

Development Histories, AMR Futures, and the Biosociality of a ‘Hotspot’

ANDREA BUTCHER
UNIVERSITY OF HELSINKI
FINLAND

Abstract

Paul Rabinow identified ‘practices of life’ as a potent site of twenty-first-century knowledge and power, arguing that instruments of genomic characterisation will reshape contemporary social relations, thus establishing a new politics of the molecular. Rabinow named this new epoch *biosociality*. In Antimicrobial Resistance (AMR) surveillance terms, gene sequencing technologies and bioinformatics programmes are used to determine resistance profiles of humans, nonhuman animals, and the environments they are embedded within. A regime of global governance has grown around the statistical analysis of the data produced by these new technologies, in which geographic locations displaying certain resistance profiles are designated as ‘hotspots’ of resistance emergence, justifying intervention in the behaviours of the populations inhabiting them.

Producers of statistical data have identified a correlation between AMR gene prevalence and abundance and national development status. They call for more research into the socioeconomic and political capacities of nations to respond to the AMR challenge. This article responds to that call by examining AMR in the context of global development. It explores the processes by which global development regimes have created and perpetuated environments conducive to the production of AMR hotspots in low-income countries. Focusing on two case studies – Bangladesh’s export aquaculture sector and rural development in the West African Republic of Benin – I speculate how histories of postcolonial development potentially configure AMR hotspots. Drawing upon Hannah Landecker’s ‘biology of history’ concept, I argue that the historical development regimes, and the ideologies that underpinned them, have contributed to AMR futures. The article concludes by cautioning that unless combined with insights from qualitative research, advances in biotechnologies – and the knowledge they produce – risk turning the molecular into the latest iteration of North–South domination, perpetuating uneven power relationships and racialised stereotypes by designating certain populations as risky producers of AMR.

Keywords

antimicrobial resistance; biosocial; hotspot; development

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To email contact Andrea Butcher: andrea.butcher@helsinki.fi.



Introduction

Paul Rabinow identified ‘practices of life’ as a potent site of new knowledge and power in the twenty-first century, in which instruments of genetic and genomic characterisation will reshape contemporary social relations and establish a new politics of the molecular (Rose 2007). Rabinow labelled this new historical moment ‘biosociality’ (Rabinow 1996, 91–111). One manifestation of biosociality is the grouping together of individuals sharing genetic characteristics to create new identities and alliances, and new possibilities for governing or intervention therein. Molecular surveillance of antimicrobial resistance (AMR) does something similar. In AMR surveillance, genomic sequencing and bioinformatics programmes produce information on the prevalence and abundance of drug-resistant genes either through genomic characterisation of human and nonhuman animal biological samples (gut, saliva or skin), or in physical environments such as soils, sediments, and water bodies. Surveillance techniques include following sentinel organisms (Collignon et al. 2018; Vikesland et al. 2019) and the metagenomic analysis of microbial communities sampled from the environment (Hendriksen et al. 2019).

Statistical analysis of genomic data is transformed into maps representing national or regional profiles of resistance prevalence and abundance. However, in the process of representing biotechnical data at scale, key contextual and historical information are removed. If taken at face value, the information depicted in such AMR cartographies risks labelling specific sites or territories as ‘hotspots’ of resistance emergence, and their resident populations as responsible. I utilise Richard Helliwell, Sujatha Raman and Carol Morris’s (2021) definition of the AMR hotspot as an environmental imaginary that shapes scientific knowledge of how the environmental dimensions of resistance manifest. When underpinned by the hotspot imaginary, the process of mapping designates sites of AMR risk as requiring intervention to prevent global transmission. This is particularly problematic when many such sites are located in low-income regions (Collignon et al. 2018; Hendriksen et al. 2019; Singh 2017; Vikesland et al. 2019). Spatially segregating populations and geographical regions according to resistance profiles can be used to designate some as biologically ‘risky’ (Nabirye 2018), justifying intervention, and potentially perpetuating geopolitical inequalities and racialised stereotypes when confronting global health controversies.

The resistance studies cited above identified a correlation between AMR gene prevalence and abundance with national development status, prompting the authors to call for more research into the economic and political capacities of different regions or countries to respond to the AMR challenge. This article responds to that call by speculating how a region’s resistance profile might be influenced by global development. Taking inspiration from Hannah Landecker’s (2016) ‘biology of history’ concept, I draw upon two case studies where I have previously engaged in qualitative fieldwork: Bangladesh’s export aquaculture sector and rural development in the Republic of Benin’s central belt. By analysing cross-disciplinary literature and development project reporting, I speculate for each—how a ‘biology of development history’ may contribute to resistant futures. These histories are configured within a political ecology of global development: its knowledge systems, forms of project delivery, political patronage and brokerage, and the material situations they determine. By examining the socioeconomic and political transformations that followed independence from colonial rule (and the continuing dominance of the global north in steering the direction of those transformations), I argue that better sociomaterial characterisation of postcolonial

development histories may be as fundamental as surveillance data in understanding a country's resistance profile.

The article is structured as follows: I begin by laying out my conceptual and methodological framing of AMR as a biosocial entity produced and rendered governable through specific enactments of science and politics. I then briefly delineate a history of global development theory and practice, before moving to the case studies, which provide evidence for how each country's resistance profile may have been influenced by the confrontation of external aid and development intervention with local political performance, and the changes to social organisation these produced. I conclude with a discussion of how, without care, a new politics of the molecular will become the latest phase in the histories of North-South domination, and argue how analysing genomic data alongside critical histories and ethnographies of development will improve knowledge of local and national resistance profiles as biosocial phenomena: produced through socioeconomic, sociopolitical, and infrastructural as well as biological matters.

Conceptual and Methodological Framing

Rabinow's conceptualisation of biosocial relations rested upon his analysis of population collectives sharing genetically predisposed biomedical conditions. With AMR research this conceptualisation is given a spatial orientation, as encapsulated in the environmental imaginary of the 'hotspot' as defined by Helliwell, Raman, and Morris ([2021](#)), mentioned in the last section.¹ As scientific imaginaries, resistance hotspots are rooted in sites demonstrating the greatest concentration of bacteria and antimicrobials, thus requiring specific types of intervention to interrupt resistance-conferring dynamics ([ibid., 1353](#)). The molecular characterisation of these so-called hotspots pinpoints low to middle income countries (LMICs) as experiencing the highest risk, reframing AMR as a problem of global southern regions ([Overton et al. 2021](#)). Shiloh Krupar and Nadine Ehlers have critiqued such practices, arguing that statistical aggregation denies the social or geopolitical production of risk, producing instead a 'future of a race-specific biopolitics of health' that is 'ontologizing structural racism in space' ([2017, 232](#)). However, one transdisciplinary global health research network, led by the late anthropologist and clinician Paul Farmer, has developed biosocial techniques for studying global health controversies that combine epidemiology, demography, clinical practice, molecular biology, and economics with anthropology, sociology, history, and political economy (see: [Farmer et al. 2013](#); [Richardson et al. 2016](#)). Bringing different disciplines and scales of analyses together charts the biosocial contingencies that configure what Assa Doron and Alex Broom ([2019, 2](#)) call 'geographies of vulnerability': circumstances in which infectious disease, including drug-resistant infectious disease, form around situations of structural inequality and impoverishment.

