Escherichia coli O157:H7 and related agents in cattle and other food animals: Biology meets Policy

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Food and Waterborne Diseases Integrated Research Network

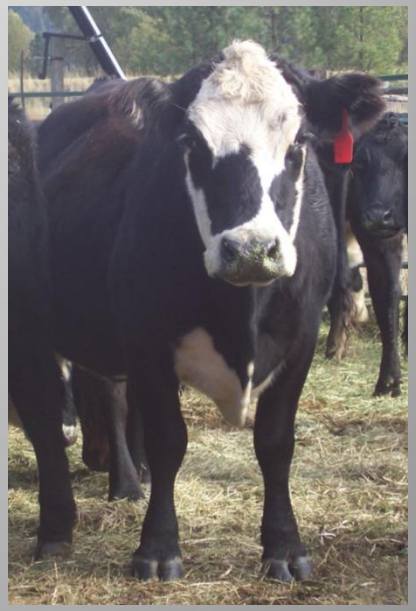
USDA United States Department of Agriculture National Institute of Food and Agriculture

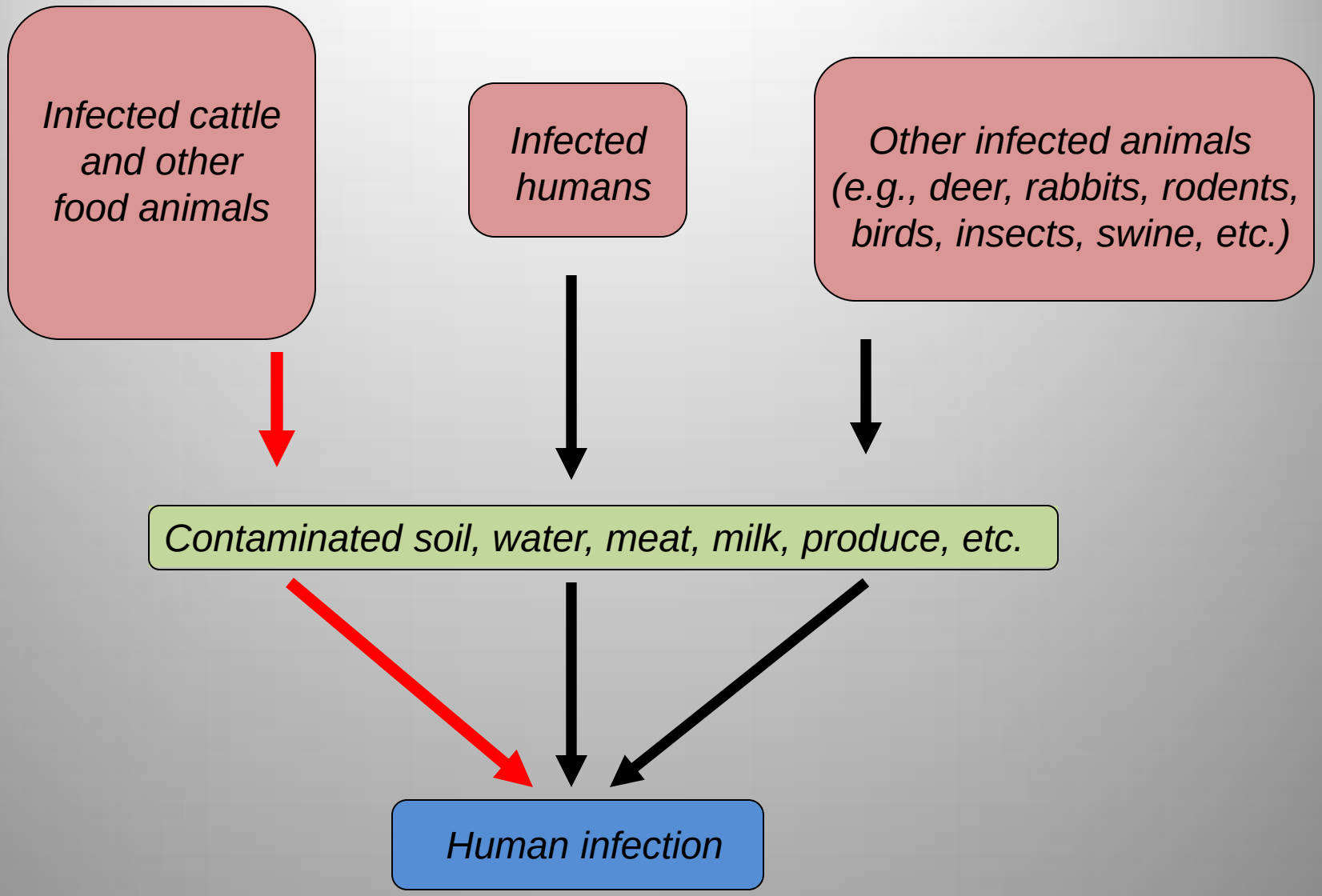
Topics

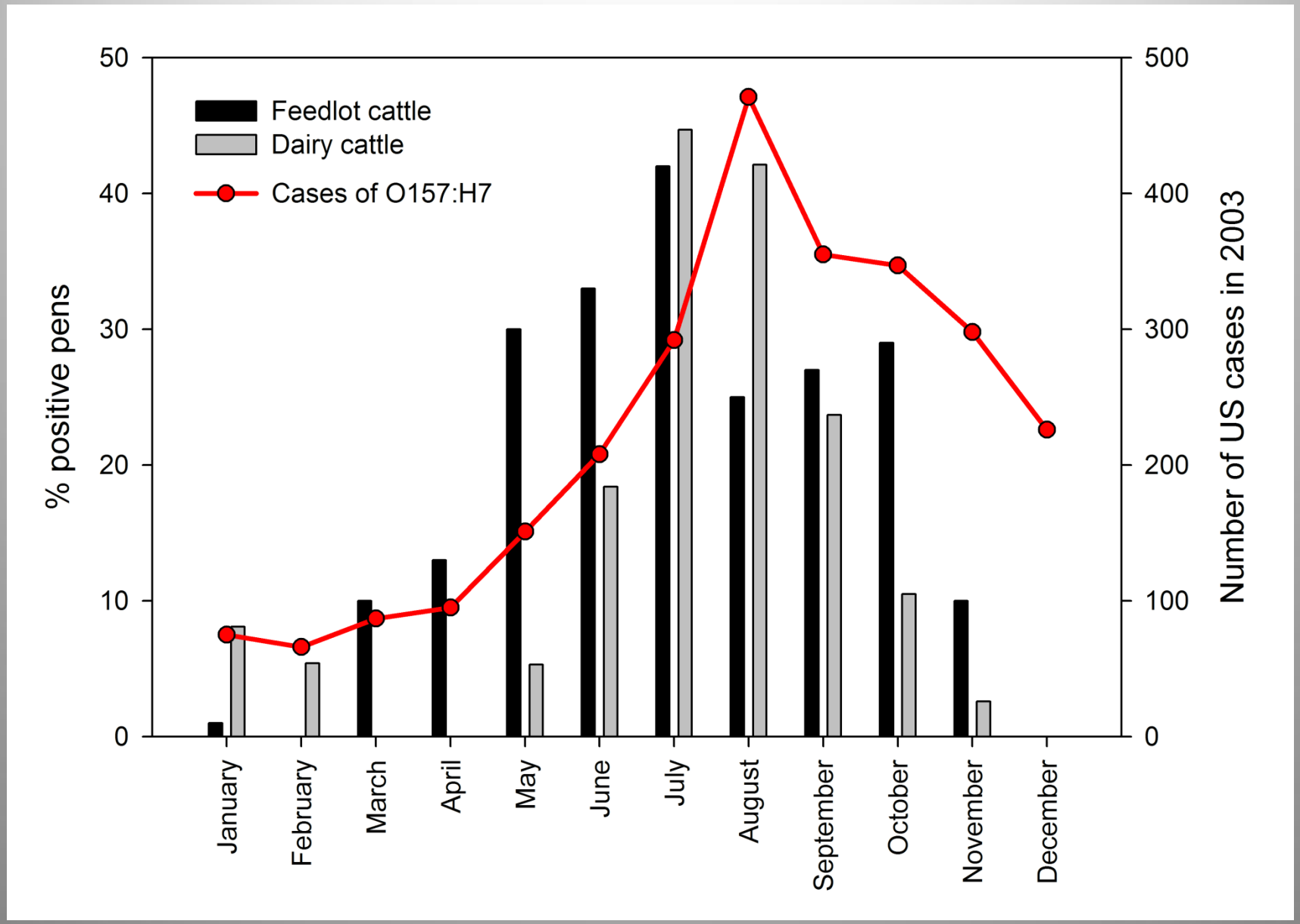
- Animal reservoirs of *E. coli* O157:H7
- Seasonal variation
- Genotypes
- Pre-harvest controls
- Post-harvest controls
- Adulterant status / recalls
- Testing
- Prioritization among food safety pathogens

