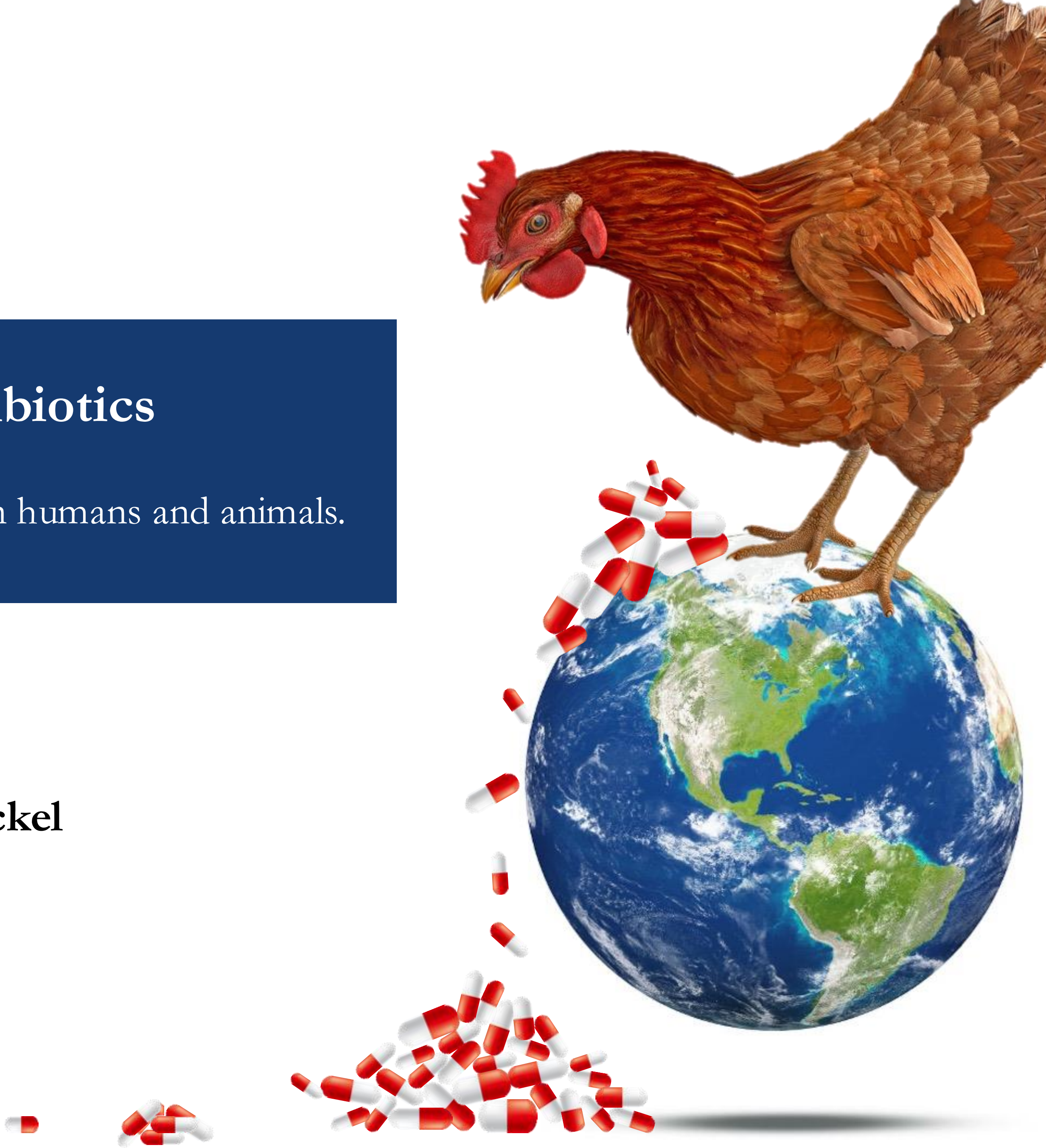
Playing Chicken with Antibiotics

Global epidemiology of antimicrobial resistance in humans and animals.



Prof. Thomas Van Boeckel

One Health Institute
University of Zürich

25.05.2025

Team Effort

Yu Wang — Food scientist

Joao do Couto Pires — Pharmacist

Cheng Zhao — Biogeographer

Laura Huber — Veterinarian

Nico Criscuolo — Ecologist

Katie Tiseo — Microbiologist

Ranya Mulchandani — Epidemiologist

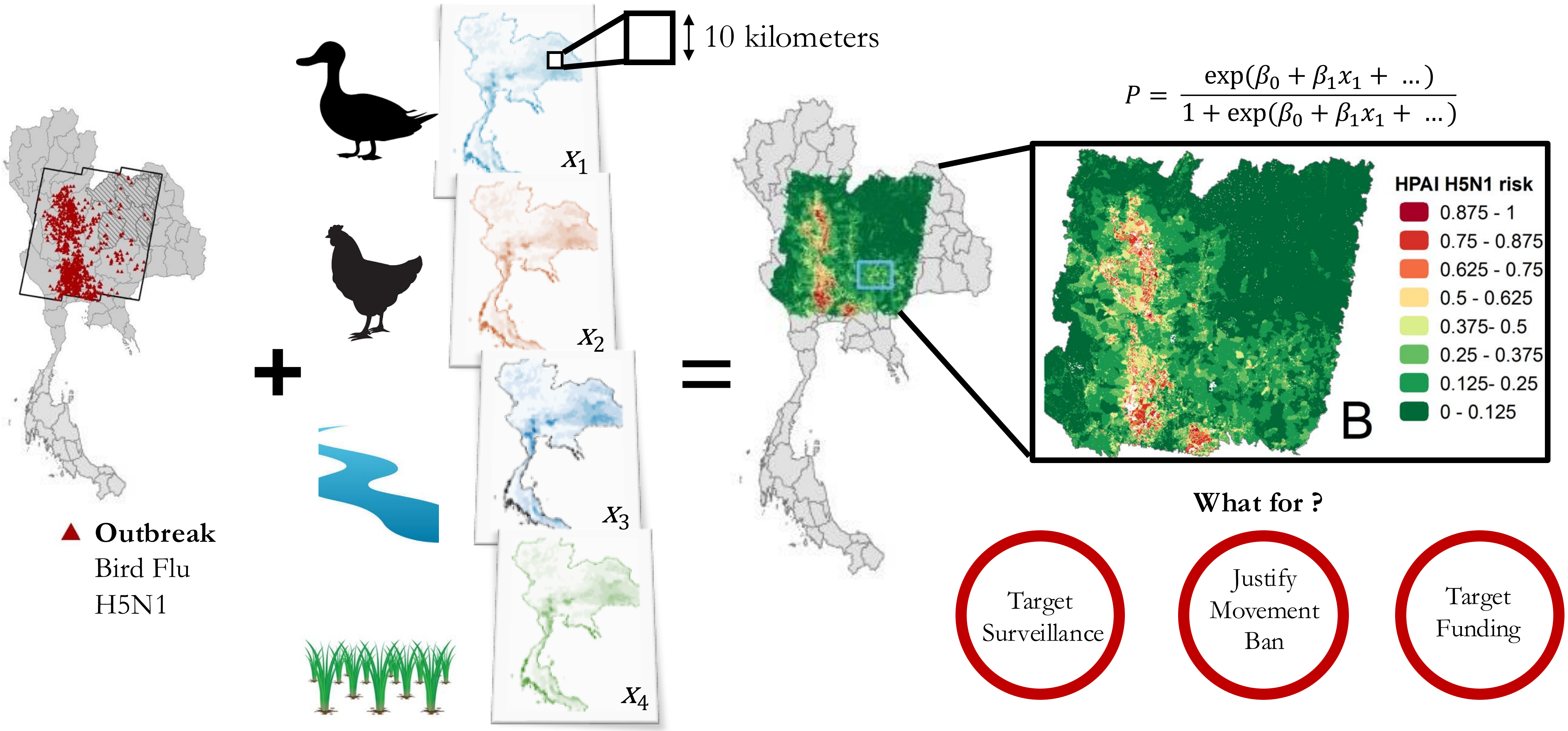
Alex Morgan — Diseases Modeler

Soushieta Jagadesh — Medical Doctor

What we do ?