¹ Helliwell, Raman, and Morris ([2021](#)) identified three additional environmental imaginaries: the pristine environment, the fluid environment and the environmental reservoir. For the purposes of the article, I focus on the hotspot only.



I approach my biosocial analysis in a similar way, combining it with Landecker's 'biology of history' concept (2016), to produce a speculative² 'biology of development history'. Landecker developed the 'biology of history' concept to explain how advances in biotechnology allowed scientists to study infectious heredity and resistance acquisition in microbes, in effect writing 'the historical record of human antibiotic use inscribed across the biology of bacteria' (*ibid.*, 21). Reading the histories of antibiotic manufacture, consumption, and bacterial evolutionary theory together allowed Landecker to develop a theory of how yesterday's knowledge of bacterial control has unintentionally produced today's widespread biological effects. Exchanging biological theory with the ideologies of twentieth- and twenty-first-century global development allows one to read localised resistance profiles as emergent in sociomaterial conditions produced through the global exercise of social, political, and economic as well as medical power ([Hinchliffe 2022](#)).

Methodologically, I take a broadly similar approach to Hannah Brown and Ann Kelly's 2014 framework for approaching the anthropological study of viral haemorrhagic fevers, by analysing disparate academic literature from multiple disciplinary sources, and synthesising them into postcolonial development histories that have influenced the (speculative) resistance profiles of my two case studies (2014). Brown and Kelly also utilised the hotspot as a heuristic, although they applied the term differently to the environmental imaginary concept – as a device for analysing the convergence of matters and agencies that create the conditions for a viral outbreak to emerge. Whilst they described this convergence as 'temporary' (*ibid.*, 281), in bacterial evolutionary terms resistance hotspots precipitate a state of enduring biotic transformation. In the context of this paper, the hotspot functions as a biosocial index of postcolonial development history.

This approach evolved from specific research questions that emerged during fieldwork across three multidisciplinary international collaborations for which I was the postdoctoral social researcher. The first project was a UK research council funded project Production Without Medicalisation: A Pilot Intervention in Global Protein Production at the University of Exeter that ran between 2017 and 2018. The empirical focus was on antibiotic use in Bangladesh's shrimp and prawn aquaculture, in response to reports of high levels of antibiotic use in this sector globally ([Cabello et al. 2016](#); [Thornber et al. 2020](#); [Watts et al. 2017](#)). A mixed methods approach, the study combined extensive surveys of the shrimp hatchery sector in the southeast of the country and crustacean farms in the southwestern delta region with field observations, qualitative interviews, and informal conversations with farmers, technicians, and farm supply shops. The documented evidence generated information on the production practices and their associated biological and socioeconomic challenges potentially driving antibiotic use.

The second and third projects were the Research Council Finland funded Antimicrobial Resistance in West Africa ([AMRIWA 2018–2022](#)) and Social Study of Antimicrobial Resistance: Healthcare, Animals and Ethics ([SoSAMiRE 2019–23](#)).

² I say speculative as there are few published genomic studies of the sites themselves.

Both were undertaken in the Republic of Benin between 2019 and 2022 (with a break of two years from 2020 to 2021 due to the Covid-19 pandemic). These multidisciplinary projects comprised of bioscientists, social scientists, and bioethicists seeking to plug regional data gaps by generating information on the flow of resistance genes between humans, animals, and environments in West Africa. The sociological components of these projects produced information on social practices of food production, healthcare, and management of water, sanitation and hygiene (WASH) in both urban and rural settings. The data for this article's case study were collected from a village in the central belt of Benin, selected in partnership with local collaborators. I spent stays of approximately four to five weeks each in this village across three visits in 2019, 2020, and 2022; conducting interviews and informal conversations, documenting WASH practices and healthcare management strategies, and participating as much as possible in social and domestic activities. Data collection in 2020 also included a small survey (26 respondents) to document household incomes, infrastructure access and healthcare practices.

The limited time spent at each site was due to the multifactorial nature and scope of each project, which included analyses of different aspects of social life associated with AMR. I therefore used development project reporting and historical analyses of cross-disciplinary academic literature (including scientific, environmental, economic, ethnographic and political economic studies) as assistance when addressing questions, I was unable to follow up in the field. These analyses demonstrated how the sites of both case studies were defined by a reliance on overseas aid or global trade, externally-managed development interventions, and local institutional and political situations. For both sites, I speculate how development histories may shape the formation of resistance hotspots in ways previously unexplored.

The Biosociality of AMR

AMR is the ability of microorganisms to acquire resistance to antimicrobials manufactured to control them. Antibiotics are a specific category of antimicrobials that receive much attention due to their ability to control dangerous bacterial infections. Their development in the twentieth century revolutionised infection control in public and veterinary health. They enabled the intensive rearing of food producing animals, facilitating the stocking of animals or aquatic organisms in higher densities by controlling disease outbreaks, and thus increasing the availability of protein biomass for human consumption. Antibiotics thus undergirded improvements in health, food security and livelihood opportunities for millions, even billions, particularly in low-income countries. Indeed, it is argued that antibiotics have become so thoroughly intertwined with today's processes of life and living that they are infrastructural to them ([Chandler 2019](#)).

Today, twentieth-century promises have become twenty-first-century threats, with the global spread of resistance to antibiotics posing an existential threat to these achievements. The industrial production, mass consumption and widespread availability of antibiotics has accelerated the evolution of resistance, reversing the gains made as bacterial pathogens evade antibiotic therapies, and triggering the emergence of new superbugs – pathogens resistant to multiple classes of antibiotics. AMR is now judged a global challenge of such severity that, if left unchecked, by 2050 will potentially result in tens of millions of deaths annually ([O'Neill 2016](#)). In 2015, the World Health Assembly agreed a Global Action Plan to ensure the continuity of antimicrobial effectiveness and prevent the decline into a post-antibiotic era ([WHO 2015](#)).

However, antibiotic use is but one determinant of AMR. Resistance is conferred through *horizontal gene transfer* (HGT), an ancient evolutionary trait whereby bacteria – using various biological information-sharing mechanisms – can acquire and exchange resistance genes to protect themselves against threatening environments. The name given to this collection of resistance conferring genes is the resistome, which has grown by orders of magnitude in the past one hundred years ([Bengtsson-Palme, Kristiansson, and Larsson 2018](#); [Gillings 2017](#); [Landecker 2016](#)).