Animal reservoirs: cattle

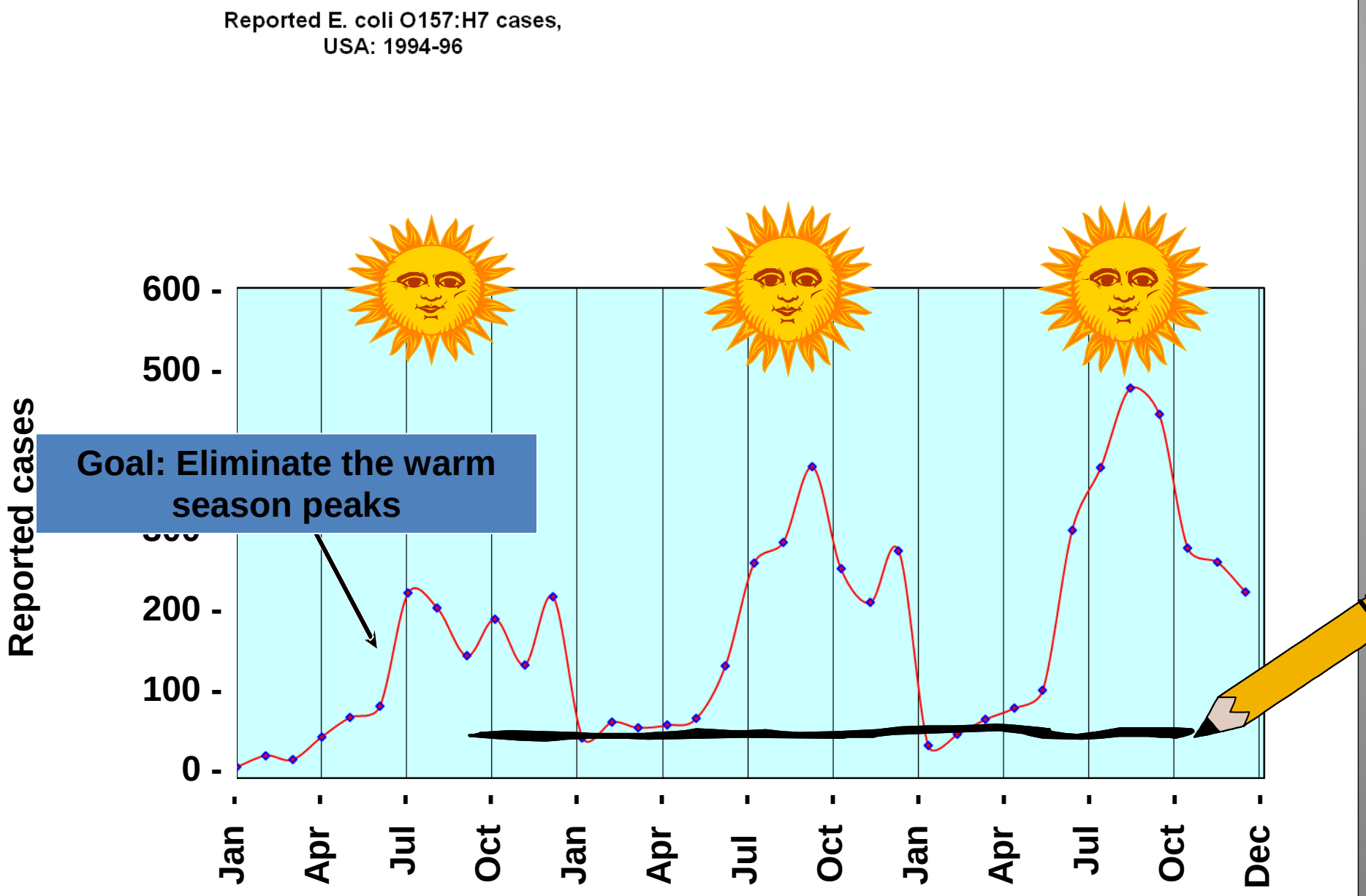
- Cattle reservoir
  - Summertime seasonal peak
  - Asymptomatic
  - Transient
  - $<10^2$ - $>10^5$ cfu/g feces
  - ID_{50} for cattle: 10^2-10^3
  - Immature animals (<2 yrs) more likely infected




Infected cattle and other food animals
Infected humans
Other infected animals (e.g., deer, rabbits, rodents, birds, insects, swine, etc.)
Contaminated soil, water, meat, milk, produce, etc.
Human infection



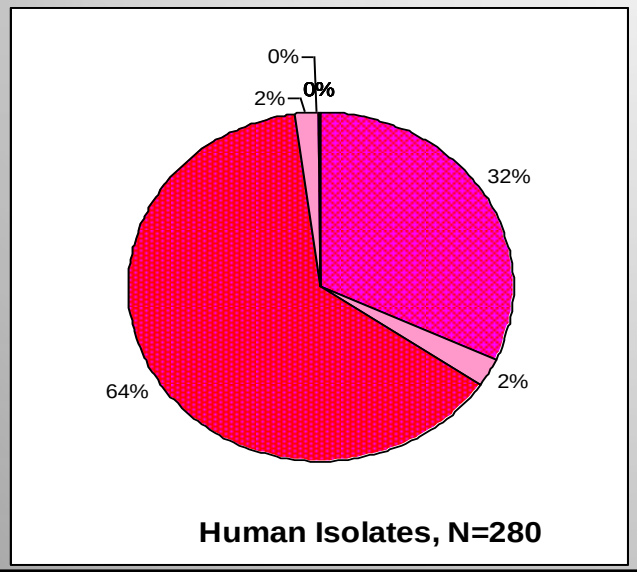
Data from CDC and Stanford et al 2005


Reported E. coli O157:H7 cases,
USA: 1994-96
Reported cases
600
500
200
100
0
Jan
Apr
Jul
Oct
Jan
Apr
Jul
Oct
Jan
Apr
Jul
Oct
Dec
Goal: Eliminate the warm season peaks