Maps

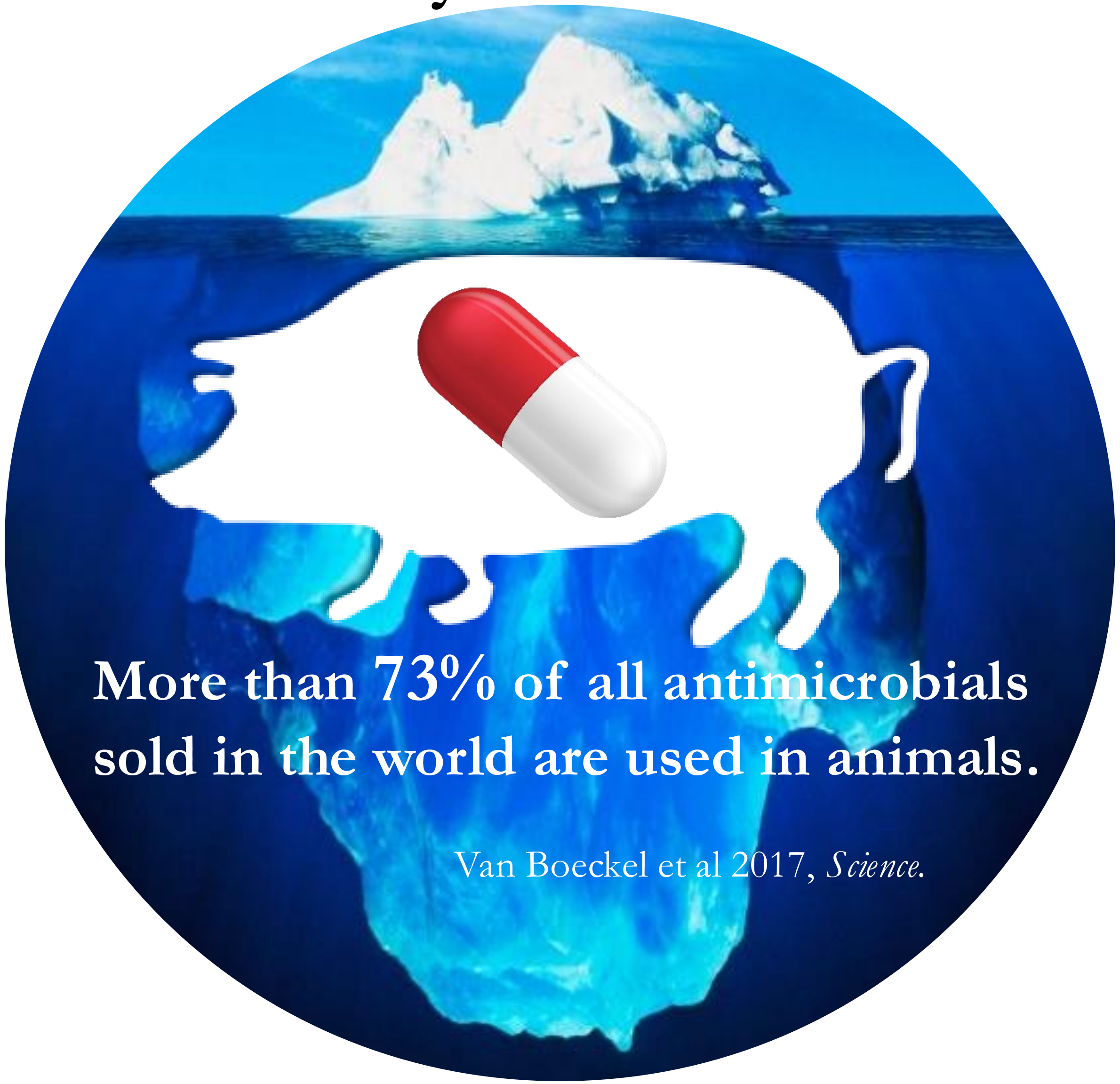
Maps of Diseases : Why and How ?



$$P = \frac{\exp(\beta_0 + \beta_1 x_1 + \ \dots)}{1 + \exp(\beta_0 + \beta_1 x_1 + \ \dots)}$$

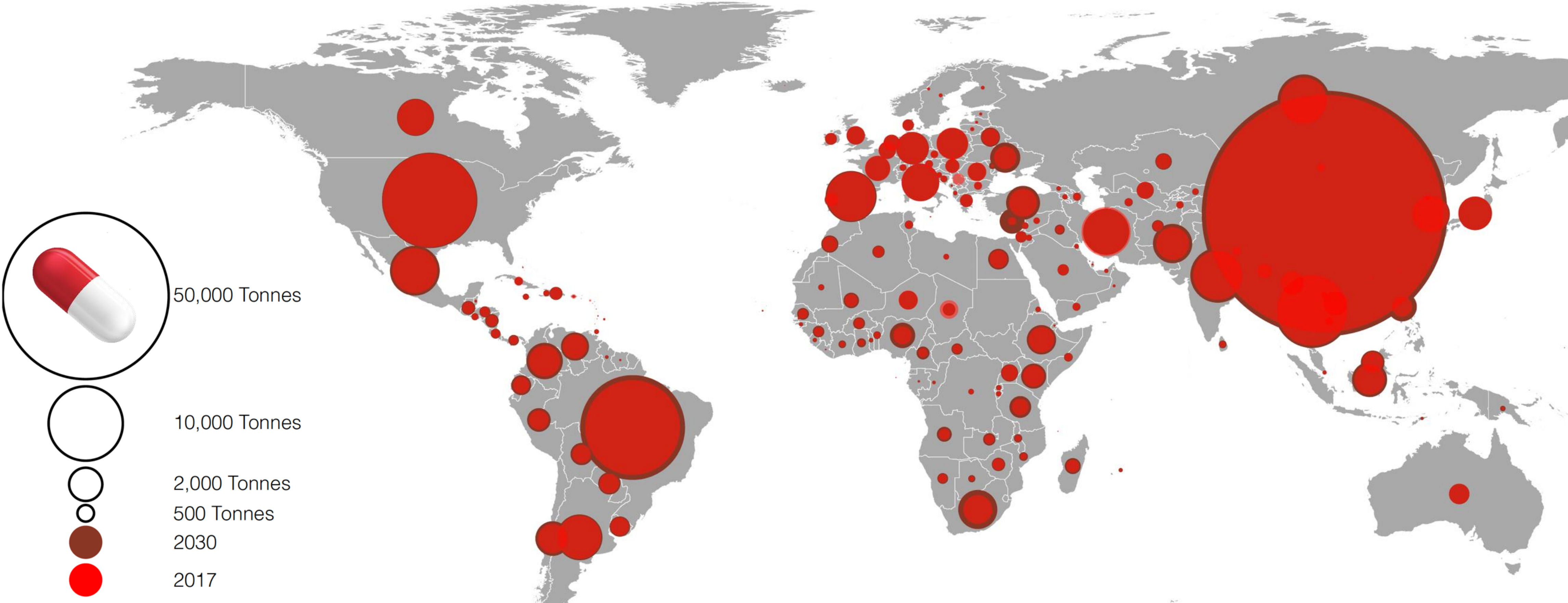
Van Boeckel et al (2012), PLoS ONE. Improving Risk Models for Avian Influenza: The Role of Intensive Poultry Farming during the 2004 Thailand Epidemic

Why Animals ?



Van Boeckel et al 2015, PNAS.

Global Antimicrobial Use in Animals



Katie Tiseo

Ranya Mulchandani

Version 1, Van Boeckel et al 2015, **PNAS**.
Version 2, Van Boeckel et al 2017, **Science**.
Version 3, Tiseo et al 2020, **Antibiotics**.
Version 4, Mulchandani et al 2023, **PLoS Global Public Health**.

