New tools for emerging foodborne pathogens

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Te Kunenga ki Pūrehuroa
MASSEY UNIVERSITY

New Zealand
FOOD SAFETY SCIENCE & RESEARCH CENTRE

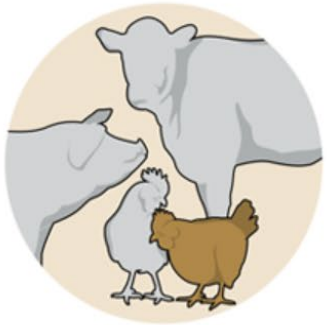
Te Niwha

Emerging Foodborne Risks

How and why pathogens emerge

The population becomes **more susceptible** to an existing pathogen, and more people fall ill.

An existing pathogen acquires **new traits** and becomes a greater threat to public health.



A pathogen suddenly appears in a **new host**—a pathogen that infected one species now infects a new species.

A pathogen emerges in a **new geographic region** that is not equipped to deal with it.

Prediction, detection, leadership and oversight

https://www.pew.org/en/research-and-analysis/data-visualizations/2016/emerging-foodborne-risks

Old foes remerging: *Listeria monocytogenes*

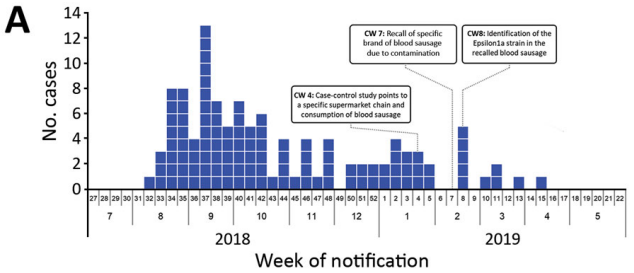
RESEARCH

Large Nationwide Outbreak of Invasive Listeriosis Associated with Blood Sausage, Germany, 2018–2019

Sven Halbedel,[1] Hendrik Wilking,[1] Alexandra Holzer, Sylvia Kleta, Martin A. Fischer, Stefanie Lüth, Ariane Pietzka, Steliana Huhulescu, Raskit Lachmann, Amrei Krings, Werner Ruppitsch, Alexandre Leclercq, Rolf Kamphausen, Maylin Meincke, Christiane Wagner-Wiening, Matthias Contzen, Iris Barbara Kraemer, Sascha Al Dahouk, Franz Allerberger, Klaus Stark,[2] Antje Flieger[2]

The outbreak was the largest identified outbreak of listeriosis in Germany and one of the largest reported in Europe during the past 25 years

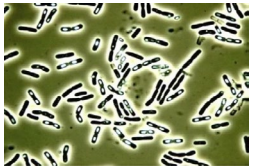
Halbedel et al., 2020



Emergence of more virulent strains of *Bacillus cereus*

frontiers in Microbiology

REVIEW
published: 19 August 2020
doi: 10.3389/fmicb.2020.01731

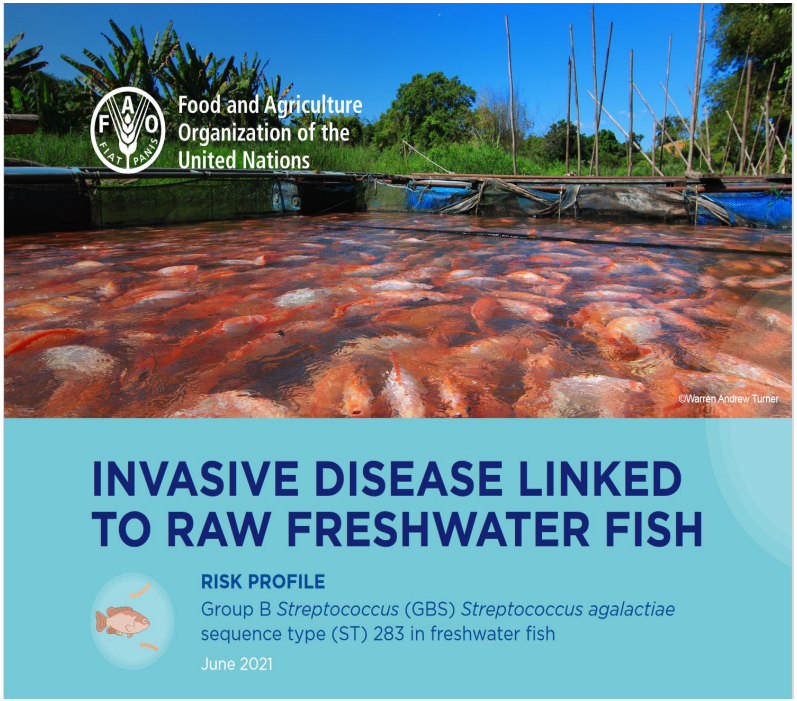


You Can't *B. cereus* – A Review of *Bacillus cereus* Strains That Cause Anthrax-Like Disease

*Victoria M. Baldwin**

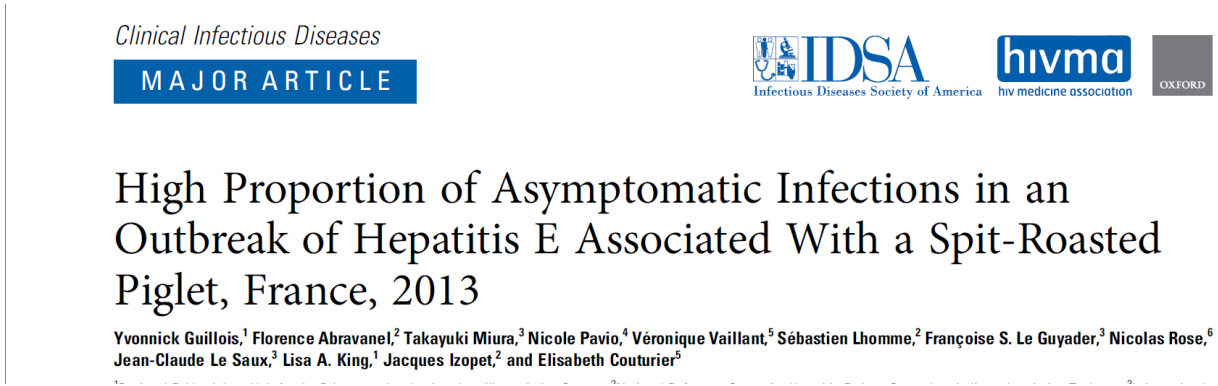
Emerging B. cereus strains, traditionally considered foodborne pathogens that establish occasional opportunistic infections, have naturally evolved to cause fatal anthrax-like disease.

A “new” food safety problem: Group B *Streptococcus*



Emerging and reemerging viruses: Hepatitis E virus

- Estimated ~20.1 million infections globally
- ~3.4 million symptomatic cases



Clinical Infectious Diseases

MAJOR ARTICLE

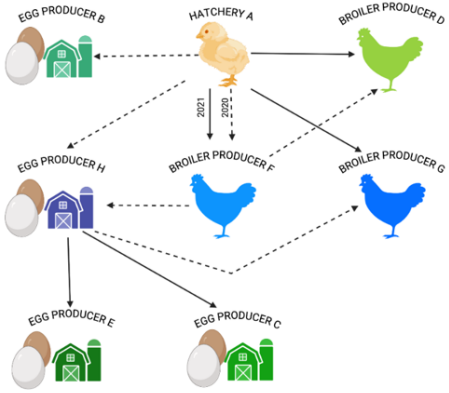
IDSA Infectious Diseases Society of America · hivma hiv medicine association · OXFORD

High Proportion of Asymptomatic Infections in an Outbreak of Hepatitis E Associated With a Spit-Roasted Piglet, France, 2013

Yvonnick Guillois,[1] Florence Abravanel,[2] Takayuki Miura,[3] Nicole Pavio,[4] Véronique Vaillant,[5] Sébastien Lhomme,[2] Françoise S. Le Guyader,[3] Nicolas Rose,[6] Jean-Claude Le Saux,[3] Lisa A. King,[1] Jacques Izopet,[2] and Elisabeth Couturier[5]

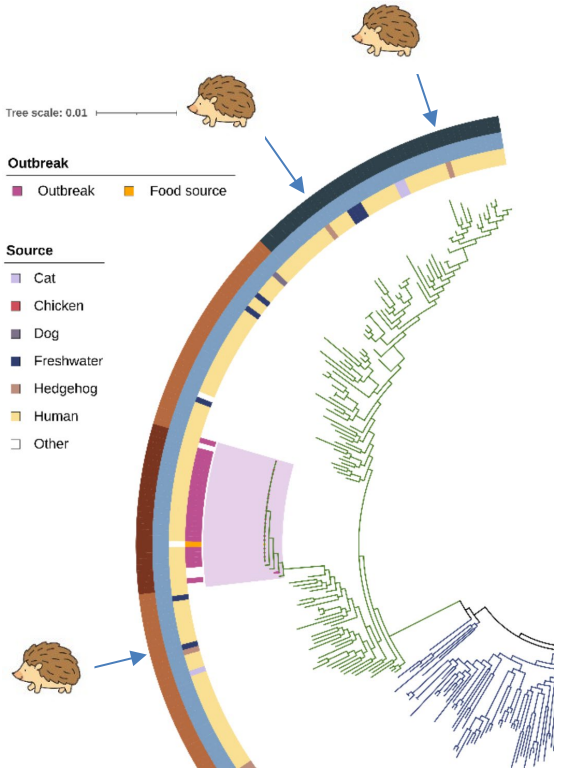
Salmonella enterica Enteritidis in New Zealand: the recent ST11 outbreak

- Strain of sequence type 11 – common international ST
- Outbreak in Auckland restaurant in 2019 (38 cases, 17 confirmed)
- National Micro Database detection Feb 2021 (raw poultry meat)
- Detection in breeder flocks (broilers and layers)