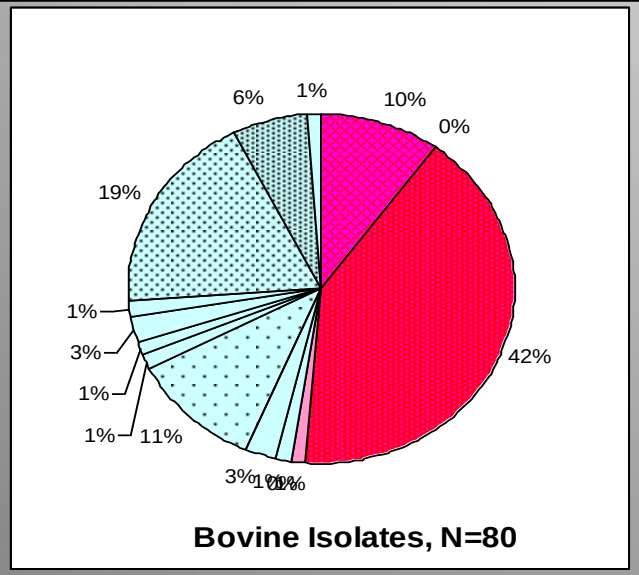
E. coli O157:H7 is highly clonal

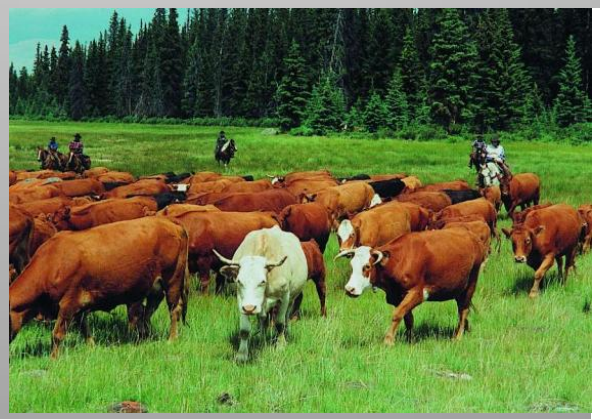
- >90% of isolates share one MLST type
- The first two sequenced strains (EDL933 and Sakai) differ by <100 SNPs
  (Leopold et al., 2009, PNAS)
- EDL933, Sakai, and the 'Spinach' outbreak strain share >96% ORFs, >>99% sequence identity among shared ORFs
  (Manning, PNAS 2008)
- Nevertheless, genetic strain differences within *E. coli* O157:H7 have been valuable for both outbreak investigation and for identifying ecological differences within the species

E. coli O157:H7 genotypes vary widely in their association with human disease



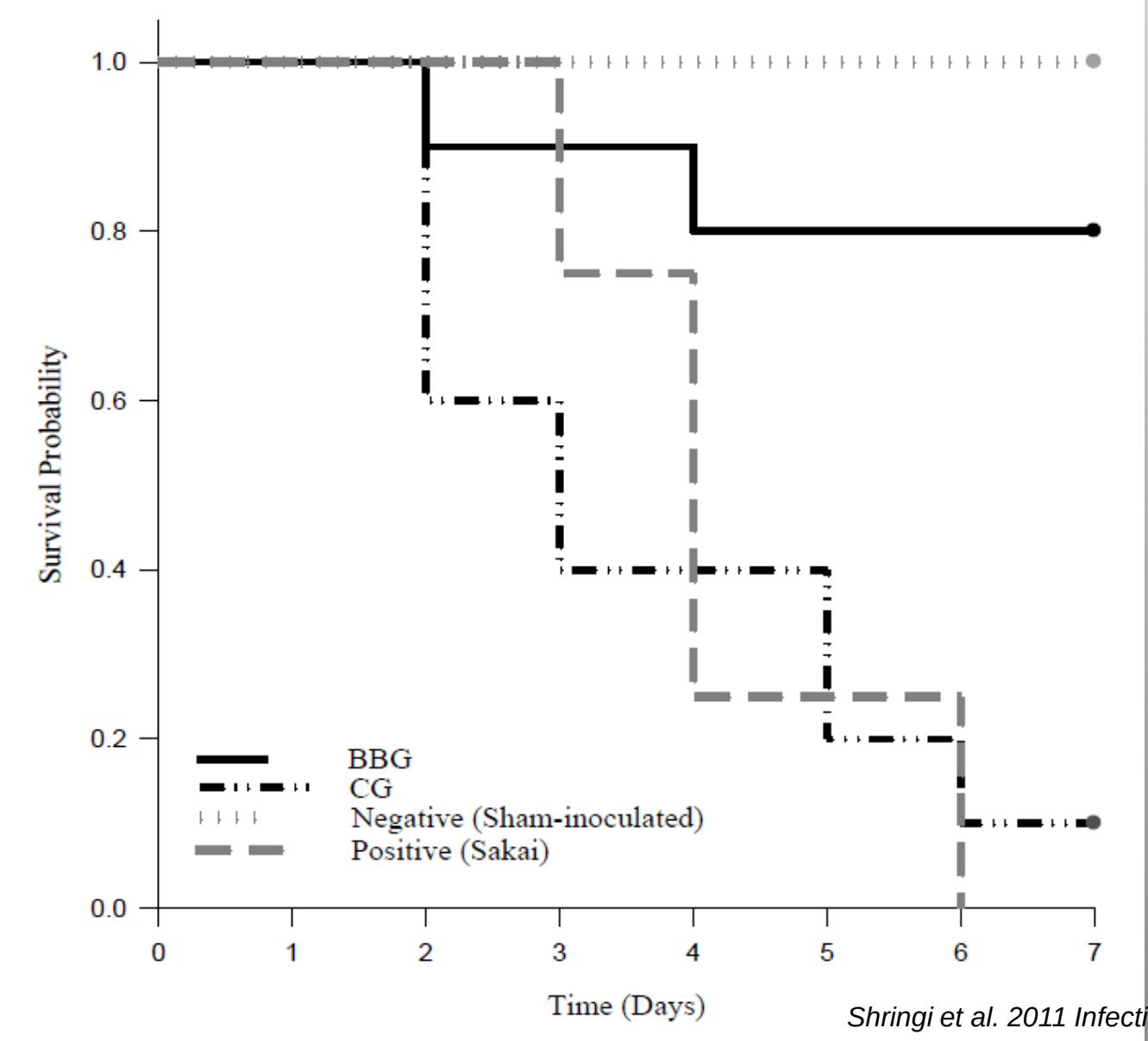
E. coli O157:H7 isolated from human patients fall into two main groups