One Pig farm in China *vs* One Pig farm in China

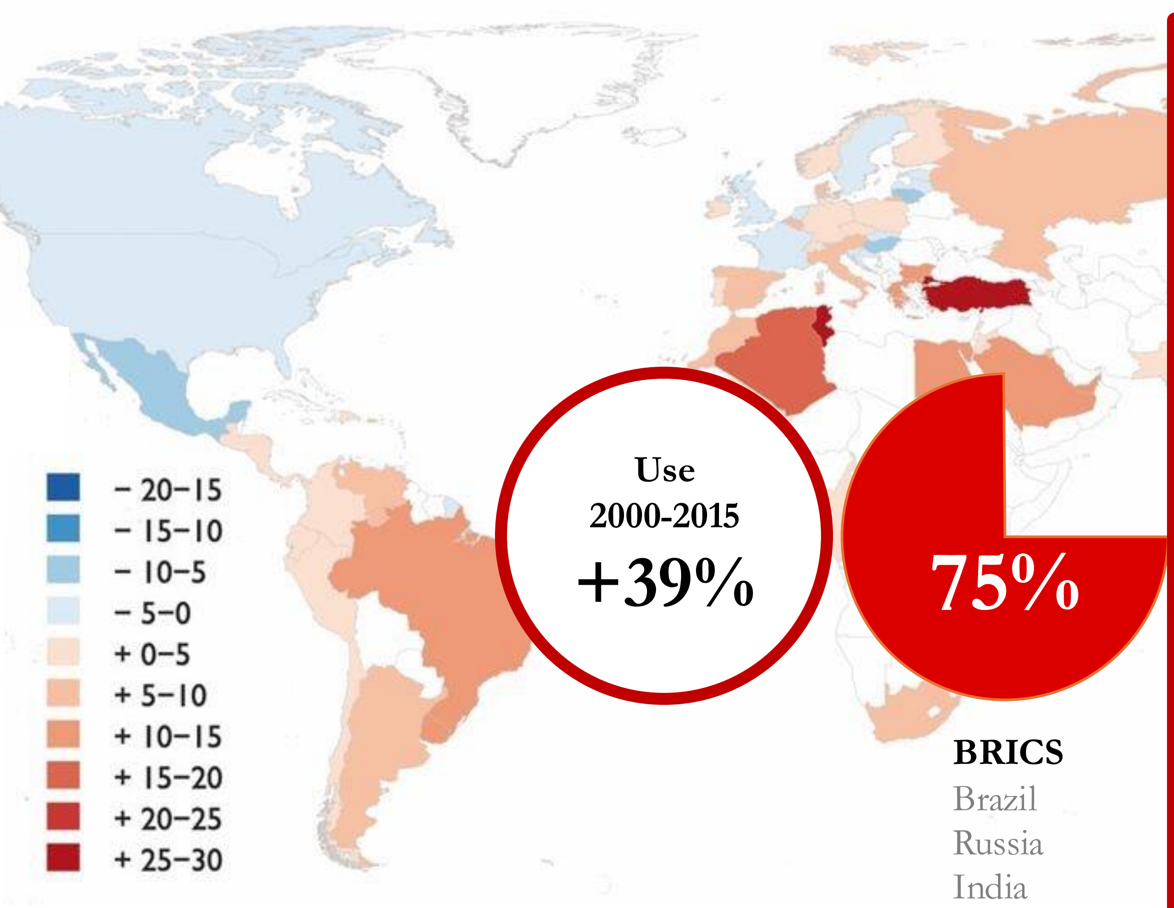
Source: The New York Times

One Pig farm in China *vs* One Pig farm in China

Source: The New York Times

Global Antimicrobial Use in Humans

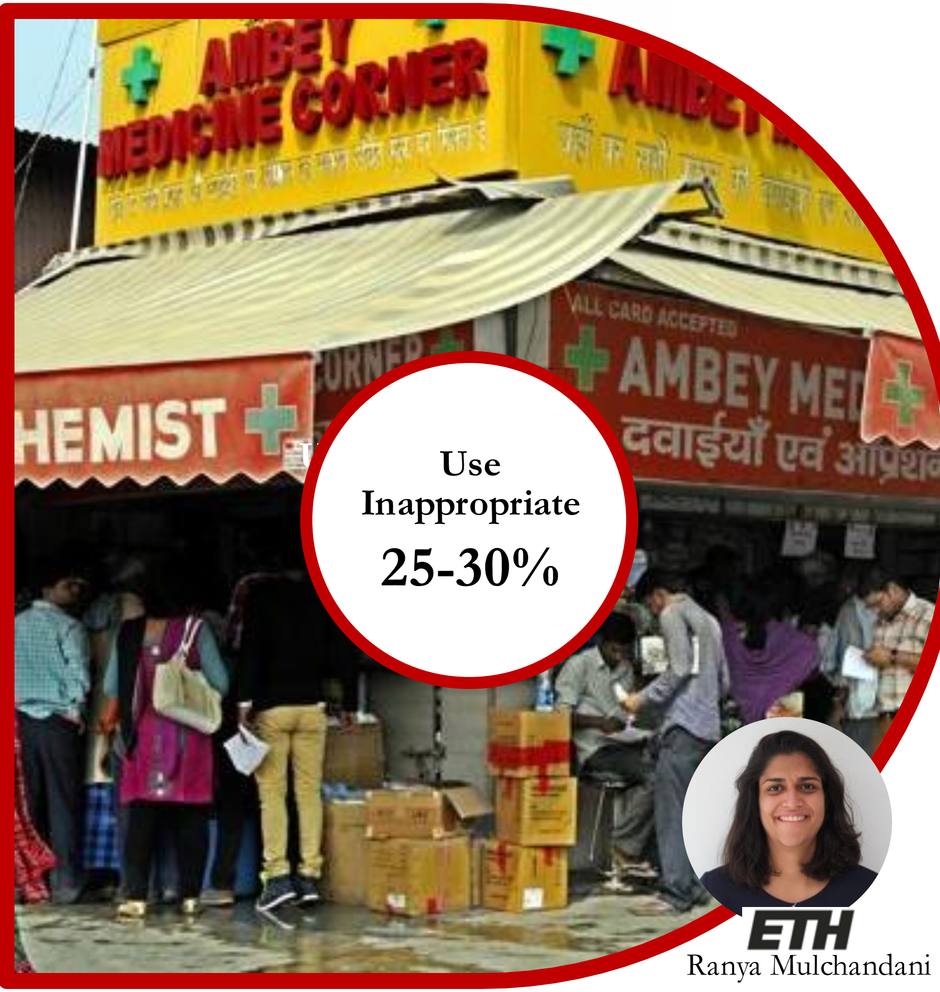
CHANGE (%)



Use
2000-2015
+39%

75%

BRICS
Brazil
Russia
India
China
South Africa



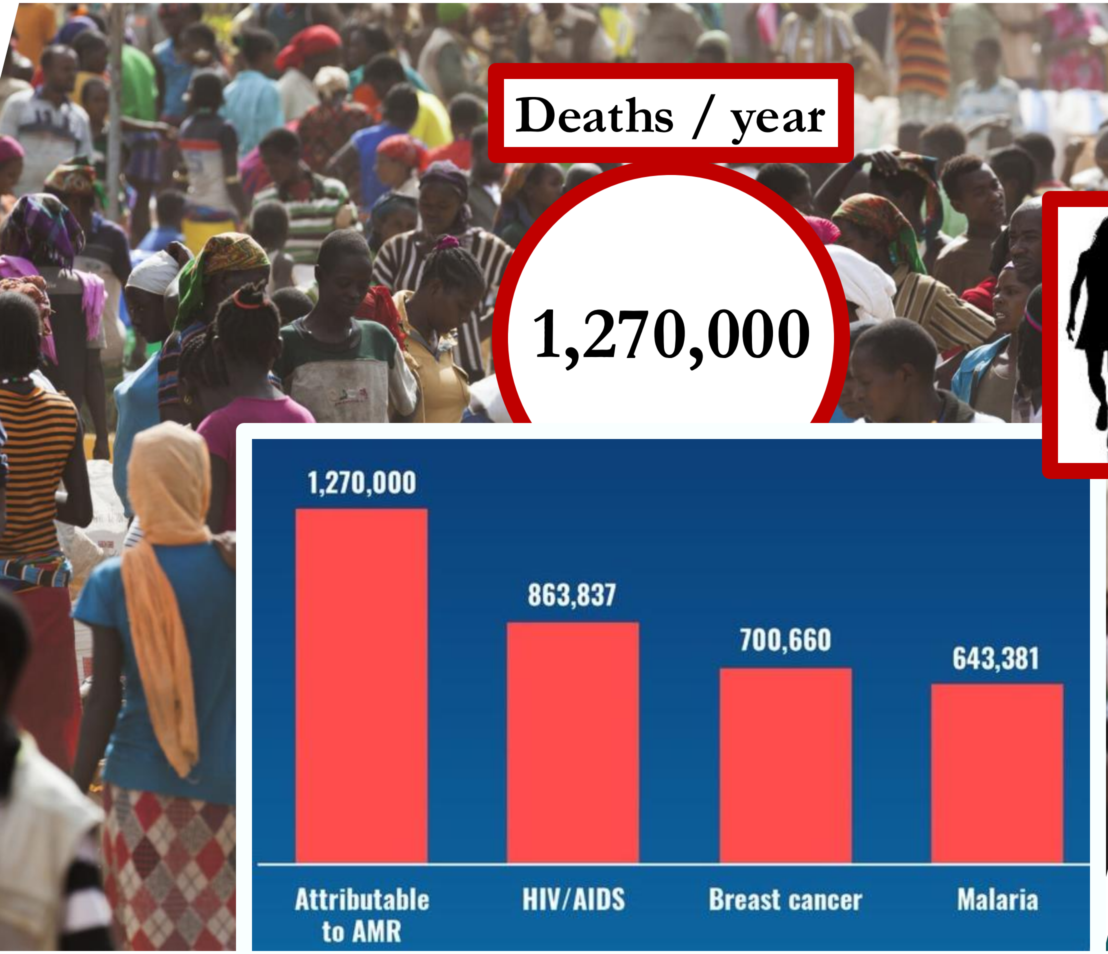
Use
Inappropriate
25-30%

ETH
Ranya Mulchandani

Van Boeckel et al, 2014. **The Lancet Infectious Diseases**
Klein, **Van Boeckel** et al 2018. **PNAS**
Klein, **Van Boeckel** et al 2024. **PNAS**

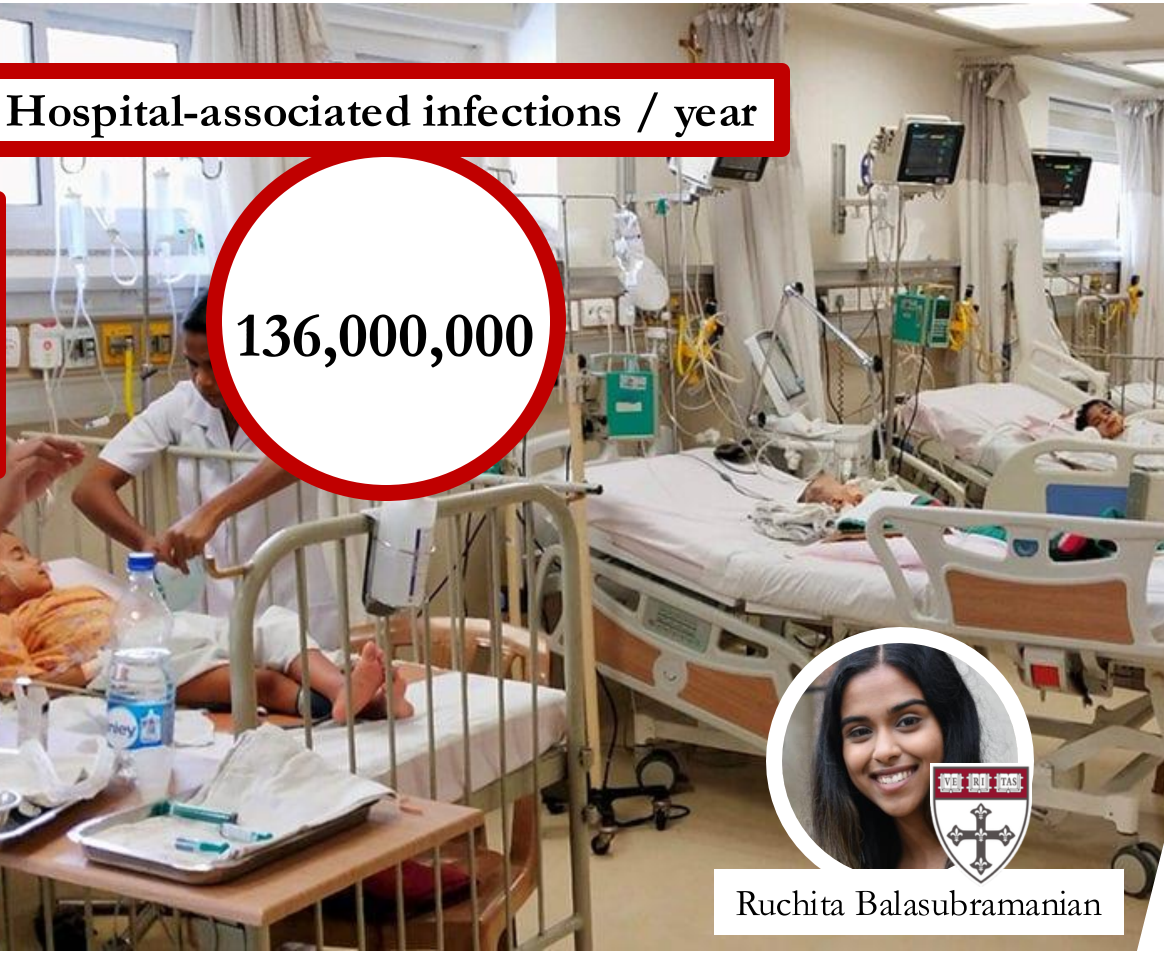
Mulchandani, **Van Boeckel** et al 2024 (BMJ Public Healths)

