97 WoS subject categories.

Table 2.7. Distribution of BBSRC AMR research article portfolio by WoS subject category, cont.

Web of Science subject category[1]	Proportion of publications (%)
CHEMISTRY, MEDICINAL	2.4
CHEMISTRY, PHYSICAL	2.2
ECOLOGY	2.1
MATERIALS SCIENCE, MULTIDISCIPLINARY	1.5
EVOLUTIONARY BIOLOGY	1.4
AGRICULTURE, DAIRY & ANIMAL SCIENCE	1.4
FOOD SCIENCE & TECHNOLOGY	1.4
MATHEMATICAL & COMPUTATIONAL BIOLOGY	1.4
MEDICINE, RESEARCH & EXPERIMENTAL	1.2
NANOSCIENCE & NANOTECHNOLOGY	1.2
CHEMISTRY, ORGANIC	1.0
CHEMISTRY, ANALYTICAL	1.0
PHYSICS, MULTIDISCIPLINARY	1.0
PHYSICS, APPLIED	0.8
TROPICAL MEDICINE	0.8
ENVIRONMENTAL SCIENCES	0.7
POLYMER SCIENCE	0.7
FISHERIES	0.6
MULTIDISCIPLINARY SCIENCES	0.6
NUTRITION & DIETETICS	0.6
PUBLIC, ENVIRONMENTAL & OCCUPATIONAL HEALTH	0.6
CHEMISTRY, APPLIED	0.5
MYCOLOGY	0.5
ORTHOPEDICS	0.5
PHYSICS, ATOMIC, MOLECULAR & CHEMICAL	0.5

[1] Only the top 40 subject categories are shown. In total, the BSBRC AMR publication portfolio covers 97 WoS subject categories.

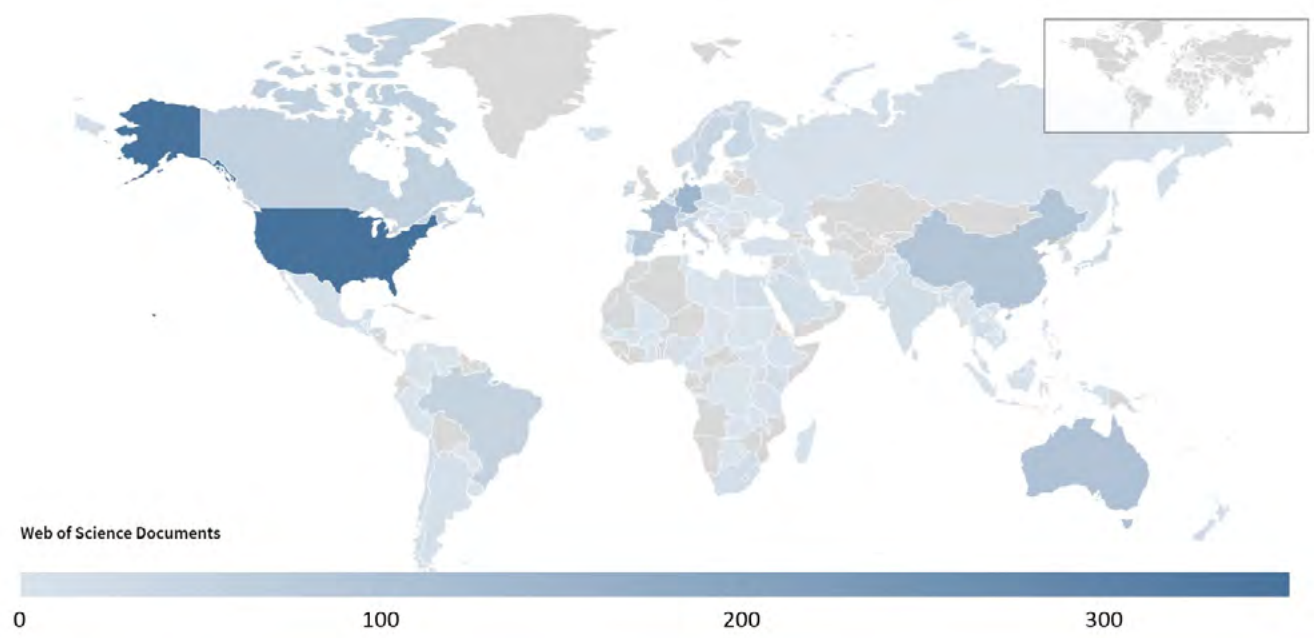
2.6 International and non-academic co-authorship

Information on international co-authorship was obtained from Web of Science. For research articles published between 2016 and 2020, 67% had an international co-author.

In total, 99 countries were listed as co-author locations within the AMR research article portfolio. The top ten countries for international co-authors by number of research articles published were USA, Germany, France, Australia, China, Netherlands, Spain, Canada, Switzerland, Brazil.

Figure 2.4 shows the global distribution of research articles by location of international co-authors.

Figure 2.4. Locations of international co-authors.



Information on non-academic co-authorship was obtained from Web of Science. For research articles published between 2016 and 2020, 3% had a non-academic co-author.

The cNCI analysis for AMR research articles published between 2016 and 2020. 754 research articles (49%) had a cNCI of more than 1. Approximately 10% or research articles were uncited to date, although the majority (8%) were papers published in 2020 and so may not have had sufficient time to be cited.

The best percentile analysis for these publications. 19% of AMR research articles were in the top 10% of all Web of Science publications. 41% of the AMR research articles were in the top 25% of Web of Science publications.

Figure 2.5. Category Normalised Citation Impact for AMR research articles (2016 to 2020)

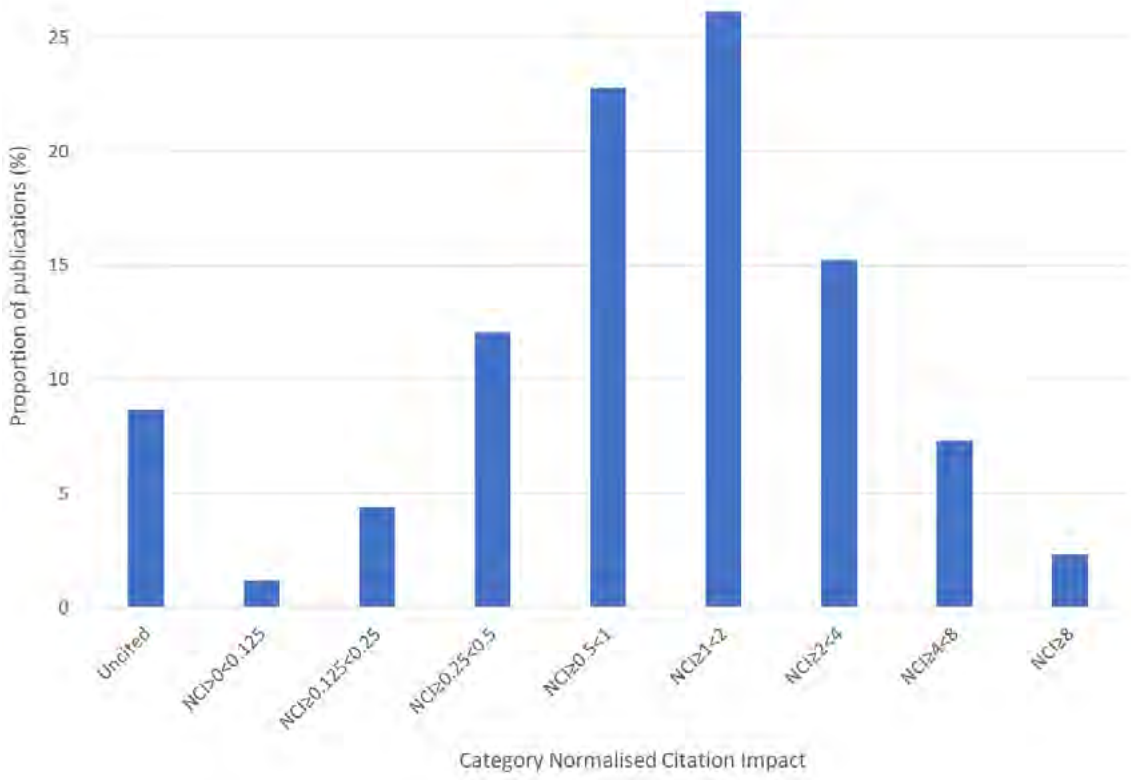
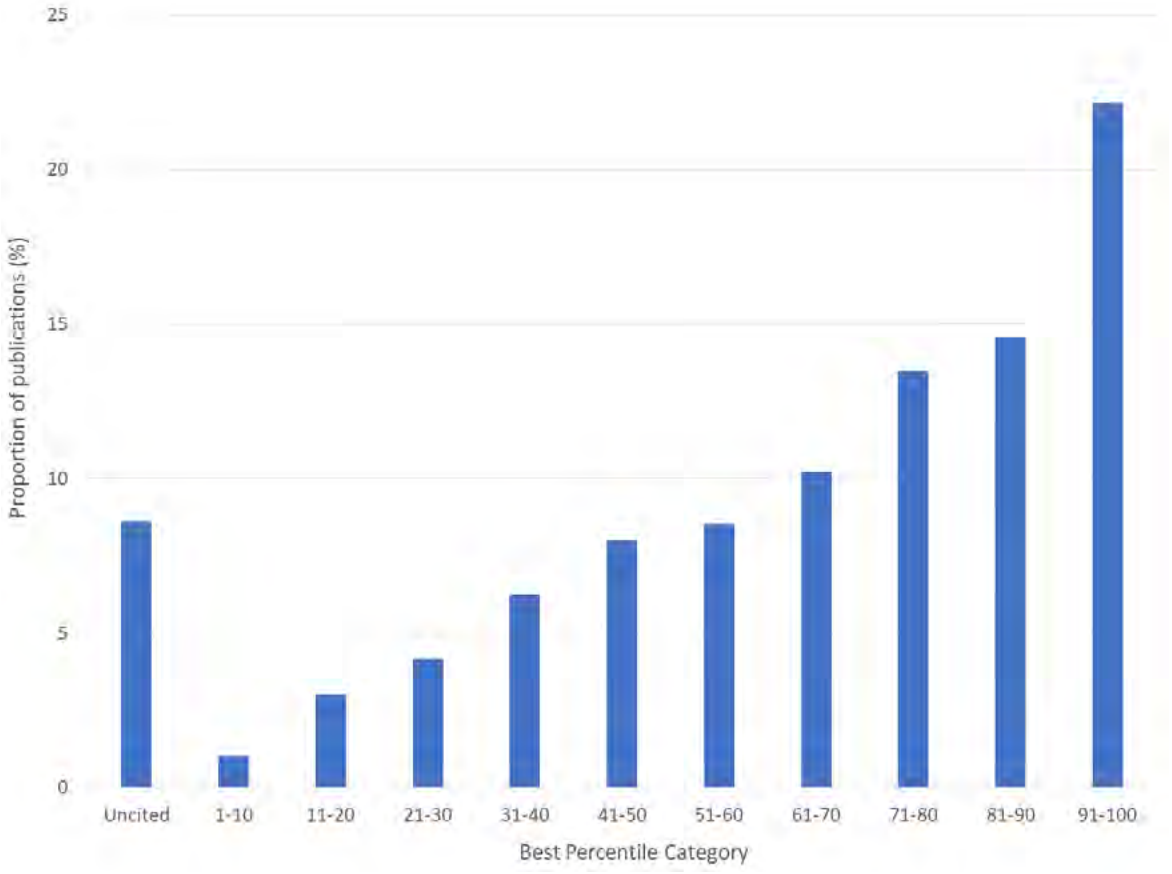


Figure 2.6. Best Percentile Analysis for AMR research articles (2016 to 2020)



Note: The 90 to 100 category represents papers that are in the top 10% of publications etc.