Salmonella Enteritidis ST183 cause of SI 'sproutbreak' in 2021

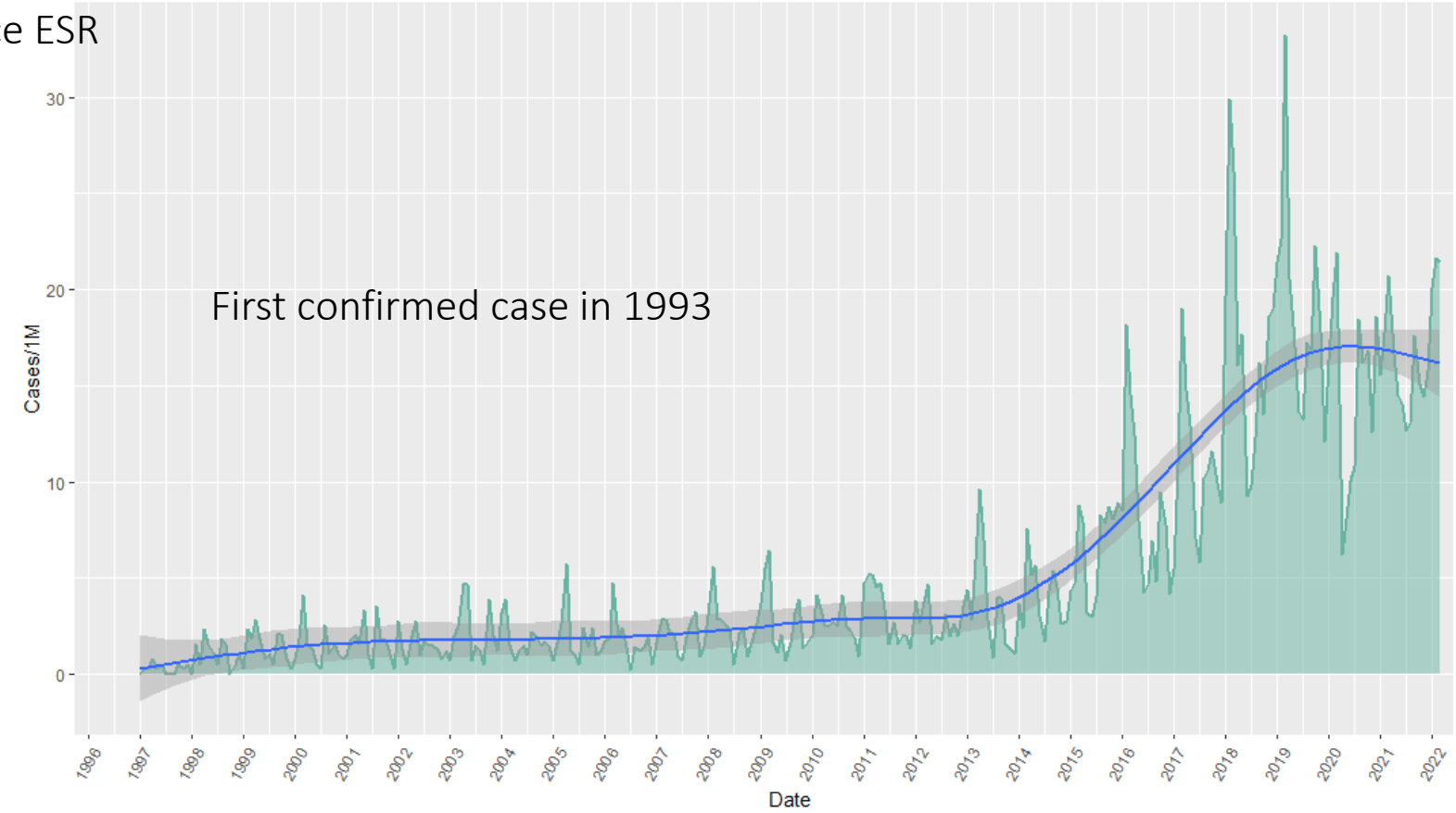
PHU	Report Month	Suspected source	Evidence	Setting	No. III	Serotype[a]
South Island PHUs	January	Packaged alfalfa and radish sprouts	WGS of case isolates matching those from opened sprout samples from a cases home/ elevated odds ratio for eating sprouts	Home or restaurant/ café/bakery	28C	*S.* Enteritidis ST183