Global Burden of Antimicrobial Resistance in Humans



Deaths / year

1,270,000



Hospital-associated infections / year

136,000,000

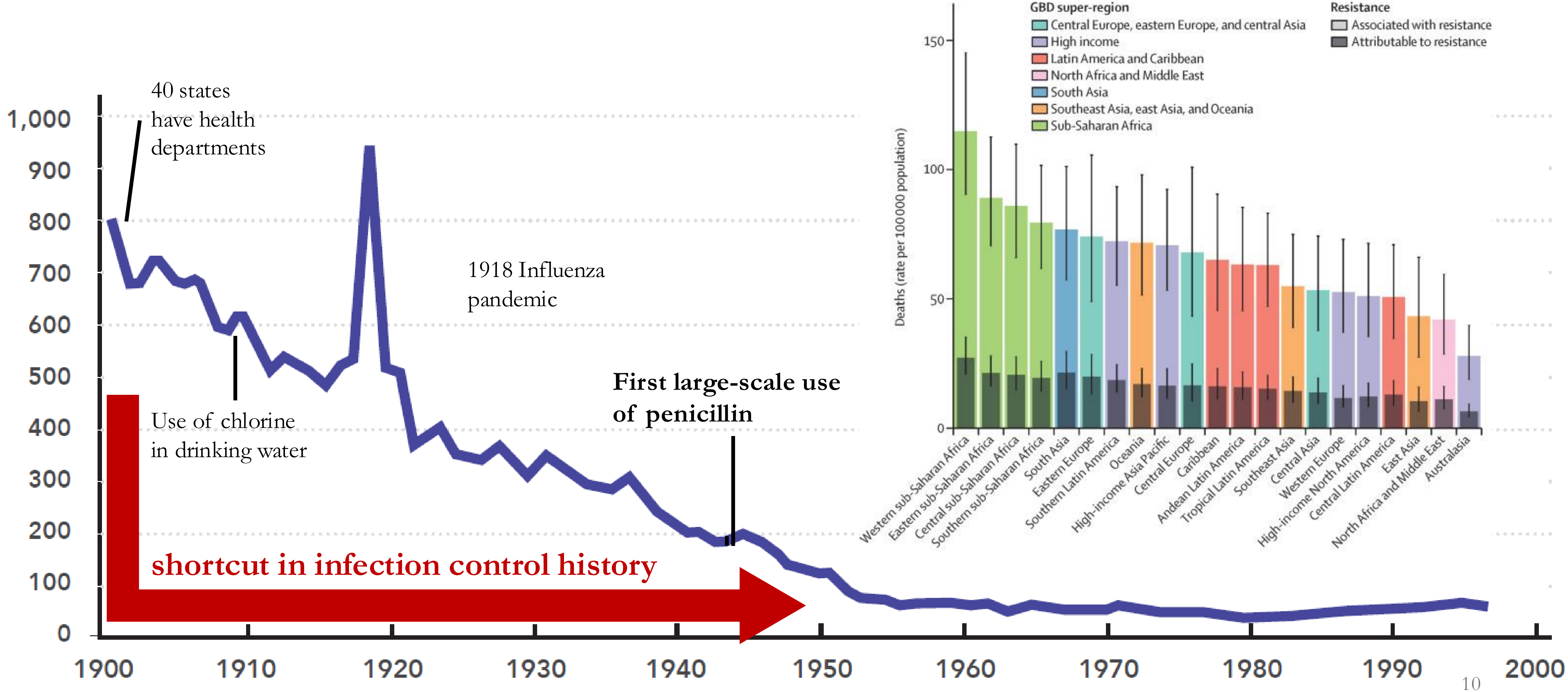
Ruchita Balasubramanian

IHME

Murray et al, **The Lancet** (2022).

Balasubramanian, Van Boeckel et al. **PLoS Med 2023**

Crude infectious disease mortality rate in the U.S (100,000)



Laxminarayan et al, 2007. *Extending the Cure*

Future AMR deaths: driven by demography

2050

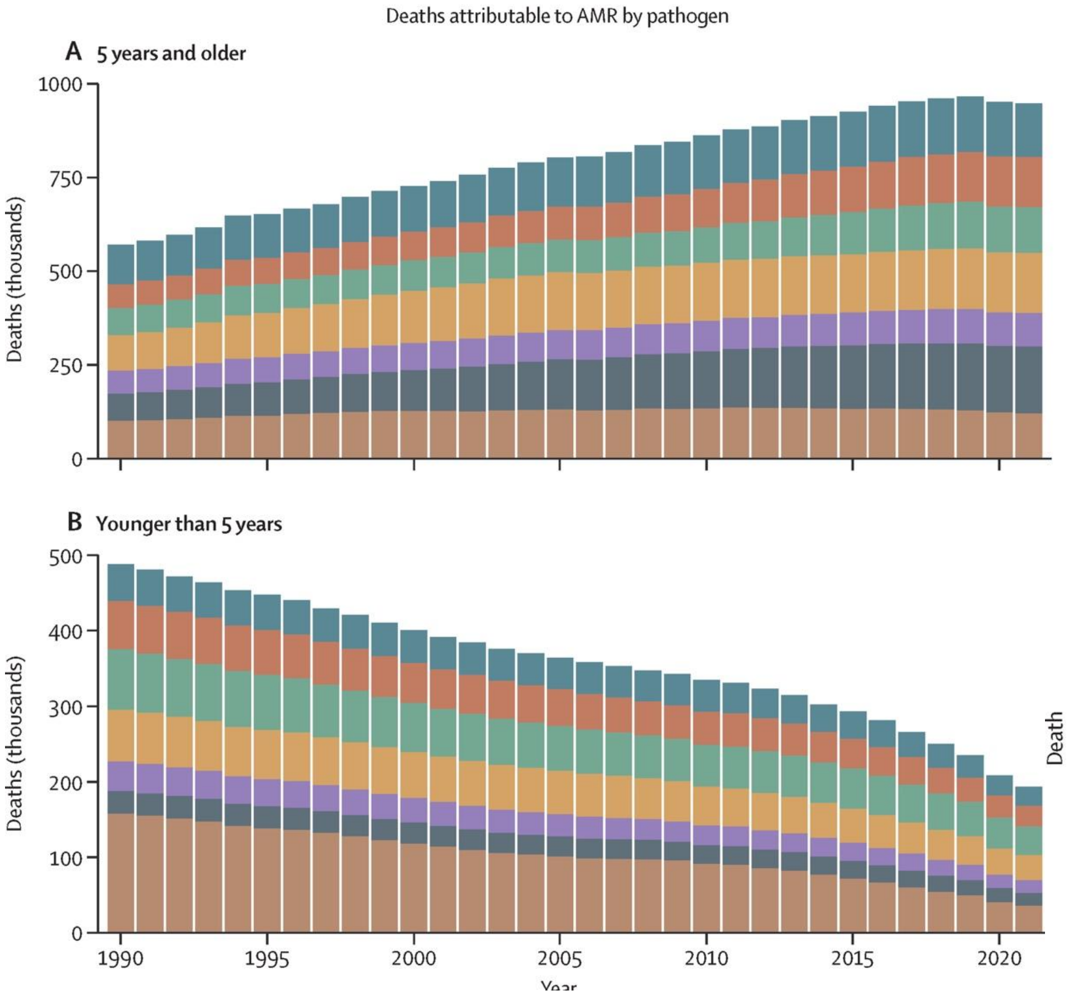
1.91 million deaths attributable to AMR

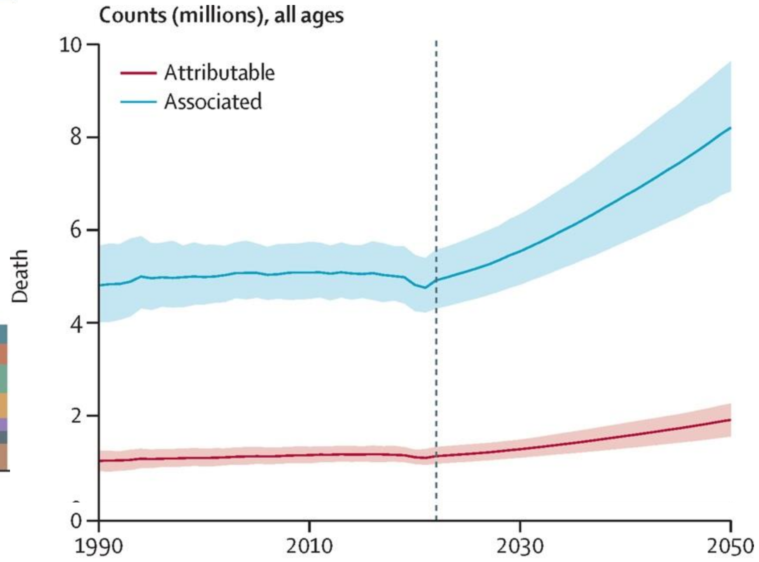
2021

1.14 million deaths attributable to AMR

Pathogen

- *Acinetobacter baumanni*
- *Escherichia coli*
- *Klebsiella pneumoniae*
- Other AMR bacteria
- *Pseudomonas aeruginosa*
- *Staphylococcus aureus*
- *Streptococcus pneumoniae*



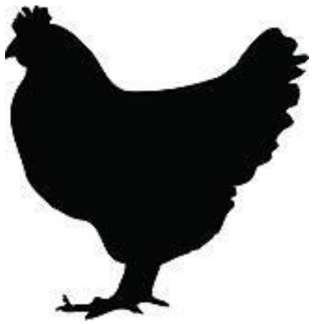


Naghavi et al (2024). The Lancet

Antimicrobial Resistance in Animals in Low- and Middle-Income Countries

135

Low- and middle-income countries (LMICs)



1

Surveillance System (public data)

Colombia

In the short term, we need an alternative data source...