Gene exchange occurred in the environment prior to human antimicrobial development. Indeed, the antibiotic therapies we rely on today were harnessed from fungi found in soil ecologies, and resistance-conferring genes are common in the microbial communities of soil and aquatic environments, determining the magnitude that resistance occurs ([Gillings 2017](#); [Taylor, Verner-Jeffreys, and Baker-Austin 2011](#); [Wright 2007](#)). The alteration and acceleration of evolutionary mechanisms occurring today began when microorganisms found themselves in a precarious situation, enduring the disturbance and pollution of their habitats due to urbanisation, industrialisation, changes to agricultural production, increasing reliance on chemicals and bacterial disinfectants, and of course the pervasive application of antibiotics in clinical and livestock sectors ([Gillings 2017](#)). Bioscience researchers are turning their attention to the production of environmental resistance hotspots: sites where highly polluting anthropogenic activities are driving resistance evolution. AMR is thus a thoroughly biosocial phenomenon, determined by anthropogenically impacted sites of environmental pollution, providing the stress and impetus for resistance gene selection.

Global Governance of AMR

Understanding how resistance develops and spreads is one of the World Health Organisation's five objectives for AMR management ([WHO 2015](#)). In scientific enactments of AMR, analysis of molecular data is a key method by which resistance prevalence and abundance becomes knowable and actionable, as researchers seek to gather reliable information that can accurately measure the global prevalence, distribution, and transmission of resistance genes to support the development of national and global policy for tackling the problem ([Collignon et al. 2018](#); [Hendriksen et al. 2019](#)). AMR global governance has assembled specific kinds of knowledge and expertise into national and supranational agencies for managing health and security, in which the globalised distribution of the threat is used to justify intervention in global southern states ([Overton et al. 2021](#)). For example, studies providing statistical maps of the abundance of AMR globally, or that report the risks of specific activities responsible for creating gene transfer hotspots, are invaluable resources for drawing attention to the pervasiveness of the AMR problem, and the magnitude of the challenge for managing it. However, as anthropologist Anna Tsing ([2012, 507](#)) argues, achieving such statistical scalability requires the removal of nuisance social relations: the destabilising 'vectors of transformation' that threaten the standardisation upon which scale relies. In the process of having AMR data produced about them, human and animal populations, environments, and their companion microbes undergo a process of deterritorialisation – denuded of the social relations in which their resistance profiles are produced – only to be reterritorialised on graphs or maps that characterise the actual or predicted abundance of resistance found. Such geographical or pathological hotspotting comes with the risk that the results will be taken at face-value, implicating certain societies as threatening according to the prevalence

and abundance of resistant genes found, presence of multidrug resistant pathogens, or evidence of emerging of superbugs.

I take the example of a choropleth map included by Rene Hendriksen et al. (2019) in their article reporting the characterisation of the bacterial resistome for untreated sewage from 60 countries. The map depicts *predicted* resistance worldwide from obtainable data on global AMR abundance; selected variables from the World Bank's Health, Nutrition and Population portal; and development indicator sets from years 2000 to 2016. Each country wears a shade of blue, with the darkest shade predicted to experience the highest AMR occurrence. According to their predictor model, Bangladesh and Benin wear the same shade: dark (but not darkest), with a predicted abundance of 468 and 475 resistant genes respectively. The authors justify their predictions due to a statistical correlation between the abundance of resistant genes found in sewage samples and Human Development Index ranking (*ibid.*, 5).

In the process of making molecular data globally scalable, they are inevitably decontextualised of the social and material relations that helped to produce them. Nonetheless, Anna Tsing's (2012) scalability critique reminds us that those relations remain *in situ*. This creates a tense moment of volatility if this relational denial leaves vulnerable geographies and economies open to accusations of causality and responsibility. In other words, if data reporting enacts prediction, it risks creating new biosocial subjectivities, 'mapped in space for the purposes of surveillance, anticipation of risk, and containment' (Krupar and Ehlers 2017, 231). This is unless consideration is given to the role of global development and national political arrangements in the creation of resistance evolutionary drivers and exchange pathways. Medical historian Warwick Anderson (2014) has posed a solution to this problem: we write critical histories of 'global' health that apply postcolonial analysis to ethnographic case studies. By doing so, he argues, we render visible the elements that Tsing identifies as nonscalable, thus demonstrating the problem with ignoring them.

The Biosociality of Global Development: Two Case Studies

Landecker assembled the biology of history critique by stitching together the history of the development, manufacture, and mass global consumption of antibiotics with twentieth-century scientific theories of bacterial reproduction. I attempt something similar by stitching together global development (defined here as a set of ideas, administrative processes, and targeted management for achieving sustained growth and social progress) with an examination of development *in situ* and the position of antibiotic use and/or AMR therein.

The poststructuralist critique of global development that gained traction during the 1990s analysed development using Foucauldian theories of power and its diffusion through policy discourses and practices (Escobar 2012; Rahnema and Bawtree 1997; Sachs 1997). Twenty-first-century theorising of the Anthropocene (that most biosocial and geosocial of concepts) brought the *materiality* of development into sharp focus (Crutzen 2002; Chakrabarty 2009; Zalasiewicz et al. 2011). The 'Great Acceleration' graphs produced by Will Steffen et al. (2015) in particular offer a striking diagrammatic representation of humanity's collective post-1950s global imprint from population increase, urbanisation, large-scale infrastructural development, intensification of land and energy resource use, and the simultaneous alteration of the planetary system's structure and behaviour.

The post-war development project sought to develop the so-called Third World using both social democratic and Marxist models of state-led development, understood at the time to be the engine of growth and industrialisation that would lift the former colonies and low-income regions out of poverty and place them on the path to progress. The global economic downturn of the 1980s gave way to the *neoliberal* model of economic growth that posited the market rather than the state to be the instrument of sustained economic growth and wealth for all. This era marked the introduction of ‘structural adjustment’ in global development, whereby the World Bank and International Monetary Fund leveraged economic influence in debt-stricken global southern countries by introducing lending programmes in exchange for the implementation of comprehensive economic liberalisation measures. These measures required that debtor countries develop an export industry, for example in mining, agriculture, or a similar industry, many of which extracted a high biological price on land and water resources. Both Bangladesh and Benin were recipients of World Bank Structural Adjustment Programmes (henceforth SAPs meaning).