Appendix 3

3.1 Addressing the UK AMR National Action Plan

The grant holder survey asked about the effectiveness of the researchers' own AMR research portfolios in addressing the National AMR Action Plan objectives. The responses are summarised in Table 3.1. 52% of respondents indicated that they had made a successful or very successful contribution to at least one strategy objective.

Table 3.1. Support for National AMR Action Strategy Objectives

Strategy objective	Proportion of grant holders (%)				
	Unsuccessful	Somewhat successful	Successful	Very successful	Don't know
Impact on the growth of resistance, as determined by the number of reported infections and the proportion resistant to specific antimicrobials (n=44)	14	7	14	7	58
Impact on reducing the level of inappropriate antimicrobial use (n= 44)	11	9	11	16	53
Increased international collaboration to minimise the spread of AMR (n=45)	4	15	17	20	44
Adoption of a "One-Health" approach (n=45)	4	16	13	18	49
Any of the above (n=46)`	4	11	15	37	33

3.2 Influence on policy and practice

11% of AMR grants with start dates between 2014 and 2018 had reported an influence on policy or practice.

Between 2016 and 2020, 70 instances of influence on policy and practice were reported as arising from the BBSRC AMR portfolio. Table 3.2 shows the variety of types of influence reported.

The majority (63%) of reported influences on policy and practice were described as having a national reach, with a further 13% having a multinational reach. The remainder were local/regional (8%), Europe (7%), Africa (4%), South America (3%), Asia (1%), North America (1%).

Table 3.2. Types of influence on policy and practice arising from the AMR portfolio

Type of influence	Proportion of all reported influences on policy and practice (%)
Participation in an advisory committee	36
Influenced training of practitioners or researchers	18
Membership of a guideline committee	15
Participation in a national consultation	14
Gave evidence to a government review	10
Implementation circular/rapid advice/letter	4
Citation in other policy documents	3

3.3 Factors that enabled economic and societal impact

As part of the grant holder survey, researchers were asked about what factors had enabled their research project to deliver wider economic and societal impact.

Table 3.3. Factors identified by surveyed grant holders as enabling academic impact

Factors enabling economic and societal impact	Proportion of respondents (%)	
	Economic Impact	Societal impact
Capital equipment funding	0	0
Further research funding	0	5
Involvement of academic disciplines outside of bioscience	3	8
Collaboration with other UK academic institutions	2	0
International academic collaboration	2	3
Academic facilities outside of grant applicants' institutions	5	0
Designing research with industry at the application stage	17	8
Engagement with industry after grant awarded	20	18
Designing research with policy makers at the application stage	0	8
Engagement with policy makers after grant awarded	2	18
Engagement with university technology transfer office	18	0
Engagement with end users/practitioners	15	13
University Policy Engagement Network	3	10
No impact of this type	8	13

3.4 Spin-out companies

Table 3.4. Spin-out companies

Company name	Incorporation date	Current status	Company synopsis	Location	Reported via
Alternox Scientific Ltd	28 February 2020	Active	Proprietary inhibitors of the enzyme alternative oxidase (AOX) to treat multi-drug and multi-compound resistant fungi.	Brighton, UK	Researchfish
Amprologix	19 June 2018	Active	Bactericidal peptide with promising efficacy and toxicity profiles for topical use against WHO priority bacteria.	Plymouth, UK	Researchfish
Antimicrobial Discovery Solutions Ltd	4 June 2015	Active	AMR consulting, partnering, reagents and research services.	Warwick, UK	Researchfish
Cromerix Ltd	21 April 2021	Active	Nitric oxide-releasing prodrug that overcomes biofilm-associated AMR by targeting biofilm dispersal mechanisms.	Loughborough, UK	Survey
Glycoform Ltd		Dissolved			Researchfish
Lucidix Biolabs Ltd	2 June 2017	Active	Rapid and specific identification of bacterial species.	Rickmansworth, UK	Survey
Mycoblade Ltd	13 October 2020	Dissolved			Researchfish
OmicAnalytics Ltd	14 March 2014	Active	Design and implementation of complex analytical studies involving genomics, proteomics and metabolomics.	Leeds, UK	Researchfish
Penrhos Bio Ltd	9 July 2019	Active	Naturally inspired ingredients that control microbial biofilms.	Liverpool, UK	Survey
Persephone Bio	14 July 2014	Active	Plant natural products company.	Norwich, UK	Researchfish
Polypharmakos	16 March 2016	Active	Discovery and development of new antimicrobial agents from natural products.	Cambridge, UK	Researchfish
Procarta Biosystems	1 March 2007	Dissolved	DNA decoy technique to restore antibiotic efficacy against resistant superbugs.	Birmingham, UK	Researchfish
Smart Biofilms	May 2021	Active – shelf company	Smart electroceutical substrates that combine with bandages and surfaces to destroy bacterial biofilms.	Durham, UK	Survey
Tecrea	27 February 2012	Active	Cell small-molecule delivery system .	London, UK	Researchfish

3.5 Analysis of the AMR publication portfolio using the Overton tool

Of the 1,550 BBSRC attributable AMR-publications (2016-2020), 53 (3.4%) have been cited in a policy paper, other official document or similar. As would be expected, the percentage is higher for earlier publication years (i.e. 6% for 2016 publications). A full unedited list of the documents identified by the Overton tool that have cited BBSRC research is shown below.

Table 3.5. Analysis of the AMR publication portfolio using the Overton tool.

Title	Published	Source name	Source country
WHO-convened global study of origins of SARS-CoV-2: China part	1970-01-01	Analysis & Policy Observatory	Australia
The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2015	2016-12-15	European Centre for Disease Prevention and Control	EU
MERS-CoV: clinical decision making support for treatment	2017-08-16	GOV.UK	UK
Antimikrobiell resistens i ville dyr	2017-10-09	Norwegian Scientific Committee for Food and Environment	Norway
ECDC, EFSA and EMA Joint Scientific Opinion on a list of outcome indicators as regards surveillance of antimicrobial resistance and antimicrobial consumption in humans and food-producing animals	2017-10-25	European Centre for Disease Prevention and Control	EU
Salmonella in livestock production in Great Britain, 2016	2017-10-31	GOV.UK	UK
Disease Control Priorities, Third Edition : Volume 9. Improving Health and Reducing Poverty	2017-11-15	World Bank	IGO
The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2016	2017-12-08	European Centre for Disease Prevention and Control	EU
Salmonella Typhi resistant to third-generation cephalosporins	2017-12-22	GOV.UK	UK
Veterinary Antimicrobial Resistance and Sales Surveillance 2016	2018-02-13	GOV.UK	UK
Small ruminant: disease surveillance reports, 2017	2018-03-07	GOV.UK	UK
Weekly Epidemiological Record, 2018, vol. 93, 13 [full issue]	2018-03-29	World Health Organization	IGO
Typhoid vaccines: WHO position paper – March 2018 – Vaccins antityphoïdiques: note de synthèse de l'OMS – mars 2018	2018-03-29	World Health Organization	IGO
WHO expert consultation on rabies: third report	2018-04-18	World Health Organization	IGO
Whole genome sequencing for foodborne disease surveillance: landscape paper	2018-04-30	World Health Organization	IGO
Veteriner Kontrol Merkez Araştirma Enstitüsü Müdürlüğü Etlik - Ankara	2018-06-06	Government of Turkey	Turkey
질병관리본부 – Centres for diseases control	2018-07-05	Korea Centers for Disease Control and Prevention	South Korea
Small ruminant: disease surveillance reports, 2018	2018-09-07	GOV.UK	UK
Pig: disease surveillance reports, 2018	2018-09-07	GOV.UK	UK
Wildlife: disease surveillance reports, 2018	2018-09-07	GOV.UK	UK
UK public health antimicrobial resistance alerts	2018-09-24	GOV.UK	UK
Scientific papers published by APHA	2018-10-01	GOV.UK	UK
AVIS et RAPPORT de l'Anses relatif à l'état des connaissances sur la contamination des poulets de chair par Campylobacter et à l'évaluation de l'impact des interventions à différents stades de la chaîne alimentaire en France	2018-10-12	ANSES	France
Salmonella in livestock production in Great Britain, 2017	2018-10-19	GOV.UK	UK
Effects of Innovation in Agriculture	2018-11-06	Institute of Economic Affairs	UK
The importance of vector abundance and seasonality	2018-11-09	European Centre for Disease Prevention and Control	EU
Reducing UK Antibiotic Use in Animals	2018-11-09	UK Parliament Research Briefings	UK

Title	Published	Source name	Source country
Infektions¬epi¬demio¬logisches Jahr¬buch für 2017 (PDF, 3 MB, Datei ist nicht barrierefrei)	2018-11-26	Robert Koch Institut	Germany
The importance of vector abundance and seasonality : results from an expert consultation.	2018-12-10	Publications Office of the European Union	EU
Genetic frontiers for conservation...technical assessment	2019-01-01	International Union for Conservation of Nature	France
Fronteras genéticas para la conservación...evaluación técnica	2019-01-01	International Union for Conservation of Nature	France
CDFA AUS 2019 Report to the Legislature	2019-01-08	Californian State Agencies	USA
Expert consensus protocol on colistin resistance detection and characterisation for the survey of carbapenem- and/or colistin-resistant Enterobacteriaceae	2019-01-14	European Centre for Disease Prevention and Control	EU
Expert consensus protocol on colistin resistance detection and characterisation for the survey of carbapenem- and/or colistinresistant Enterobacteriaceae.	2019-01-15	Publications Office of the European Union	EU
Genetically Modified Organisms: John Innes Centre (19/R52/02)	2019-01-16	GOV.UK	UK
Genetically Modified Organisms: Rothamsted Research (19/R08/01)	2019-02-08	GOV.UK	UK
Evidence needed for antimicrobial resistance surveillance systems	2019-04-07	World Health Organization	IGO
Eradication therapy for complex in people with cystic fibrosis	2019-04-18	Guidelines in PubMed Central	USA
Infektions¬epi¬demio¬logisches Jahr¬buch für 2018 (PDF, 4 MB, Datei ist nicht barrierefrei)	2019-07-25	Robert Koch Institut	Germany
The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2015.	2019-08-16	Publications Office of the European Union	EU
ECDC/EFSA/EMA second joint report on the integrated analysis of the consumption of antimicrobial agents and occurrence of antimicrobial resistance in bacteria from humans and food-producing animals.	2019-08-16	Publications Office of the European Union	EU
Characterization of Renibacterium salmoninarum and bacterial kidney disease to inform pathogen transfer risk assessments in British Columbia / L.D. Rhodes and C. Mimeault.: Fs70-5/2019-018E-PDF Publications - Canada.ca	2019-08-23	Government of Canada	Canada
Genetically Engineered Animals: From Lab to Factory Farm	2019-09-11	Friends of the Earth US	USA
Knowledge, attitudes and practices of livestock and aquaculture producers regarding antimicrobial use and resistance in Vietnam	2019-09-19	Food and Agriculture Organization of the United Nations	IGO
Chief Medical Officer annual report 2019: partnering for progress	2019-09-20	GOV.UK	UK
Pukkellaks - risiko for biologisk mangfold og akvakultur	2019-09-26	Norwegian Scientific Committee for Food and Environment	Norway
The European Union summary report on trends and sources of zoonoses and zoonotic agents and food-borne outbreaks in the European Union in 2016.	2019-10-03	Publications Office of the European Union	EU
Review of Progress on Antimicrobial Resistance	2019-10-08	Chatham House	UK
Pulling Together to Beat Superbugs Knowledge and Implementation Gaps in Addressing Antimicrobial Resistance	2019-10-16	World Bank	IGO
AVIS et RAPPORT de l'Anses relatif à l'évaluation du risque dans le cadre du dispositif de surveillance de la tuberculose bovine	2019-10-16	ANSES	France
Salmonella in livestock production in Great Britain	2019-10-18	GOV.UK	UK
When Antibiotics Fail	2019-10-20	Council of Canadian Academies	Canada
Archiv Seismo Info 2019	2019-12-12	Government of Switzerland	Switzerland

