



Beef Safety- *Salmonella* Outbreaks and Risk Assessment

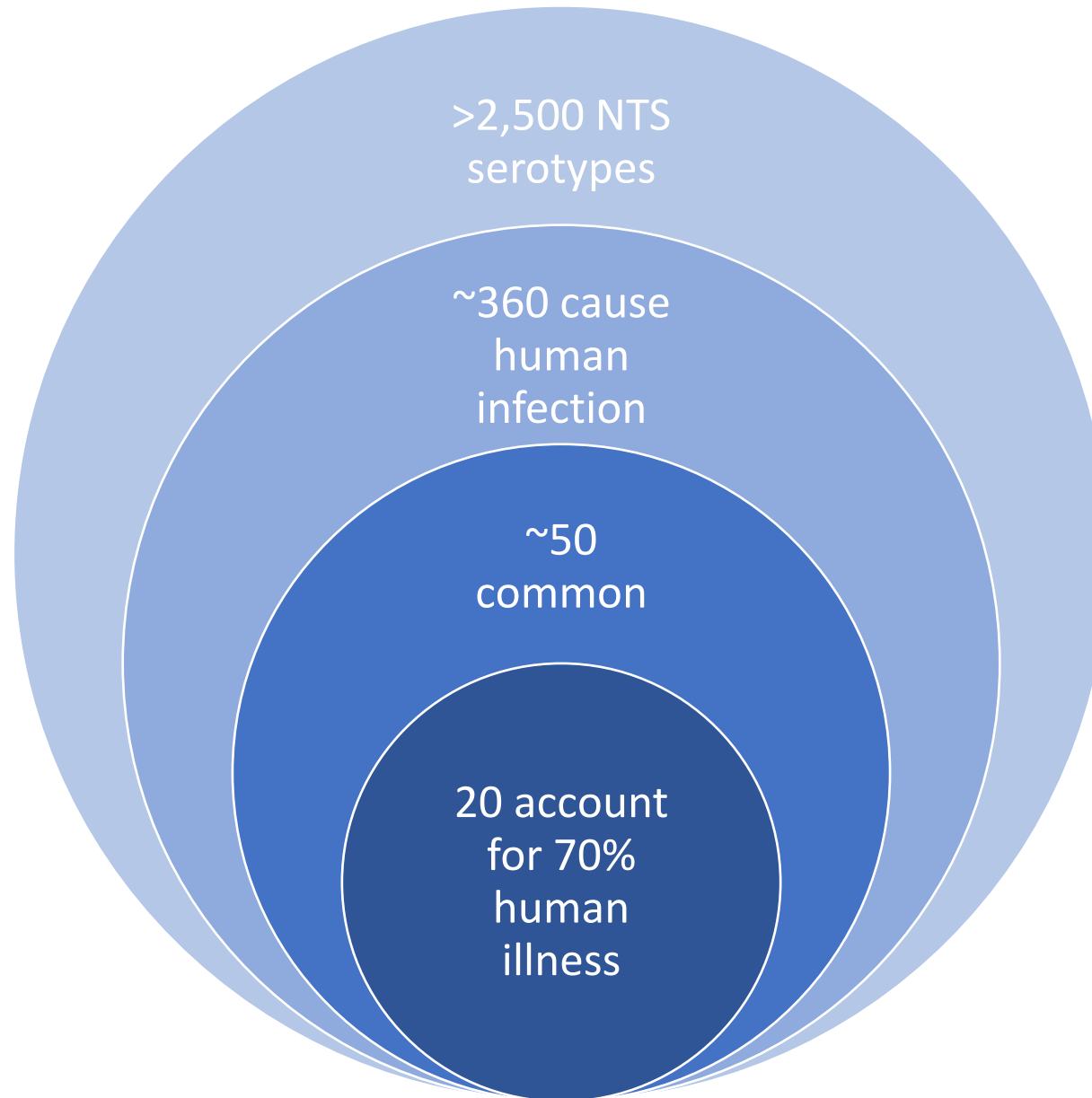
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**MINNESOTA INTEGRATED
FOOD SAFETY CENTER OF EXCELLENCE**

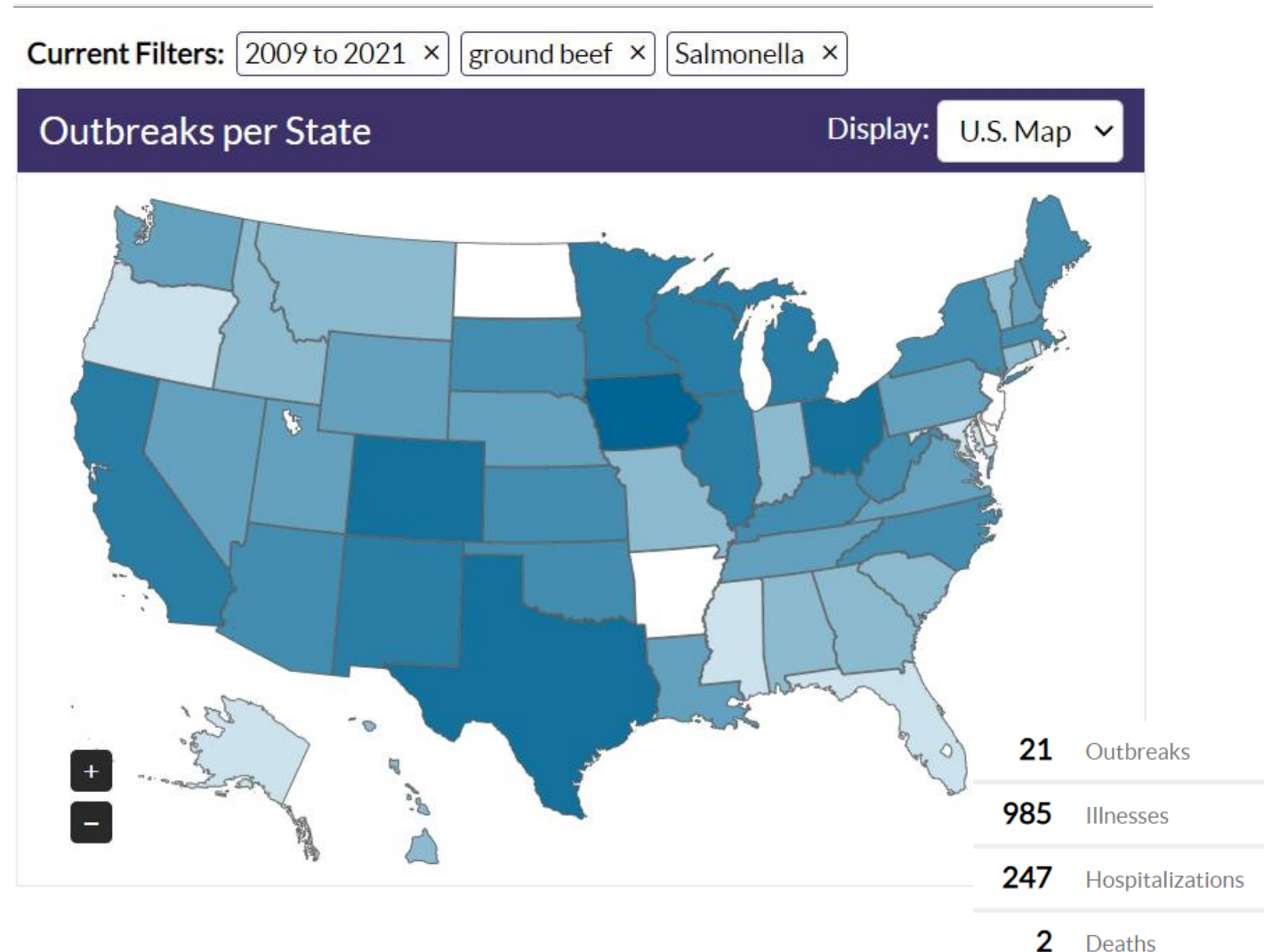
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CDC. National *Salmonella*
Surveillance Overview.
Atlanta, Georgia: US
Department of Health and
Human Services, CDC, 2011.



