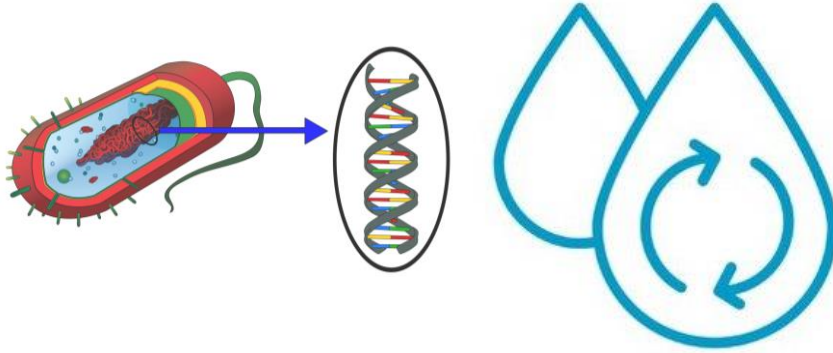
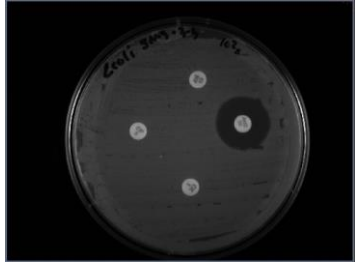


# *AMR and Climate Change*



Amy Pruden



University Distinguished Professor  
Civil & Environmental Engineering  
Virginia Tech  
USA

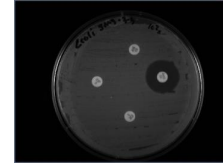
# Trajectory and Consequences of Inaction

## Climate Change



- Sea level rise
- Heat waves
- Droughts
- Floods
- Wildfires
- Water scarcity
- Unpredictable weather hurting agricultural production/food security
- Increased displacement of human populations
- Loss of habitat and shifting habitats for wildlife

## AMR

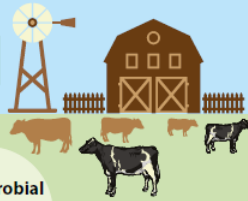


- Antibiotics lose efficacy for treating bacterial infections
  - Pneumonia
  - Septicemia
  - Urinary tract infections
- Routine surgeries become more dangerous
- Neonates and immunocompromised at even greater risk
- Loss of efficacy of other antimicrobials (e.g., fungicides)
- Death rates surpass cancer by 2050
- A post-antibiotic era mirroring the early 20<sup>th</sup> century

# Antimicrobial resistance and the environment

The environment is key to antibiotic resistance. Bacteria in soil, rivers and seawater can develop resistance through contact with resistant bacteria, antibiotics, and disinfectant agents released by human activity. People and livestock can then be exposed to more resistant bacteria through food, water, and air.

**Human antibiotic use** jumped 36% in the 2000s



Up to **75% of antibiotics** used in aquaculture may be lost into the surrounding environment



**70% of antibiotics** are used by animals

Manure fertilizers cause antibiotic contamination in surface runoff, groundwater and drainage networks

**Antimicrobial use** for livestock will jump 67% by 2030

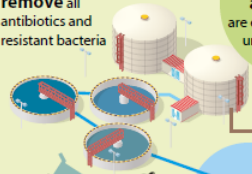
Antibiotics are increasingly used to boost animal growth in intensive farming, especially in developing countries

Antibiotics can be absorbed by plants and crops



**Major waste flows** including wastewater, manures and agricultural run-off contain antibiotic residues and antibiotic-resistant bacteria

Wastewater treatment plants **cannot remove** all antibiotics and resistant bacteria



Up to **80% of consumed antibiotics** are excreted through urine and faeces

**30% of antibiotics** are used by humans

Antibiotic resistant bacteria may be present in **raw source water** and **treated drinking water**

Antimicrobial concentrations in most effluents are **too low to be lethal** to exposed bacteria, but may be sufficient to induce antimicrobial resistance

A vast array of **contaminants in municipal and industrial wastewater** increases pressure on bacteria to become resistant



**More than 50% of municipal solid waste** ends up in landfills and open dumps. This can include unused or expired drugs.