Title	Published	Source name	Source country
Risk assessment guidelines for infectious diseases transmitted on aircraft (RAGIDA) - Middle East Respiratory Syndrome Coronavirus (MERS-CoV)	2020-01-22	European Centre for Disease Prevention and Control	EU
Agrumi più dolci : il CREA svela il segreto del gene NOEMI	2020-02-13	Government of Italy	Italy
질병관리본부 – Centre for disease control	2020-02-20	Korea Centers for Disease Control and Prevention	South Korea
The European Union Summary Report on Antimicrobial Resistance in zoonotic and indicator bacteria from humans, animals and food in 2017/2018	2020-03-03	European Centre for Disease Prevention and Control	EU
Sustainable food systems through diversification and indigenous vegetables: An analysis of the Arusha area	2020-03-30	European Centre for Development Policy Management	Netherlands
Addressing Antimicrobial Resistance - The Aspen Institute	2020-04-09	Aspen Institute	USA
Governing Value Chains for Inclusive and Sustainable Development	2020-04-29	Institute of Development Studies	UK
Water, sanitation, hygiene (WASH) and wastewater management to prevent infections and reduce the spread of antimicrobial resistance (AMR)	2020-05-31	Food and Agriculture Organization of the United Nations	IGO
Technical brief on water, sanitation, hygiene and wastewater management to prevent infections and reduce the spread of antimicrobial resistance	2020-06-01	World Health Organization	IGO
Coronavirus Disease 2019 and Diabetes: The Epidemic and the Korean Diabetes Association Perspective	2020-06-01	Guidelines in PubMed Central	USA
Valto: ICT-ala, ilmasto ja ympäristö : ICT-alan ilmasto- ja ympäristöstrategiaa valmistelevan työryhmän väliraportti	2020-06-12	Government of Finland	Finland
Exploring the Socioeconomic Importance of Antimicrobial Use in the Small-Scale Pig Sector in Vietnam	2020-06-14	Food and Agriculture Organization of the United Nations	IGO
GLASS method for estimating attributable mortality of antimicrobial resistant bloodstream infections	2020-06-18	World Health Organization	IGO
Preparing for a challenging winter 2020/21	2020-07-13	The Academy of Medical Sciences	UK
NERVTAG: Respiratory viral infections, their interactions with SARS-CoV-2 and implications for a winter resurgence of COVID-19, 16 July 2020	2020-07-31	GOV.UK	UK
UK Seafood Innovation Fund Baseline Review	2020-08-10	GOV.UK	UK
Biodata and biotechnology: Opportunity and challenges for Australia	2020-09-01	Australian Strategic Policy Institute	Australia
SARS-CoV, MERS-CoV and SARS-CoV-2 : what is known about these epidemic coronaviruses	2020-09-08	Government of Cuba	Cuba
The European Union summary report on antimicrobial resistance in zoonotic and indicator bacteria from humans, animals and food in 2017/2018.	2020-09-15	Publications Office of the European Union	EU
Committee On Agriculture	2020-09-17	Food and Agriculture Organization of the United Nations	IGO
GLASS whole-genome sequencing for surveillance of antimicrobial resistance	2020-09-22	World Health Organization	IGO
Valto: The ICT sector, climate and the environment : Interim report of the working group preparing a climate and environmental strategy for the ICT sector in Finland	2020-10-05	Government of Finland	Finland
CRP 2020 Reviews: FISH	2020-11-01	CGIAR	France

Title	Published	Source name	Source country
Техническая записка о значении водоснабжения, санитарии, гигиены и обращения со сточными водами для профилактики инфекций и снижения распространения устойчивости к противомикробным препаратам	2020-11-17	World Health Organization	IGO
AVIS et RAPPORT de l'Anses relatif à « Antibiorésistance et environnement - État et causes possibles de la contamination des milieux en France par les antibiotiques, les bactéries résistantes aux antibiotiques et les supports génétiques de la résistance aux antibiotiques	2020-11-17	ANSES	France
Note d'orientation technique relative à l'eau, l'assainissement et l'hygiène et la gestion des eaux usées pour prévenir les infections et réduire la propagation de la résistance aux antimicrobiens	2020-11-18	World Health Organization	IGO
Veterinary Antimicrobial Resistance and Sales Surveillance 2019	2020-11-18	GOV.UK	UK
Aspects immunologiques et virologiques de l'infection par le SARS-CoV-2	2020-12-01	Haute Autorité de Santé	France
질병관리청 - Centre for disease control	2020-12-10	Korea Centers for Disease Control and Prevention	South Korea
SARS-CoV-2 genomic sequencing for public health goals: interim guidance, 8 January 2021	2021-01-08	World Health Organization	IGO
Genomic sequencing of SARS-CoV-2: a guide to implementation for maximum impact on public health, 8 January 2021	2021-01-08	World Health Organization	IGO
Bruk av lyd til overvåking av norsk natur - en mulighetsstudie - Miljødirektoratet	2021-01-21	Norwegian Environment Agency	Norway
Séquençage génomique du SARS-CoV-2 à des fins de santé publique : orientations provisoires, 8 janvier 2021	2021-01-26	World Health Organization	IGO
Secuenciación del genoma del SARS-CoV-2 con fines de salud pública: orientaciones provisionales, 8 de enero de 2021	2021-01-26	World Health Organization	IGO
Reflection paper on the use of aminopenicillins and their beta-lactamase inhibitor combinations in animals in the European Union: development of resistance and impact on human and animal health - First version (new)	2021-02-28	European Medicines Agency	EU
Royal Society submission to the Defra consultation on the regulation of genetic technologies	2021-03-18	Royal Society	UK
CPE en colistine resistentie	2021-04-06	Rijksinstituut voor Volksgezondheid en Milieu	Netherlands
The European Union Summary Report on Antimicrobial Resistance in zoonotic and indicator bacteria from humans, animals and food in 2018/2019	2021-04-08	European Centre for Disease Prevention and Control	EU
COG-UK: Impact of travel restrictions on importations to England from May to September 2020, 16 March 2021	2021-04-09	GOV.UK	UK
UK SMI ID 1: introduction to the identification of bacteria and fungi from culture	2021-04-22	GOV.UK	UK
Información Científica-técnica	2021-05-07	Government of Spain	Spain
Weekly Epidemiological Record, 2021, vol. 96, 25 [full issue]	2021-06-25	World Health Organization	IGO
Review of global influenza circulation, late 2019 to 2020, and the impact of the COVID-19 pandemic on influenza circulation – WHO European Region, 2005–2019 – Bilan de la circulation mondiale de la grippe entre fin 2019 et fin 2020 et effets de la pandémie de COVID-19 sur la circulation de la grippe	2021-06-25	World Health Organization	IGO
Comité OMS d'experts sur la rage, troisième rapport	2021-07-14	World Health Organization	IGO
Understanding ecosystems and resilience using DNA	2021-08-11	GOV.UK	UK
Pandemic Preparedness: What Role for the Private Sector?	2021-09-13	Manhattan Institute	USA

Appendix 4

4.1 Researchers' motivations for conducting AMR research

The grant holder survey examined researchers' motivation for conducting AMR research. Researchers were asked about a specific grant proposal and asked to identify (i) the drivers they considered when designing the proposal and (ii) whether the research had subsequently delivered against these drivers. The results are shown in Table 4.1.

Table 4.1. Researchers' motivations for conducting AMR research

Research driver	Proportion of respondents (%)	
	Motivation	Delivered
Development of novel antimicrobials	26	15
Development of novel alternatives to antimicrobials	17	12
Understanding the fundamental microbiology of organisms to understand how resistance develops or is maintained	34	24
Development of novel diagnostics to enable rapid identification of antimicrobial-resistant organisms or the presence of resistance genes	9	5
Understanding the selection pressures for antimicrobial resistance and the dynamics of transmission at the genetic, organism or host level	17	9
Maximising translational opportunities, such as by working with an industrial partner or veterinary practitioner	11	9
Finding a solution to a real-world problem (e.g. new antivirals to tackle a specific virus)	18	10
Improvements to human health	28	7
Improvements to animal health	26	7
Improvements to plant health	11	2

4.2 Co-design of research proposals at the outset

As part of the grant holder survey, researchers were asked about whether other academics or non-academics had provided a substantial contribution to the design of their sample grant proposal at the outset:

Table 4.2. Co-design of research proposals with academics

Groups that contributed to co-design of the research proposal	Proportion of respondents (%)
Academic researchers (bioscience)	97
Academic researchers (clinical/veterinary)	19
Academic researchers (social science)	5
Academic researchers (other disciplines)	19
International researchers from developed countries	15
International researchers from Low and Middle Income countries	15

Table 4.3. Co-design of research proposals with non-academics

Groups that contributed to co-design of the research proposal	Proportion of respondents (%)
Industry, including industry associations and levy boards	31
Policy makers (e.g. Defra, RUMA)	6
End users/practitioners (e.g. doctors, patients, vets, farmers)	16
Charity	1
Not-for-profit, social enterprise	3

4.3 Partnerships enhancing delivery of outcomes and impacts from AMR research

The grant holder survey asked about the effectiveness of non-academic partnerships in enhancing the delivery of the outcomes and impacts from researchers' AMR research portfolio. Results are shown in Table 4.4.