Following the Communist Bloc’s collapse in the 1990s, democratisation and governance restructure joined economic liberalisation as a requirement of aid and debt forgiveness. At the beginning of the twenty-first century, this crystallised into the United Nation’s Sustainable Development Goals (SDGs), with a further shift in emphasis towards sustainable and human-centred development indices. These were accompanied by a delivery model that favoured bilateral partnerships between international funding bodies and development providers, and in-country civil society or non-governmental organisations, justified with the reasoning that locally managed, community-led development was more socially and environmentally appropriate ([Chambers 1997](#); [United Nations 1981](#)). However, the partnerships created new challenges. Finances were oriented towards single issues or specific sectors and organised around limited budgets with tight implementation deadlines. Rather than decisions being taken locally, budget holders controlling the project parameters determined how recipients were expected to participate ([Cooke and Kothari 2001](#); [Mosse 2005](#)). However, projects promoting small-scale sustainability in food production, rural development, and decentralised WASH or energy infrastructures did not adequately consider the unanticipated ways that their activities might contribute to further environmental degradation. Environments associated with inefficient hygiene and sanitation management, or that increase levels of chemical pollution and nutrient runoff, are also associated with the acceleration of AMR evolution and transmission.

Each phase of global development – whether that be post-war industrialisation, liberalised export and trade, or twenty-first-century partnering for poverty reduction and sustainable development – has contributed in one way or another to an increased volume of toxic and polluting substances being discharged into the environment. They contributed to the kinds of environmental disturbances that are antibiotic and threatening to microbes, thus accelerating the rate of resistance information sharing ([Bengtsson-Palme, Kristiansson, and Larsson 2018](#); [Gillings 2017](#)). These unintended biological consequences of previous development thought and practice – and their antibiotic outcomes – are the focus of the two case studies.

Bangladesh’s Export Aquaculture

Aquaculture is one of the fastest growing global food sectors, with 90 per cent of production concentrated in south and southeast Asia ([FAO 2018](#)). This growth is accompanied by expert concerns that global aquaculture is exacerbating conditions for resistance evolution and transmission, particularly intensive production

systems that rely on chemical inputs – including antibiotics – to sustain productivity ([Cabello et al. 2016](#); [Stentiford et al. 2017](#); [Taylor, Verner-Jeffreys, and Baker-Austin 2011](#); [Thornber et al. 2020](#); [Watts et al. 2017](#)). Aquatic systems in general are fertile territory for accelerating resistance evolution, particularly those producing high organic loads and toxic wastes such as intensive aquaculture ([Taylor, Verner-Jeffreys, and Baker-Austin 2011](#)). Furthermore, experts are concerned that emerging diseases linked to intensification of production increase the reliance on antibiotics for managing the health of fish and crustaceans ([Watts et al. 2017](#)). As a result, aquaculture ponds have been identified as risk hotspots for gene sharing and transfer, influencing future resistance profiles ([Cabello et al. 2016](#); [Thornber et al. 2020](#); [Watts et al. 2017](#)).

The project Production Without Medicalisation sought to address these concerns by generating information on the biosocial drivers of antibiotic use in Bangladesh's export aquaculture sector, for informing the development of suitable interventions for managing AMR risk. Bangladesh is the fifth largest producer of aquaculture products globally, producing 2.4 million tonnes of farmed fish and crustaceans in 2018 according to the Food and Agriculture Organisation's (FAO) Fisheries and Aquaculture Statistics handbook ([FAO 2020](#)). Whilst low in comparison to its shrimp producing neighbours (for example China or Vietnam), this figure was striking because it was achieved despite the low number of intensive farms that characterised other Asian crustacean exporting nations. Due to a reported reliance on antibiotics in shrimp and prawn aquaculture, the focus of the study was upon the export sector ([Cabello et al. 2016](#); [Watts et al. 2017](#)). However, it became clear early during fieldwork that Bangladeshi crustacean farmers were not routinely using antibiotics to treat their stock. Conversations with the wider network of shopkeepers and development agencies confirmed that whilst antibiotics were used in the hatcheries supplying the seed (or postlarvae) for farmers, sales of antibiotics for use on farms themselves were low ([Hinchliffe, Butcher, and Rahman 2018](#)). These predominantly traditional or improved traditional methods for farming shrimp and prawn challenged the representation of this sector as a significant AMR risk ([ibid.](#)). Nevertheless, I consider here the possibility that this form of production may be vulnerable to, as well as contributing to, a growing environmental resistome ([Zakaria et al. 2023](#)), given the high organic loading and bacterial diversity that result from production ([Watts et al. 2017](#)), and the farms' embeddedness in a delta region of a rapidly industrialising country ([Metcalf 2003](#)).

Emergence and Expansion

As of 2011, there were close to 200,000 crustacean farms in the southwestern delta region cultivating native tiger shrimp (*Penaeus monodon*) and/or giant river prawn (*Macrobrachium rosenbergii*) in open ponds ranging from 0.1 to 1 hectare in size, covering an area of 250,000 hectares ([Belton et al. 2011](#)). Approximately 90 per cent of Bangladesh's crustacean farmers either traditional or improved-extensive culture systems. The remaining 10 per cent managed modernised semi-intensive farms. Intensively managed production systems practiced monocropping (stocking of a single species) in closed water pond systems, stocked in higher densities, and relied on chemical inputs and commercial feeds. By contrast, traditionally managed/improved-extensive farms required less investment, with culture environments closely resembling the crustaceans' natural mangrove habitat. These ponds (known as *gher*) were modified rice paddies enclosed by dykes, which relied on tidal flooding with saline water for shrimp, and the input of fresh water from nearby rivers for freshwater prawn. Smallholder farming systems stocked in lower densities and

practiced polyculture cropping strategies (stocking multiple species of crustacean and finfish). Projects promoting small-scale farming had introduced some improvements such as species control, a modest introduction of commercial feeds, and some inorganic and probiotic inputs ([Karim et al. 2014](#)).

Across both intensive and traditional systems, we found that the majority of shrimp farmers stocked their ponds with hatchery-reared post larvae, and improvement schemes encouraged stocking with premium quality seed sources guaranteed to be free from specific production diseases ([Akber et al. 2017](#); [Butcher, Rahman, and Hinchliffe 2021](#); [Karim et al. 2014](#); [Keus et al. 2017](#); [Rahman et al. 2018](#)). Generally, however, improved-extensive farms remained low maintenance in character and required fewer additional inputs. This included antibiotics, although these were used in greater quantities in the hatcheries and upon intensive farms ([Butcher, Rahman, and Hinchliffe 2021](#); [Hinchliffe, Butcher, and Rahman 2018](#)). Smallholder farms integrated aquaculture with rice production, either alternately or concurrently depending on area and salinity levels. They also stocked at intervals, primarily determined by hatchery production cycles and the availability of postlarvae. This had the advantage of spreading the financial risk should one crop succumb to disease. In comparison, the all-in, all-out monocropping system of intensive farms increased the likelihood of antibiotic use should producers have to rescue a crop due to disease ([ibid.](#)).