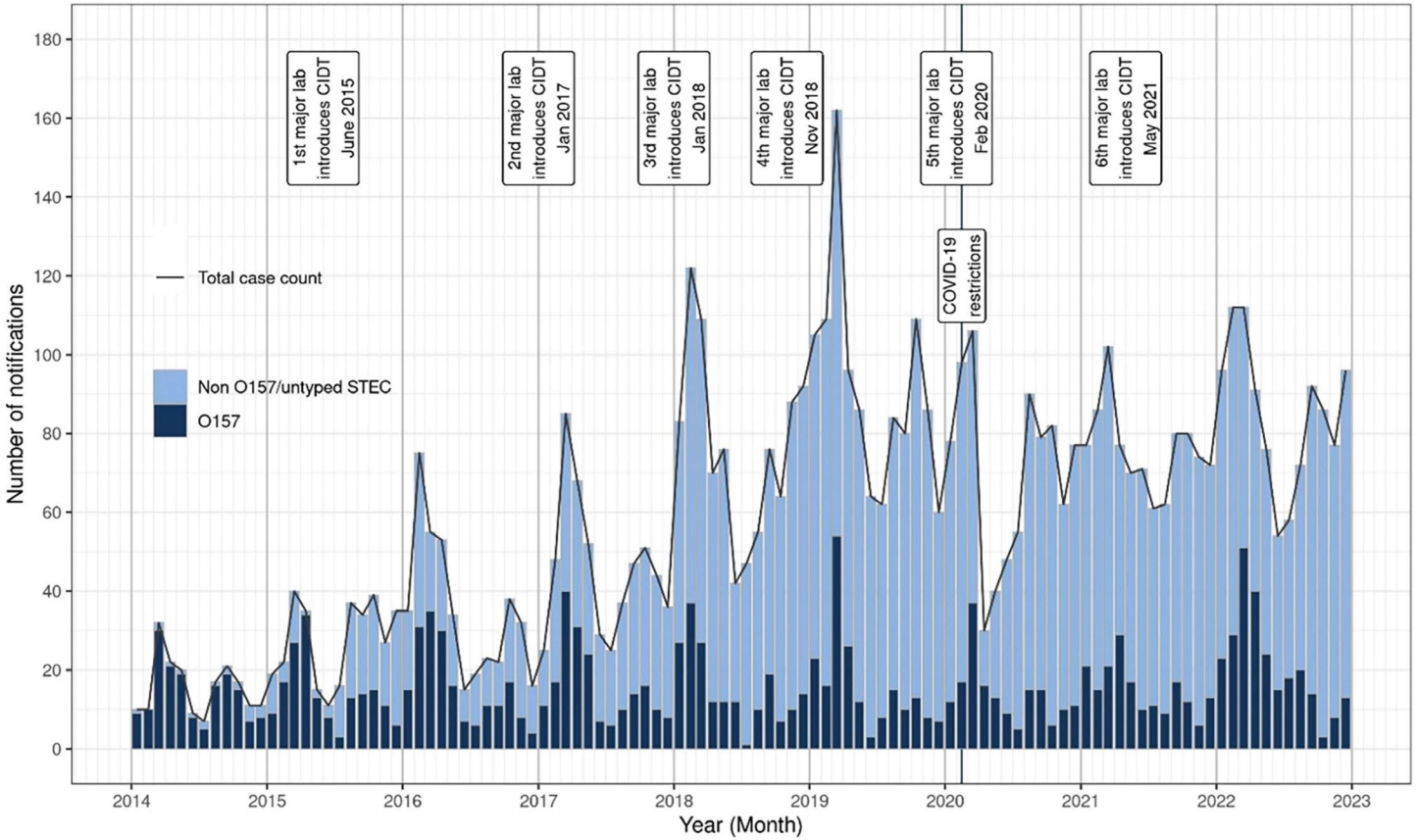
Strydom et al, submitted

Toxigenic *E. coli* in New Zealand: 1997-2022

Source ESR

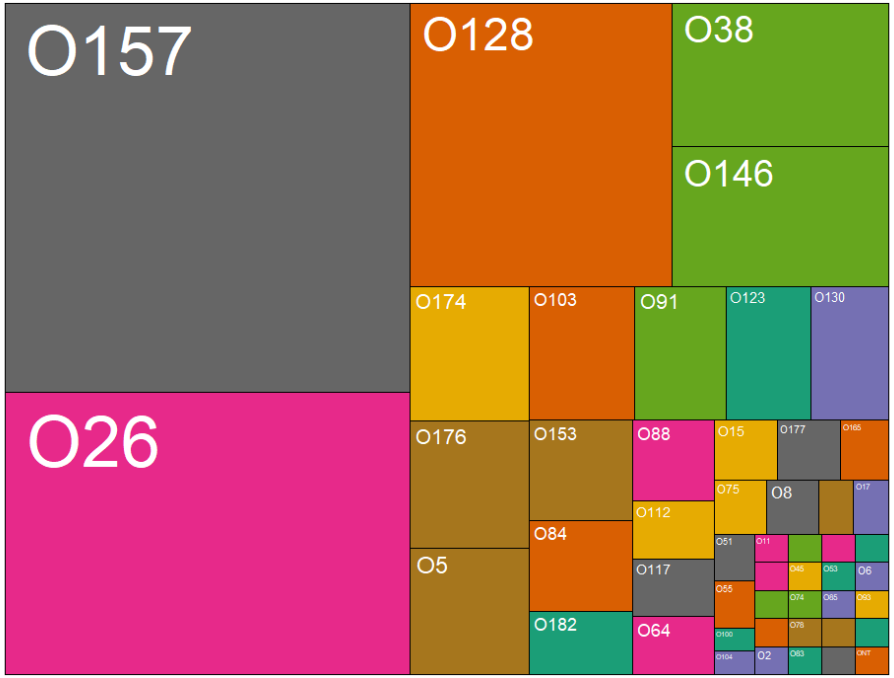


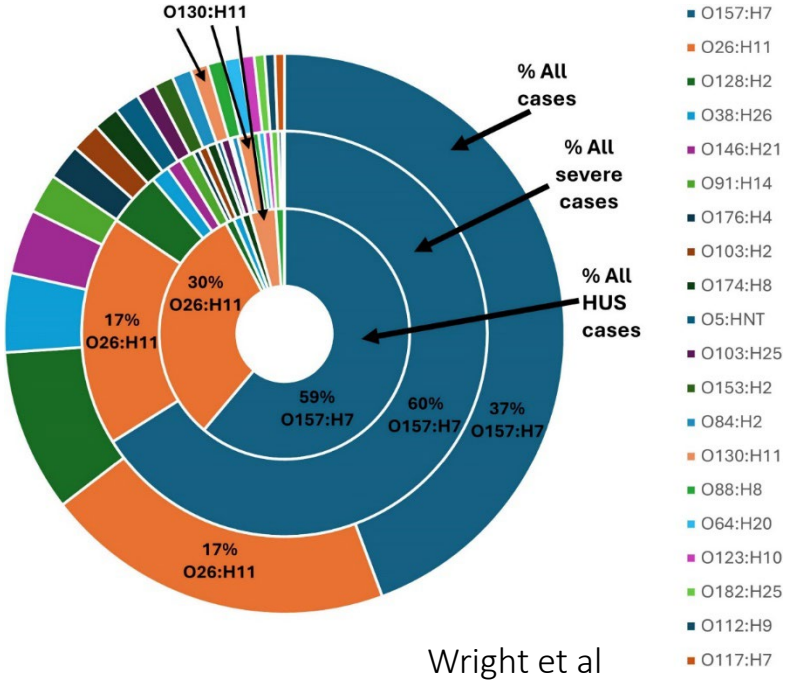
Trends in toxigenic *E. coli* in New Zealand: 1997-2022



Wright et al 2025 *Front Microbiol*

Serotypes in human cases in 2020

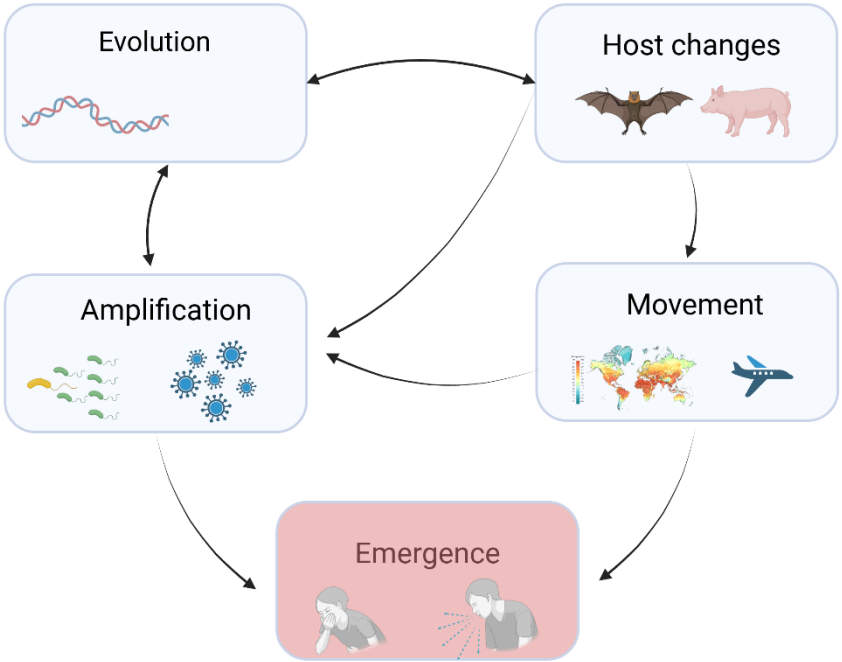




Data source: ESR Public Health Surveillance
https://surv.esr.cri.nz/enteric_reference/vtec_isolates.php?we_objectID=5148

Wright et al 2025 *Front Microbiol*

Events/processes that lead to emergence of a new infectious agent



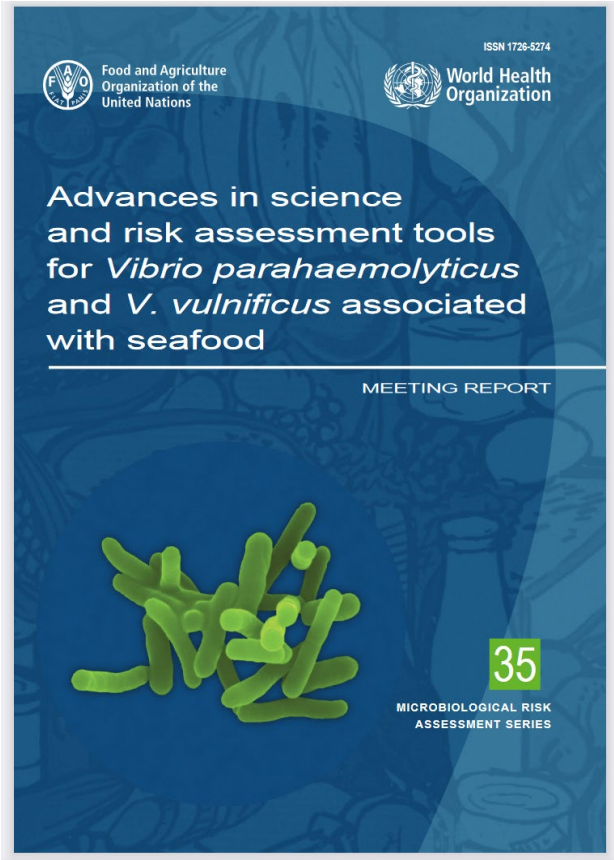
Bhilegaonkar, French et al ICMSF, in prep

New Variant of *Vibrio parahaemolyticus*, Sequence Type 3, Serotype O10:K4, China, 2020

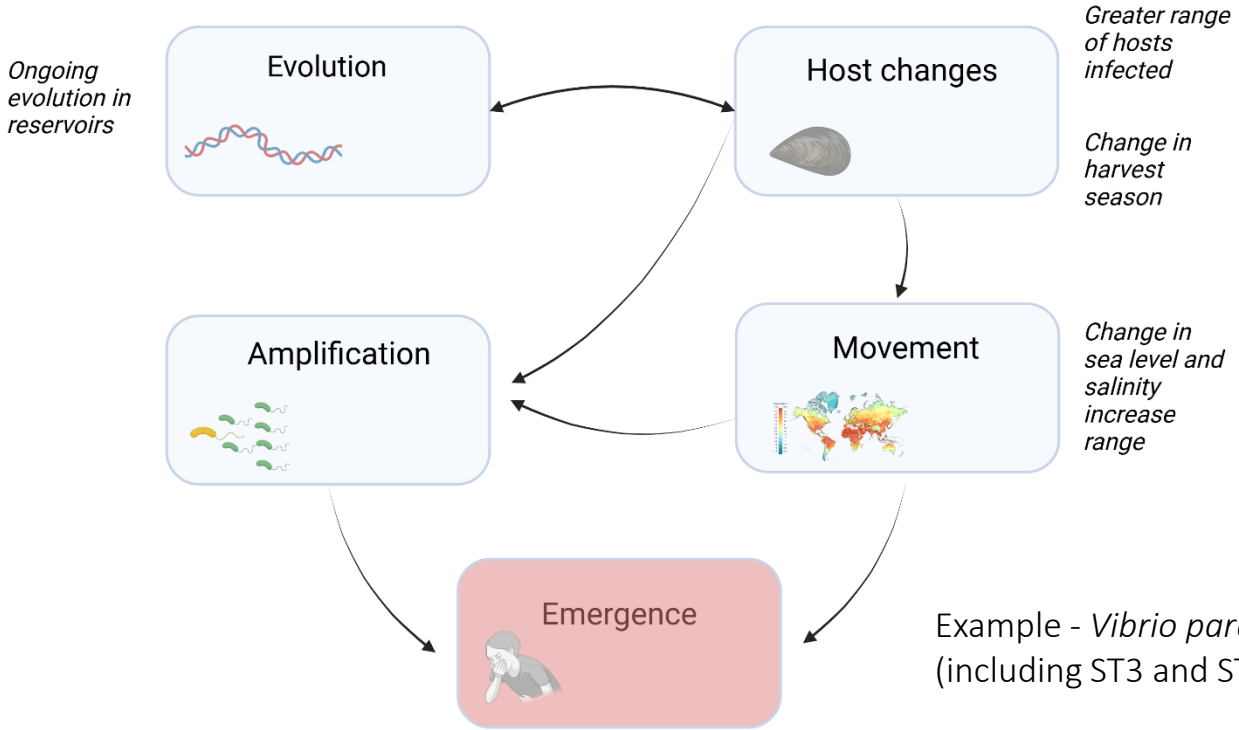
Yan Huang,[1] Yue Du,[1] Hong Wang,[1] Dongmei Tan, Airong Su, Xiugui Li, Biao Kan, Lan Lan, Cong Qu, Bo Pang,[2] Yunliang Shi,[2] Mei Lin[2]

- ST 43 and ST 636 also emerging
- New and highly pathogenic strains emerged with significantly lower ID_{50}

Emerging Infectious Diseases; 28, 2022



Events/processes that lead to emergence of a new infectious agent



Example - *Vibrio parahaemolyticus* (including ST3 and ST36)