Source: Samsara (2011)

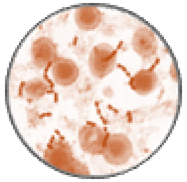
Point Prevalence Surveys (n=901)

Reshma Silvester

Bacteria

E. coli *S. aureus* *Campylobacter* *Salmonella*

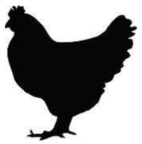


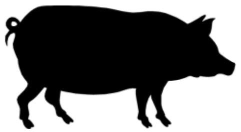



Cheng Zhao

Host

Chicken Cattle Pigs

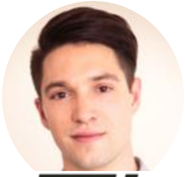




Julia Song

Drugs

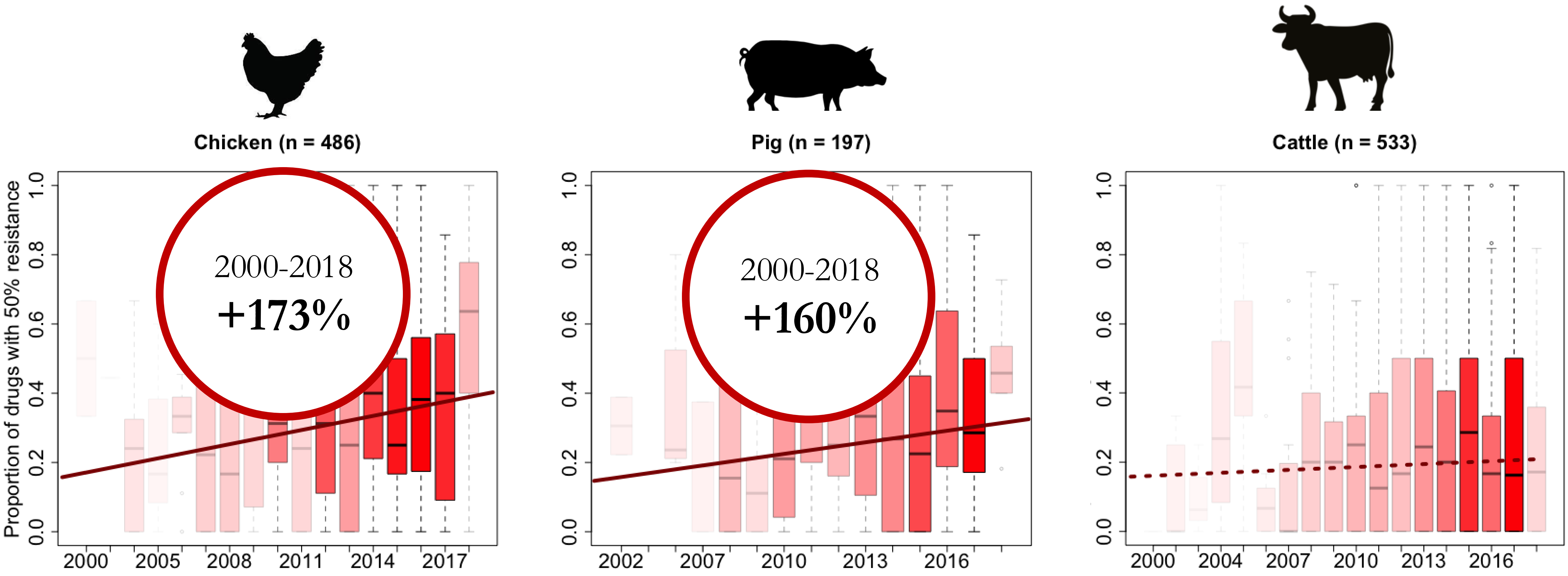
Drug/Pathogens recommended by AGISAR
WHO Advisory Group on Integrated
Surveillance of Antimicrobial Resistance



Joao Pires

Global trends in AMR in using point prevalence surveys

P50: proportion of antimicrobials tested in a survey with resistance prevalence higher than 50%



Science Van Boeckel & Pires et al. 2019. Global Trends in Antimicrobial Resistance in Animals in Low- and Middle-Income Countries.

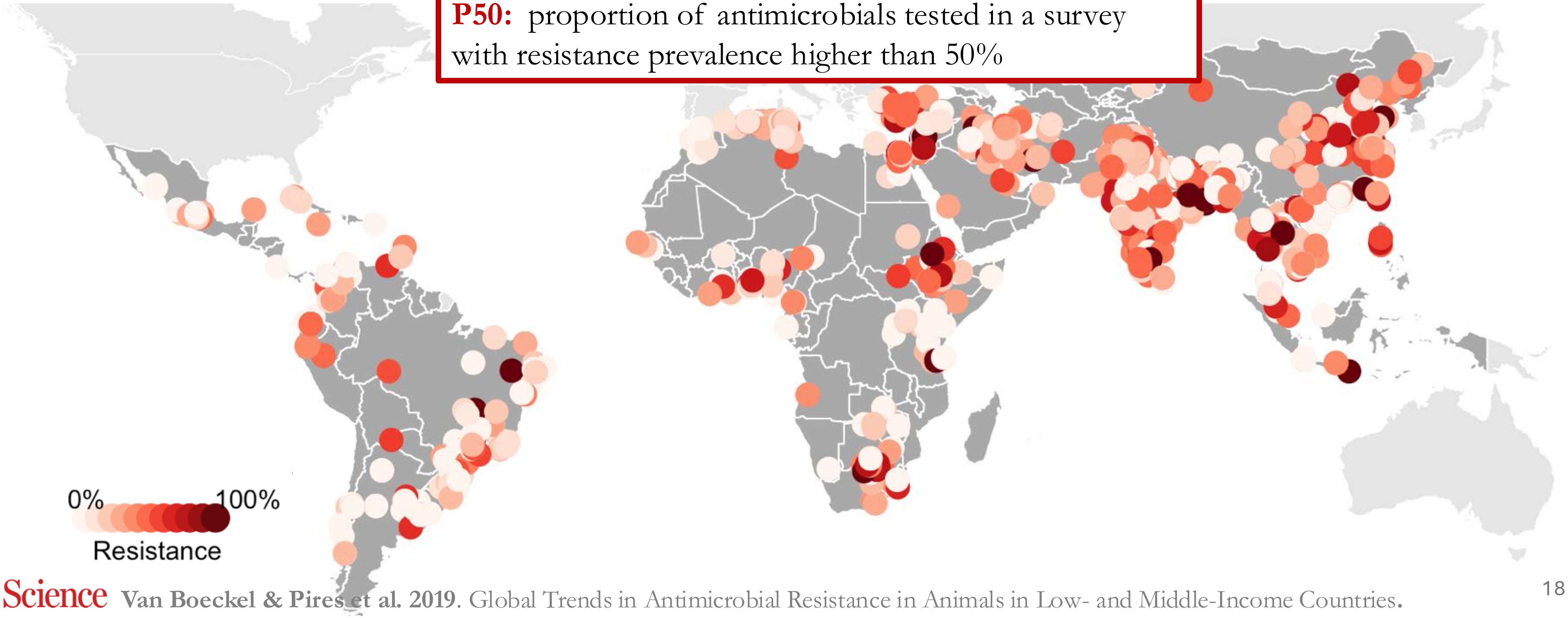
Point-Prevalence Surveys of AMR in Animals

Surveys
n = 901

resistance rates
n = 12,933

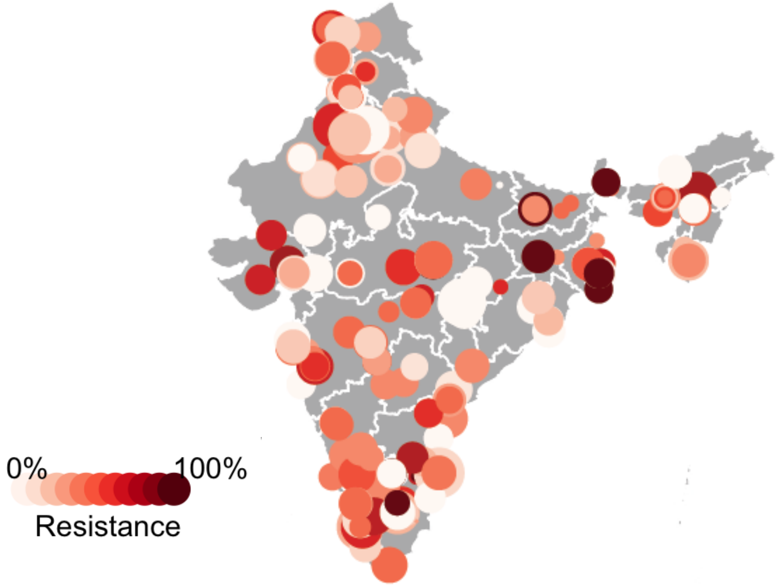
biological samples
n = 285,000

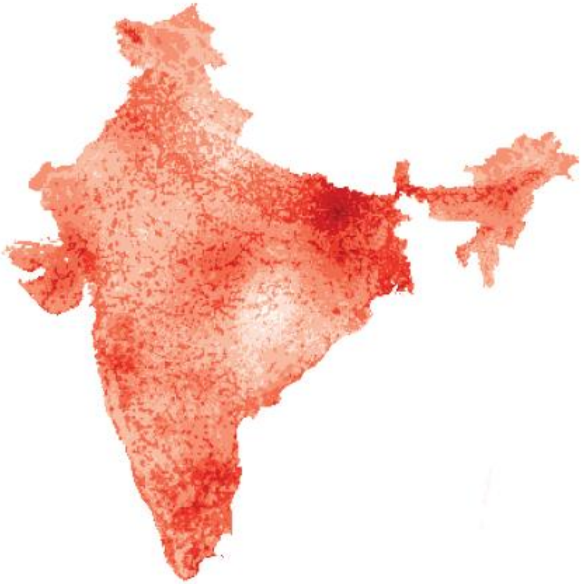
P50: proportion of antimicrobials tested in a survey with resistance prevalence higher than 50%



Science **Van Boeckel & Pires et al. 2019**. Global Trends in Antimicrobial Resistance in Animals in Low- and Middle-Income Countries.