**Multi-drug resistant bacteria** are prevalent in marine waters and sediments in close proximity to aquaculture, industrial and municipal discharges



## AMR in the Environment is Complex and Multidimensional

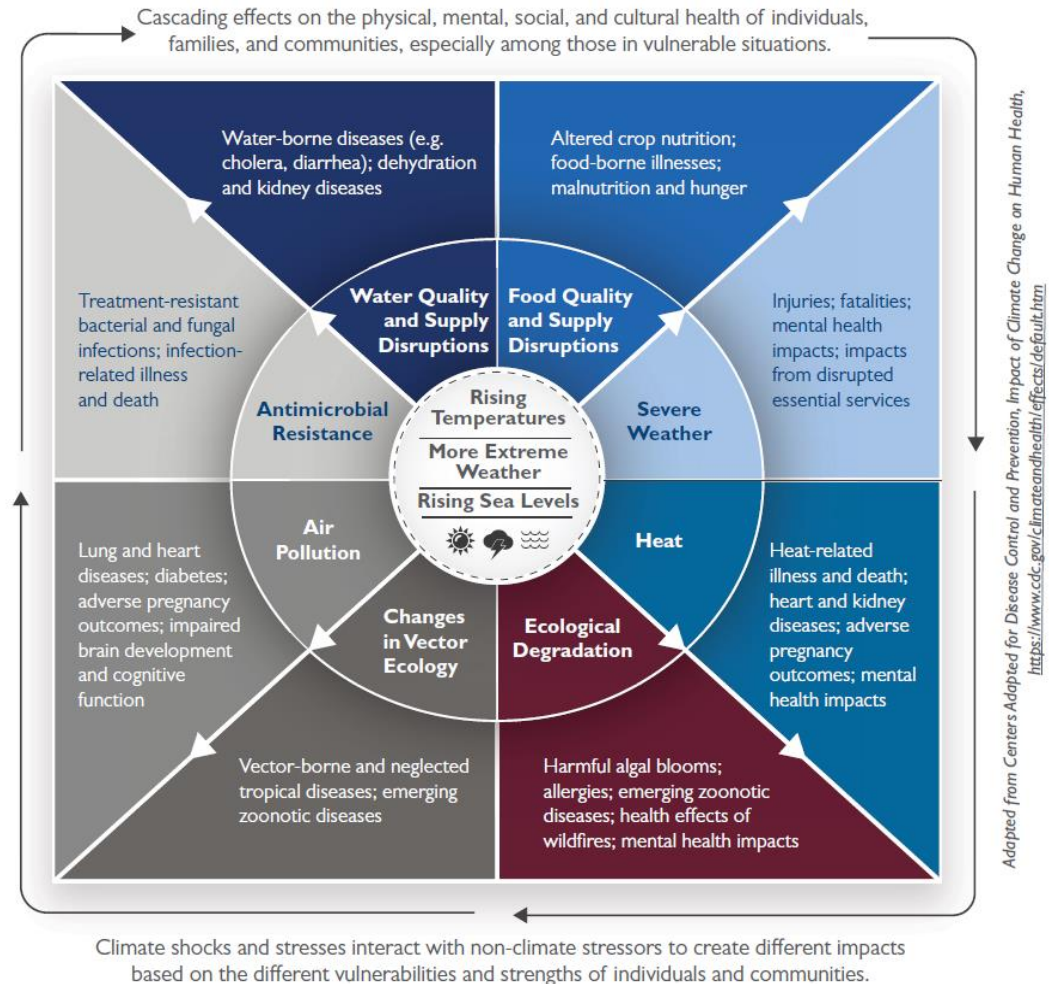


FRONTIERS 2017

Emerging Issues of Environmental Concern



# Climate Change Can Exacerbate AMR



# Climate Change can Exacerbate AMR

## Increased Temperatures

- Increased growth/metabolic rates of pathogens
- Shift ecology of pathogens and vectors and opportunity for emerging disease

## Increased Storm Events

- Increased dispersal of AMR
- Increased vulnerability to infection following natural disaster
- Coastal, peri-urban and well water communities most likely to be affected

## Water Scarcity

- Water reuse technology and practice does not currently take into account AMR
- Need to ensure that water reuse practices do not perpetuate the spread of AMR



# Demonstrating an Integrated Antibiotic Resistance Gene Surveillance Approach in Puerto Rican Watersheds Post-Hurricane Maria

Benjamin C. Davis, Maria Virginia Riquelme,\* Graciela Ramirez-Toro, Christina Bandaragoda, Emily Garner, William J. Rhoads, Peter Vikesland, and Amy Pruden\*