Table 4.4. Effectiveness of partnerships with non-academics

Type of non-academic partnership	Proportion of grant holders (%)			
	Not at all effective	Somewhat effective	Effective	Very effective
Industry, including industry associations and levy boards (e.g. AHDB)[1] n=29	3	24	28	45[2]
Policy makers (e.g. RUMA) n=13	8	38	38	16
End users/practitioners (e.g. doctors, patients, vets, farmers) n=20	0	35	30	35
Charity n=7	0	43	57	0
Not-for-profit, social enterprise n=7	14	71	15	0

[1] The survey did not distinguish between businesses, industry associations and levy boards.

[2] The panel noted that although researchers found partnerships with industry very effective this did not necessarily translate into wider societal and economic impacts. The panel noted that input from the levy boards might be less likely to lead to commercial outcomes than with other industry partners.

4.4 Partnerships with government departments and other public bodies

The survey also examined the effectiveness of partnerships with specific government departments and other public bodies in enhancing the delivery of the outcomes and impacts from researchers' AMR research portfolio in Table 4.5.

The number of grant holders who indicated that they had developed a partnership with a government department or other public body was low.

Government department of public body	Proportion of grant holders (%)				
	Not applicable	Not at all effective	Somewhat effective	Effective	Very effective
Animal and Plant Health Agency n=43	38	4	2	4	0
Veterinary Medicines Agency n=43	36	2	7	5	2
Defra n=42	35	5	7	2	2
DHSC n=42	39	5	2	0	0
Foreign Commonwealth and Development Office n=45	39	2	2	7	2
Food Standards Agency n=43	39	2	2	5	0
WHO/FAO/OIE n=45	37	4	2	4	7

Appendix 5

5.1 Length of time conducting AMR research

As part of the grant holder surveys, researchers were asked about (i) whether AMR was the main focus of their research and (ii) for how long they had been conducting research as an independent scientist. The results are shown in Tables 5.1 and 5.2 respectively.

Table 5.1. Focus of grant holders' research programme

	Proportion of respondents (%)
AMR is the main focus of my research programme	59
I conduct AMR research, but it is not the main focus on my research programme	32
I no longer conduct AMR research	9

Table 5.2. Grant holders' previous experience of conducting AMR research

Experience of conducting research as an independent scientist	Proportion of respondents (%)
Up to 5 years	22
Between 6 and 9 years	22
Between 10 and 15 years	32
Between 16 and 19 years	7
20 years or more	17

5.2 Funding sources used by researchers

Researchers were also asked about where they had obtained grant funding to support their AMR research. The results are shown in Table 5.3.

Table 5.3. Investment sources used by researchers to support their AMR research

Investment source	Proportion of respondents (%)
BBSRC[1]	71
Industry	41
Other UKRI	36
Wellcome Trust	22
Newton / Global Challenge Research Fund (GCRF) / or The Global AMR Innovation Funds	21
Cross-council AMR initiative	21
European Union	14
Other funding - Cystic Fibrosis Trust, National institute for Health Research, University funding and charities	22

[1] Excludes the researcher's BBSRC grant that was the subject of the survey.

Publications analysis can also be used to examine the extent to which other UKRI research councils are contributing to publication outputs arising from BBSRC funded AMR research (and vice versa). The analysis may also provide an indication of multidisciplinary working where, for example, the publication output has been supported by more than one UKRI research council.

Funder attribution information was obtained from InCites for the BBSRC AMR publication portfolio. Of the 1,550 research articles published between 2016 and 2020, 1,453 (94%) had funder attribution data available. Table 5.4 shows the number and proportion of these publications that also acknowledged funding from another UKRI research council.

Table 5.4. BBSRC-attributable publications that acknowledged support from another UKRI research council

WoS funder attribution	Number of research articles	Proportion of research articles %
BBSRC	1,257	86%[1]
MRC	339	23%
EPSRC	184	13%
NERC	63	4%
Any other research council	472	32%

[1] This figure is not 100% as not all of the papers reported as attributable to BBSRC in Researchfish have a BBSRC funder acknowledgement in InCites.

Table 5.5. BBSRC AMR research article portfolio by InCites Citation Topics

InCites Citation Topic category[1]	Proportion of research articles (%)
Clinical & Life Sciences	70
Agriculture, Environment & Ecology	18
Chemistry	10
Physics	1
Mathematics	0.6
Social Sciences	0.3
Electrical Engineering, Electronics & Computer Science	0.1
Earth Sciences	0.1

[1] Within the Citation Topic classification system, each publication may only be assigned to a single category.

BBSRC AMR research: science areas

1. This section provides further research grant data analysis and publications analysis.

2. The VOSviewer tool[1] was used to examine the science areas covered by the grants and publications portfolios in more detail. This tool offers text mining functionality that can be used to construct and visualise term maps of key terms from the scientific text.

3. Research grant analysis is shown in Figures 5.3.1- 5.3.3. Trends in AMR expenditure are shown in Figure 5.3.1. A research topic co-occurrence network provides an overview of the coverage of the grant portfolio (see Figure 5.3.2). The titles and technical abstracts of the 439 AMR research grants with spend between 2016 and 2020 were analysed using VOSviewer to examine the science areas covered by the AMR portfolio in more detail (Figure 5.3.3).

4. Publications analysis follows in Figures 5.3.4-5.3.8. The titles and abstracts of the 1,550 AMR research articles published between 2016 and 2020 were analysed using VOSviewer.Figure 5.3.4 shows a term map of the BBSRC AMR publications.

5. Further information on the science areas covered by the AMR publication portfolio was obtained using the Web of Science subject categories. Each publication mapped to one or more subject categories, based on the journal it is published in (i.e. this is not an article-specific classification). Table 2.5 shows the breakdown of the 1,550 AMR research articles published between 2016 and 2020 by WoS subject category. A co-occurrence network visualisation of WoS assigned classifications is also shown in Figure 5.3.5.

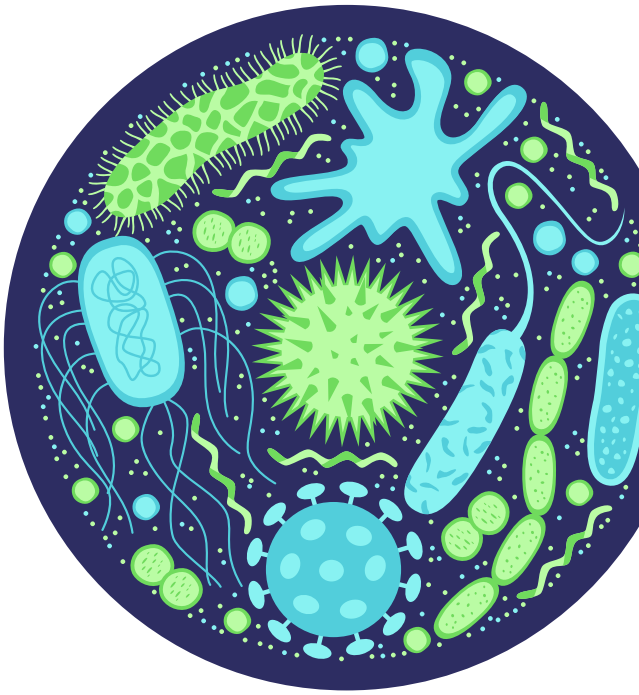
6. To provide additional context on the contribution of BBSRC AMR research to the wider UK research and innovation landscape, a portfolio of UK AMR publications was identified using a key word search in Web of Science. Research articles published between 2016 and 2020 were examined.

7. 2,381 publications with a UK-based author were identified. This is likely to be an underestimate of the overall size of the UK AMR publication portfolio, but provides a sufficient sample to conduct the analysis. The dataset included 241 BBSRC-attributable publications.

8. Figures 5.3.6 shows the VOSviewer term map of the UK AMR publication portfolio and Figure 5.3.7 shows a term map of the UK AMR publication portfolio with an overlay of BBSRC terms frequently occurring.

9. The VOSviewer term map of the whole UK AMR publication portfolio is presented. There are visualisations showing the same term map, with a map overlay identifying the contribution of a selected group of funders (see figure 5.3.8):
   - BBSRC
   - Medical Research Council
   - Wellcome Trust
   - European Commission
   - NIHR

10. The analysis suggests that BSBRC is making a distinctive contribution to the UK AMR research landscape.



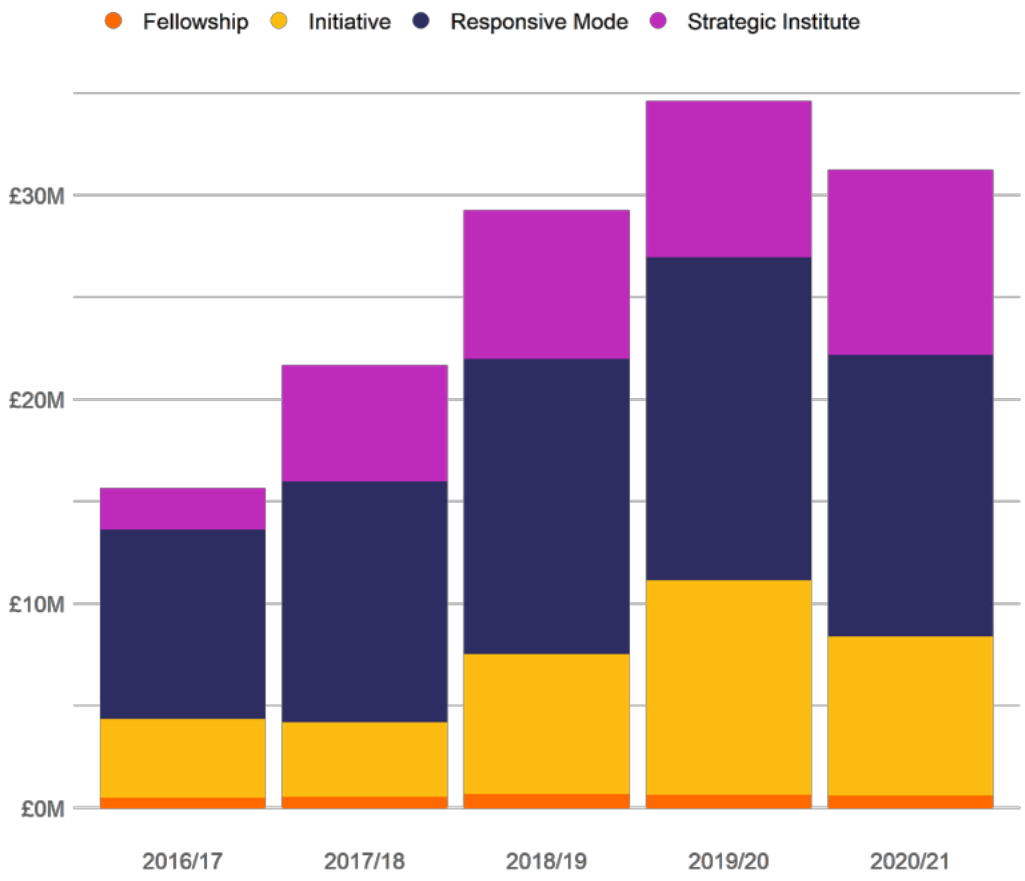
1. www.vosviewer.com/

5.3 BBSRC AMR publication portfolio analysis

The BBSRC Antimicrobial Resistance (AMR) portfolio encompasses:

- Research focused on combatting resistance to antimicrobial agents or the development of mitigation strategies.
- The study of AMR in microbes associated with animal, plant and soils systems plus relevant understanding of how such resistance could lead to the transfer of AMR to human pathogens or human commensal bacteria.
- Research focused on a single or multiple pathogens, either in isolation or as part of a complex microbial community (including microbiomes).
- Research aiming to understand the fundamental microbiology of the development and maintenance of resistance and/or the mode of action of antimicrobials.
- Investigation of the selection pressures for antimicrobial resistance and the dynamics of transmission at the genetic, organism and host level.
- Research underpinning the development of novel antimicrobials and alternatives to antimicrobials
- Development of novel diagnostics to enable rapid identification of antimicrobial-resistant organism or the presence of resistance genes.