Salmonella Outbreaks and Risk Assessments

- Overview of public health surveillance
 - Transformative effect of whole genome sequencing
- Importance for source attribution and risk assessments
- Impact for industry

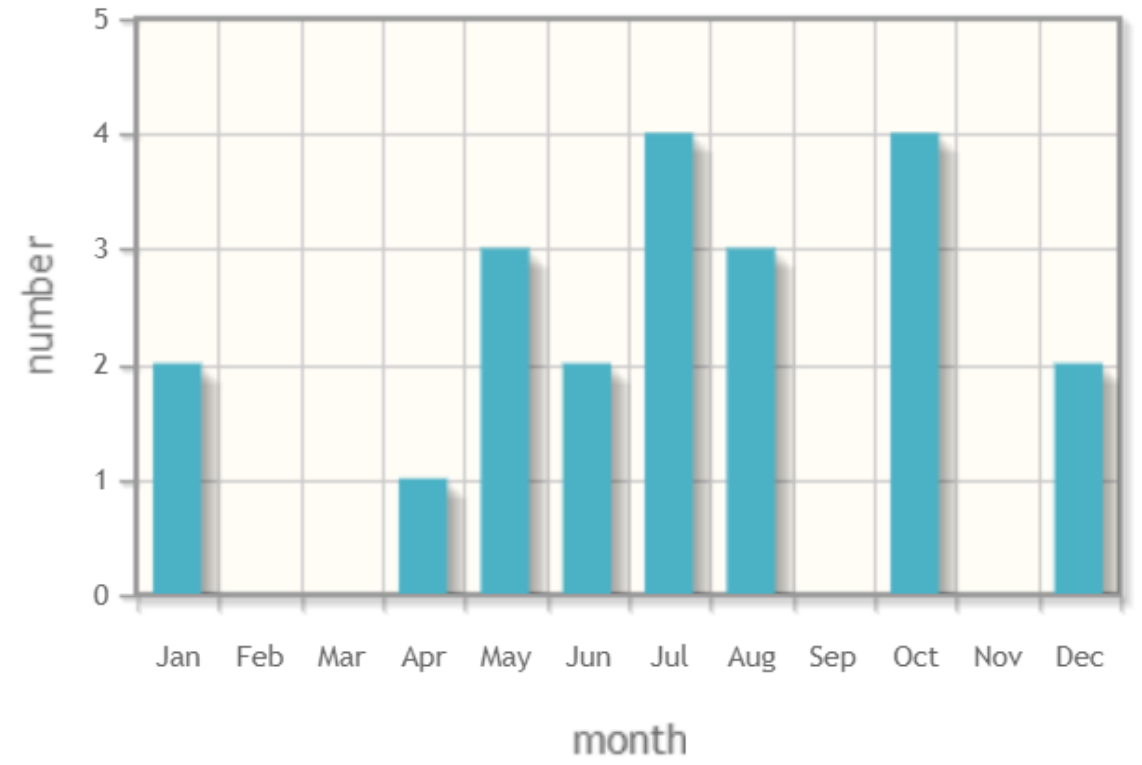


Salmonella Outbreaks Associated with Ground Beef, US, 2009-2021

Outbreaks per Year*

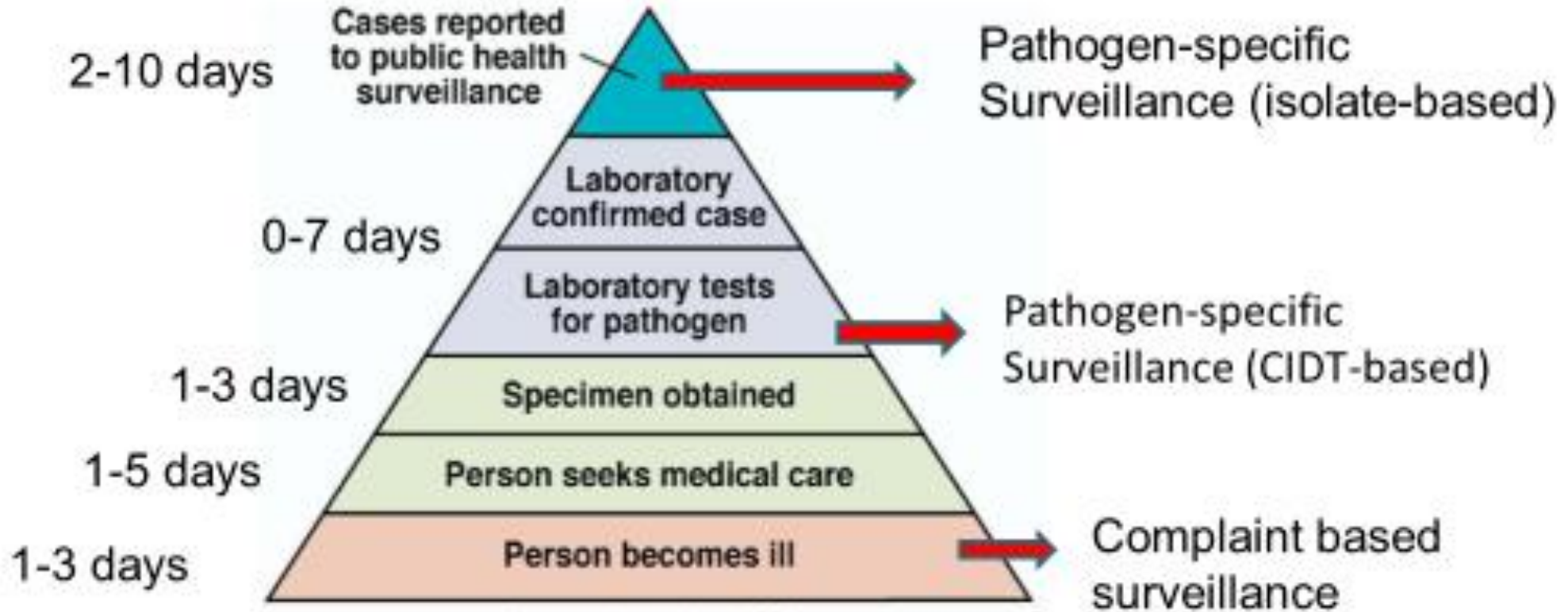


Outbreaks per Month



Primary Sources for Outbreak Detection

Cumulative: 2-4 weeks



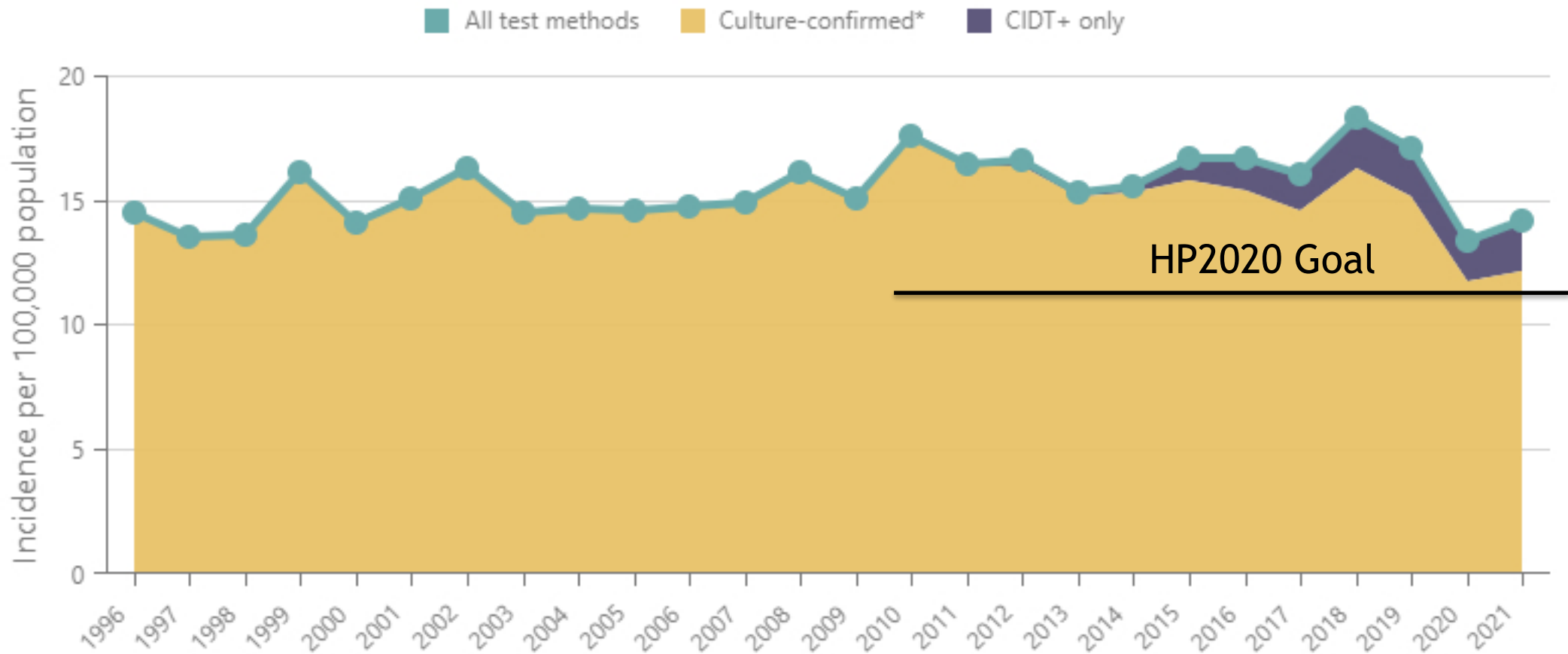
Source: adapted from CDC,
http://www.cdc.gov/foodnet/surveillance_pages/burden_pyramid.htm,
accessed Sept 4, 2008