Bangladesh's crustacean export industry began in the 1970s in response to the global demand for shrimp and prawns. Smallholder farmers began switching from rice cultivation to commercial aquaculture, either persuaded by its profitability, or through forced land conversion by powerful commercial interest groups and local elites ([Adnan 2013](#); [Akber et al. 2017](#); [Islam 2008a](#)). Forced conversions were further provoked by the imposition of the World Bank's SAP in the 1980s, which Bangladesh responded to by exploiting international demand for garments and imported shrimp ([Joffre et al. 2010](#); [Pokrant 2014](#)). Bangladesh's SAP stimulated a brief period of investment in intensive farming systems supported by external financing from Asian development banks, whereby some twenty-five intensive shrimp farms were established near Cox's Bazar in southeast Bangladesh ([Debnath et al. 2016](#); [Pokrant 2014](#)). The country's shrimp hatchery sector was established alongside these farms to provide them with the sources of traceable postlarvae required for international markets. In 1992, under increasing pressure from foreign donors to convert land into aquaculture production and boost export earnings, the Government of Bangladesh imposed the Shrimp Zone Rules in the southwest of the country. Common land previously identified for redistribution to the peasantry under land distribution schemes was instead captured by powerful commercial organisations, who had obtained licenses for the purposes of promoting shrimp farming ([Adnan 2013](#); [Paprocki and Cons 2014](#)). Large-scale production was finding its foothold in the sector's commercial development.

The situation changed with the arrival of White Spot Disease in 1994, a viral infection lethal to penaeid shrimp. First detected in Taiwan in 1992, White Spot's arrival in Bangladesh devastated the intensive industry in the southeast and halted land appropriation in the southwest, as risk averse commercial enterprises shifted their profit-making activities towards collecting land rentals or controlling the supply chain through domination of export. Investment in intensive technologies waned, and the risk for production returned to smallholder farmers, who lacked the investment capacity and the technical know-how required for more technically complex intensive systems, which have remained peripheral since then ([Joffre et al. 2010](#)).

The reversal in intensification coincided with the shift in global development delivery towards global northern donor/southern NGO partnerships and an emphasis on environment sustainability. Smallholder farming was thus promoted as a sustainable livelihood strategy, with the sector orienting itself towards the 'organic' (i.e. improved-extensive) market ([Hensler 2013](#); [Islam 2008b](#); [Paul and Vogl 2012](#)). Farmers were encouraged to transition to commercial aquaculture with support from externally financed, locally delivered improvement schemes designed to enhance the outcomes of homestead farming. Farmers continued to cultivate rice alongside their aquaculture production, whilst being further encouraged to 'green' their pond dykes by cultivating additional vegetables where possible. By 2014 the government of Bangladesh had established the 'National Shrimp Policy', laying the groundwork for sustainable, environmentally-responsible shrimp production and income generation on smallholder farms ([Akber et al. 2017](#)), although pressure to improve commercial output and increase export earnings remained (*ibid.*; [Keus et al. 2017](#)). Aquaculture as a national priority now featured prominently in Bangladesh's 'Country Investment Plan', its 'Five-Year Plan', and a USAID 'Feed the Future intervention' (*ibid.*), and given its integrated and low maintenance character, smallholder farming was being promoted as a sustainable livelihood strategy and internationally certified method of organic production ([Hensler 2013](#); [Paul and Vogl 2012](#)).

With these regulatory and development finance instruments, smallholder export aquaculture realised its mandate as a method of achieving sustainable farming, poverty reduction, and generating foreign currency exchange. These different phases in Bangladesh's export aquaculture history (the early transition from rice paddy to crustacean production, the withdrawal of commercial organisations from the farms themselves, and the promotion of smallholder farming as a sustainable rural development and livelihood strategy) explain the conversion of vast tracks of agricultural land into the high volume of small-scale, low investment aquaculture plots.

Pathogenic Outcomes

The shift from macroeconomic policies to poverty-focused, improved-extensive, and integrated forms of commercial farming appeared to fulfil requirements for socially, economically, and environmentally sustainable export production. Furthermore, the financial and disease risk management strategies practiced by small-scale farmers (integrated rice paddy production, polycropping, and stocking at multiple intervals) appeared to inhibit the use of antibiotics ([Hinchliffe, Butcher, and Rahman 2018](#)). During interviews however, farmers described producing shrimp and prawn in enduring states of pathogenicity, with pond environments that were increasingly hard to manage. They reported experiencing fluctuations in temperature or salinity, sudden drops in oxygen, or an overgrowth of algal blooms with putrid soils and foul-smelling black waters that they were unable to remedy. Furthermore, farmers reported confronting the emergence of new production diseases that they did not recognise and were struggling to treat. In many cases, the result was mortality of their stock and heavy production losses (see also [Sudenkaarne and Butcher 2024](#)).

Despite being low input systems with culture environments more closely resembling the crustaceans' natural habitat, the mass conversion of land for aquaculture exponentially increased the volume of organic wastes entering an aquatic environment already stressed by polluting wastes from

urbanisation, terrestrial farming, and the development of energy and pharmaceutical industries. The significant increase in pond cover meant the population of shrimp and prawn in the local environment had also increased exponentially in the previous fifty years, and with it the higher volume of nutrient wastes they produced. Furthermore, these low-tech open systems lacked filtration technologies to filter water entering and leaving the ponds. The delta region had been transformed into vast expanse of open farming systems, relying on coastal waters and river systems already receiving a high volume of untreated effluents from other industries, and facing severe water resilience issues ([Mallik, Arefin, and Shahadat 2018](#); [Roy et al. 2018](#); [Sudenkaarne and Butcher 2024](#)).

Receiving waters were vulnerable to the kinds of organic wastes, toxic chemicals and heavy metals that create the environments for accelerated resistance evolution ([Gillings 2017](#); [Taylor, Verner-Jeffreys, and Baker-Austin 2011](#); [Watts et al. 2017](#)). The manufacture of antimicrobial therapies in pharmaceutical factories near Khulna City provided yet another pathway of antibiotic residues into local waters. Thus, not only was there an increased risk of pathogen transmission between ponds, and between the pond and the wider environment, the conditions for AMR emergence and transmission had also significantly increased ([Akber et al. 2017](#); [Joffre et al. 2010](#); [Kautsky et al. 2000](#)). Finally, the climate crisis and its effects on ocean temperatures and salinity levels ([Ahmed, Occhipinti-Ambrogi, and Muir 2013, 225](#)) was further stimulating the kinds of environmental perturbations that Michael Gillings ([2017](#)) identified as intensifying of microbial self-defence mechanisms. Thus, even without routine antibiotic use, Bangladesh's export aquaculture still typified an AMR hotspot to be intervened upon.