“New” tools:
Genome sequencing and meta-omics

- Now established as valuable tools for food safety
- Many applications
  - Diagnostics
  - Source attribution and source tracking
  - Resistance profiling
  - Within plant transmission (resident strains)

nature reviews microbiology
https://doi.org/10.1038/s41579-024-01051-z

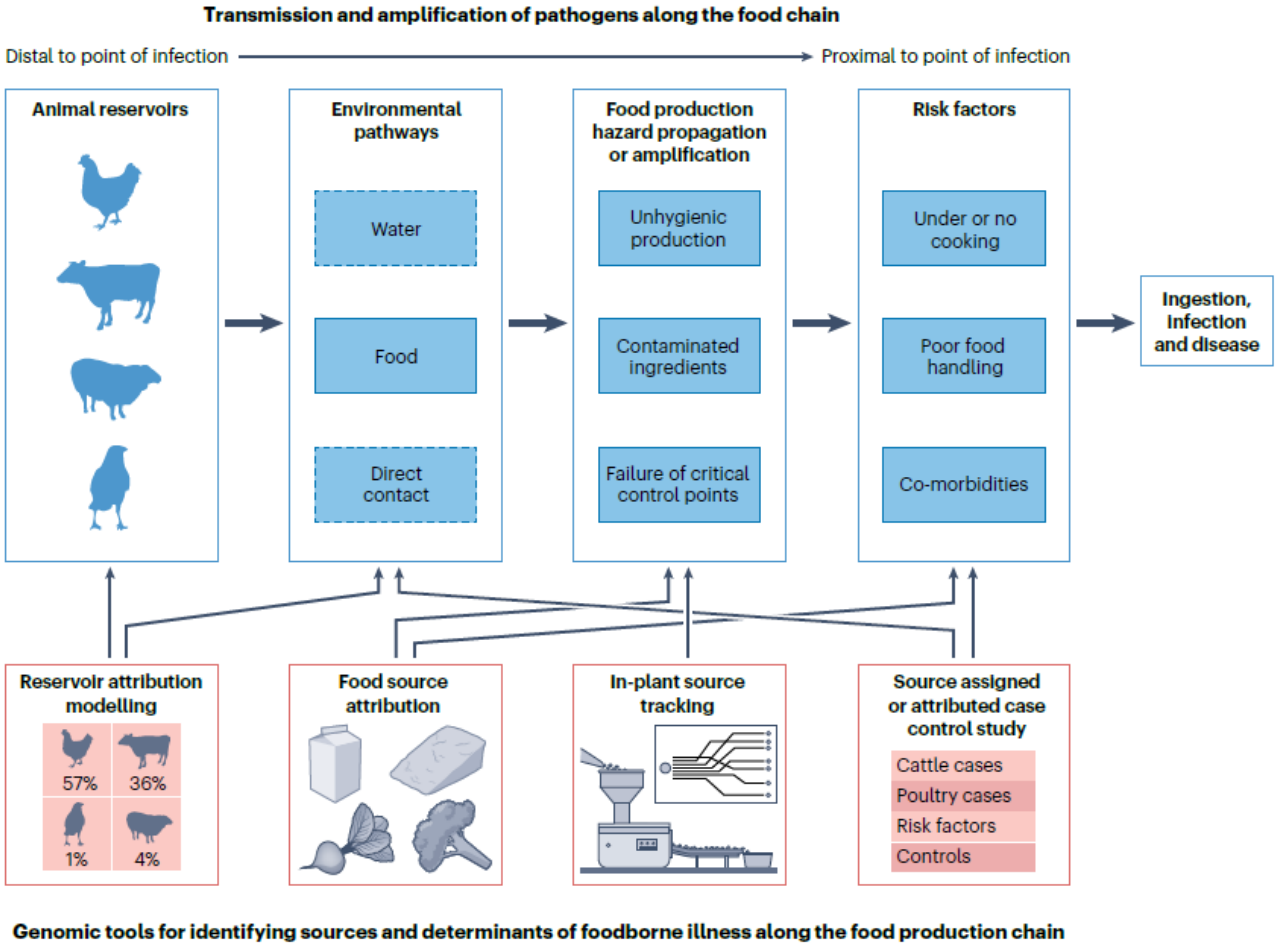
Review article
Check for updates

Foodborne bacterial pathogens: genome-based approaches for enduring and emerging threats in a complex and changing world

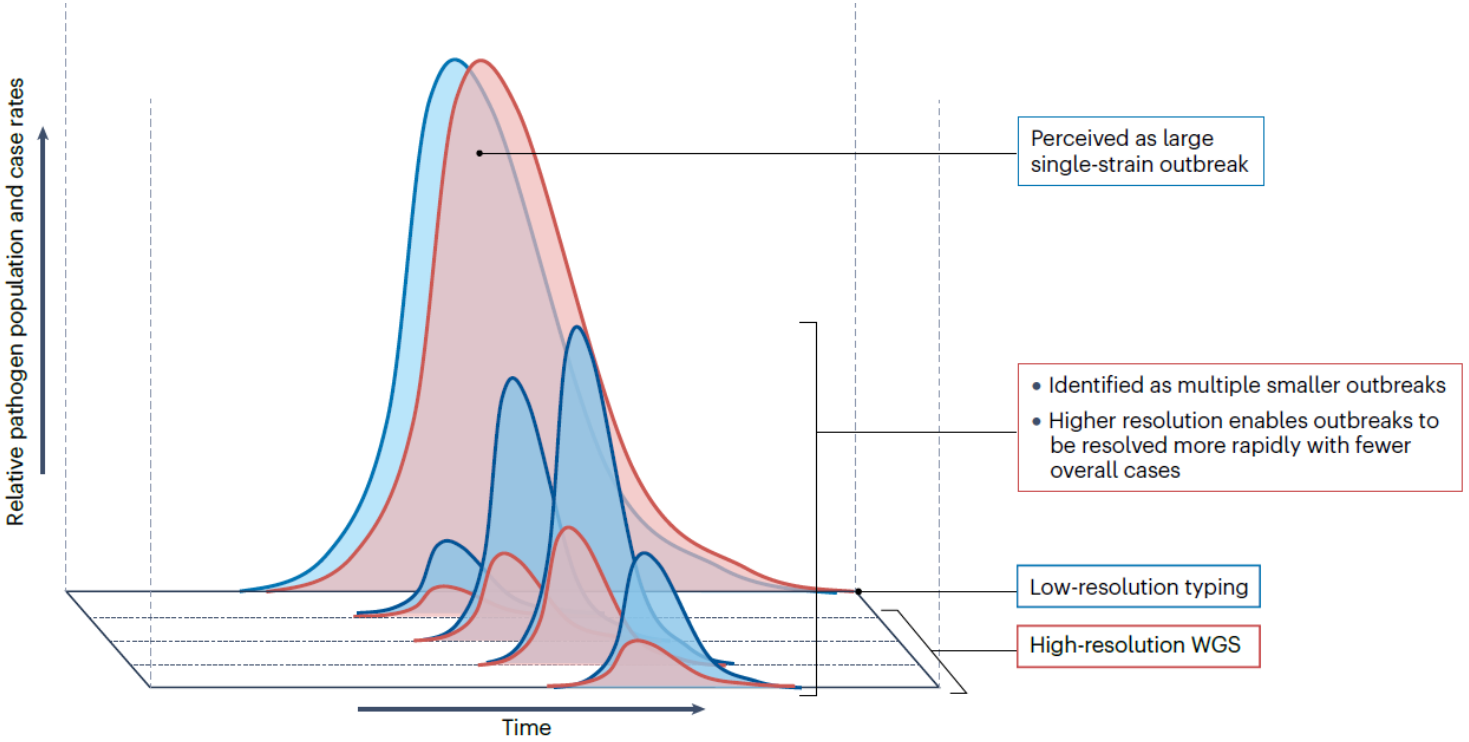
Alison E. Mather[1,2], Matthew W. Gilmour[1,2], Stuart W. J. Reid[3] & Nigel P. French[4]

Source tracking/attribution framework

Mather, Gilmour, Reid, French 2024
Nature Reviews Microbiology



Whole Genome Sequencing and outbreak investigation



Mather, Gilmour, Reid and French, 2024. *Nature Reviews Microbiology*

Recent application of WGS in NZ

MICROBIAL GENOMICS

RESEARCH ARTICLE

Strydom *et al.*, *Microbial Genomics* 2025;11:001525

DOI 10.1099/mgen.0.001525

MICROBIOLOGY SOCIETY

OPEN DATA OPEN ACCESS

Temporal reconstruction of a *Salmonella* Enteritidis ST11 outbreak in New Zealand

Hugo Strydom[1,2,*], Jackie Wright[3], Collette Bromhead[4], David Welch[5], Ernest Williams[1], Kerry Mulqueen[6], Joep de Ligt[7], Patrick J. Biggs[2,8,9], Shevaun Paine[10], Sarah Jefferies[10] and Nigel French[2,9]

Non-culture based detection

Journal of Food Protection, Vol. 85, No. 3, 2022, Pages 448–464
https://doi.org/10.4315/JFP-21-301

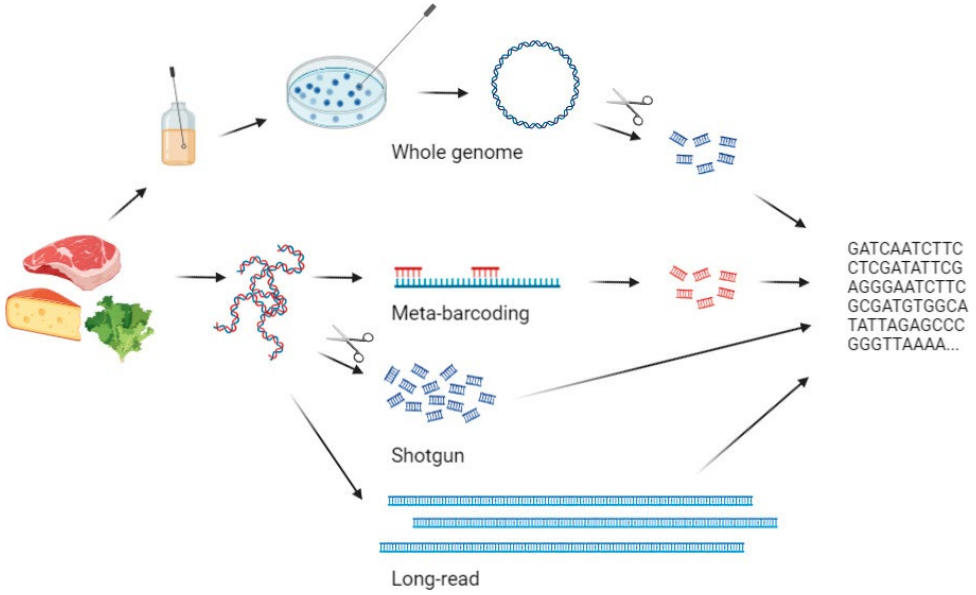
Review

Metagenomics Approaches for Improving Food Safety: A Review

CRAIG BILLINGTON *https://orcid.org/0000-0003-3433-4220*,* JOANNE M. KINGSBURY *https://orcid.org/0000-0002-5939-7255*, AND
LUCIA RIVAS *https://orcid.org/0000-0001-9666-495X*