Figure 5.3.1. BBSRC expenditure in AMR 2016-2020



Funding Mechanism	2016/17	2017/18	2018/19	2019/20	2020/21
Fellowship	0.5M	0.6M	0.7M	0.7M	0.6M
Initiative	3.9M	3.6M	6.8M	10.5M	7.8M
Responsive Mode	9.2M	11.8M	14.5M	15.8M	13.8M
Strategic Institute	2M	5.6M	7.2M	7.6M	9M
Total	**15.6M**	**21.6M**	**29.2M**	**34.6M**	**31.2M**

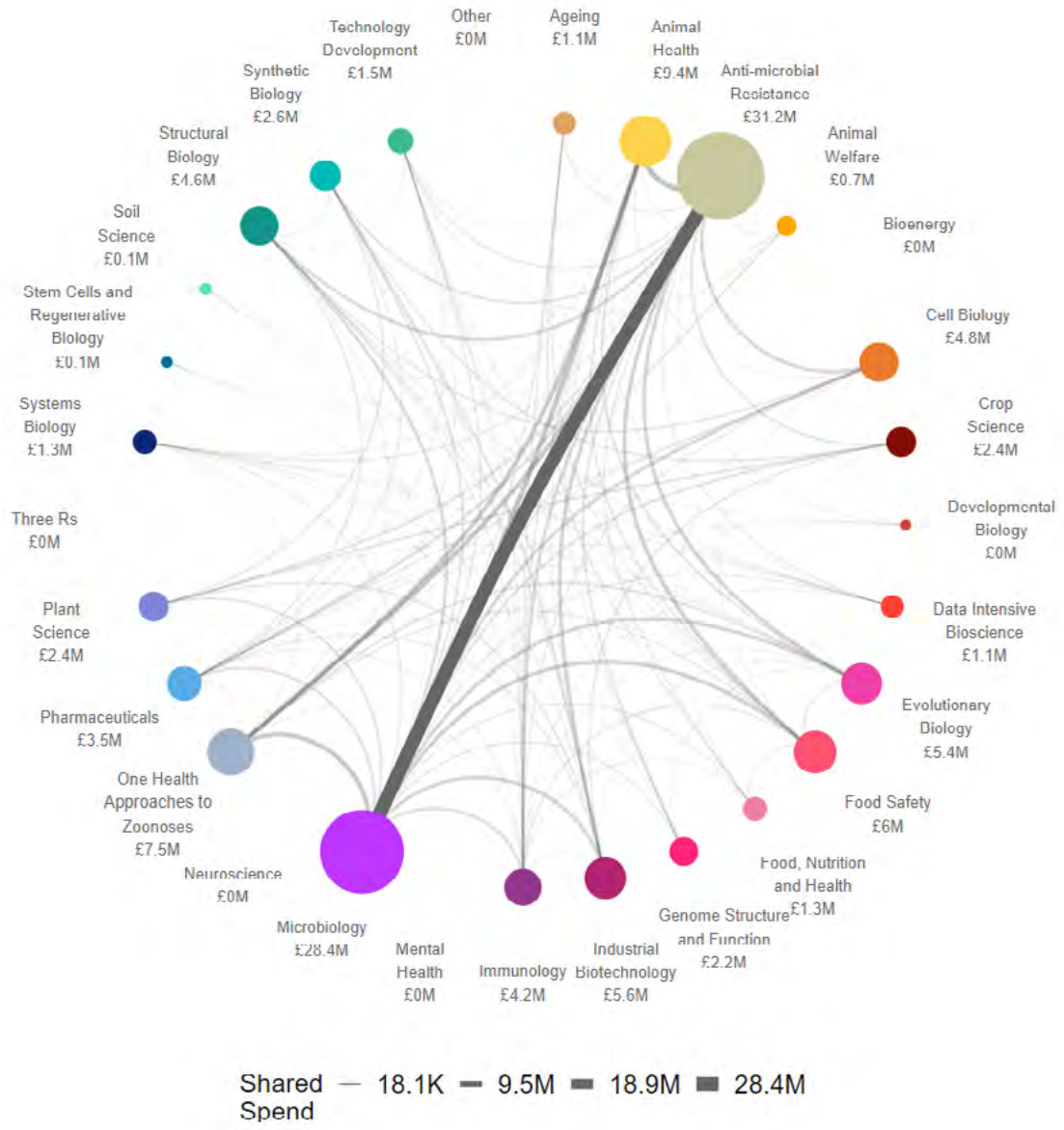
5.3 BBSRC AMR publication portfolio analysis

A research topic co-occurrence network for BBSRC AMR awards with expenditure in the 2020/21 financial year.

Awards are classified against the BBSRC research topic taxonomy.

Nodes show the total expenditure for each research topic. Edges (links between nodes) show the expenditure of awards classified in both topics.

Figure 5.3.2. Research topic co-occurrence network of BBSRC AMR research portfolio (20/21 expenditure)



5.3 BBSRC AMR publication portfolio analysis

Term map of the BBSRC AMR portfolio from project descriptions (Title, Technical Summary, Objectives and Confidential Descriptions).

Term maps provide a visual representation of a collection of texts.

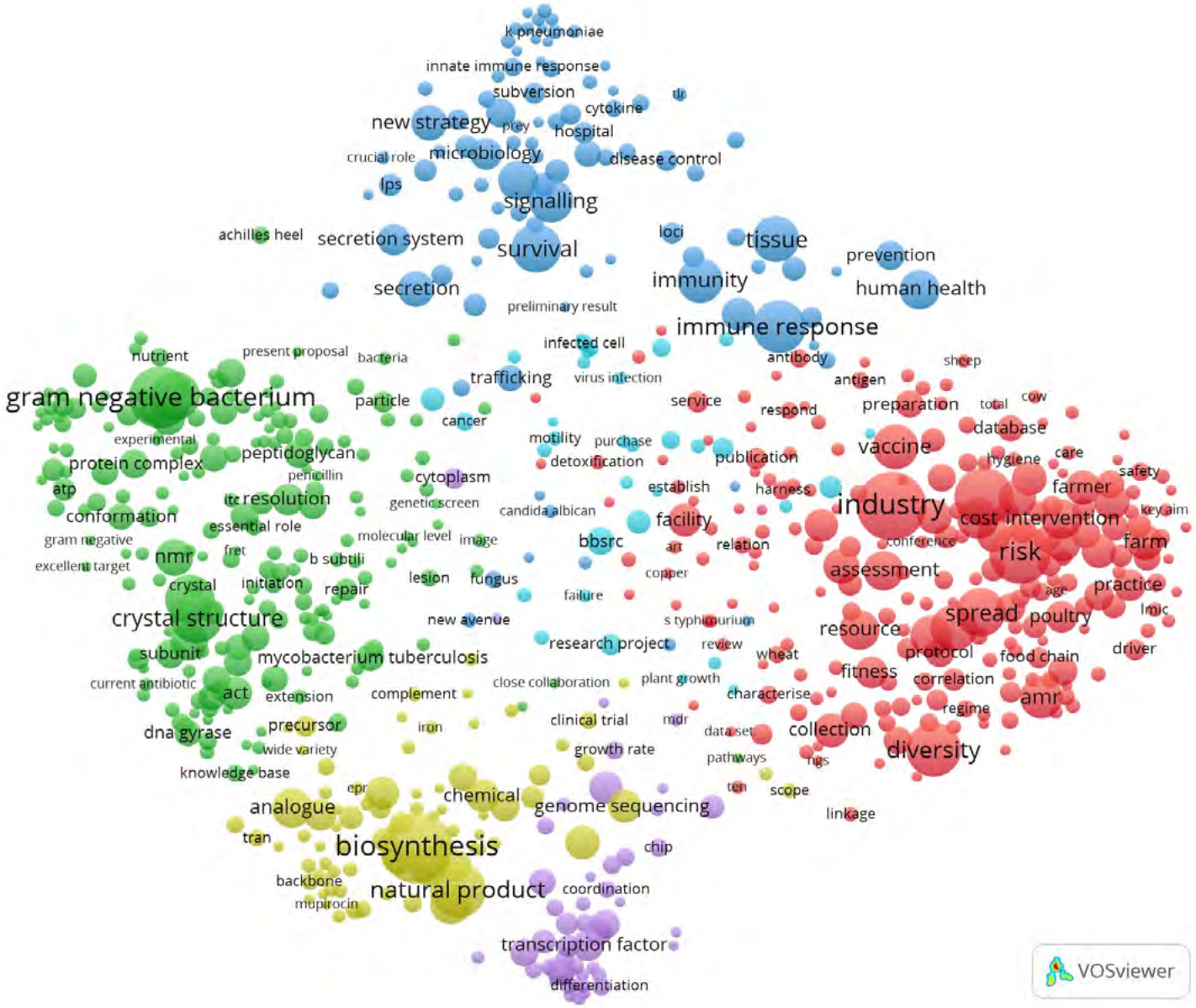
Terms extracted from the text are represented by bubbles. The size of a bubble indicates the number of awards in which the term occurs.

The proximity of two terms (approximately) indicates their relatedness. In general, the smaller the distance between two terms the more frequently the terms co-occur.

Term co-occurrences allow clusters of related terms to be identified, these are shown in different colours.

The horizontal and vertical axes have no special meaning.

Figure 5.3.3. Term map of BBSRC AMR research portfolio



5.3 BBSRC AMR publication portfolio analysis

Term maps provide a visual representation of a collection of texts.