For reasons of space, I have been highly selective in how I report the situation, omitting evidence of how supply chain control mechanisms and intermediary influenced farming strategies and producer decision-making ([Islam 2008a](#); [van der Pijl 2014](#)). Nor do I examine the continued reliance on antibiotics in Bangladesh's hatchery sector, which produced the sources of postlarvae that farmers required for their production ([Butcher, Rahman, and Hinchliffe 2021](#)). Nevertheless, the study highlights the potential for hotspot configuration at the convergence of global markets, development paradigms, and polluting wastes. As a biosocial condition, it has manifested as an intertwining of food production, political controversies over land entitlement and usage, and the material conditions of localised pond environments.

Rural Development and Underdevelopment in Benin

The objectives of the multidisciplinary projects AMRIWA and SoSAMiRE included generating knowledge of social practices facilitating resistance circulation between humans, nonhuman animals and environments in both rural and urban settings. The rural investigation of both projects was conducted in a village in a central Beninese commune,³ where I stayed during visits in 2019, 2020, and 2022. This was a large village of some 300 households and 2,000 inhabitants, mainly engaged in agricultural production of cereals and tubers

³ Benin's territory is divided into 12 Departments, which are further subdivided into communes, then into districts or arrondissements, and finally into neighbourhood or village level (quartier).

destined for domestic markets, as well as cotton, rice, and soy for international export. Despite relatively good productivity, financial returns were low, and the village suffered from significant underdevelopment. Energy and telecommunications infrastructure was mediocre, with just a few shops or houses owning solar panels, although some families had solar lamps for lighting and charging mobile phones. The road connecting the village to the commune's administrative centre was untarmacked, and often impassible during rainy seasons. Sanitation infrastructure was woefully lacking, with the overwhelming majority of households practicing open defecation at sites located in forested areas at the village periphery, unable to afford the 250,000 CFA Francs (approximately €400) required to build a pit latrine and concrete shelter. Whilst spatially separate from the village, transfer of faecal matter into residential areas could occur via the feet of human inhabitants and scavenging animals. Although the village theoretically had a water tower supplying a chlorinated source for a fee of 25cfa (approximately €0.22 EUR) per 25 litres, outages were common, and many households relied upon untreated well water for consumption. Furthermore, despite the village's size, and despite a government target of universal access to public healthcare within five kilometres of one's home ([Tanou, Kishida, and Kamiya 2021](#)), the nearest healthcare unit and pharmacy were twelve kilometres away. Few of the cash impoverished households could afford the transport costs, let alone the hospital fees or high costs of retail medicines.

Instead, villagers relied on medicines procured via the illegal drugs market routed through Nigeria. This was despite a severe crackdown on informal drugs markets following a reform of the pharmaceutical sector in 2018. As the pressures of commercial agriculture production stole more of the villagers' time, opportunities for collecting wild-growing medicinal plants diminished, and with it the common knowledge of traditional remedies. Reliance on illegally traded antibiotics increased in the form of tablets and injectable liquids (that people drank), which were still in liberal use. Two informal 'doctors' residing in the village (former healthcare assistants with basic training in some primary care procedures) held surgeries in their homes, and for a small fee administered syringes containing a cocktail of illegally procured antimalarials and strong antibiotics (for example ciprofloxacin) to patients experiencing fever. Defecation sites received the residues of these antibiotics either via human wastes or the dumping of bottles and blister packs. Furthermore, villagers manually emptied concrete sumps connected to outdoor bathing cubicles and dumped the wastewaters at the defecation sites, concerned that otherwise the sumps would attract mosquitoes, and with them malaria and other mosquito-borne infections. Anecdotally, a local environmental geographer expressed concern that during the rainy season, ground water was being contaminated by faecal matter via soil diffusion, and by extension the well water households relied upon.⁴

Given that sites of untreated sewage are highlighted as key hotspots of evolutionary resistance ([Gillings 2017](#); [Helliwell, Raman, and Morris 2021](#); [Hendriksen et al. 2019](#); [Munk et al. 2022](#)), such sanitation practices, combined with the widespread availability of black-market pharmaceuticals and self-medication

⁴ Samples collected AMRIWA found resistance genes in the different water sources used by the villagers, but these have not been properly analysed, so I am unable to refer to them here.

practices, marked villages such as these as sites of concern. What follows is an examination of the trajectories taken by rural development and national healthcare that turn villages into contact zones where antibiotic use, impoverishment, and limited access to development gains converge to create potential sites of resistance evolution and emergence.

Commercial Agriculture

Given its tropical climate and highly fertile soils, agriculture is positioned as an important driver of rural development, economic growth, and improved food security ([Hinnou, Obossou, and Adjovi 2022](#)). According to a recent FAO report ([2013](#)), approximately 80 per cent of Benin's population earn some form of living from agriculture. As with Bangladesh, much of this production consisted of low mechanised small and medium sized farms ([Djohy and Edja 2022](#); [Hinnou, Obossou, and Adjovi 2022](#)), with some increase in inputs, notably pesticides ([African Development Bank 2015](#); [Djohy and Edja 2022](#); [Sossou, Nassi, and Hinnou 2023](#)). Despite forming a strong pillar of Benin's development approach, agricultural productivity remained suboptimal, and economic returns were woeful, a result of underinvestment and complicated value chains in the form of a diversity of agencies and cooperatives with unaligned objectives ([Hinnou, Obossou, and Adjovi 2022](#); [Sossou, Nassi, and Hinnou 2023](#)).

Much of central Beninese agriculture is located in villages of relatively recent origin, a 'frontier zone' ([Le Meur 2006b](#)) of rural-to-rural migration that began during the early-twentieth century when Benin was still under French colonial rule. The anthropology literature describes how this migration was triggered by the commercialisation of cotton and palm oil production, with groups migrating to more productive agricultural land in the central zone ([Lavigne Delville 2019](#); [Le Meur 2002](#), [2006a](#), [2006b](#)). Following independence from France in 1960, the early period of the new Republic of Dahomey (as it was called until 1975) was characterised by a model of economic development and modernisation based on state investment, industrialisation, and free trade, with a continued reliance on France for economic and administrative support ([Ibikoule and Lee 2021](#)). By 1975, internal instability and distrust of Western influence in the nation's development resulted in a military takeover, and the establishment of a socialist dictatorship by Mathieu Kérékou, which pursued a Marxist-Leninist model of state economic and social development planning. Dahomey was renamed Benin, and the regime sought to extract itself from European domination of its economy and development. The government adopted a centralised and planned economy, with agriculture centrally positioned to guarantee food security and provide raw materials for national industrialisation ([Sossou, Nassi, and Hinnou 2023](#)). However, by the late 1980s the socialist state was bankrupt, a result of economic mismanagement, corruption, and foreign debts due to an industrialisation strategy that nevertheless still relied on global financial support ([Bierschenk 2009](#)). By 1989, Benin was forced to accept the first of two SAPs and economic liberalisation.⁵ The State withdrew from direct participation in the agricultural sector, and responsibility for production was transferred to farmers.