Salmonella infections by year; 1996-2021

Incidence per 100,000 population – FoodNet sites; all test methods

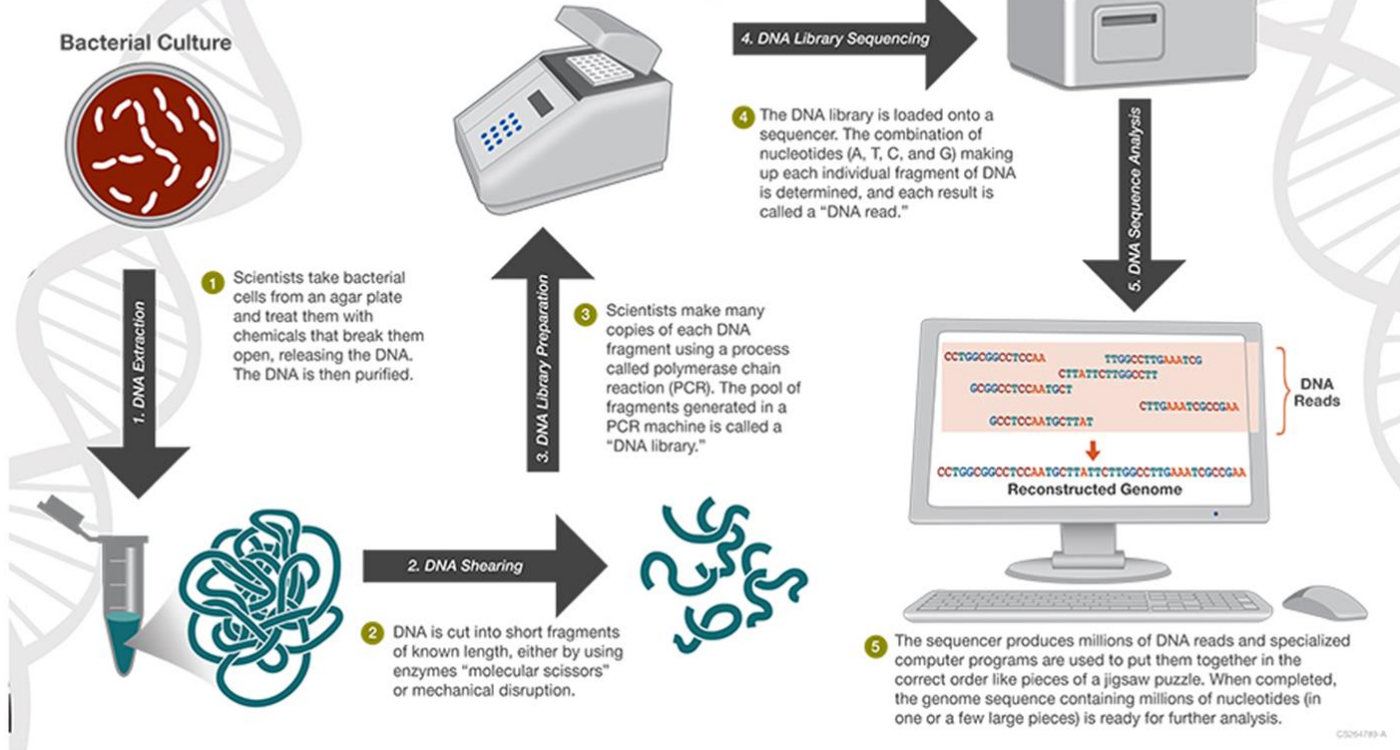
* Culture-confirmed includes those infections confirmed by culture only or by culture following a positive CIDT.

Source: FoodNet, Centers for Disease Control and Prevention

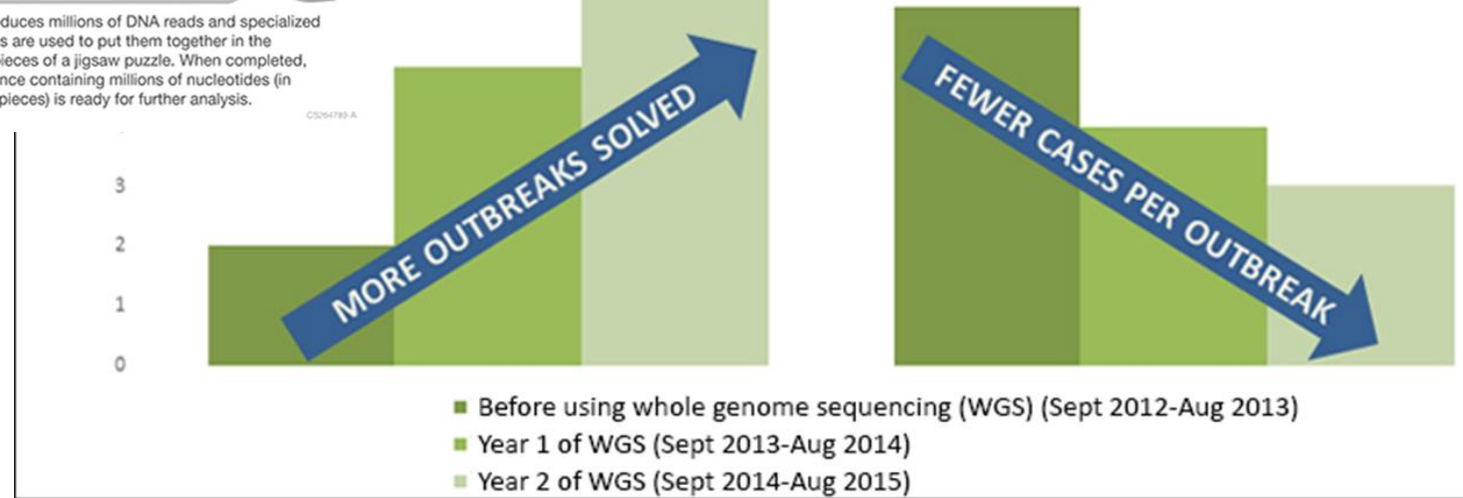


The Whole Genome Sequencing (WGS) Process

WGS is a laboratory procedure that determines the order of bases in the genome of an organism in one process. WGS provides a very precise DNA fingerprint that can help link cases to one another allowing an outbreak to be detected and solved sooner.



Whole genome sequencing improves the detection and investigation of foodborne outbreaks



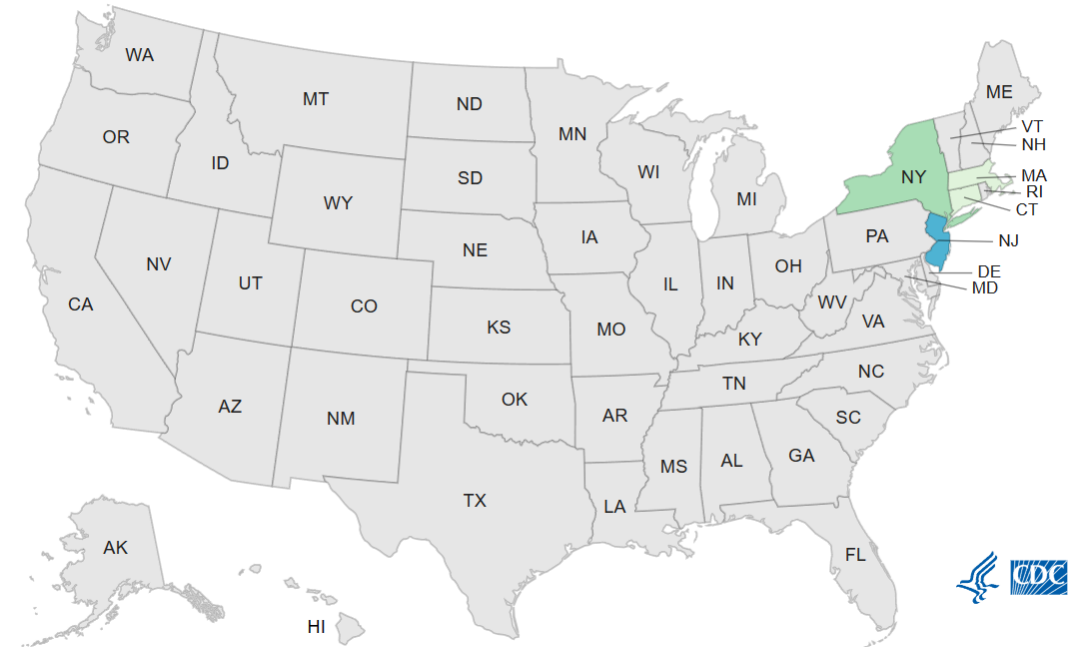


Increasing the specificity of food exposure information provided by case-patients is as important as increasing the specificity of the case definition.