Cite This: <https://dx.doi.org/10.1021/acs.est.0c05567>



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Metrics & More

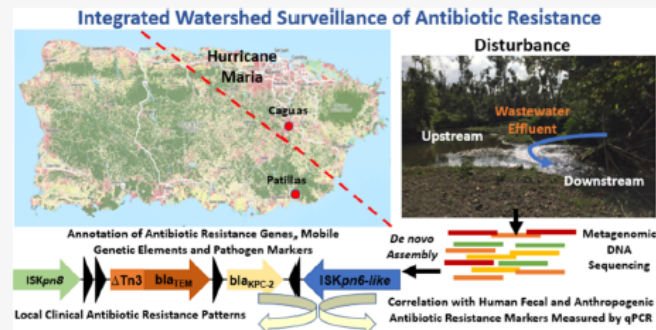


Article Recommendations



Supporting Information

**ABSTRACT:** Comprehensive surveillance approaches are needed to assess sources, clinical relevance, and mobility of antibiotic resistance genes (ARGs) in watersheds. Here, we examined metrics derived from shotgun metagenomic sequencing and relationship to human fecal markers (HFMs; *crAssphage*, enterococci) and anthropogenic antibiotic resistance markers (AARMs; *int11*, *sul1*) in three distinct Puerto Rican watersheds as a function of adjacent land use and wastewater treatment plant (WWTP) input 6 months after Hurricane Maria, a category V storm. Relative abundance and diversity of total ARGs increased markedly downstream of WWTP inputs, with ARGs unique to WWTP and WWTP-impacted river



# Example: Northward migration of *Naegleria fowleri*

## Deadly infections

Between 1962 and 2012 there were 128 confirmed cases of primary amebic meningoencephalitis in the United States. The rare and deadly infection is most common in the south.



Source: Centers for Disease Control and Prevention

PIONEER PRESS

ESKAPE pathogen ideal incubation temperatures:

<i>Escherichia coli</i>	36°
<i>Staphylococcus aureus</i>	35° - 37°
<i>Klebsiella pneumoniae</i>	36°
<i>Acinetobacter baumannii</i>	37°
<i>Pseudomonas aeruginosa</i>	36°
<i>Enterococcus spp.</i>	36°

# Tackling a grand challenge: Lessons learned from climate change

- Grappling scientifically with a complex, multifaceted phenomenon
- Communicating effectively to the public
- Understanding and addressing barriers to action
  - What are the real and perceived trade-offs?
  - Understanding stakeholder perspectives
  - Political will
  - Most immediate problems tend to get the attention (Policy in a crisis)
- Need systems thinking (convergence) to holistically address problem
- Identifying synergistic benefits of action



# Analogous Actions

## Climate Change

- Paris Agreement
- Net zero CO<sub>2</sub> emissions by 2050
- Mitigation (reduce, avoid, and sequester GHGs)
- Technology and Innovation (e.g., renewable energy)
- Adaptation (e.g., restore landscapes)
- Finance, investment in research and solutions

## AMR

- WHO GAP, quadripartite, and NAPs
- Reducing AMU and emissions
- Mitigation (e.g., wastewater treatment)
- Technology and innovation (e.g., vaccines, diagnostics)
- Improve access and appropriate use for vulnerable populations
- Finance...

**Example synergistic solution:** *Implementing locally-relevant cultivation practices that reduce GHG, reduce N & P emissions, and attenuate AMR.*

# Environmental Dimensions of **Antimicrobial Resistance**

Summary for Policymakers



“*AMR challenges* cannot be understood or addressed separately from the **triple planetary crisis** of *climate change*, *biodiversity loss* and *pollution and waste*, all of which are driven by **unsustainable consumption and production**”

- Need for global action!
- Enhance environmental governance, planning, and regulatory frameworks
- Identify and target priority AMR-relevant pollutants
- Improve reporting, surveillance, and monitoring
- Prioritize financing, innovation, and capacity development



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Analytical Studies

G7/G8 Health Ministerial Meetings

## G7 Health Ministers' Communiqué

Berlin, May 20, 2022

[\[PDF\]](#)

1. We, the G7 Health Ministers, met in Berlin, Germany, on 19 and 20 May 2022, at an extraordinary time of multiple, acute crises. We affirm our common values as a strong

1. COVID-19 Pandemic
2. Antimicrobial Resistance “Silent” Pandemic
3. Climate Change

*“As part of the G7 Pact for Pandemic Readiness, we commit to strengthening and supporting the development of **integrated, interoperable and interdisciplinary surveillance and cross-sectoral surveillance capabilities that aim to cover all countries, multiple pathogens, antimicrobial resistance and human, animal, environmental, and climate-related inputs**, as part of the One Health approach, to reduce the risk of future cross-sector health threats.... “non-invasive”...national wastewater surveillance systems...”*



# Thank You!





# Take-Home Messages

- Complexity
- Synergistic Action!