⁵ Benin was subject to two SAPs from 1989–91, and 1991–94.

However, despite the creation of supporting agricultural extension services during this period, small to medium scale farmers found themselves producing without accompanying infrastructural or technical improvements, with production remaining largely manual ([Djohy and Edja 2022](#); [Sossou, Nassi, and Hinnou 2023](#)). Furthermore, farmers were now vulnerable to greater market instability, high production costs, and low farm-gate prices. Export markets were subject to global price fluctuations, leaving farmers vulnerable to greater economic risk ([Assouto, Houensou, and Semedo 2020](#); [Minot and Daniels 2005](#); [Sossou, Nassi, and Hinnou 2023](#); [Togbé et al. 2014](#)). State and externally financed schemes providing access to subsidies, credit, and land tenure were not sufficiently sustained over time ([Lavigne Delville 2019](#); [Sossou, Nassi, and Hinnou 2023](#)). In the village where I stayed, arguments related to price volatility frequently broke out, as farmers strategised to gain the best returns in a precarious economic landscape over which they had no control.

Administrative Decentralisation

Economic restructuring coincided with a period of democratic renewal (*renouveau démocratique*), and the reorganisation of the political administration into a decentralised system. Planning and implementation of agricultural improvements, basic infrastructure and service delivery was devolved to the territorial unit of the commune, administered by mayoralities and town halls. The intention behind administrative decentralisation (which took until 2013 to complete) was global development's assertion that it would improve local access to resources and services provided by the State. In practice, however, power became nebulous and defuse, with the communes' capacities to deliver upon development objectives significantly moderated by a mosaic of foreign and local development agencies, political brokerage, State service delivery, and a heavy reliance on external financial aid ([Bierschenk 2009](#); [Bierschenk and de Sardan 2003](#)). During interviews, town hall officials complained of the difficulties implementing any kind of development due to severe underfunding and inefficient resource transfer from the State, as well as an overreliance on global development agencies (such as the World Bank or USAID), European bilateral partnerships, or gifts from powerful local patrons for achieving development outcomes. Development programmes were less likely to target villages at a distance from administrative centres, particularly when connecting roads were in poor condition. In 2017, responsibility for rural drinking water supply was handed to a national agency with accompanying financial and technical expertise resource ([Comair, Delfieux, and Sou 2021](#)). Its aim was to improve water coverage in rural areas. According to town hall officials however, as of 2022 the agency was still not fully operational on the ground, and water tower repairs or refurbishments were not being carried out. Combined with manual, economically high-risk agriculture, the result was a cash strapped and time poor cadre of farmers residing in satellite villages with little in the way of water supply or sanitation infrastructure, and limited choices when it came healthcare decision-making.

Healthcare

Biomedical healthcare options in Benin included public hospitals, private clinics, retail pharmacies, and until recently informal markets. Carine Baxerres, Kelley Sams, Roch Hounghin, Daniel Arhinful, and Jean-Yves Le Hesran ([2022, 225–248](#)) highlight the important place of medicines across Beninese society both domestically and professionally, with both traditional remedies and biomedicines occupying key positions. Self-medication remains widely practiced, either with traditional remedies, or by purchasing chemical

therapies from retail pharmacies or informal drug sellers. Whilst perceptions of autonomy and popular knowledge in managing one's health strongly influence decisions to practice self-medication, so too does the financial inability to access clinical expertise ([ibid.](#); [Edoh et al. 2016](#)). Despite the legal requirement of a prescription to dispense antibiotics, many pharmacies continue to supply customers without one, and the informal drugs market continues to operate (although its influence is much reduced following largescale reform of the pharmaceutical sector in 2018, which cracked down hard on illegal supply routes and 'counterfeit' drugs).

During the SAPs period, Benin restructured its public healthcare sector into a decentralised health system, the method promoted by the World Health Organisation (WHO) to fulfil the aims of the 'Bamako Initiative' for attaining universal primary healthcare in Sub-Saharan Africa, of which Benin was a signatory ([Beyer 1998](#)). As with other development sectors, public health service delivery in Benin was supported by bilateral partnerships and global agencies such as WHO and UNICEF. However, whilst town halls had responsibility for constructing healthcare premises, they relied on the Ministry of Health (MoH) to staff and equip them. Interviews with both a Ministry and a town hall official disclosed how a shortage of trained staff and available equipment meant many care units were non-operational, prompting the MoH to impose a moratorium on equipping and staffing new facilities until existing ones received support (see also [Edoh et al. 2016](#)). This included the village where I stayed. Where facilities did operate, the high fees and reported disrespectful treatment of healthcare staff further prevented people from accessing this method of healthcare ([Baxerres and Cassier 2022, 225–248](#); [Edoh et al. 2016](#)).

Public healthcare was supplemented by a substantial private sector of clinics ([ibid.](#)), and private retail pharmacies ([Baxerres and Cassier 2022, 72–93](#)), the latter of which I discuss here. Unlike development and public health delivery (with their reliance on partnerships with global and bilateral associations) pharmaceutical distribution was administered by a monopoly analogous to the French model, which tightly controlled distribution and sale of medicines and pharmaceutical consumables ([ibid.](#))⁶ Pharmaceutical retail was controlled by the National Order of Pharmacists (Ordre National des Pharmaciens or ONP), a corporate body and legal entity that both represented and regulated the pharmaceutical profession and its activities. For decades, ONP fought to keep the sector autonomous, ferociously opposing the licensing of multinational operations ([Baxerres and Cassier 2022, 52–71](#)). However, a limited pharmaceutical manufacturing base has resulted in reliance on foreign markets for their pharmaceutical needs, which favoured European drugs manufacturers ([ibid.](#); [Baxerres and Cassier 2022, 72–93](#)). Prior to the 2018 reforms, wholesalers, distributors, and retail outlets were governed by strict regulations, which stipulated 90 per cent of their

⁶Public and private hospitals or clinics procure their pharmaceuticals from a separate agency. Until 2020, this was the Centrale d'Achat de Médicaments Essentiels et Consommables Médicaux (CAME), a financially autonomous association with the mandate to supply pharmaceutical consumables under supervision from the MoH. CAME was granted greater latitude in procurement of generic medicines to protect against economic shocks in global pharmaceutical markets. As part of the pharmaceutical reforms, CAME was replaced by Société Béninoise pour l'Approvisionnement en Produits de Santé en abrégé. Space does not permit a fuller discussion.

stock must be treatments included in the National List of Essential Medicines ([ibid.](#)). Pharmacists were required to register with ONP, and obliged to procure their stock from one of five wholesalers, supported by a modest number of distribution firms. Setting oneself up as a pharmacy or distributor, and obtaining the necessary licenses and stock, required much expenditure, and whilst government price setting prevented competition between wholesalers,⁷ reliance on global markets meant the sector was vulnerable to price instability and high import costs. The result was a limited number of wholesale, distribution, and retail outlets with little incentive to branch out into underpopulated rural areas, which were underserved. At the time of writing, ONP's website had recorded 328 registered pharmacy outlets in Benin for a population of approximately 13.5 million ([ONPB n.d.](#)), which according to the literature operate almost exclusively in the southern coastal and urban areas ([Baxerres and Cassier 2022, 72–93](#)). Taken together, the shortage of clinical units and retail pharmacies in rural areas, and the moratorium on commune-level staffing and equipping healthcare facilities created a scarcity of healthcare options for the rural interior, leaving a vacuum that informal markets filled. These markets had access to cheaper, generic Asian and Nigerian pharmaceuticals – albeit completely unregulated and without the attendant clinical prescription expertise ([ibid.](#)). In 2022, the informal market continued to operate in the village, albeit with less visibility compared to my previous visits of 2019–2020. Given the lack of alternative health options, the government's attempt to eradicate them had instead pushed them further underground.