The National Molecular Subtyping Network for Foodborne Disease Surveillance



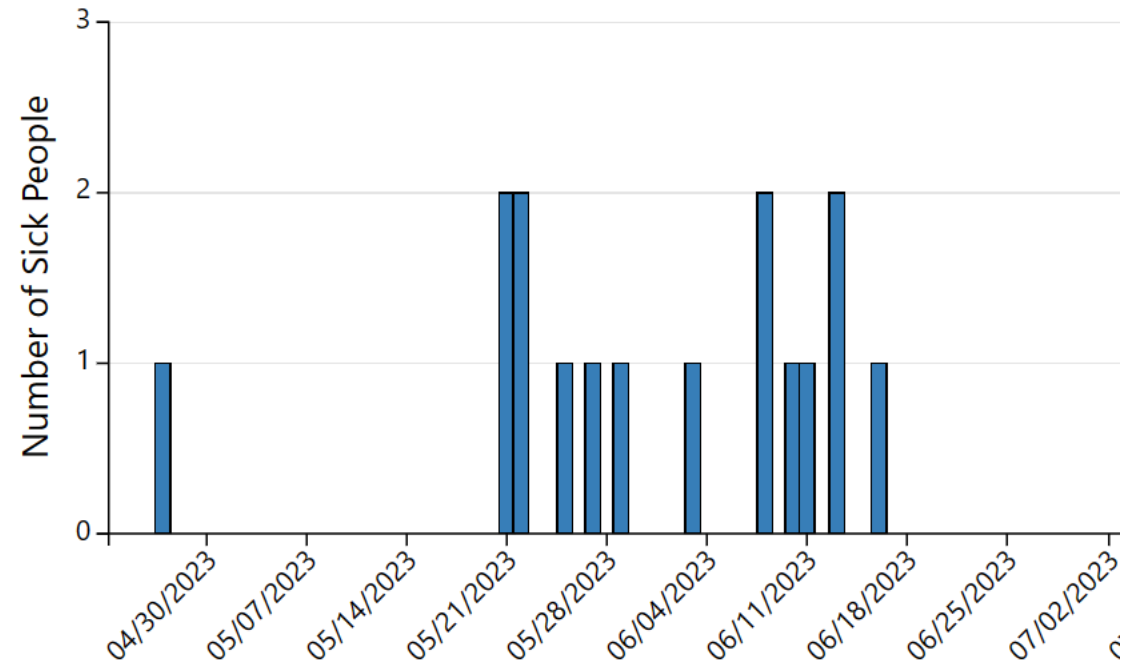
Salmonella Outbreak Linked to Ground Beef



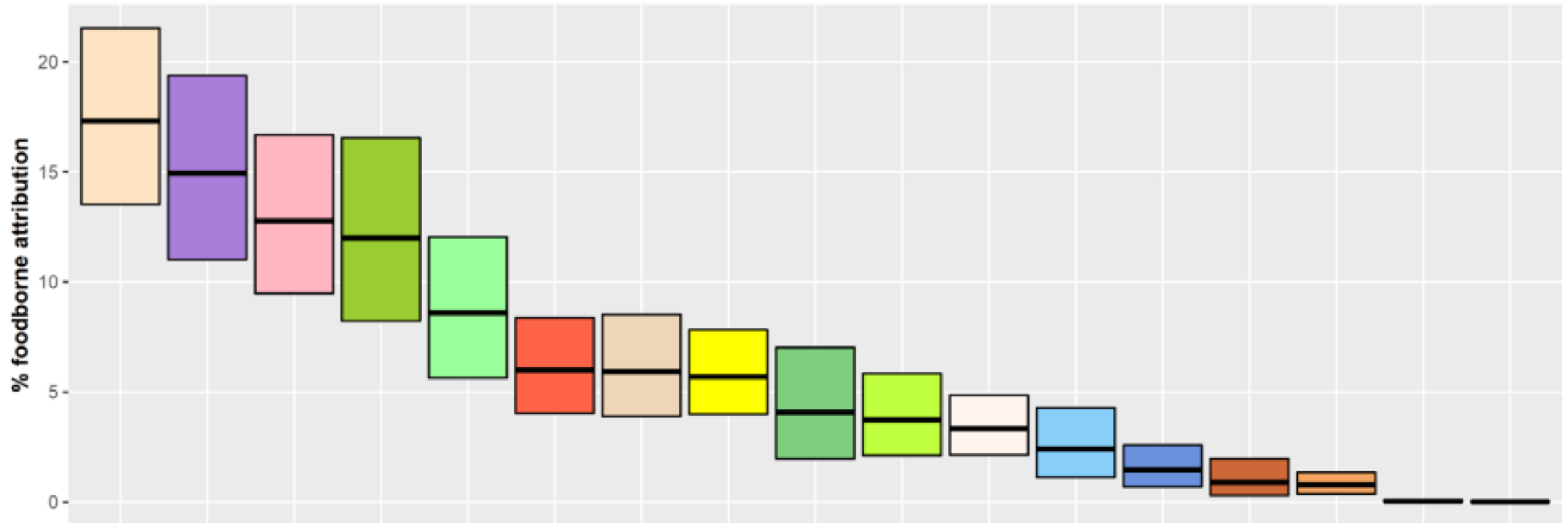
August 2002

Salmonella Outbreak Linked to Ground Beef

- 16 ill
- Age 0 to 97 years, 19% under 5 years
- 56% female
- 14 interviewed, 9 (64%) ate ground beef, all named same grocery store chain.
- Routine FSIS ground beef surveillance sample in March 2023 was closely related to bacteria from sick people's samples.