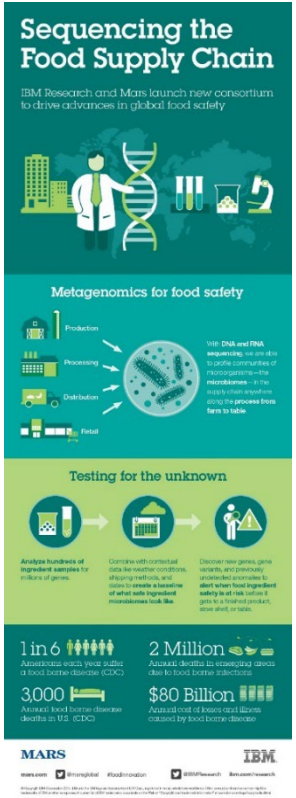
Metagenomics and food safety

- “Metagenomics is part of the next disruptive revolution in food safety diagnostics.”
- “Entire microbiomes of foods, ingredients, or environmental samples can be identified.”
- Whole metagenome sequencing



Billington et al 2022 JFP

Meta-omics initiatives: microbiome of food chain



Environmental microbiomes roadmap

APPROVED: 30 Jan 2024
doi: 10.2903/sp.efsa.2024.EN-8602

Roadmap for the integration of environmental microbiomes in risk assessments under EFSA's remit

Frédéric Debode[1], Simon Caulier[2], Sébastien Demeter[2], Benjamin Dubois[1], Vanessa Gelhay[1], Julie Hulin[1], Yordan Muhovski[1], Véronique Ninane[1], Gilles Rousseau[1], and Claude Bragard[2]

1) Walloon Agricultural Research Centre (CRA–W), Gembloux, Belgium
2) Université catholique de Louvain (UCLouvain), Louvain–La–Neuve, Belgium

Meta-omic applications: metagenomics

Billington et al 2022 JFP

TABLE 1. *Comparison of different meta-omic technologies*

Approach	Potential application to improve food safety	Example of application
Metagenomics	• Measures changes in microbial population structure over time and in response to stimuli • Culture independent, reducing bias and saving time • Can identify emerging or previously unknown risks	Routine monitoring of raw ingredient microbiome can reveal changes in numbers and types of microorganisms present that alert the processor to potential changes in product safety or quality risk profiles, triggering investigation and remediation actions

Can assemble whole genomes from metagenomic data (MAGs)

Meta-omic applications: metatranscriptomics

TABLE 1. *Comparison of different meta-omic technologies*

Approach	Potential application to improve food safety	Example of application
Metatranscriptomics	• Shows which organisms are alive and metabolically active • Can measure changes in gene expression in response to stimuli • Understanding transcriptional regulation informs opportunities for new interventions	An understanding of changes in gene expression when enteric pathogens colonize produce or of pathogen responses to different food cooling regimes informs improvements in food chain management

Billington et al 2022 JFP

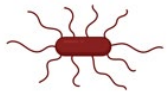
Benefits and hurdles

Billington et al 2022 JFP

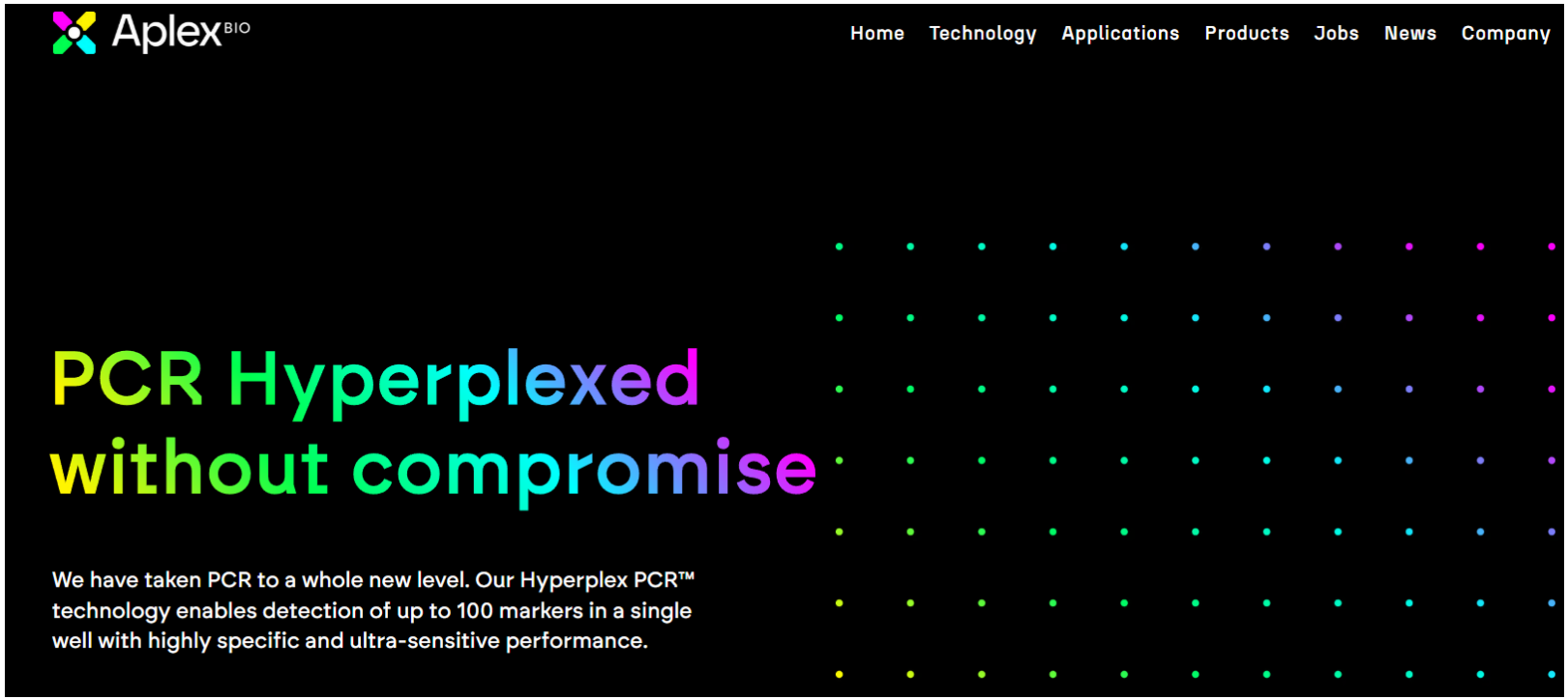
TABLE 5. *Risks and associated benefits and hurdles for the introduction of metagenomics to improve food safety*

Risk	Benefits	Hurdles
Discovery of new pathogens	Enables better attribution and management of foodborne disease	Adds to the portfolio of pathogens to be assessed and managed for risk; identification of matching sequences based on extant WGS data, which potentially biases risk assessments for newly described pathogens
Cost of instrumental analysis per sample is higher	Detects multiple species in one test; technology is advancing rapidly, with costs expected to decrease	Cost of bioinformatics will exceed that of raw data generation
Lack of bioinformatics expertise in both industry and regulators	Automation of data analysis and customizable reporting facilitating interpretation of results	Requires retraining and/or recruitment, infrastructure investment, and development of easy-to-use reporting tools
Lack of standard methods	Standardization of methods and automation leads to greater comparability and reliability of results	Requires government and industry champions to propose and set standards
Open data	Increased ability to share data brings improvements in food safety nationally and internationally	Increased data storage costs; privacy and data stewardship, ownership, and liability; data security
Cannot distinguish live from dead organisms	Presence of organism's genetic material indicates a potential safety or quality failure that can be acted upon earlier than possible with traditional techniques	May not be able to determine whether an organism is alive or dead at the sampling point or time, which is important for some applications (e.g., monitoring interventions)