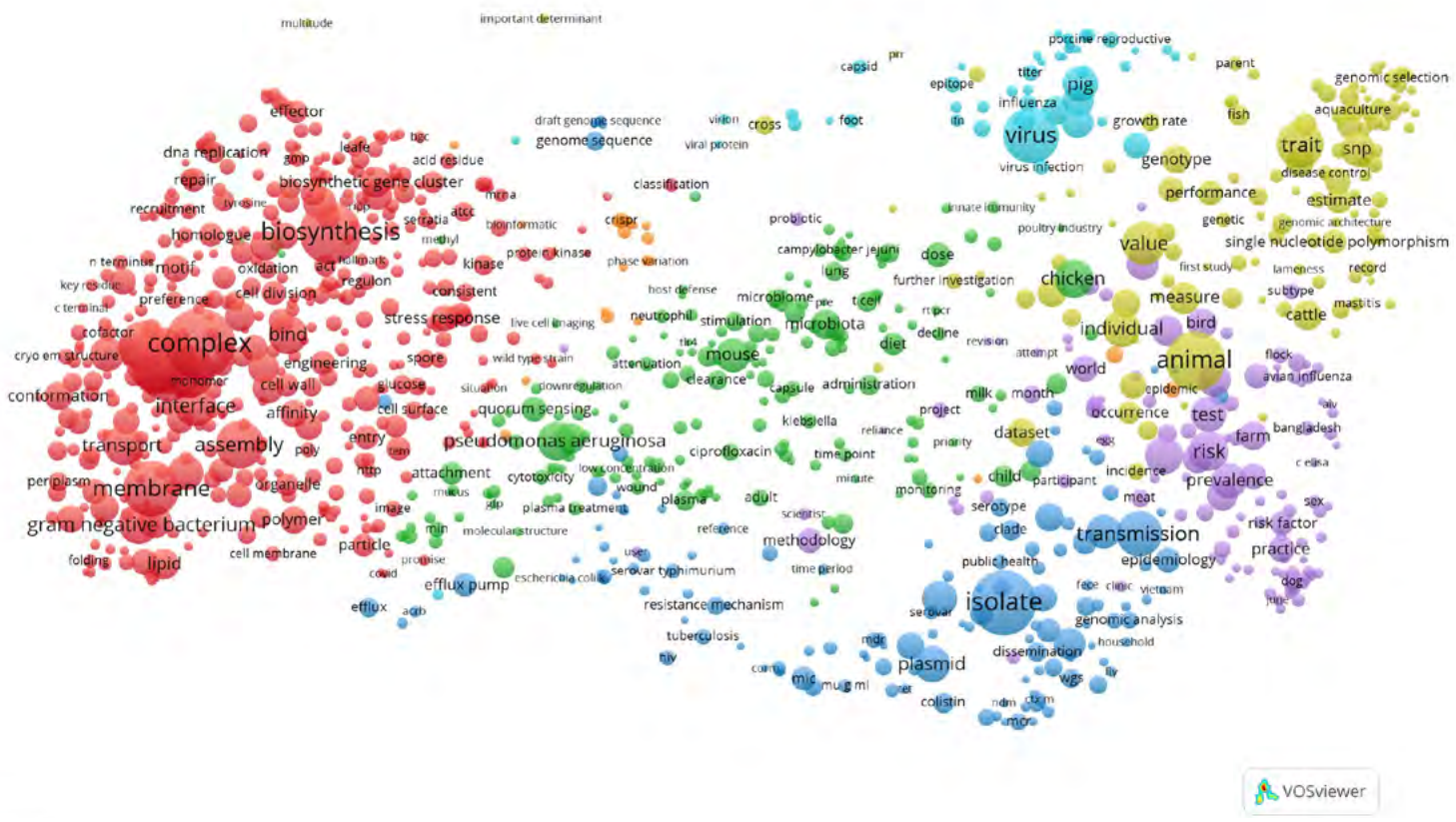
Terms extracted from publication title and abstracts are represented by bubbles. The size of a bubble indicates the number of publications in which the term occurs.

The proximity of two terms (approximately) indicates their relatedness. In general, the smaller the distance between two terms the more frequently the terms co-occur.

Term co-occurrences allow clusters of related terms to be identified, these are shown in different colours.

The horizontal and vertical axes have no special meaning.

Figure 5.3.4. Term map of BBSRC AMR publication portfolio 2016-2020



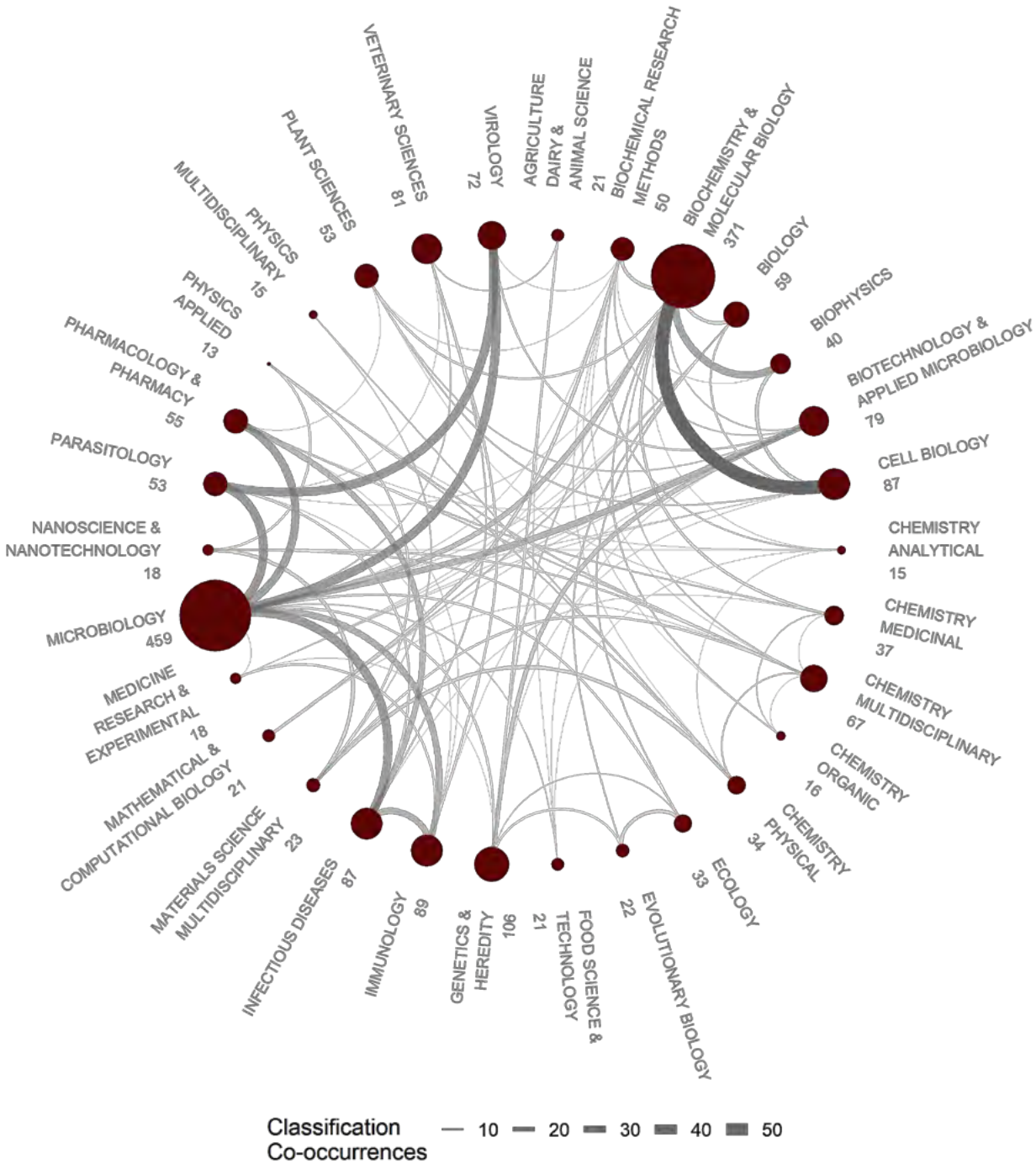
5.3 BBSRC AMR publication portfolio analysis

A co-occurrence network showing the relationship between Web of Science assigned classifications to BBSRC AMR publications.

The Top 30 classifications are shown.

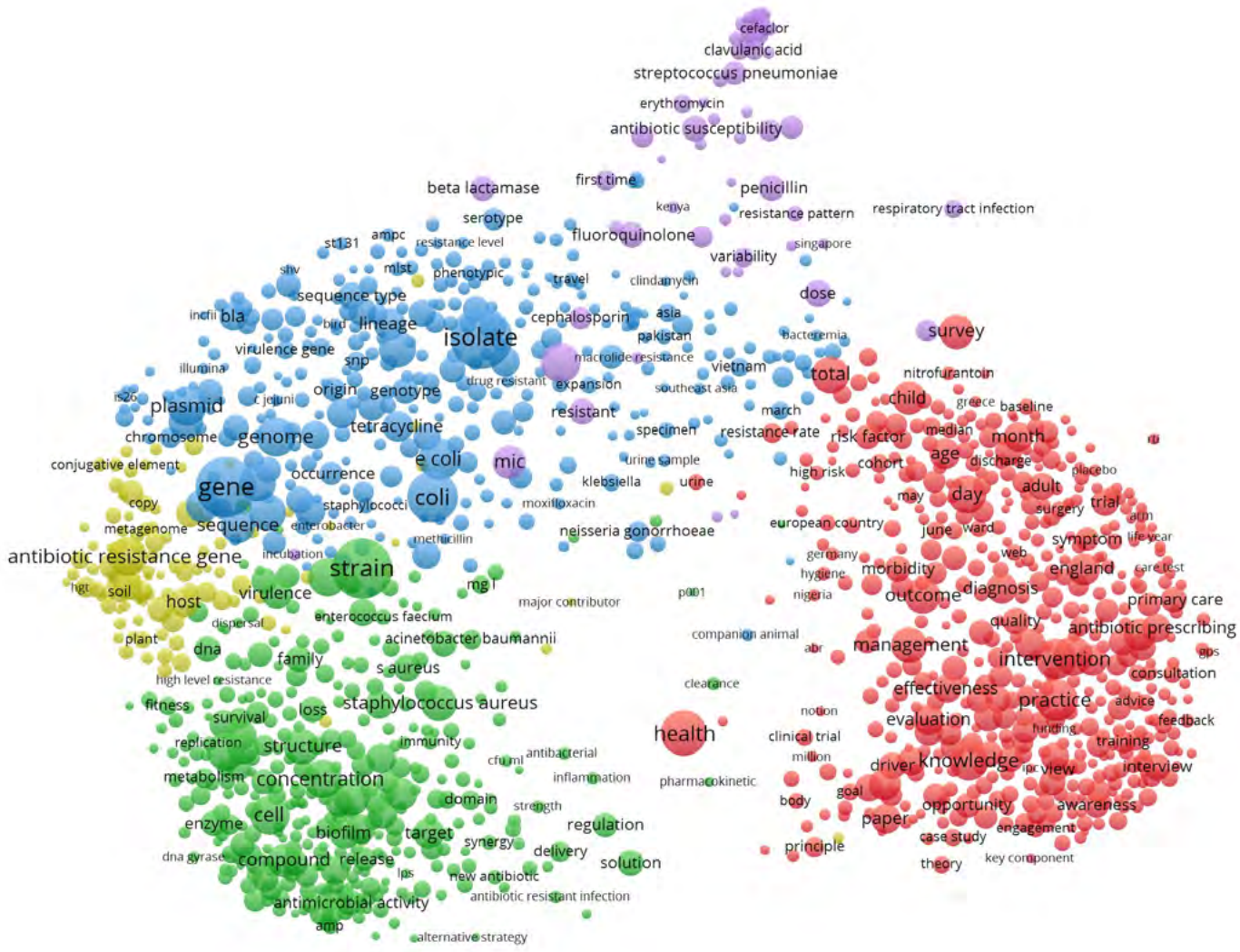
Note: these classifications are assigned at the level of the journal not the individual research article.