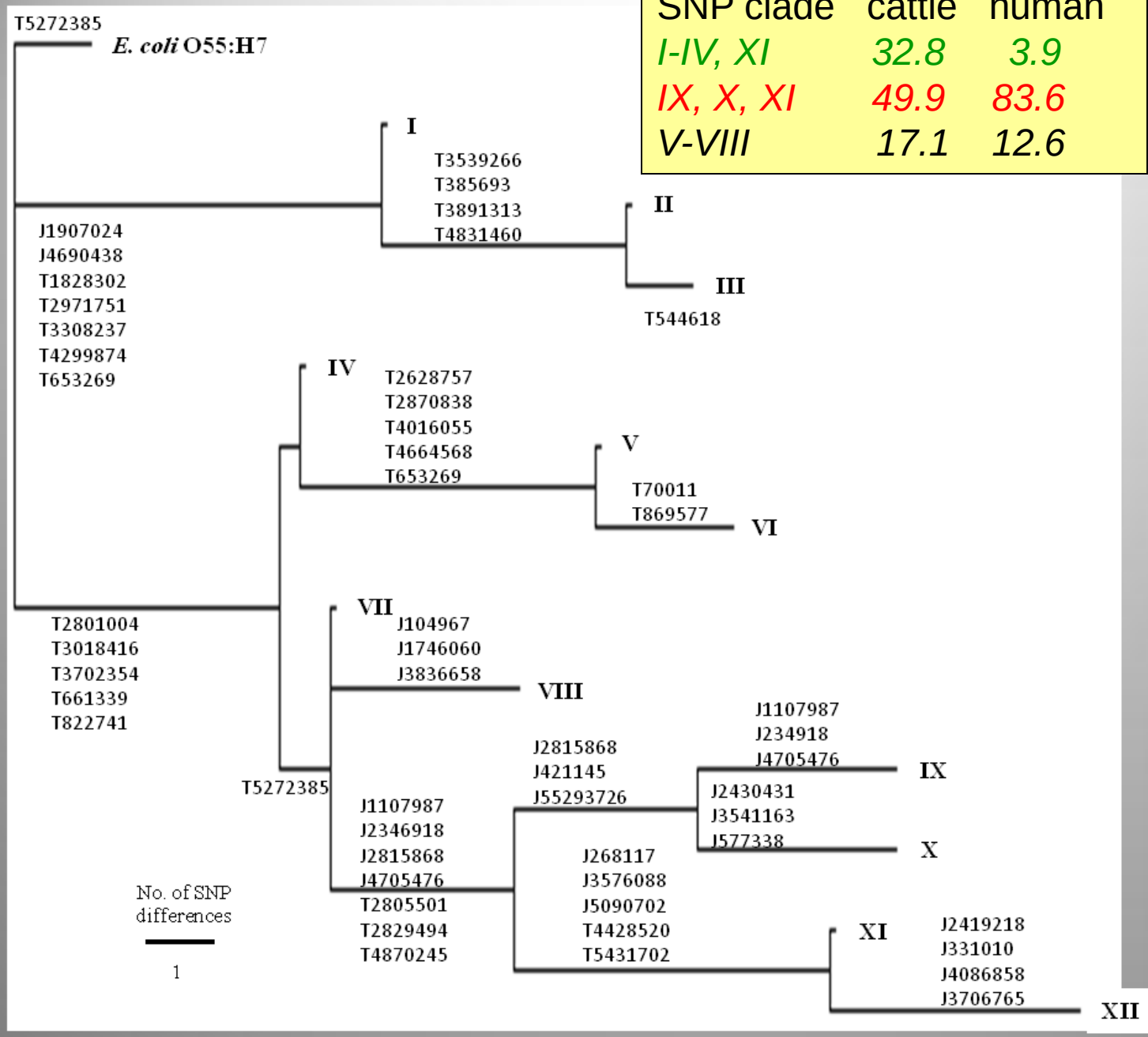
E. coli O157:H7 isolated from cattle are more diverse, and about half of cattle strains are strongly under-represented among clinical isolate

Differential virulence of *E. coli* O157:H7 SBI genotypes in a piglet model



Shringi et al. 2011 Infection & Immunity

SNP clade	cattle	human
I-IV, XI	*32.8*	*3.9*
IX, X, XI	*49.9*	*83.6*
V-VIII	*17.1*	*12.6*