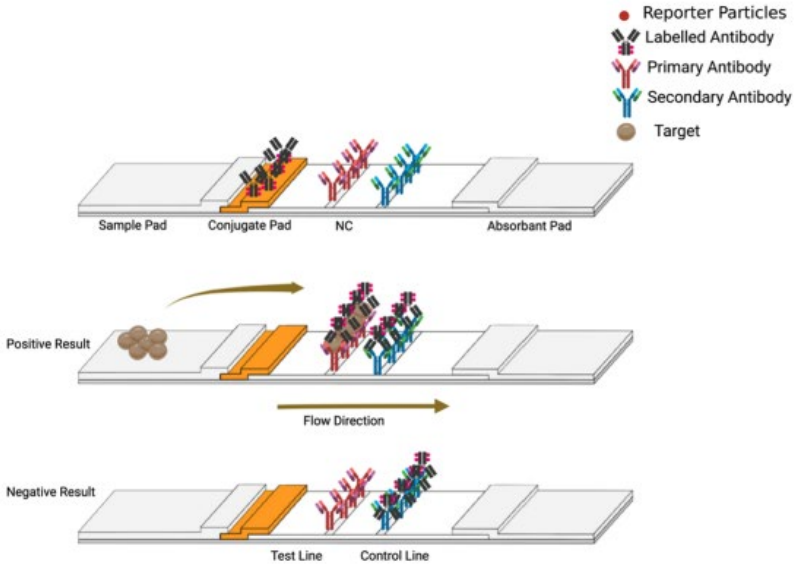
$$$

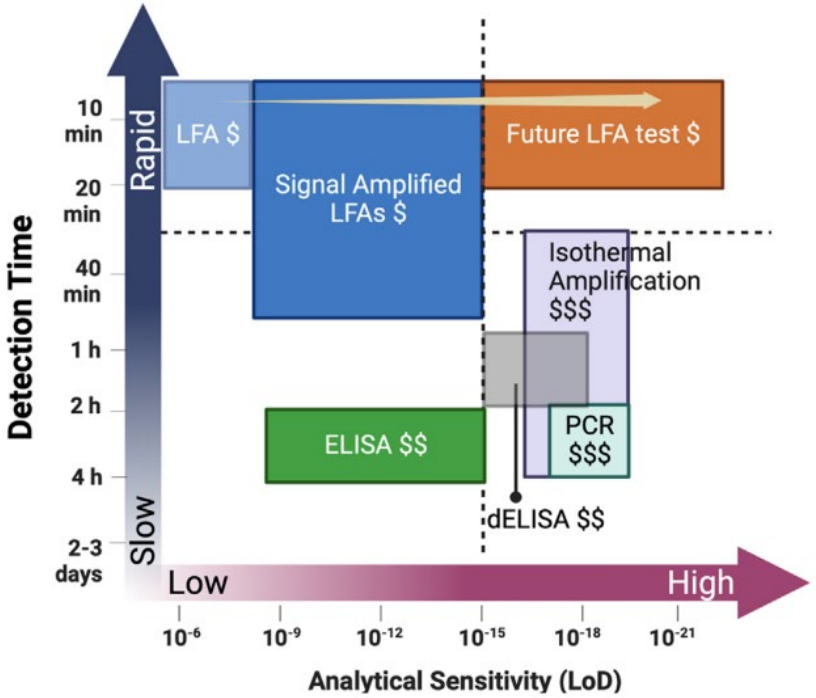


Other non-culture diagnostics



Lateral flow assays (incl. RATs)

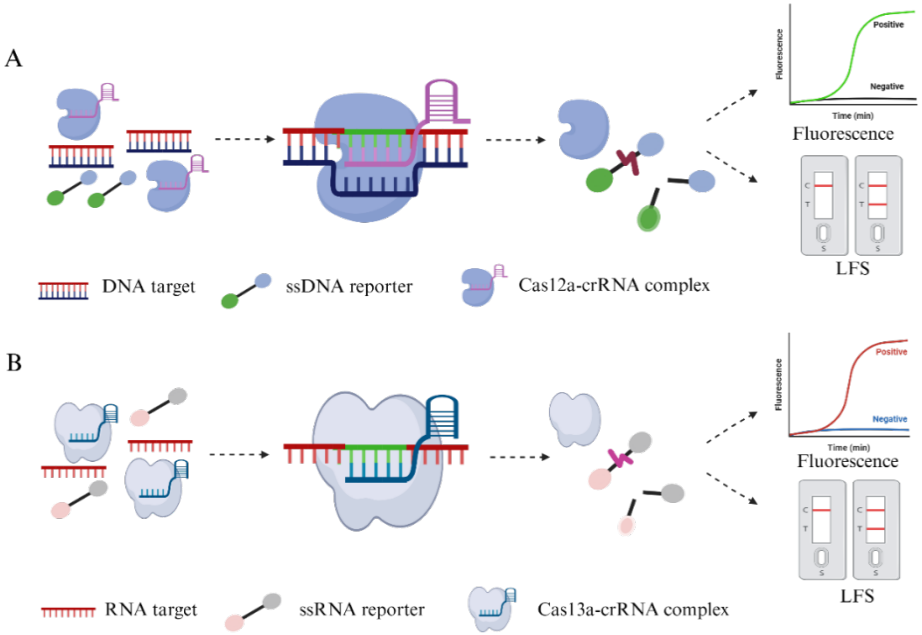




Younes et al 2023 A review of rapid food safety testing: using lateral flow assay platform to detect foodborne pathogens. *Critical Reviews in Food Science and Nutrition*

Isothermal amplification for detection

- Loop-mediated isothermal amplification (LAMP)
- Recombinase polymerase amplification (RPA)
- No need for thermal cycling
- Can combine RPA + CRISPR-Cas



Chunyang Ma, 2025 under review

RPA-CRISPR/Cas12a

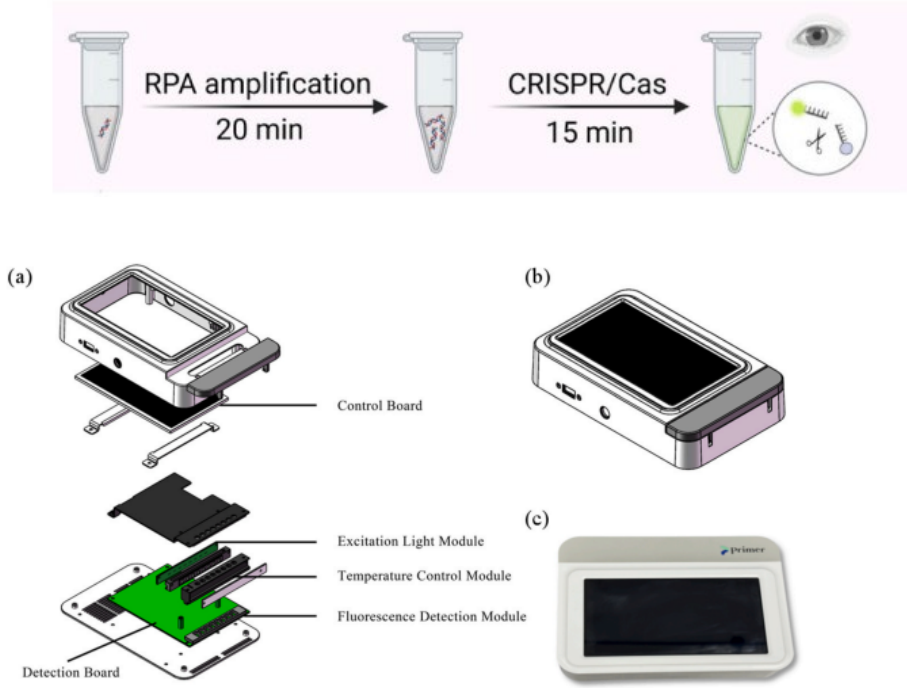
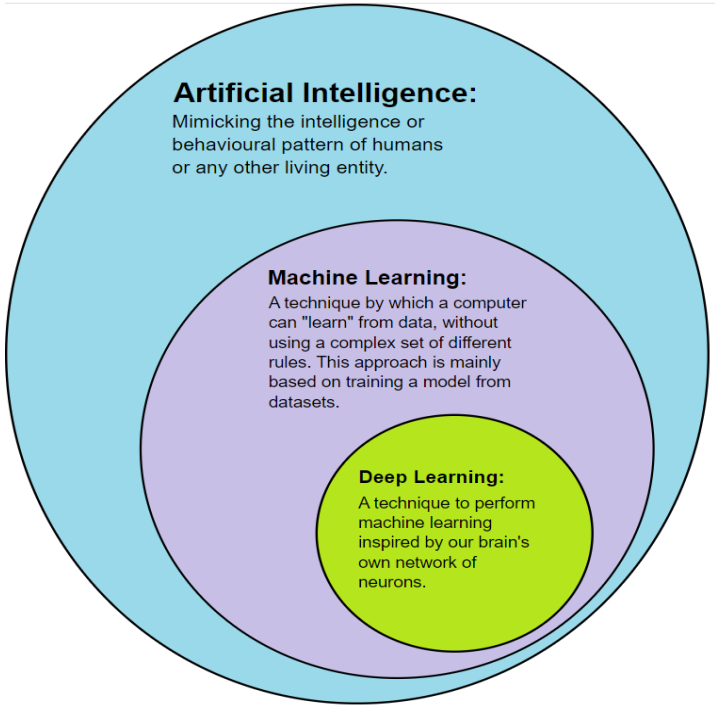


Fig. 5. Schematic diagram of the handheld molecular POC detector for multiplex RPA-CRISPR. (a): Structural diagram of the POC detector. (b): Model of the POC detector. (c): Photograph of the POC detector.

"rapid, cost-effective, and equipment-free"

Wang et al Talanta 2026. Detection of *Clostridium perfringens* and toxin typing



Artificial Intelligence

Aim: to improve decision making

- Better prediction
- More rapid prediction

- Pattern recognition
- Classification (e.g. ML)
- Large Language Models
- Deep learning (e.g. NNs)

"methods and software that enable machines to perceive their environment, learn from it, and take intelligent actions to maximize the chances of achieving defined Goals" FAO 2025

Data for Artificial Intelligence-informed decision making

- Primary data
- generated specifically for food safety or tracking purposes
  - biological/chemical monitoring
  - livestock data
  - inspection data
  - alert and recall data
  - outbreak surveillance data
  - proprietary company supply-chain track-and-trace data
  - genomic data

- Novel Data streams
- Not generated for food safety purposes
  - e-commerce
  - social media
  - crowdsourced consumer reviews
  - company message and feedback boards

Examples: food safety

- Detecting emerging pathogens
- Source attribution
- Prediction of bacterial phenotype based on genome sequence
- Hyperspectral imaging to quantify and identify microbes
- Identify restaurants violating health codes
- Predict food import firms likely to fail FDA site inspections

RESEARCH ARTICLE

Machine learning to predict the source of campylobacteriosis using whole genome data

Nicolas Arning[1]*, Samuel K. Sheppard[2], Sion Bayliss[2], David A. Clifton[3], Daniel J. Wilson[1]

RESEARCH Open Access

Transmission pathways of *Campylobacter jejuni* between humans and livestock in rural Ethiopia are highly complex and interdependent