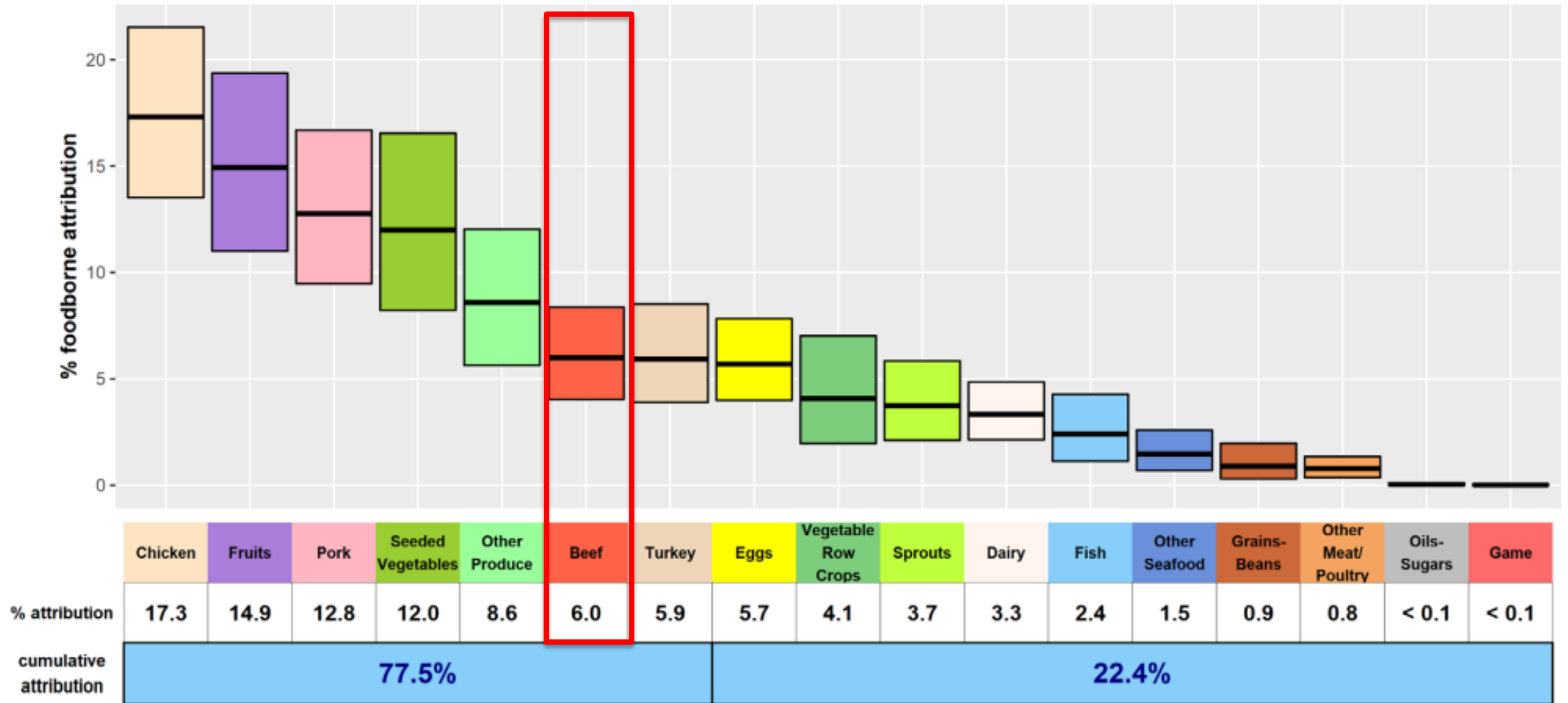


Salmonella Attribution to Food Categories, 2020



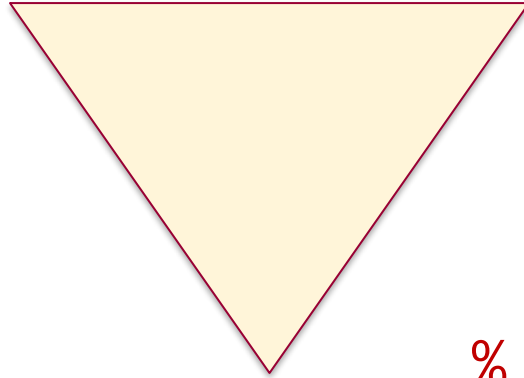
	Chicken	Fruits	Pork	Seeded Vegetables	Other Produce	Beef	Turkey	Eggs	Vegetable Row Crops	Sprouts	Dairy	Fish	Other Seafood	Grains-Beans	Other Meat/Poultry	Oils-Sugars	Game
% attribution	17.3	14.9	12.8	12.0	8.6	6.0	5.9	5.7	4.1	3.7	3.3	2.4	1.5	0.9	0.8	< 0.1	< 0.1
cumulative attribution	77.5%								22.4%								

Salmonella Attribution to Food Categories, 2020



Risk Assessment Models

Top-down models:



Number of human illnesses



Attribution estimates

% human illnesses due to ground beef

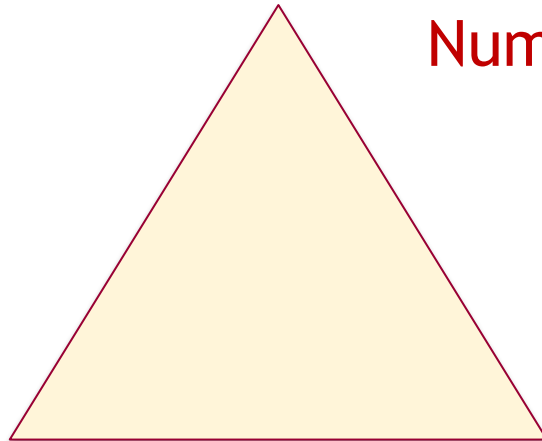
Number human illnesses due to ground beef



Preparation and consumption scenarios

Prevalence of *Salmonella* in ground beef

Bottom-up models:



FSIS Raw Product Sampling and Testing

- 52 week “moving window” testing approach
- Frequency dependent upon daily production volume
- Increased NTS prevalence in ground products
- HACCP Plans



USDA FSIS Quarterly Sampling Reports on Salmonella. Q1, 2023

Product	Number of Samples	Number of Positives	Percent Positive
Young Chicken Carcasses	2442	117	4.79%
Chicken Parts (legs/breast/wings)	3698	306	8.27%
Comminuted Chicken	471	127	26.96%
Mechanically Separated Chicken	30	26	86.67%
Total for Raw Chicken	6663	580	8.70%
Young Turkey Carcasses	412	0	0.00%
Comminuted Turkey	301	50	16.61%
Mechanically Separated turkey	22	12	54.55%
Total for Raw Turkey	735	62	8.44%
Raw ground beef - Retail	126	5	3.97%
Raw ground beef	2617	28	1.07%
Total for Raw Beef	4302	76	1.77%
Comminuted pork	1545	246	15.92%
Pork Cuts	576	41	7.12%
Total for Raw Pork	2121	287	13.53%

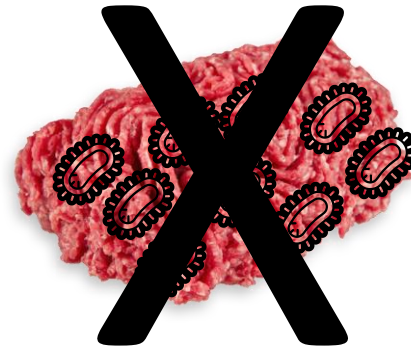
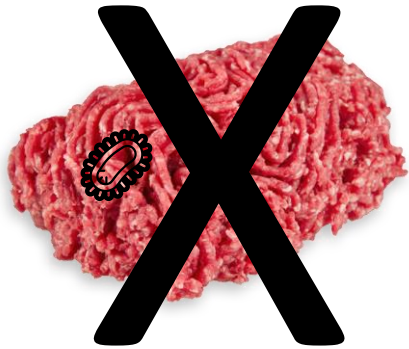
Limitations in Prevalence-Based Performance Standards

Prevalence: $3/8 = 37.5\%$



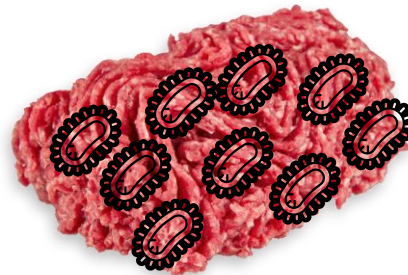
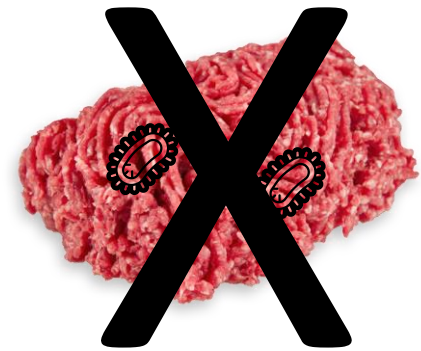
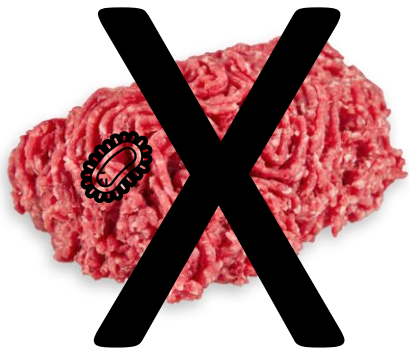
Limitations in Prevalence-Based Performance Standards

Prevalence: $1/6 = 16.7\%$

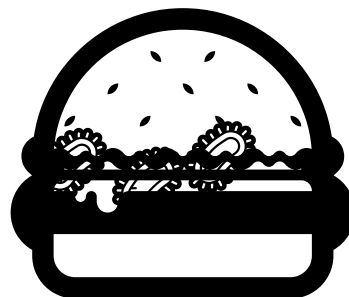
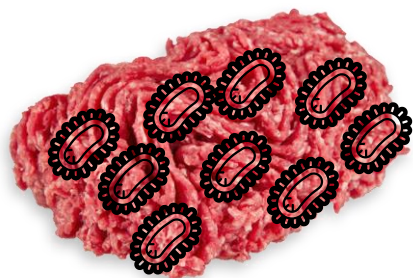


Limitations in Prevalence-Based Performance Standards

Prevalence: $1/6 = 16.7\%$



Limitations in Prevalence-Based Performance Standards



Ground Beef Risk Assessment

- Estimate annual reductions in *Salmonella* infections when highly contaminated ground beef lots were diverted from consumption.
- Estimate contribution of high and low-virulent and multi-drug resistant (MDR) serotypes on the total number of illnesses and burden of disease.
- Prioritize risk-based pathogen mitigation strategies.