No. (%) of *E. coli* O157:H7

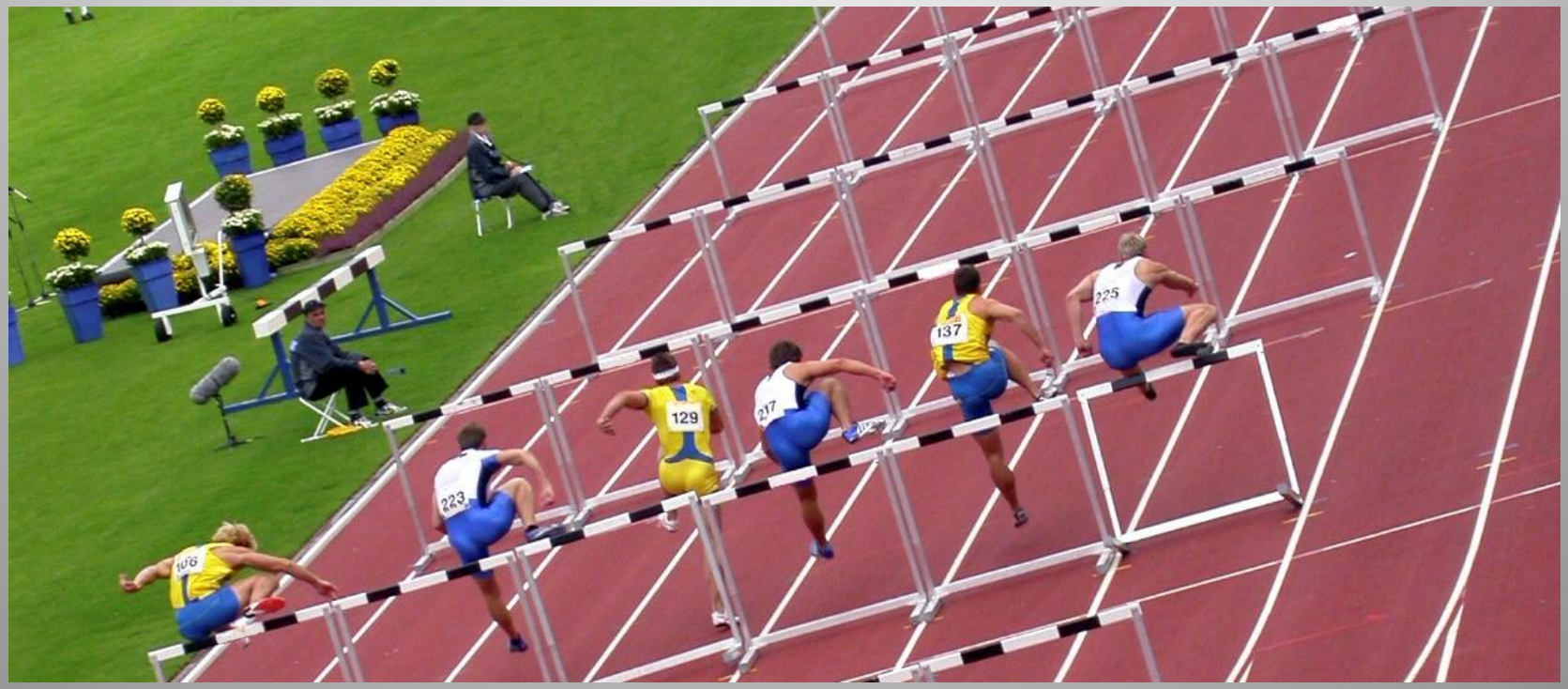
cattle	human	
7 (2.9)	0	Bovine origin
5 (2)	0 (0)	
47 (19.3)	3 (2.3)	
2 (0.8)	2 (1.6)	
11 (4.5)	8 (6.3)	
22 (9)	7 (5.5)	
1 (0.4)	1 (0.8)	
8 (3.3)	0	
5 (2)	21 (16.4)	Bovine and clinical origin
32 (13.1)	48 (37.5)	
19 (7.8)	0	
85 (34.8)	38 (29.7)	

E. coli O157:H7 genetic clades

- SNP (and SBI) genotypes:
  - Identify EHEC O157 lineages
  - Are differentially represented in human disease
  - Differ in piglet model virulence
  - Not currently considered, but relevant to both diagnostic and regulatory efforts

- *E. coli* O157:H7 genotypes in the bovine reservoir
  - Are much more diverse than clinical isolates
  - Must be taken into account to understand the full diversity of the species
  - Are hugely under-studied vs clinical isolates

Strategies for Control of *E. coli* O157:H7: The multiple hurdle approach



Cattle Farm Management and Husbandry Effects

Similar prevalence of detection of E. coli O157:H7 across widely different management systems!

Pre-harvest control of *E. coli* O157:H7

- Manure management
- Watertrough and feedbunk management
- Feed components
- Probiotics / DFM
- Vaccination

Summertime peak: 50-100% prevalence

~2 million positive cattle slaughtered / month

Post-harvest control of *E. coli* O157:H7

- Animals carry *E. coli* O157:H7 with them to the beef processing plants, both by GIT and hides
- *E. coli* O157:H7 is transferred to the carcass surface by either direct contact with contaminated hides or feces, or by aerosols (primarily from hides)
- For speed and accuracy, non-pathogenic bacteria (APC and Enterobacteriaceae) are used to monitor processes

Koohmaraie et al., 2005; Nou et al. 2003

Because of its public health significance, the vast scientific evidence showing the high incidence in cattle, the severity of the illness, and outbreaks due to this pathogen, these events prompted FSIS (1994) to declare *E. coli* O157:H7 as an adulterant in meat (beef) products.