Nitya Singh[1†], Cecilie A. N. Thystrup[2†], Bahar Mummed Hassen[3], Menuka Bhandari[4], Gireesh Rajashekara[5], Tine M. Hald[2], Mark J. Manary[6], Sarah L. McKune[7], Jemal Yusuf Hassen[8], Helen L. Smith[8], Jonathan C. Marshall[9], Nigel P. French[10], Arie H. Havelaar[1*] and The CAGED Research Team Members consisted of

Food Research International 147 (2021) 110577

Contents lists available at ScienceDirect

Food Research International

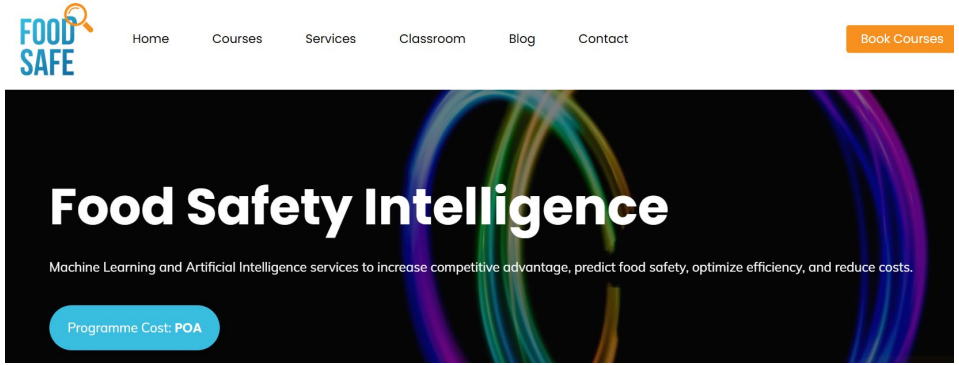
journal homepage: www.elsevier.com/locate/foodres

Hyperspectral imaging and deep learning for quantification of *Clostridium sporogenes* spores in food products using 1D- convolutional neural networks and random forest model

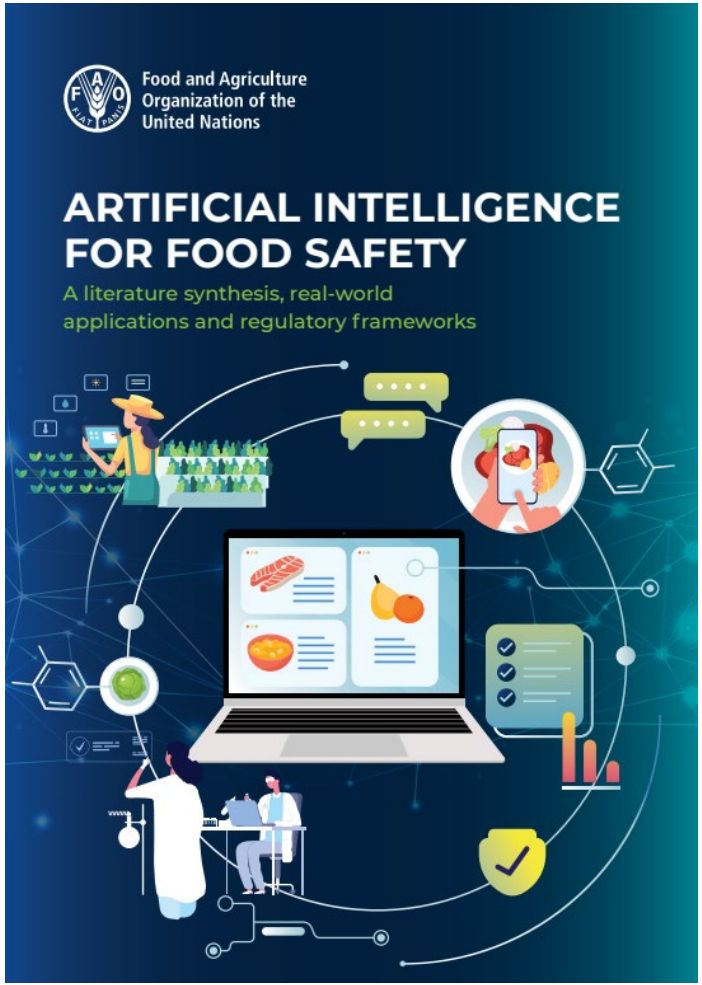
Aswathi Soni[a,*,1], Mahmoud Al-Sarayreh[a], Marlon M. Reis[a], Gale Brightwell[a,b]

[a] AgResearch, Palmerston North, New Zealand
[b] New Zealand Food Safety Science Research Centre, New Zealand

Applications for food safety

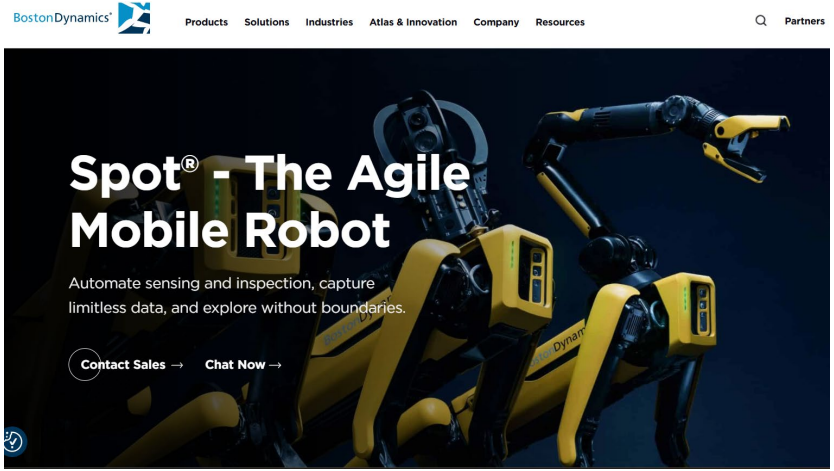


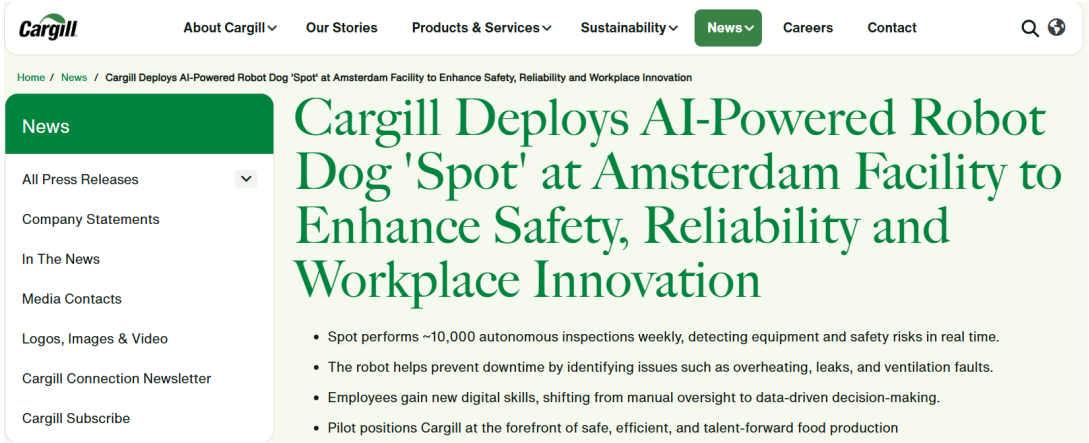
https://www.foodsafe.net.nz/food-safety-services/food-safety-intelligence/



van Meer, F. van der Velden, B. & Takeuchi, M. 2025. Artificial Intelligence for food safety – A literature synthesis, real-world applications and regulatory frameworks. Rome, FAO. https://doi.org/10.4060/cd7242en