Mapping hotspots of resistance in animals



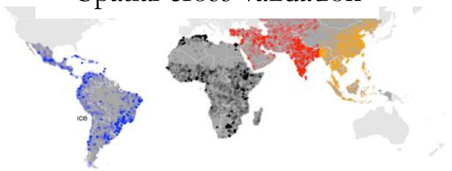


Resistance Here = **Resistance Nearby** + **Covariates (risk factors):** antimicrobial use, animal densities, temperature, travel time to cities,…

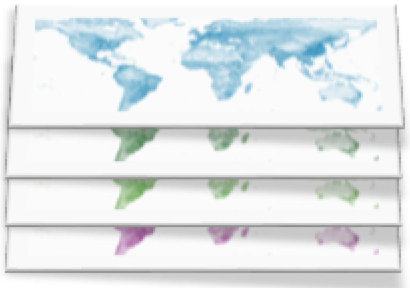
$$P_{50}(x_0, y_0). \quad = \quad \sum_{i=1}^{n} \lambda_i \cdot P_{50}(x_i, y_i) \quad + \quad \sum_{k=1}^{P} \beta_k \cdot Cov_k(x_0, y_0)$$

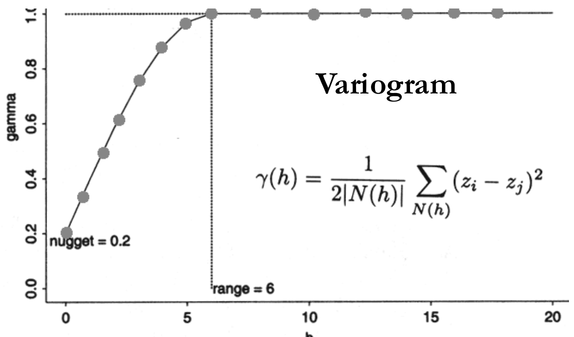
Step 2
Stacking with Universal Kriging

Spatial cross-validation



Covariates

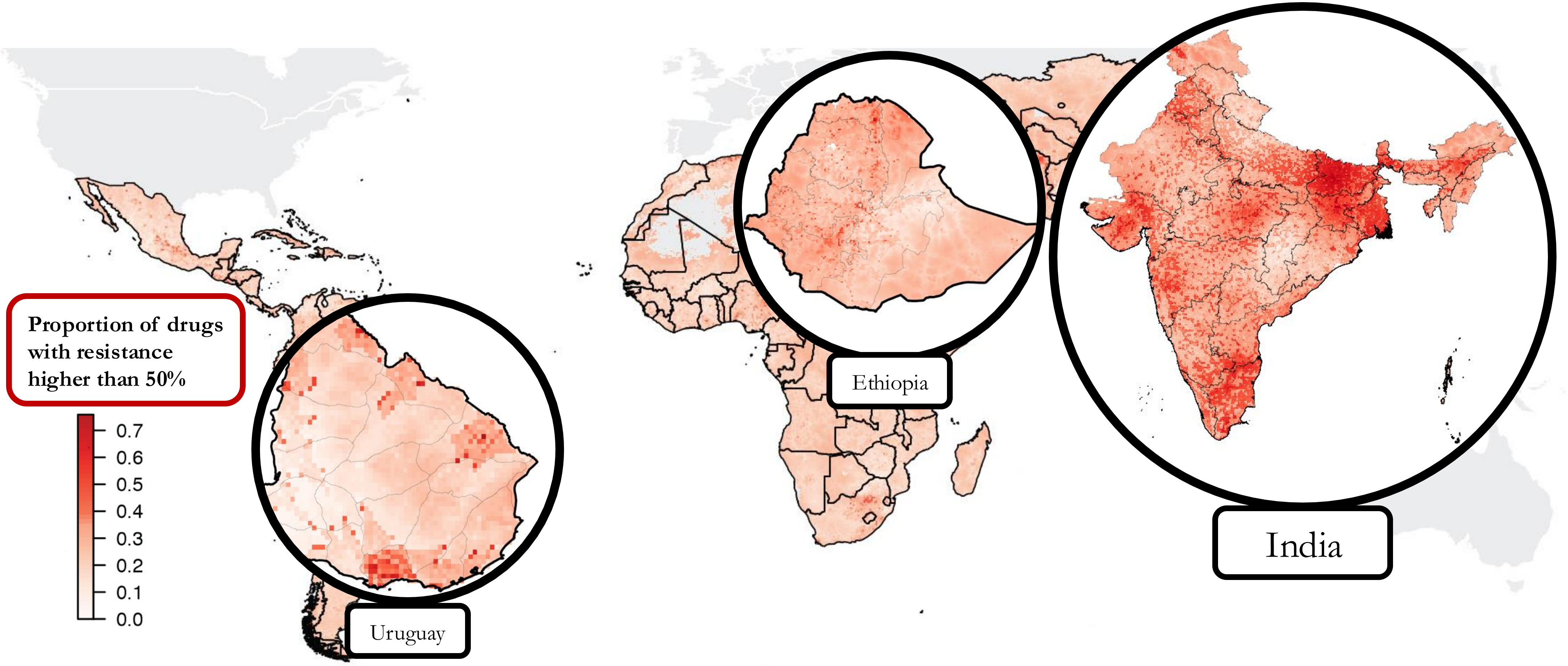




$Cov_1 = P_{Boosted\ Regression\ Trees}$
$Cov_2 = P_{Neural\ Networks}$
$Cov_3 = P_{LASSO\ Regression}$

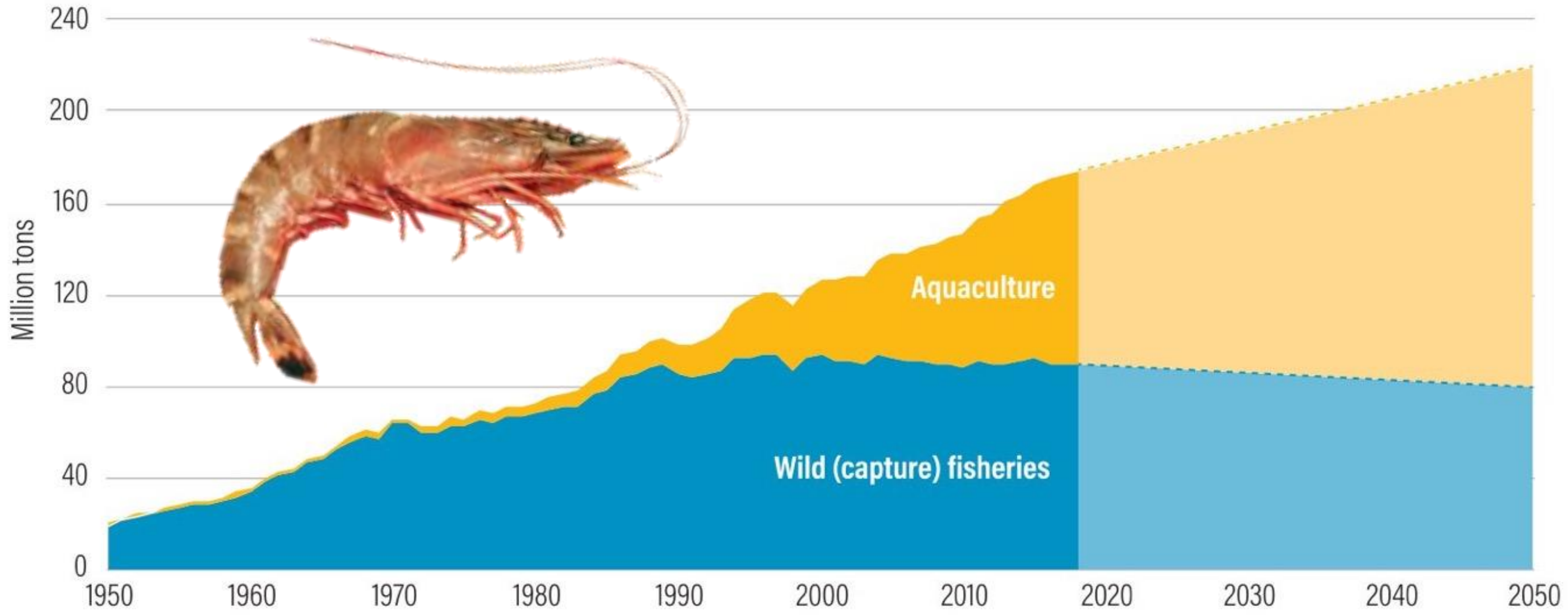
Step 1
trend models

Mapping hotspots of resistance in animals



Van Boeckel* & Pires*, *Science* 2019.

Aquaculture



Production volumes from cultured fish has overtaken wild fisheries, and is growing faster terrestrial livestock as a source of animals protein.

Source: FAO

Global trends in antimicrobial use in Aquaculture

Vaccinating salmon: How Norway avoids antibiotics in fish farming

October 2015 World Health Organization

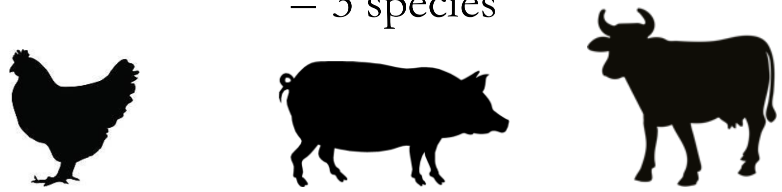
Norway has cut antibiotic use in salmon—one of the principal foods consumed in the country and a major export—to virtually zero. This has led to a flourishing industry and a reduction in the risk of antibiotic resistance in humans.