FSIS Enumeration Data

1060 *Salmonella* enumerated samples (2010-2020)

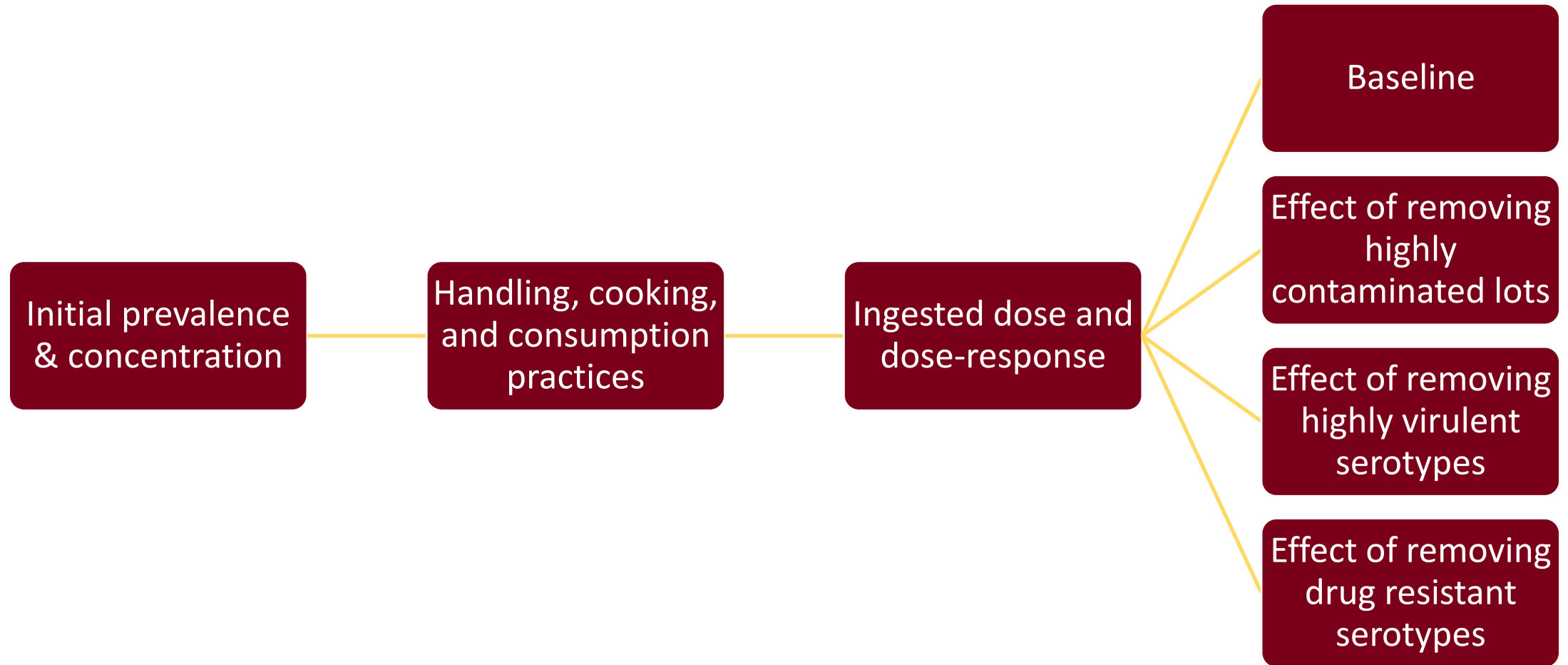
- *Salmonella* prevalence in models varied from 1.43 – 1.47%
- 13.7% met high virulence criteria
- 15.9% MDR

Very low *Salmonella* prevalence in production lots sampled

- >1 MPN/g = 2.4% production lots
- >10 MPN/g = 0.4% production lots

Average concentration = 0.017 MPN/g (4.07 MPN/g)

Risk Assessment Process - Ground Beef



High Virulence Criteria

- Listed as a top 10 serotype isolated from human illnesses according to the most recent CDC *Salmonella* Annual Report

OR

- Identified as an outbreak causing serotype by the National Outbreak Reporting System

AND

- Was not individually over-represented in risk estimates using CDC and FoodNET serotype reporting data