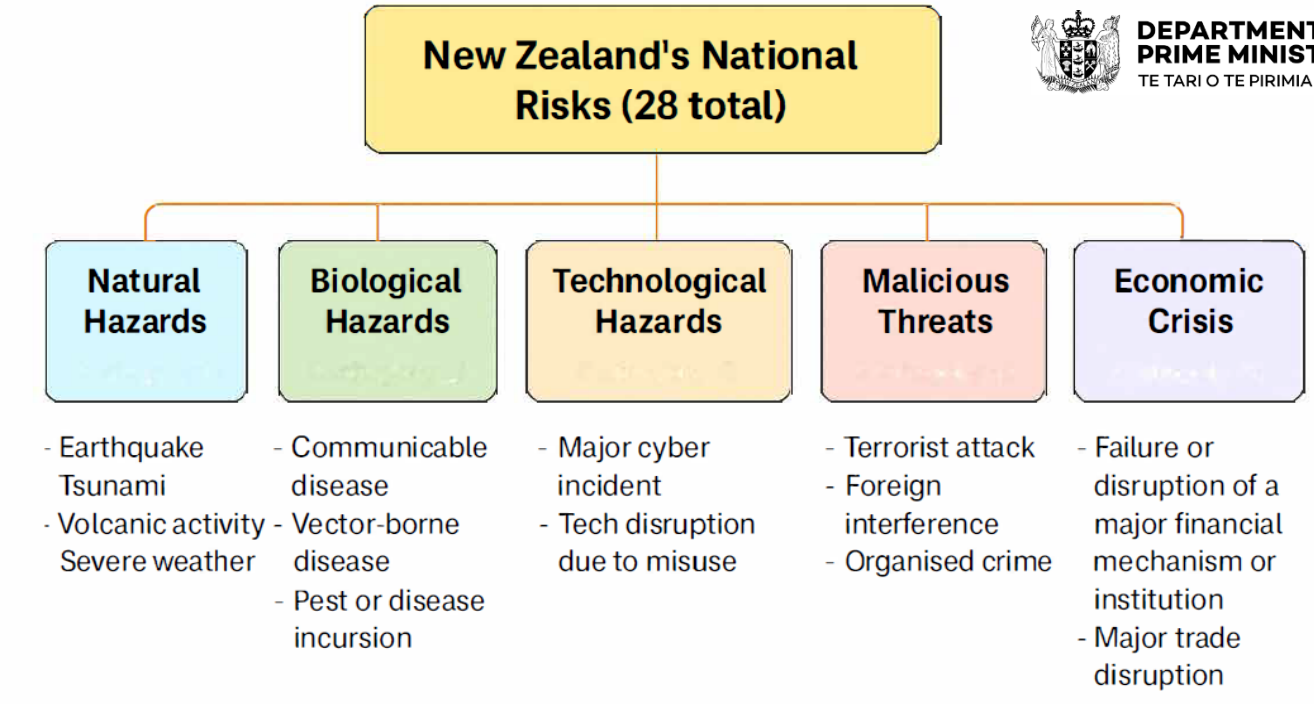
Robotics and AI





Pandemic planning and implications for food industry

National Risk and Resilience Framework



DEPARTMENT OF THE PRIME MINISTER AND CABINET
TE TARI O TE PIRIMIA ME TE KOMITI MATUA

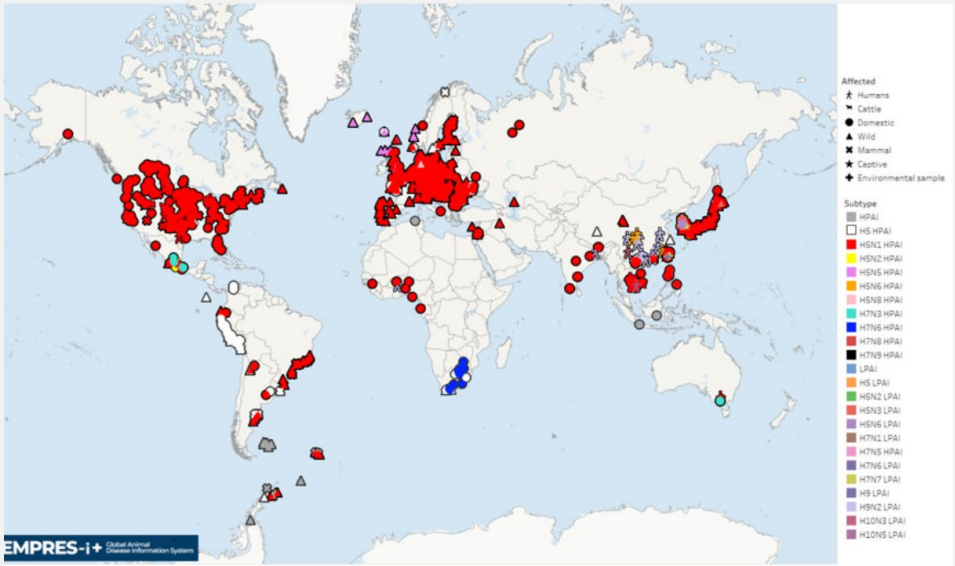
Te Niwha

Avian influenza: Recent trends

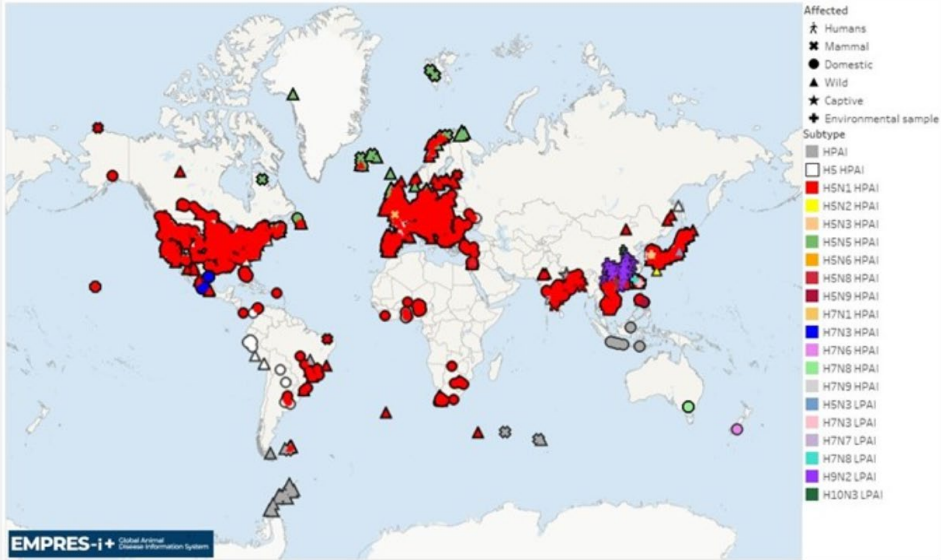
Food and Agriculture Organization of the United Nations

Discover

Home › Situation updates › Global AIV with Zoonotic Potential

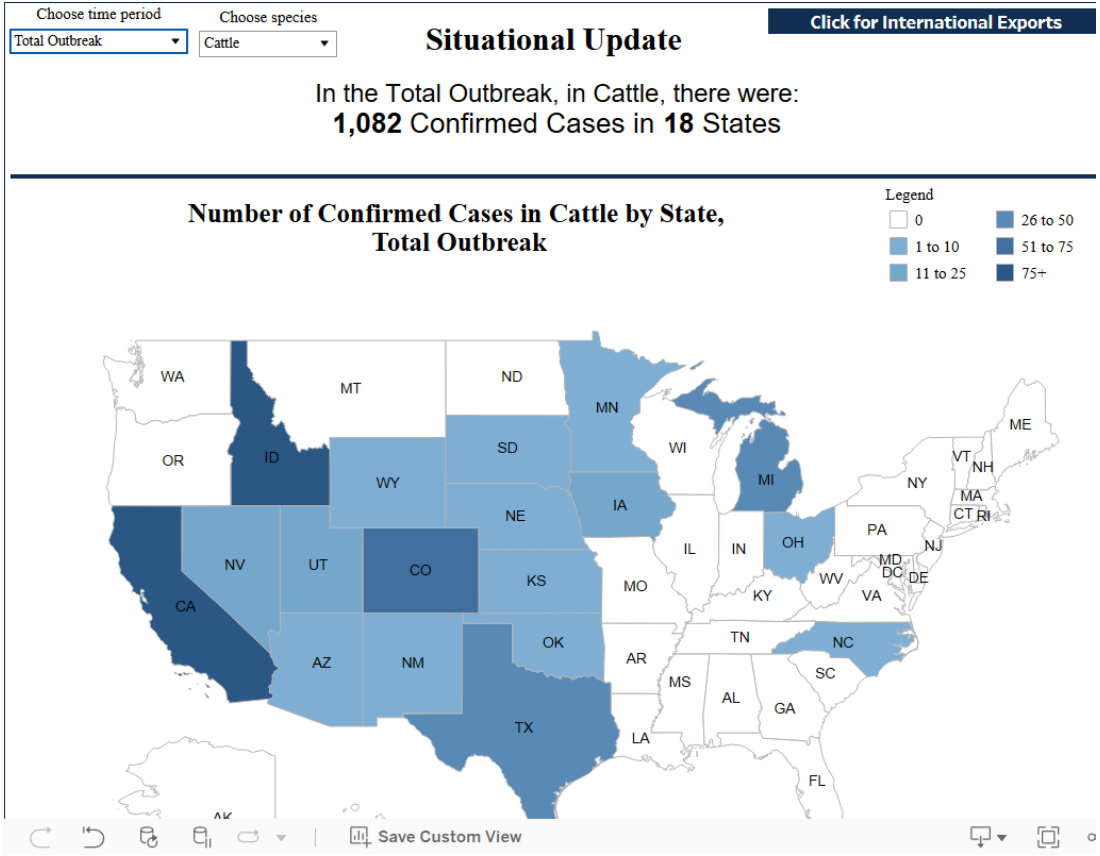


To 2024



To 2025

Over 1000 cattle farms affected



The NEW ENGLAND JOURNAL of MEDICINE

CORRESPONDENCE

Highly Pathogenic Avian Influenza A(H5N1) Virus Infection in a Dairy Farm Worker

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High levels in raw milk – exposure

Situation here…

News | Opinion | Sport | Culture | Lifestyle — The Guardian

Environment | Climate crisis | Wildlife | Energy | Pollution

New Zealand

This article is more than 11 months old

New Zealand rushes vaccination of endangered birds before deadly strain of H5N1 bird flu arrives

Michelle Duff in Wellington

Thu 22 Aug 2024 02.23 BST

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New Zealand's kakī (black stilt) is part of a trial to vaccinate native birds against the H5N1 avian flu strain. Photograph: Carla Smit

Small trial on native birds is part of preparations for arrival of deadly strain of H5N1 avian flu, which has not yet been reported in New Zealand

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NEW ZEALAND / COUNTRY

Controls lifted at Otago poultry farm after high pathogenic bird flu eradicated

5:38 pm on 28 April 2025

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Gianina Schwanecke, Producer/Presenter

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Preparing for a pandemic zoonosis - such as avian influenza

- Collaboration between fields of expertise that do not typically collaborate
  - All of Government response
- Surveillance, humans, wildlife, livestock
- Vaccination
- Health and safety of workers
- Taonga / endangered species
  - HPAI Vaccine trials on 5 species
- Culling of livestock, movement restrictions
- Impact on farming and food production

Risk to humans from H5N1 bird flu remains low but we must prepare - WHO

By **Jennifer Rigby** and **Gabrielle Tétrault-Farber**

February 9, 2023 5:34 AM GMT+13 · Updated 5 months ago

Aa

Summary

- Foodborne pathogens are emerging and reemerging continually
- Many drivers for emergence – including climate change and changes in food production practices
- Detection: new culture and non-cuture based diagnostics
- Open sharing of e.g. (meta)genomic data can result in improvements in food safety nationally and globally, but:
  - –increases data storage costs
  - –issues related to data privacy, stewardship, ownership and security
  - –Increases potential liability for food companies
- Similar issues with use of artifical intelligence
- Avian influenza existential threat

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