http://www.fsis.usda.gov/PDF/PHVt-Food_Microbiology.pdf

An adulterant:
"any poisonous or deleterious substance
which may render it (a food product) injurious to health…"

Declaration of adulterant status
had major effects on beef production facilities:

1) Installation of sophisticated complex facilities for haircoat and carcass treatment
2) Risk of recalls for products testing positive

Post-harvest control of *E. coli* O157:H7

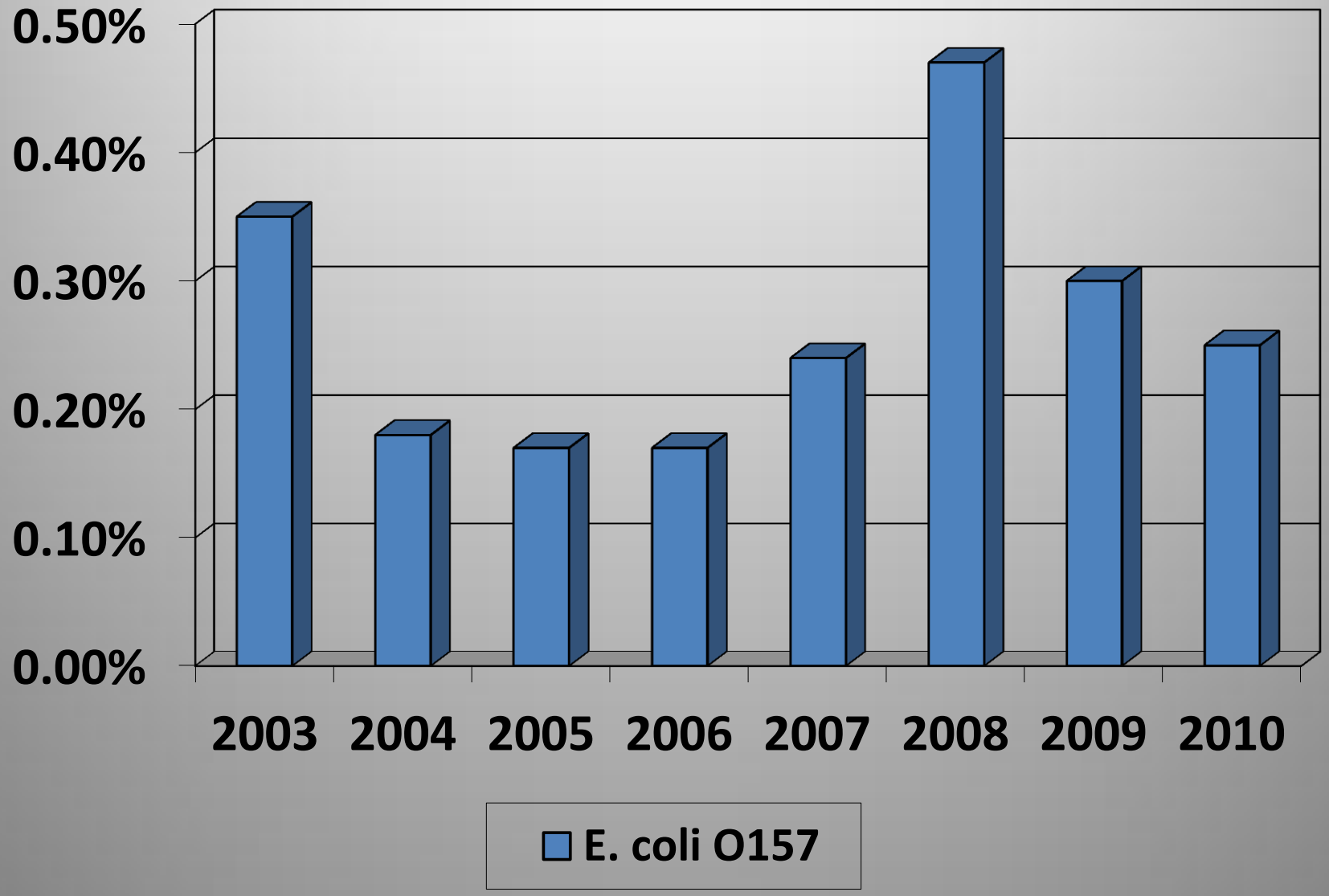
- Hide/hair treatments
  - Chemical de-hairing
  - Cetylpyridinium chloride, phosphoric acid, chloroform, sodium hydroxide, ozonated water, acid chloride rinses
- Carcass treatments
  - Steam vacuuming
  - Organic acids / hot water
  - Steam pasteurization
  - Low dose radiation