Consumption Scenarios and Proportion of High- and Low-Virulence Serotypes

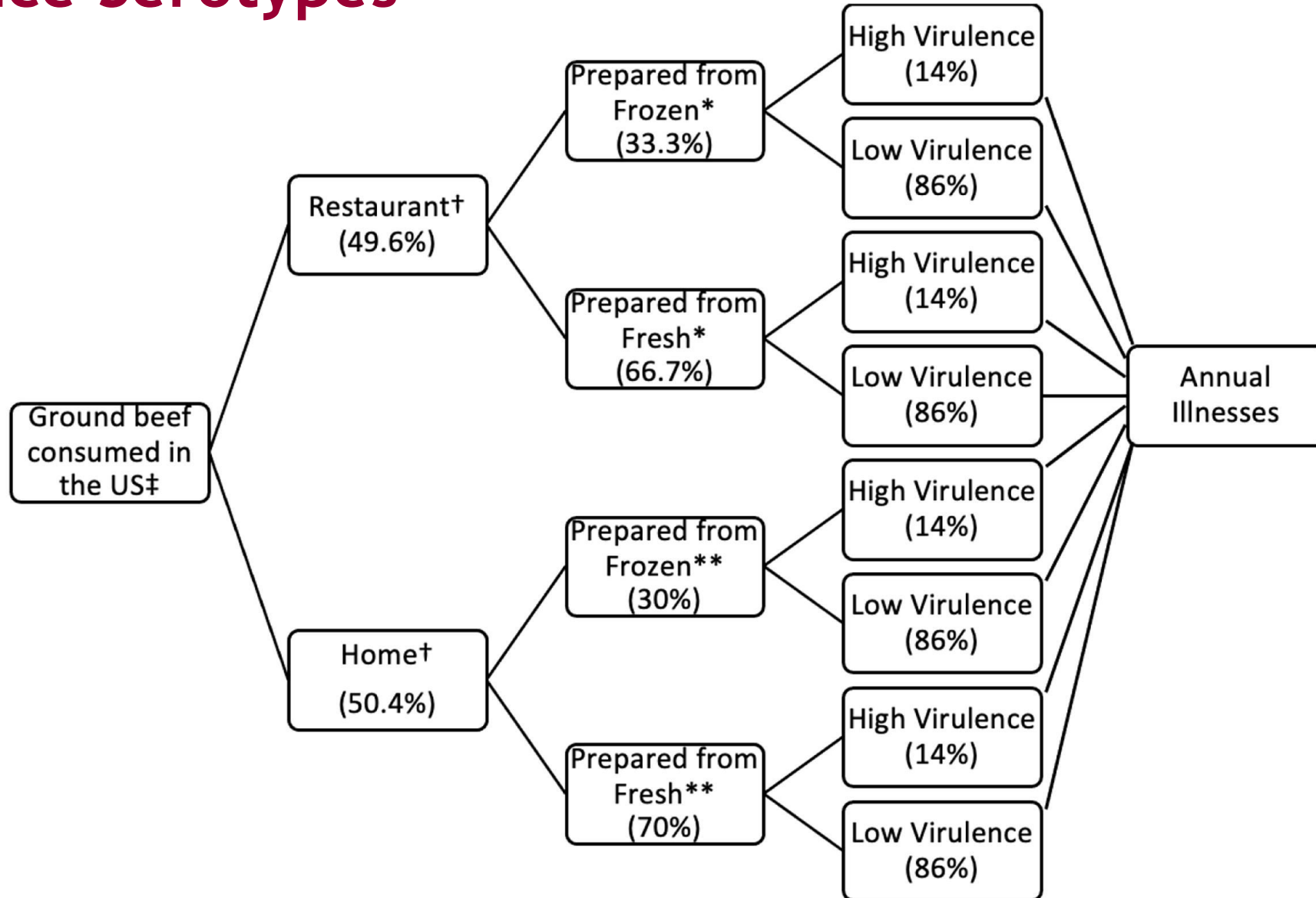


Figure 1. Linear Thermal Profile for Thawed or Fresh Products

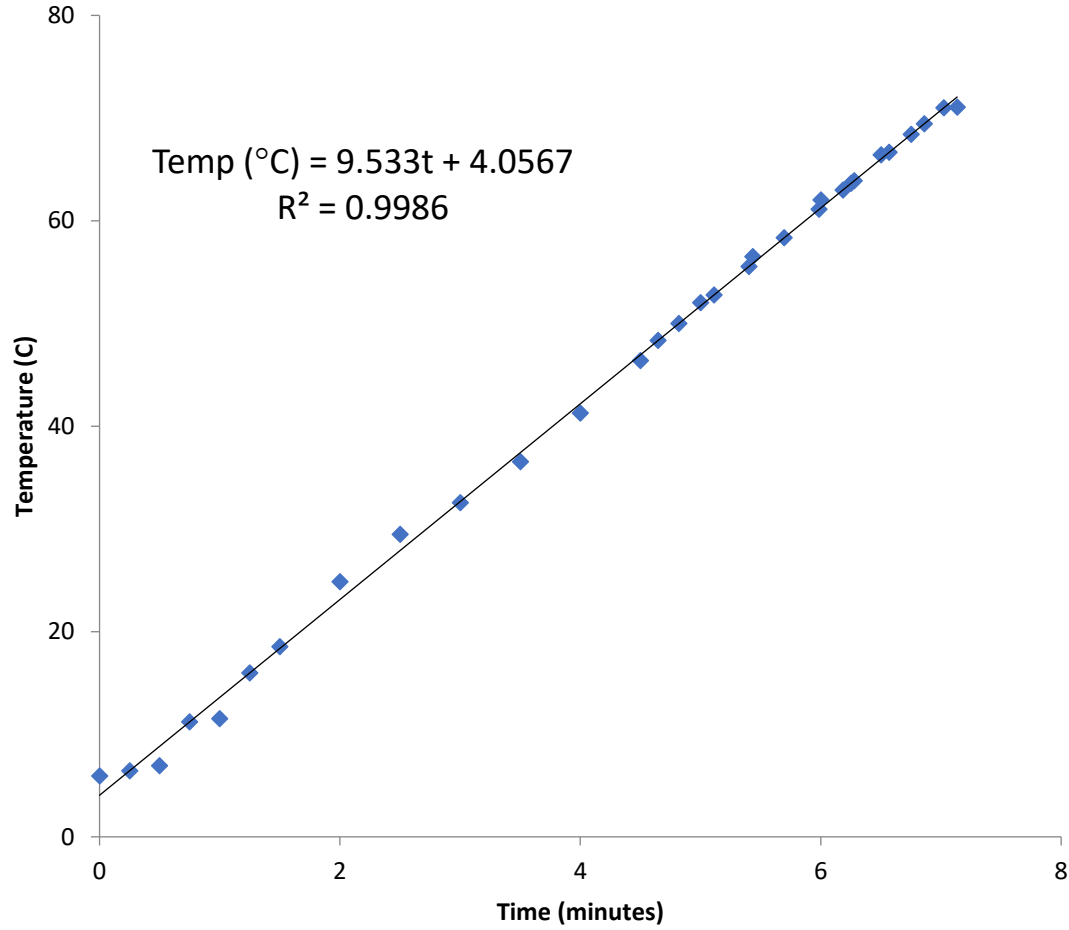
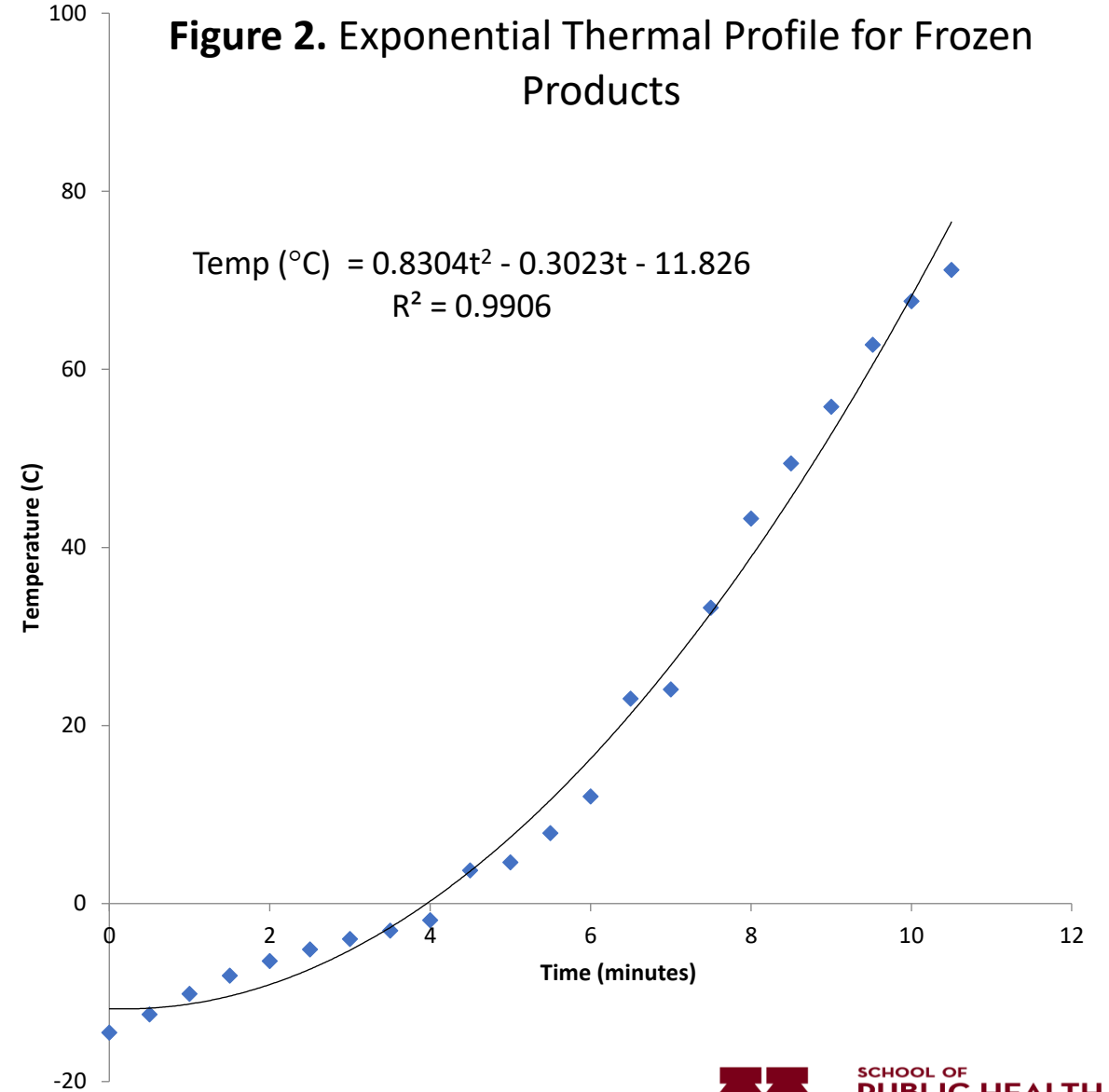
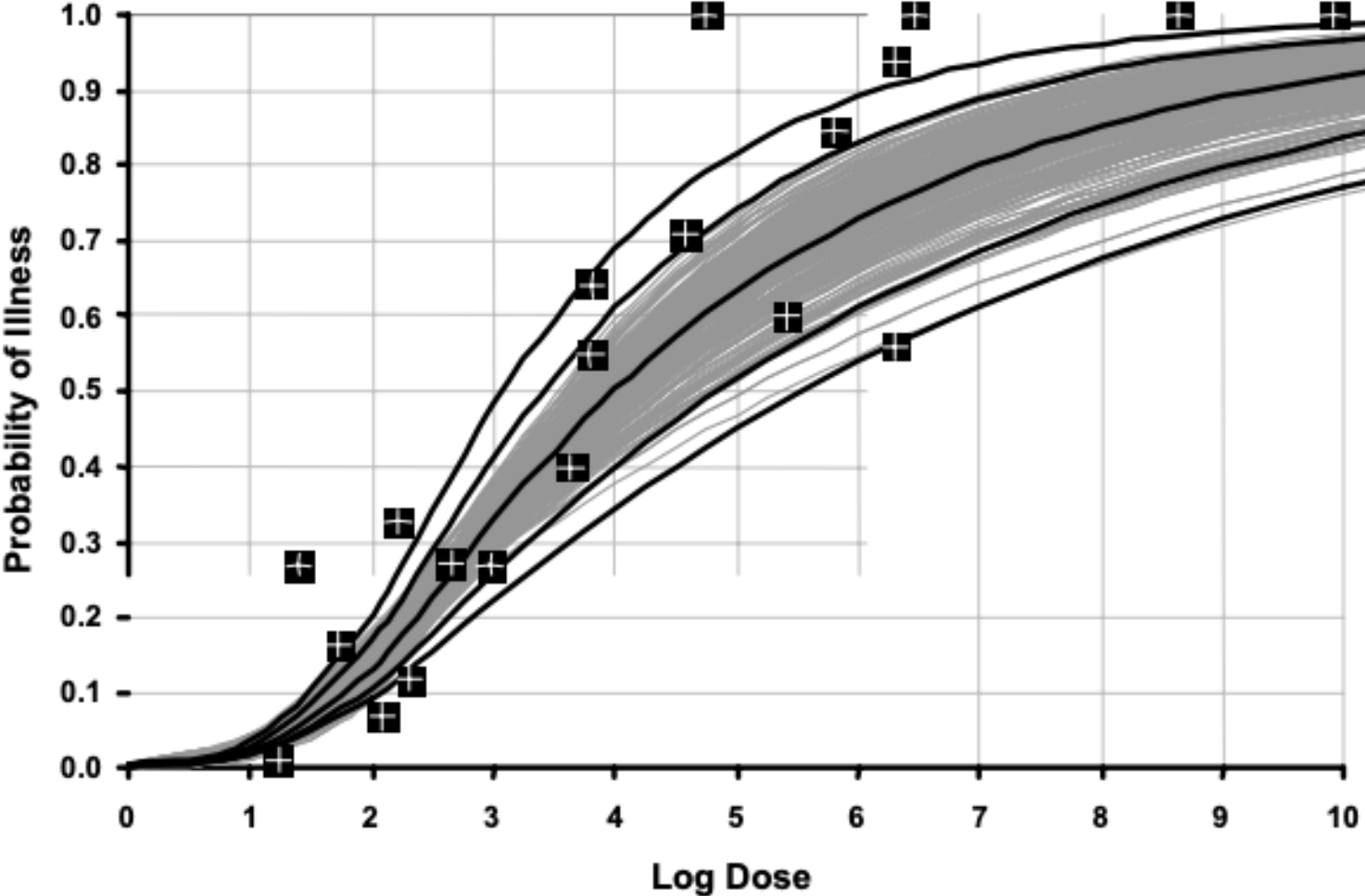