Once again, I have omitted much detail: the mosaic of state and non-state actors competing for influence across various periods of agricultural reform ([Minot and Daniels 2005](#); [Sossou, Nassi, and Hinnou 2023](#)), perceptions of autonomy and popular knowledge in health seeking practices ([Baxerres 2014](#); [Baxerres and Cassier 2022](#)), and the transformation of early-twentieth-century cross-border trade in pharmaceuticals into an informal, and later illegal market ([Baxerres 2014](#); [Baxerres and Cassier 2022, 52–71](#)). However, this contracted analysis, assembled from diverse disciplinary academic literature, still illustrates how factors potentially influencing hotspot formation in Beninese villages converged at the proximity of underinvestment in agriculture, poor financial returns for farmers, reliance on overseas aid for infrastructure and public health management, and a pharmaceutical monopoly whose practices and regulatory procedures promoted a high cost, low distribution retail pharmaceutical sector. These sectors, their associated policies, and funding mechanisms were themselves configured by colonial legacies, global financial institutions, overseas development interventions, and global markets. Residues of unregulated antibiotics were finding their way into village soils through faecal matter of impoverished families at open defecation sites, in villages where sanitation infrastructure was too expensive to install, potentially seeping into sources of water for wells and boreholes that could not be adequately maintained, eventually to be consumed by humans and other animals. Thus speculatively, neighbourhoods in which development failures thrive risk becoming contact zones of resistance, bringing people and nonhuman animals into closer contact with environments in which gene exchange thrives.

⁷Although wholesalers found innovative strategies for side hustles, see [Baxerres and Cassier 2022, 64](#).

How Development Histories Created AMR Futures

The two studies have drawn attention to the ‘non-scalable’ social and material relations that lie behind surveillance data determining the presence of a resistance hotspot. I argue that hotspots (defined here as an environmental imaginary shaping scientific knowledge of resistance) function as biosocial indices of colonial and postcolonial development histories and their microbial consequences. In Bangladesh’s export aquaculture, the hotspot indexed the historical unfolding of global development finance, structural adjustment programmes, disease outbreaks, the shifts in policy to intensive production, and back to small-scale poverty-focused interventions – whilst simultaneously trying to improve commercial production output for export. In the postcolonial experience of Beninese rural development, it was political brokerage, aid dependency, and free markets that brought the village population into closer contact with both unregulated antibiotics and fertile environments of resistance evolution and spread: an untreated water supply, faecal matter from open defecation, and contaminated soils. This contact was enabled by forms of underdevelopment: the policies that failed, and the short-term technocratic solutions oriented towards single issues or specific sectors.

These site-specific forms of land appropriation and ownership, aid transfers, export economies, food security, and inadequate management of sanitation and wastewaters are the non-scalable relations that I argue help determine a country’s resistance profile. I use them to consider a ‘biology of development history’, whereby AMR futures are being created from development pasts and presents. Landecker (2016, 37) explains how the ‘biology of history refers to a recursive structure in which knowledge is produced in and through matter that itself has been altered by previous modes of thought’. These previous modes of thought refer to the certainty at the beginning of the antibiotic era that – through antibiotic means – humanity would gain mastery over biology, achieving a revolution in global health and food productivity. Likewise, global development is confronting its own biology of history, in which the philosophies of economic liberalisation and good governance, implementation bureaucracies, and short-term technocratic solutions have contributed to the production and characterisation hotspots of resistance evolution. In the two case studies examined, the potential for resistance vulnerability was nascent within the initiatives: in the receiving waters of the Bangladesh’s delta region as they collected the wastes generated by economic restructuring, export-orientation, and smallholder aquaculture; and in Beninese frontier agricultural villages, where antibiotic use met the neo-imperial ‘ruination’ (Stoler 2008) of rural development policy and public health delivery.

Landecker (2016, 21) observes how with the assistance of sequencing technologies, scientists discerned in genetic sequences the radical transformation of microbial evolutionary and metabolic capacities. This, she says, brought scientists face-to-face with the evidence that yesterday’s theories were in error (ibid., 37). However, in the new politics of the molecular there is a danger that, rather than examining the consequences of erroneous theories, regimes of global AMR governance will instead use such evidence to justify continued intervention in vulnerable populations on the grounds of biological risk. Helliwell, Raman, and Morris (2021) hint at as much when they describe how the information generated by today’s sequencing and statistical analysis technologies has enacted a scientific environmental imaginary that not only stabilises sites of dynamic human-microbial relations, but that also provides the impetus for certain kinds of action to be taken upon them. Rather than acknowledging the social and ecological vulnerabilities

nascent in global development paradigms, AMR global governance (as inscribed in supranational action plans) prescribes more of the same: more external intervention, more technical fixes, more protection of global arrangements that are implicated in global vulnerabilities currently faced. The material realities produced through scientific practices become politicised when used to legitimise specific types of intervention. Paying greater attention to the idiosyncratic and nonscalable relations that shape a country's unique history may go some way to ensuring AMR interventions do not cause harm, and avoiding future 'political and cultural contestations around issues of responsibility and bacterial relations' (Doron and Broom 2019, 8). I hope to have demonstrated that, through applying a concept of 'biology of development history', resistome characterisation and statistical analysis can be combined with social science analysis of postcolonial development trajectories. This form of AMR knowledge production can be used to map the ways that specific forms of progress, economy, and social organisation are implicated in the production of hotspots of resistance as environmental and biological processes, and in doing so avoid perpetuating the historical dominance and structural vulnerabilities that have characterised global and national development interventions until now.

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Author Biography

Andrea Butcher is a senior researcher in sociology for the Finnish Multidisciplinary Centre of Excellence in Antimicrobial Resistance Research (FIMAR) and a member of the Centre for the Social Study of Microbes (CSSM) at University of Helsinki. Her work focuses on AMR in global development contexts.

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