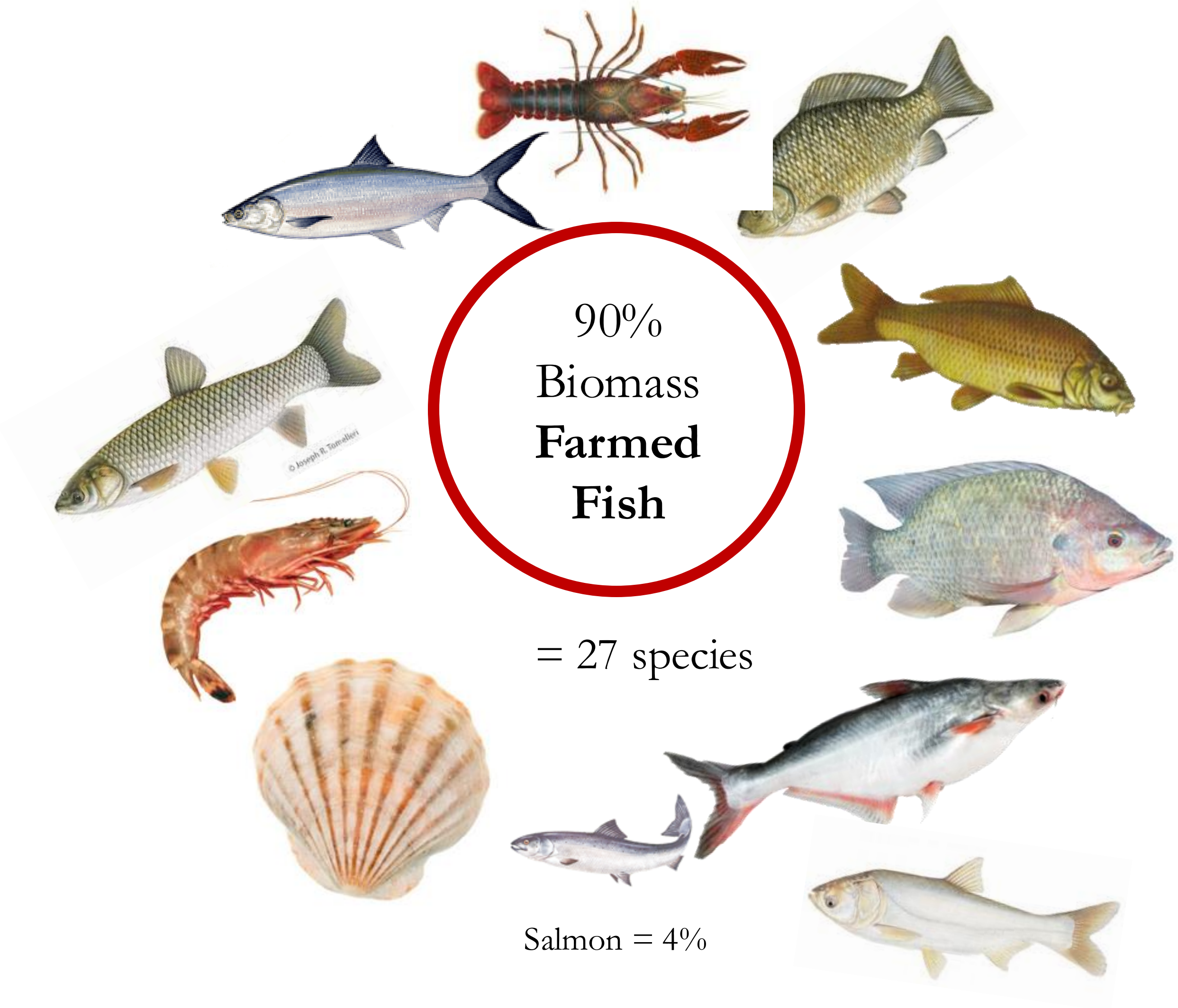
Aeromonas salmonicida
furunculosis

Terrestrial Animals vs Aquaculture

90%
Biomass
Livestock

= 3 species





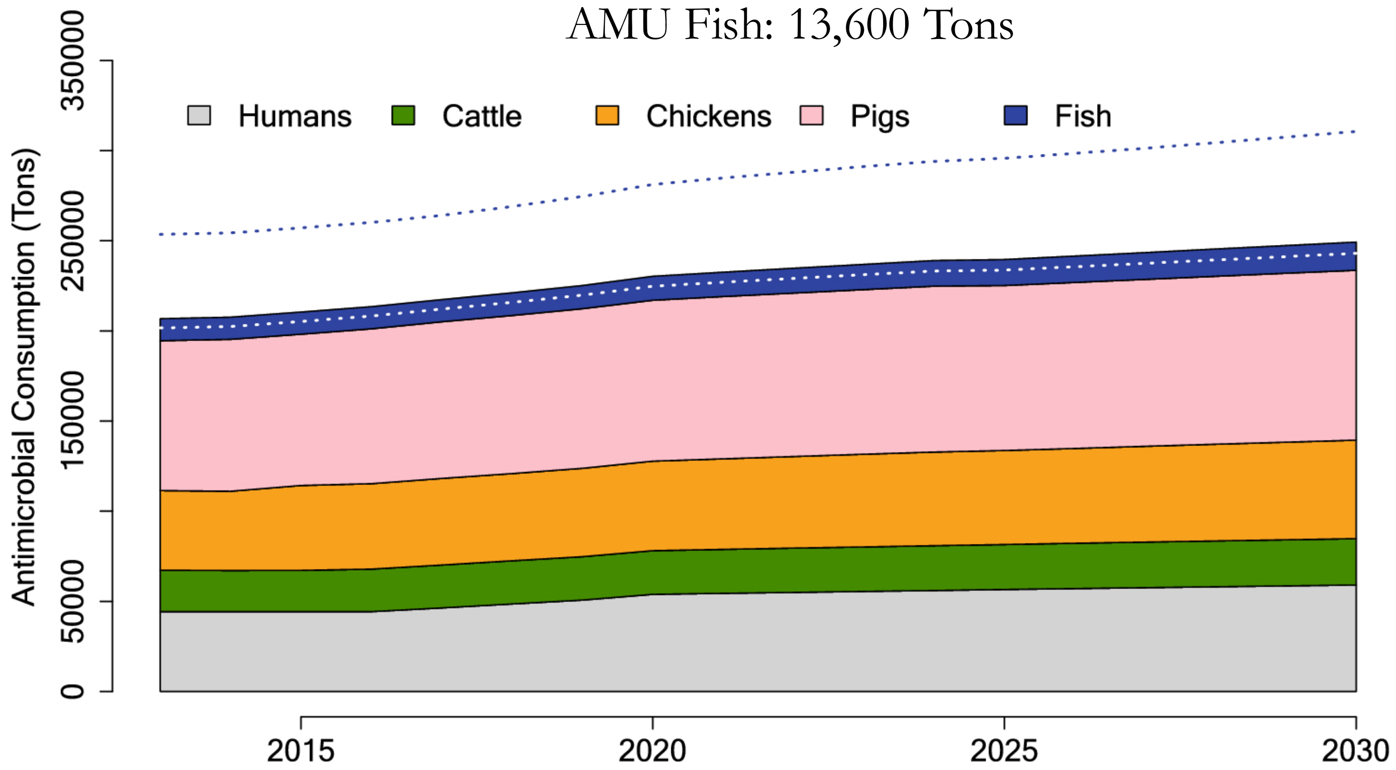
90%
Biomass
Farmed Fish

= 27 species

Salmon = 4%

Aquaculture – Antimicrobial Use

AMU Fish: 13,600 Tons



"We know that we know very little"

Dan Schar

146 Surveys

2 surveys

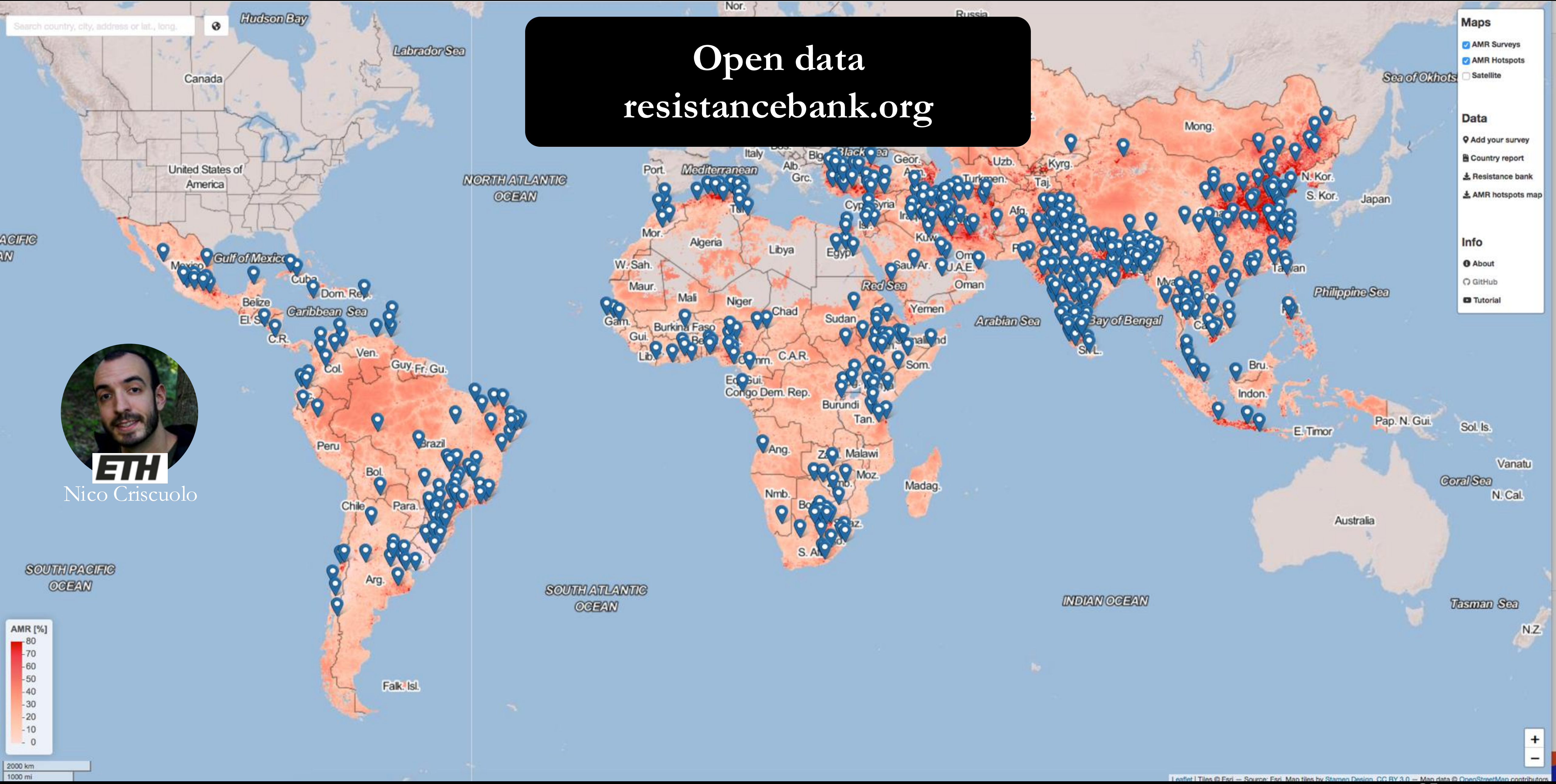
Most commonly farmed fish in the world (China)