Figure 2. Exponential Thermal Profile for Frozen Products



High Virulence NTS *Salmonella* Dose-Response



Results

Table 1. Risk estimate comparisons after removal of lots based on relative *Salmonella* characteristics

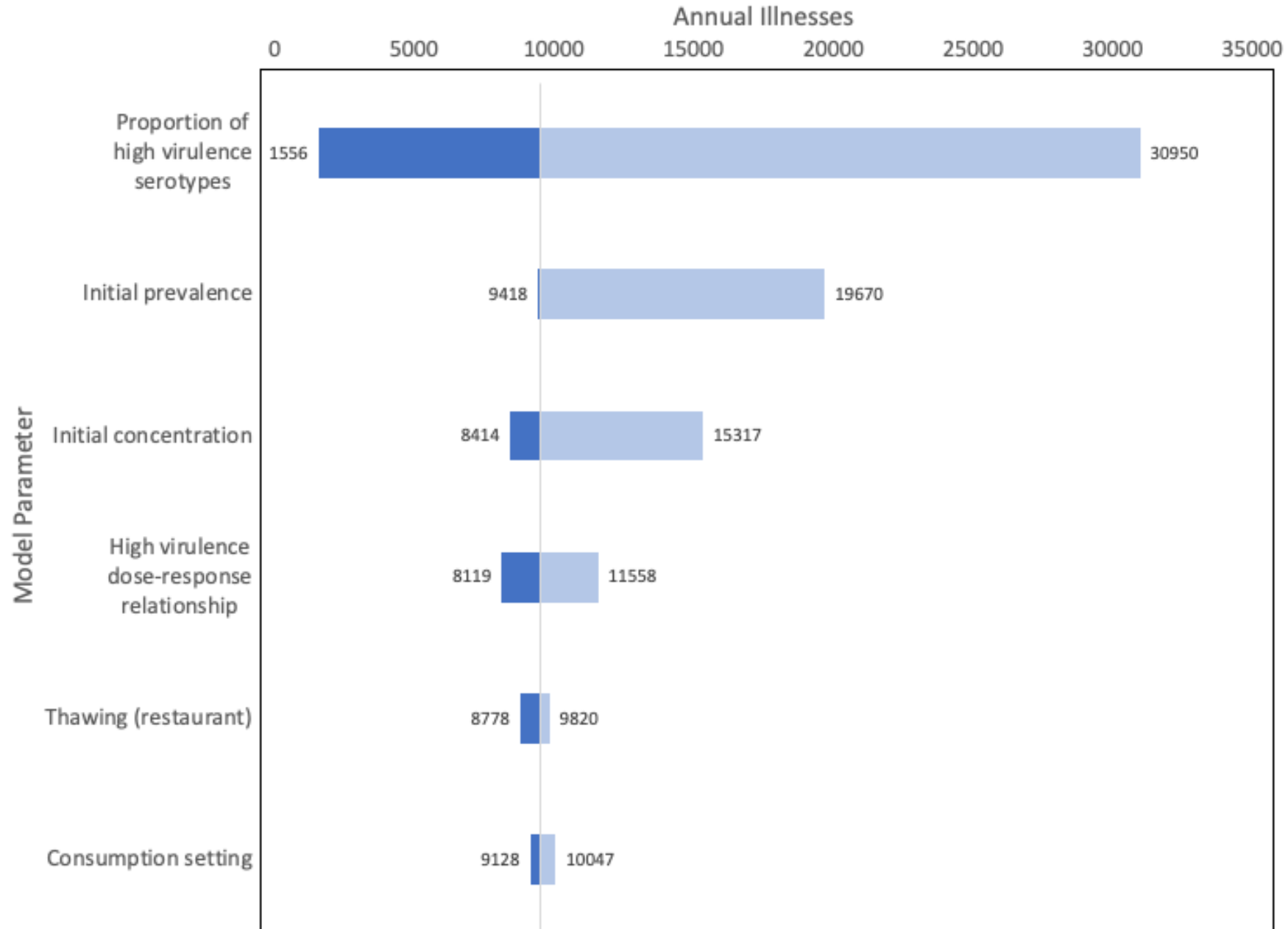
Model	Annual Illnesses*	Reduction from Baseline (%)
Baseline	8,980	-
>10 MPN/g removed	7,759	13.6
>1 MPN/g removed	5,686	36.7
Highly virulent lots removed	300	96.7

*Unadjusted for under-reporting

Table 2. Annual salmonellosis illness estimates separated by consumption scenarios and virulence profile at baseline

Consumption Scenario	Annual Illnesses by Virulence Profile		
	High-virulence (90% CI)	Low-virulence (90% CI)	Total
Home, Fresh (n = 3.2x10 ⁹)	3360 (2360, 4480)	116 (43, 1020)	3476 (2403, 5500)
Home, Frozen (n = 1.6x10 ⁹)	2690 (1900, 3590)	93 (35, 819)	2783 (1935, 4409)
Restaurant, Fresh (n = 3.5x10 ⁹)	1250 (882, 1670)	43 (16, 379)	1293 (898, 2049)
Restaurant, Frozen (n = 1.5x10 ⁹)	1380 (968, 1840)	48 (18, 417)	1428 (986, 2257)
Total	8680 (6110, 11580)	300 (112, 2635)	8980 (6222, 14215)

Tornado diagram illustrating sensitivity analysis of ground beef baseline model



MDR *Salmonella* Removal

Removal of MDR *Salmonella*:

- 21% decrease in Years of Life Disabled
- 56% decrease in Years of Life Lost
- **45% reduction in Disability Adjusted Life Years**

Project Highlights:

~9,000 annual cases of salmonellosis attributable to ground beef

Removing >1 MPN/g
resulted in a 36.7%
reduction in illnesses

Removing >10 MPN/g
resulted in a 13.6%
reduction in illnesses

Removing MDR
Salmonella reduces
burden of disease by 45%

Presence of highly virulent *Salmonella* was the most impactful
model parameter

Research Highlights

Consumption Model	Baseline	Removal of lots >10 MPN/g (% decrease)	Removal of lots >1 MPN/g (% decrease)	After Cross-contamination (% increase)
Ground Beef	8,980	7,759 (13.6)	5,686 (36.7)	15,310 (70.5)
Ground Pork	10,590	-	5,632 (46.8)	11,851 (11.9)

- >90% annual illnesses attributable to high virulence NTS serotypes
- Significant illness reduction at each pathogen concentration threshold
- Cross-contamination effectively managed after removal of highly contaminated production lots

Impacts for Industry

- Most ground beef is contaminated at low concentrations and majority of *Salmonella* serotypes not highly virulent.
- Human illnesses are driven by high levels of contamination and highly virulent *Salmonella* serotypes.
- **To reduce *Salmonella* illnesses due to consumption of ground beef, identify and remove products**
 - contaminated above threshold of 1MPN/g
 - contaminated with virulent *Salmonella* serotypes, MDR *Salmonella*

Data Gaps to Improve Risk Assessment Models

- Dose-response relationships for *Salmonella* strains
- AMR-specific burden of disease estimates
- Levels of detection for testing
- Cross-contamination coefficients