Figure 5.3.5. Topic co-occurrence network of BBSRC AMR publications



5.3 BBSRC AMR publication portfolio analysis

Figure 5.3.6. Term map UK AMR publication portfolio



5.3 BBSRC AMR publication portfolio analysis

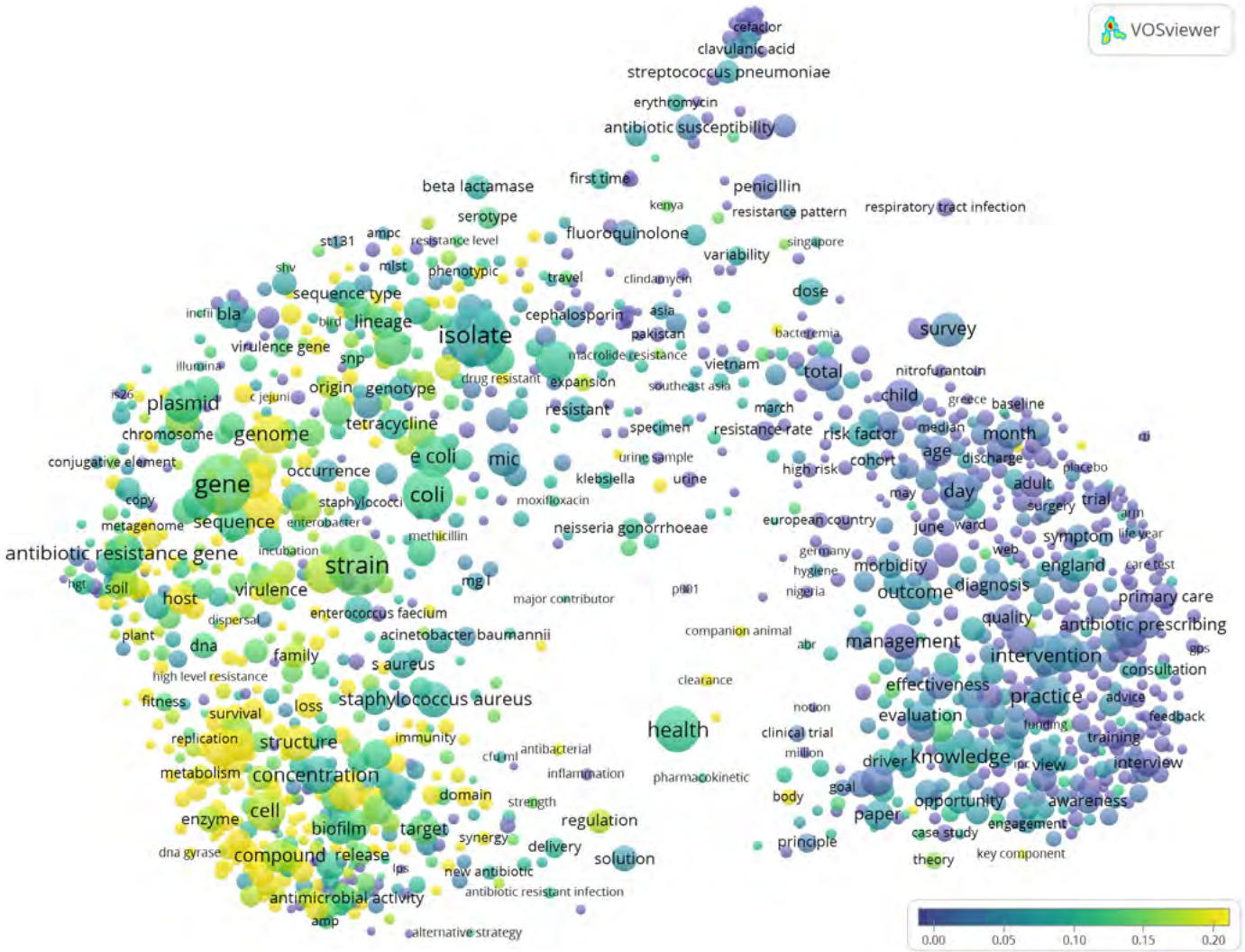
A Term Map Overlay visualises the topics of focus for a group of texts within a collection.

Terms frequently occurring in BBSRC supported publications are coloured in yellow and green, terms infrequently occurring are coloured blue and purple.

The colour scale describes the number of publications attributed to BBSRC which contain a given term as a proportion of the total number of documents in which a term occurs.

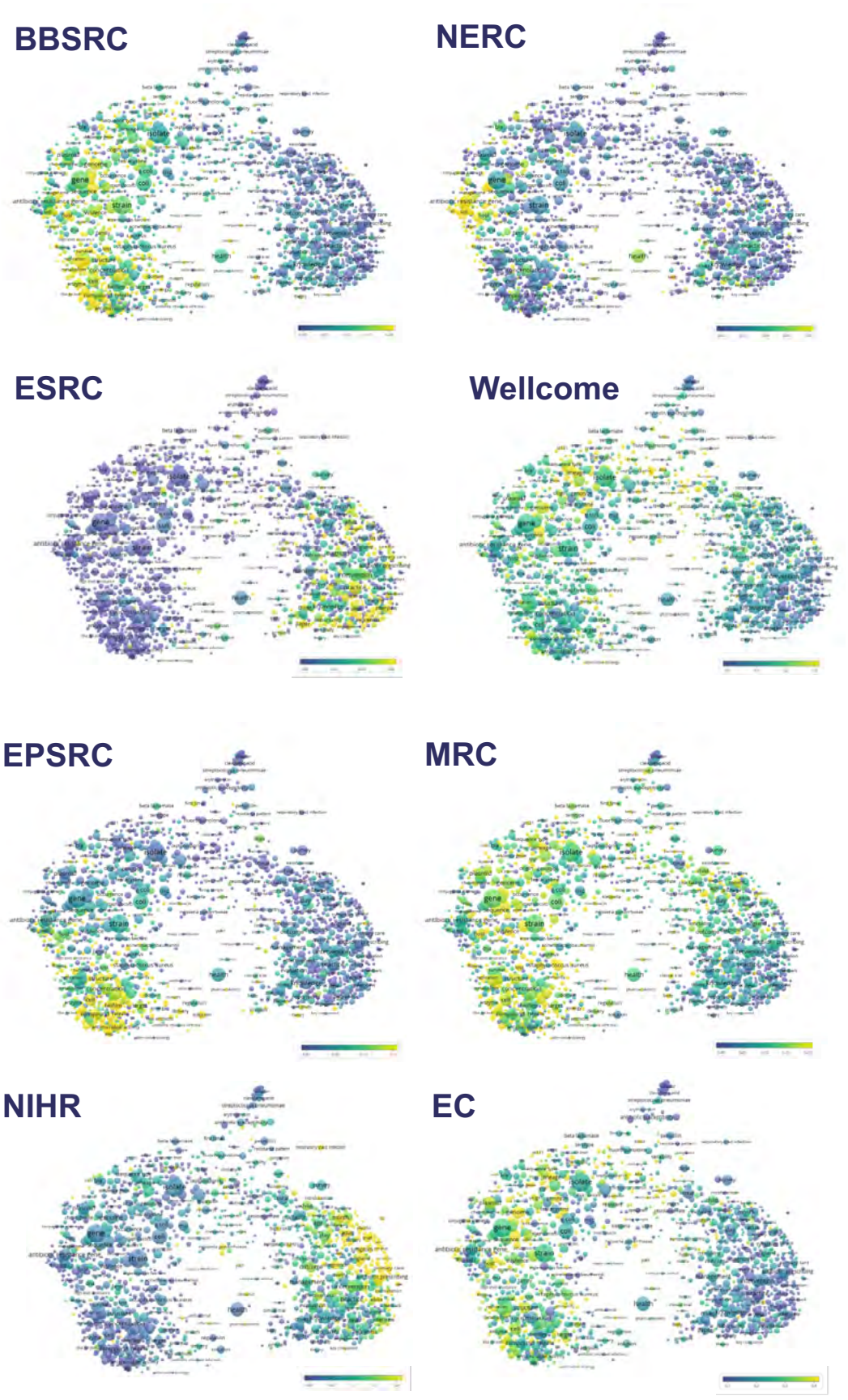
These overlays can be used to compare the research supported by different funders; as shown on the subsequent page.

Figure 5.3.7. Term map UK AMR publication portfolio: overlay BBSRC



5.3 BBSRC AMR publication portfolio analysis

Figure 5.3.8. Term map UK AMR publication portfolio: overlays by funder



Appendix 6

Effectiveness and impact of BBSRC's investments in antimicrobial resistance

6.1 ABOUT YOU

All personal data provided to UK Research and Innovation via this survey will be processed in accordance with current UK data protection legislation and the EU General Data Protection Regulations 2016/679 (GDPR) where appropriate. Further details can be found in the guidance notes and on the UK Research and Innovation Privacy Notice www.ukri.org/privacy-notice

1. Please confirm your details are correct:

Name:

Organisation:

If not, please enter correct details here

2. Are you currently active in AMR research?

Please consider AMR research funded by BBSRC and other organisations

◯ Yes – AMR is the main focus of my research programme

◯ Yes – I conduct AMR research, but it is not the main focus of my research

◯ No – I am no longer conduct AMR research

If yes, how long have you been conducting AMR research as an independent scientist?

Please only consider your time as an independent scientist (i.e. do not include your time as a PhD student or postdoctoral researcher)

◯ 0-5 years ◯ 6-9 years ◯ 10-15 years ◯ 16-19 years ◯ 20+ years

3. Where have you gained grant funding to support your AMR research?

Please select all that apply

◯ Cross-council AMR initiative

◯ Newton / GCRF/ The Global AMR Innovation Fund

◯ Other BBSRC

◯ Other UKRI

◯ Wellcome Trust

◯ EU grants

◯ Industry

Other – please specify

6.2 YOUR RESEARCH PROPOSAL

In the following section we are interested in how you approached your BBSRC research proposal.

4. Which of the following drivers were your motivation when designing your research proposal, and which of these options did your research proposal deliver against?

Please select all that apply

	Motivation	Delivered
Development of novel antimicrobials	◯	◯
Development of novel alternatives to antimicrobials	◯	◯
Understanding the fundamental microbiology of organisms to understand how resistance develops or is maintained	◯	◯
Development of novel diagnostics to enable rapid identification of antimicrobial-resistant organisms or the presence of resistance genes	◯	◯
Understanding the selection pressures for antimicrobial resistance and the dynamics of transmission at the genetic, organism or host level	◯	◯
Maximising translational opportunities, such as by working with an industrial partner or veterinary practitioner	◯	◯
Finding a solution to a real-world problem (e.g. new antivirals to tackle a specific virus)	◯	◯
To contribute to Government policy	◯	◯
Improvements to human health	◯	◯
Improvements to animal health	◯	◯
Improvements to plant health	◯	◯

Other – please specify

5. Please indicate whether any of the following groups provided a substantial contribution to the design of the research grant at the outset?