Grass Carp
Ctenopharyngodon idella

Silver Carp
Hypophthalmichthys molitrix

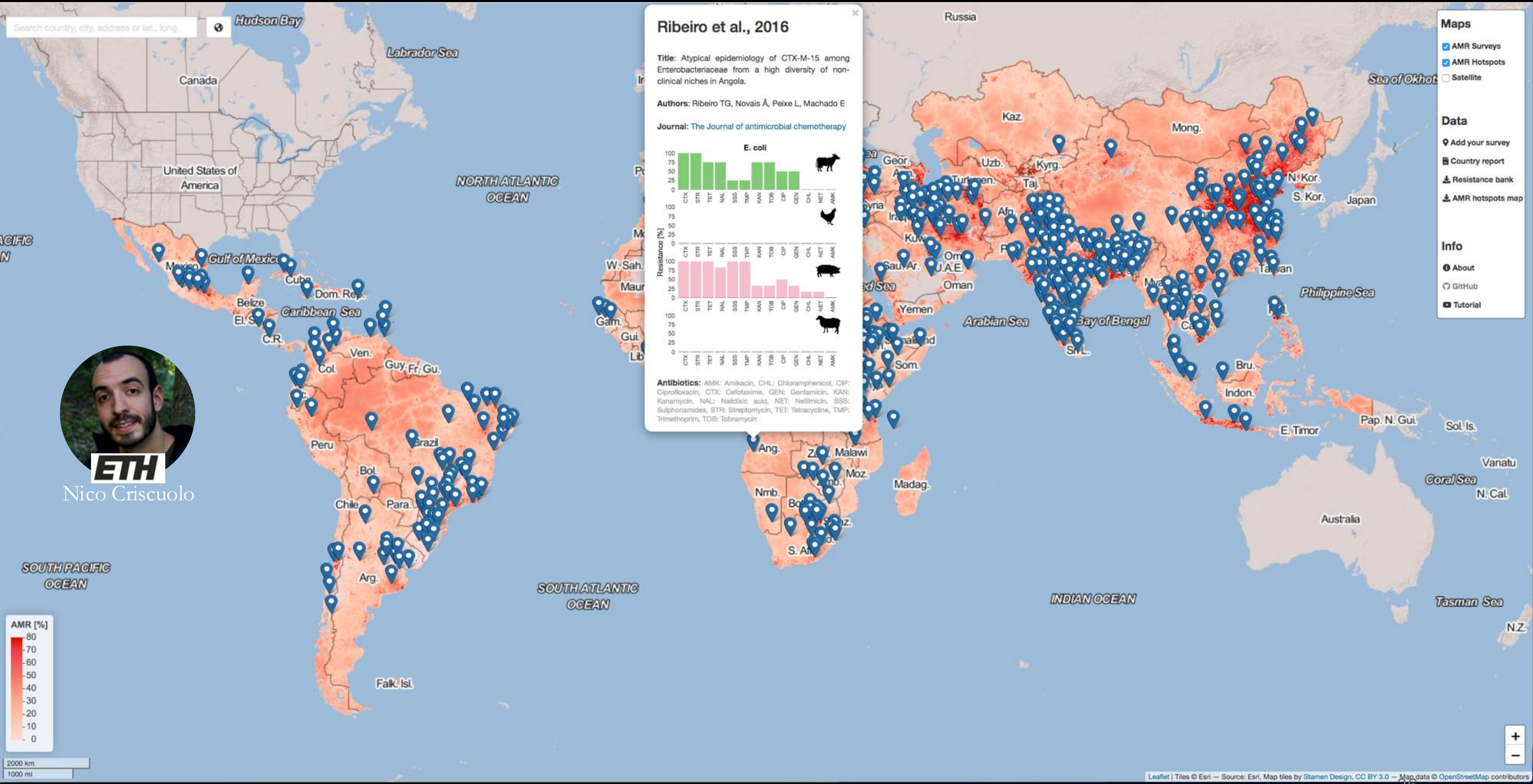
Schar, **Van Boeckel et al 2020**, Global trends in antimicrobial use in aquaculture. **Scientific Reports**

Open data
resistancebank.org



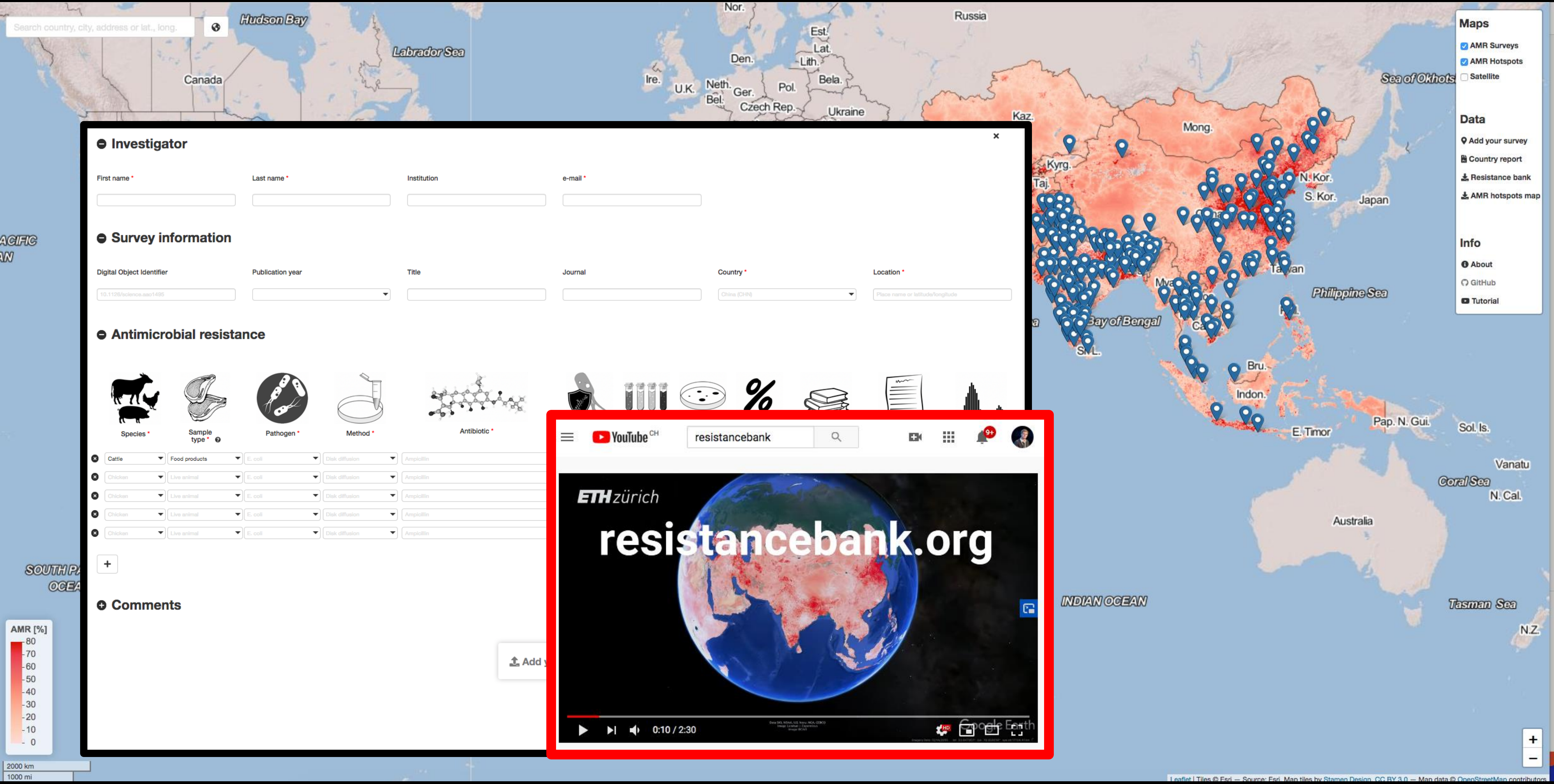
ETH
Nico Criscuolo

Criscuolo, Van Boeckel et al. Scientific Data 2021. resistancebank.org, an open-access repository for surveys of antimicrobial resistance in animals



Nico Criscuolo

Criscuolo, Van Boeckel et al. Scientific Data 2021. resistancebank.org, an open-access repository for surveys of antimicrobial resistance in animals



Maps
AMR Surveys
AMR Hotspots
Satellite
Data
Add your survey
Country report
Resistance bank
AMR hotspots map
Info
About
GitHub
Tutorial
Investigator
First name *
Last name *
Institution
e-mail *
Survey information
Digital Object Identifier
Publication year
Title
Journal
Country *
Location *
Antimicrobial resistance
Species *
Sample type *
Pathogen *
Method *
Antibiotic *
Cattle
Food products
Comments
AMR [%]
80
70
60
50
40
30
20
10
0
resistancebank
ETH zürich
resistancebank.org
0:10 / 2:30

Take Home Messages

In high-income countries, antimicrobial stewardship campaigns have had positive, long-lasting effects on antimicrobial use in humans. However, **ageing populations** pose new challenges to further reductions in resistance.

Low- and middle-income countries (LMICs) account for a disproportionate share of the **global AMR burden**, although data quality remains insufficient to fully document these trends. **Over-the-counter** antimicrobial use, limited access to hygiene, sanitation, doctors likely contribute to **inappropriate use** and rising resistance.

In animals, **high-income countries**—including Belgium—have achieved **substantial reductions in veterinary antibiotic** use; however, globally these gains remain **modest.** In contrast, AMR **levels in animals are rising** in **LMICs**, under growing global demand for animal products. During the last high-level UN General Assembly meeting on AMR, **no consensus** could be reached on setting global reduction **targets for veterinary antimicrobial** use