http://www.nytimes.com/2007/12/06/business/06meat.html

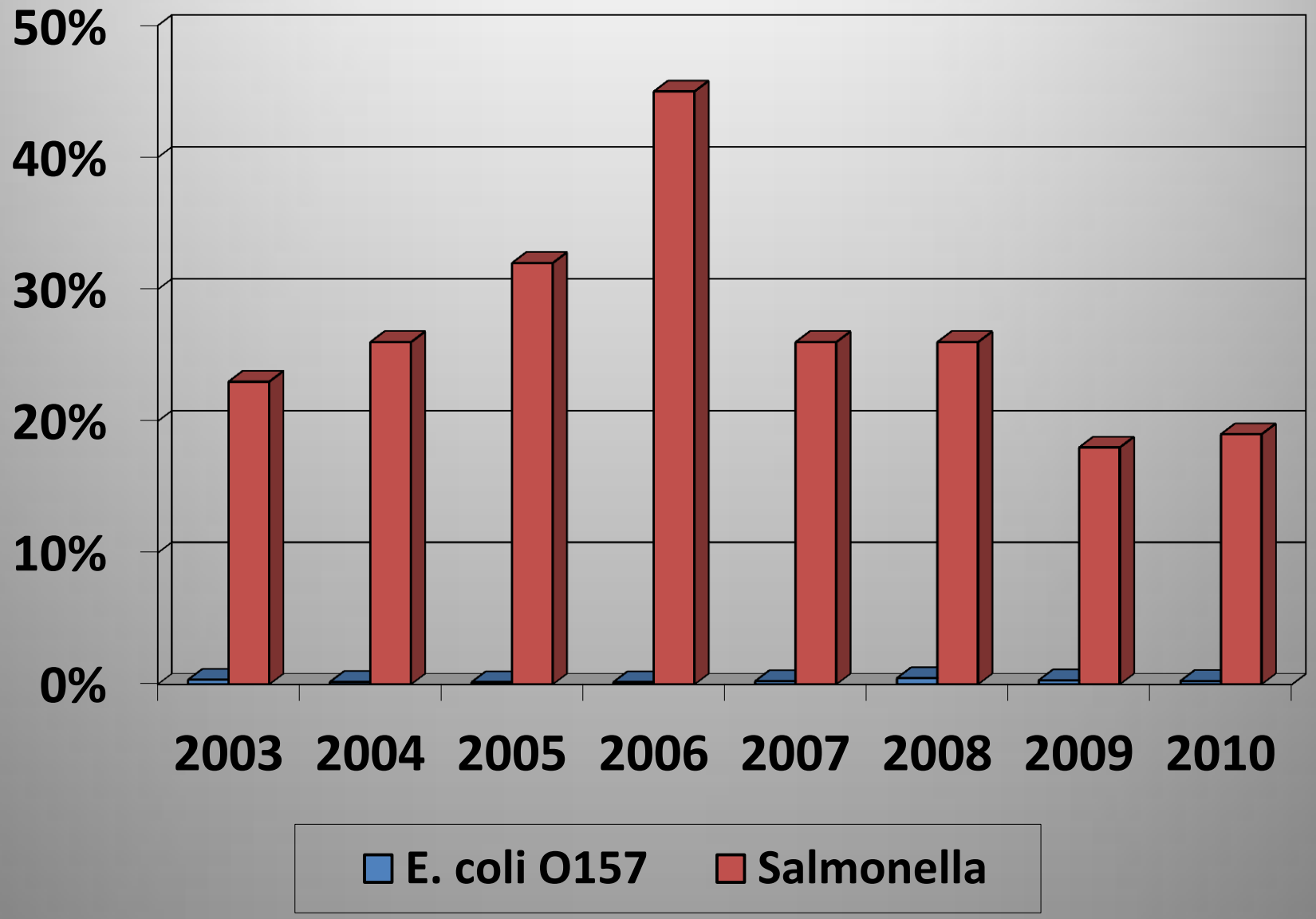
Post-harvest control of *E. coli* O157:H7

- Process improvements
  - Carcass spacing
  - Improved lighting
  - Knife rotation
  - Improved cooling
- Test and hold procedures
  - Greatly improves response to recalls

FSIS detection of *E. coli* O157:H7 in routine testing of ground beef



FSIS detection of *E. coli* O157:H7 in ground beef and *Salmonella* in ground chicken



Detection of *E. coli* O157:H7 Triggers Food Recalls

- *E. coli* O157:H7 is considered an 'adulterant'
  - 2009 – 2010: 25 recalls

- Microbiologic sampling: 19 recalls
  - Average size: 15,572 lbs
  - Average recall success: 51.2%
  - Recalled, but not acquired: 138,572 lbs

- Illness traceback: 6 recalls
  - Average size: 389,395 lbs
  - Average recall success: 27.4%
  - Recalled, but not acquired: 1,792,817 lbs

Causes of Deaths (~2003 - 2010)	Annual Deaths	Lifetime Death Risk
Heart disease	652,486	1 in 5
Cancer	553,888	1 in 7
Stroke	150,074	1 in 23
Hospital-acquired Infections	99,000	1 in 38
Car accidents (2009)	44,757	1 in 100
Suicide (2009)	31,484	1 in 121
MRSA (resistant bacteria)	19,000	1 in 197
Drowning	3,306	1 in 4,919
Non-typhoidal Salmonella	378	1 in 9,915
Sun/heat exposure	273	1 in 13,729
Lightning	47	1 in 83,930
Escherichia coli O157:H7	20	1 in 187,403
Fireworks	11	1 in 340,733
Shark attack	1	1 in 3,748,067
Escherichia coli non-O157	0-1	≤1 in 3,748,067

National Safety Council data; http://www.flmnh.ufl.edu/; CDC

Summary

- *E. coli* O157:H7 – a multi-faceted problem
- No effective controls in animal reservoirs
- No current prospect of an *E. coli* O157:H7-free food supply or environment
  - How much should society spend on this problem?
  - How safe is safe enough?

Questions?