Please select all that apply

Academic

- ◯ Academic researchers (bioscience)
- ◯ Academic researchers (clinical/veterinary)
- ◯ Academic researchers (social science)
- ◯ Academic researchers (other disciplines)
- ◯ International researchers from developed countries
- ◯ International researchers from Low and Middle Income countries*

** Low and Middle Income Countries are countries eligible for Official Development Assistance and are listed at:* www.oecd.org/dac/financing-sustainable-development/development-finance-standards/DAC-List-of-ODA-Recipients-for-reporting-2020-flows.pdf

Other – please specify

Non-academic

Please tick all that apply

- ◯ Industry, including industry associations and levy boards e.g. AHDB
- ◯ Policy makers e.g. Defra, RUMA
- ◯ End users/practitioners e.g. doctors, patients, vets, farmers,
- ◯ Charity
- ◯ Not-for-profit, social enterprise

Other – please specify

6.3 YOUR RESEARCH GRANT

In the following section we are interested in what your BBSRC research grant delivered.

6. How successful has the project been in meeting the objectives you set out in your original application?

	Too soon to know	Not at all successful	Somewhat successful	Successful	Very successful
Research objectives	◯	◯	◯	◯	◯
Impact objectives (benefits)	◯	◯	◯	◯	◯

7. Were there any outcomes arising from this project that were unanticipated at the outset?

◯ Yes ◯ No

If yes, what were the unanticipated outcomes and please explain their significance

8. As part of the evaluation we will be highlighting your achievements to an independent review panel.

Please provide examples of success for specific outputs, outcomes or impacts related to this BBSRC grant and explain their significance.

Please give one example per box of up to 150 words each and include hyperlinks where possible.

Academic: e.g. publication (please provide the DOI / WoS / PubMed I/d):

Economic: e.g. a new technology or Innovation/commercialisation technology transfer:

Societal: e.g. contribution to public policy:

9. What has enabled this research project to deliver tangible academic, economic and societal impact?

	Academic	Economic	Societal
No impact of this type	◯	◯	◯
Capital equipment funding	◯	◯	◯
Further research funding	◯	◯	◯
Involvement of academic disciplines outside bioscience	◯	◯	◯
Collaboration with other UK academic institutions	◯	◯	◯
International academic collaboration	◯	◯	◯
Academic facilities outside of grant applicants' institutions	◯	◯	◯
Designing research with industry at the application stage	◯	◯	◯
Engagement with industry after grant awarded	◯	◯	◯
Designing research with policy makers at the application stage	◯	◯	◯
Engagement with policy makers after grant awarded	◯	◯	◯
Engagement with university technology transfer office	◯	◯	◯
Engagement with end users/practitioners	◯	◯	◯
University Policy Engagement Network	◯	◯	◯

Other – please specify

10.What were the barriers to delivering economic and societal impact from your AMR research grant, and what if any lessons learned are there?

6.4 YOUR AMR RESEARCH PORTFOLIO

In the following section we are interested in delivery related to your broader AMR research portfolio i.e. this can be outside the scope of the specific grant mentioned in the previous section, but funded through BBSRC only.

11. What are your best examples of impacts delivered by your BBSRC AMR-related portfolio?

Please give one example per box of no more than 150 words each and include hyperlinks where appropriate.

Economic:

Societal:

12. If you have collaborated with researchers in another country / countries during your AMR research what has been the advantages and disadvantages of the international approach

Benefits: what has this collaboration enabled that a purely UK-based approach could not?

Challenges: what may have disadvantaged the project?

13. Overall if you have developed new partnerships, how effective have they been in enhancing delivery of outcomes and impacts from your AMR research?

Organisations outside the academic community

	Not applicable	Not at all effective	Somewhat effective	Effective	Very effective
Industry, including industry associations and levy boards, e.g. AHDB	◯	◯	◯	◯	◯
Policy makers e.g. RUMA	◯	◯	◯	◯	◯
End users/Practitioners e.g. doctors, patients, vets, farmers	◯	◯	◯	◯	◯
Charity	◯	◯	◯	◯	◯

Public bodies

	Not applicable	Not at all effective	Somewhat effective	Effective	Very effective
Animal and Plant Health Agency	◯	◯	◯	◯	◯
Veterinary Medicines Agency	◯	◯	◯	◯	◯
Defra, DHSC	◯	◯	◯	◯	◯
Foreign Commonwealth and Development Office (previously DfID)	◯	◯	◯	◯	◯
Food Standards Agency	◯	◯	◯	◯	◯
WHO / FAO / OIE	◯	◯	◯	◯	◯

Other – please specify

14. Please highlight any outputs, outcomes and impact that would not have been achieved unless there was an interaction with this / these partnership(s).

Please explain their significance.

6.5 YOUR AMR RESEARCH PROPOSAL

In the following section we are interested in delivery related to your broader AMR research portfolio i.e. these can be outside the specific grant mentioned in the previous section, but research funded through BBSRC only.

15. Please comment on the benefits of this / these partnership(s)?

16. Please comment on the challenges of this / these partnership(s)?

17. There were four key identified measures in the UK's National Action Plan 2013-2018. How successful has your wider AMR portfolio of work been in facilitating a contribution to any of these areas.

Please select all that apply

	Unsuccessful	Somewhat successful	Successful	Very successful	Don't know
Impact on the growth of resistance, as determined by the number of reported infections and the proportion resistant to specific antimicrobials	◯	◯	◯	◯	◯
Impact on reducing the level of inappropriate antimicrobial use	◯	◯	◯	◯	◯
Increased international collaboration to minimise the global spread of AMR	◯	◯	◯	◯	◯
Adoption of a "One-Health" approach	◯	◯	◯	◯	◯

6.6 GENERAL FEEDBACK

18. How effective are BBSRC's finding mechanisms for supporting AMR research? Please indicate which mechanisms have been effective in supporting the elements listed below of the AMR research agenda.

	Responsive mode, including strategic long and large grants	Fellowships	Doctoral training programs	Technology and resources calls*	Newton / GCRF / GAMRIF	Other BBSRC calls
Research and collaboration						
High-quality AMR research	◯	◯	◯	◯	◯	◯
Co-design of AMR research calls with relevant stakeholders	◯	◯	◯	◯	◯	◯
Multidisciplinary / interdisciplinary AMR research	◯	◯	◯	◯	◯	◯
Strong AMR research community	◯	◯	◯	◯	◯	◯
Collaboration and partnership between researchers and relevant stakeholders	◯	◯	◯	◯	◯	◯
Collaboration with countries where AMR is more significant/endemic	◯	◯	◯	◯	◯	◯
Leadership and training						
International leadership	◯	◯	◯	◯	◯	◯
Training the next generation of researchers (post-doctoral researchers, early-career fellows, technicians, PhDs etc	◯	◯	◯	◯	◯	◯
Influencing global AMR policy	◯	◯	◯	◯	◯	◯
UK's reputation in AMR	◯	◯	◯	◯	◯	◯

*ALERT, Tools and Resources Development Fund, Bioinformatics and Biological Resources

19. Which features of BBSRC's work have supported you as a researcher and how can we improve our support for AMR research?

Please comment

20. Please provide any other comments relevant to this evaluation.

REFERENCES AND ACRONYMS

i. www.gov.uk/government/publications/uk-5-year-action-plan-for-antimicrobial-resistance-2019-to-2024
ii. www.gov.uk/government/publications/uk-5-year-antimicrobial-resistance-strategy-2013-to-2018
iii. https://post.parliament.uk/type/postnote/page/34/
iv. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/322358/Outcome_measures.pdf
v. Responsive mode research grants – BBSRC (https://bbsrc.ukri.org/funding/grants/)
vi. Our fellows – www.ukri.org/councils/bbsrc/career-and-skills-development/fellowships/our-fellows/
vii. BBSRC call support file (www.ukri.org/opportunity/20alert-mid-range-equipment-funding/)
viii. Global Challenges Research Fund (GCRF) – BBSRC (www.ukri.org/our-work/collaborating-internationally/global-challenges-research-fund/)
ix. Newton Fund – BBSRC (www.ukri.org/our-work/collaborating-internationally/newton-fund/)
x. www.ukri.org/our-work/browse-our-areas-of-investment-and-support/international-partnerships-with-the-biotechnology-and-biological-sciences-research-council/
xi. https://bbsrc.ukri.org/research/institutes/strategically-funded-institutes/
xii. https://bbsrc.ukri.org/about/reviews/research-evaluation/1209-ipa-sa-link-evaluation/
xiii. https://bbsrc.ukri.org/funding/grants/priorities/combatting-antimicrobial-resistance/
[i] https://mrc.ukri.org/research/initiatives/antimicrobial-resistance/tackling-amr-a-cross-council-initiative/
xiv. https://impact.ref.ac.uk/casestudies/CaseStudy.aspx?Id=38781
xv. One Health refers to combatting spill-over infections at the animal-human-environment interface, with a focus on prediction, prevention, response and recovery principles to improve the health and wellbeing of animals and people in their environments.
xvi. Launched in June 2015, the BEAM (Biotech companies in Europe combating AntiMicrobial Resistance) Alliance is a strong Network of approx. 70 small and medium-sized European companies involved in developing innovative products and kits to tackle antimicrobial resistance (AMR), including small molecule antibiotics, biologics, products with a prophylaxis indication, microbiome-based and phage-based therapies, immune targeting therapies, anti-biofilm agents and medical devices including in vitro diagnostics. https://beam-alliance.eu
xvii. www.who.int/antimicrobial-resistance/interagency-coordination-group/IACG_AMR_Invest_innovation_research_boost_RD_and_access_110618.pdf
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xx. https://npronet.com/
xxi. www.biofilms.ac.uk/
xxii. https://bbsrc.ukri.org/research/international/engagement/global-challenges/zels/
xxiii. www.food.gov.uk/news-alerts/news/ps192-million-for-cross-government-surveillance-project-to-protect-public-health

AHDB	Agriculture and Horticulture Development Board
AB	Antibacterial
ABR	Antibacterial resistance
AMR	Antimicrobial resistance
BBSRC	Biotechnology and Biological Sciences Research Council
BVA	British Veterinary Association
cNCI	Category Normalised Citation Impact
Defra	Department for Environment, Food and Rural Affairs
DHSC	Department of Health and Social Care
Dstl	Defence Science and Technology Laboratory
DTP	Doctoral Training Partnerships
ECR	Early Career Researcher
EFSA	European Food Safety Authority
FAO	Food and Agriculture Organisation
FSA	Food Standards Agency
GCRF	Global Challenges Research Fund
GECO	Global Effort on Covid-19
IGO	Intergovernmental Organisation
IKC	Innovation Knowledge Centre
LMIC	Lower and middle income countries
ODA	Official Development Assistance
OIE	World Organisation for Animal Health
MRC	Medical Research Council
NBIC	National Biofilms Innovation Centre
NIHR	National Institute for Health Research
NSF	National Science Foundation
POC	Proof of Concept
RUMA	Responsible Use of Medicines in Agriculture
SME	Small and medium sized company
TTO	Technology Transfer Office
UNEP	UN Environment Programme
VMD	Veterinary Medicines Directorate
WHO	World Health Organisation
WOS	Web of Science


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