Microbial water quality and produce safety

Salinas River Symposium: Reconnecting the River

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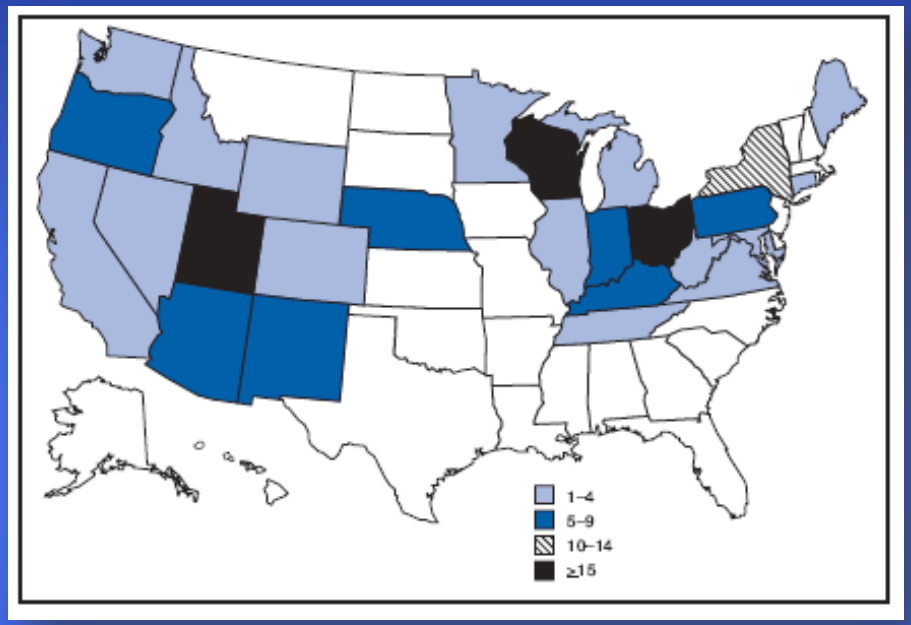
UNIVERSITY of CALIFORNIA Agriculture & Natural Resources

California high value produce feeds the US

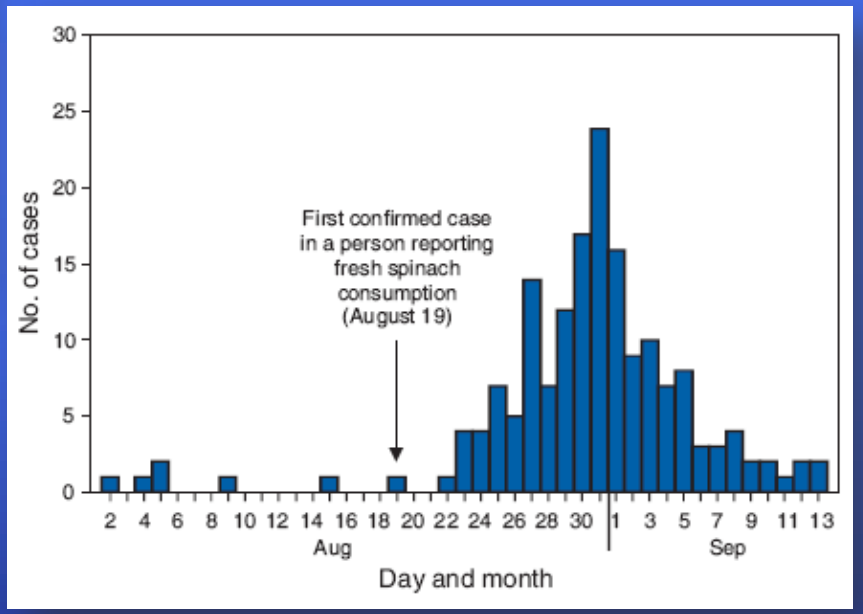
Group	Commodity		CA production (cwt)	Annual servings (billions / yr)	% of US total
Berries	Fresh strawberries		36,750,000	11.0	88.7
	Fresh raspberries		1,080,000	0.4	62.2
Grapes	Table grapes		19,500,000	15.6	90.1
Leafy greens	Head lettuce		36,750,000	29.4	75.3
	Leaf lettuce		10,557,000	8.5	85.9
	Romaine		17,614,000	14.1	71.5
	Spinach, fresh market		3,822,000	3.1	61.9
Nuts	Almonds, shelled		20,300,000	32.5	100
	Pistachios, in shell		4,440,000	4.8	100
	Walnuts, shelled		2,720,000	4.4	100
Tomatoes	fresh market		12,425,000	5.0	40.9

Fall 2006 spinach outbreak of *E. coli* O157:H7

Product originated from a field in San Benito County, CA

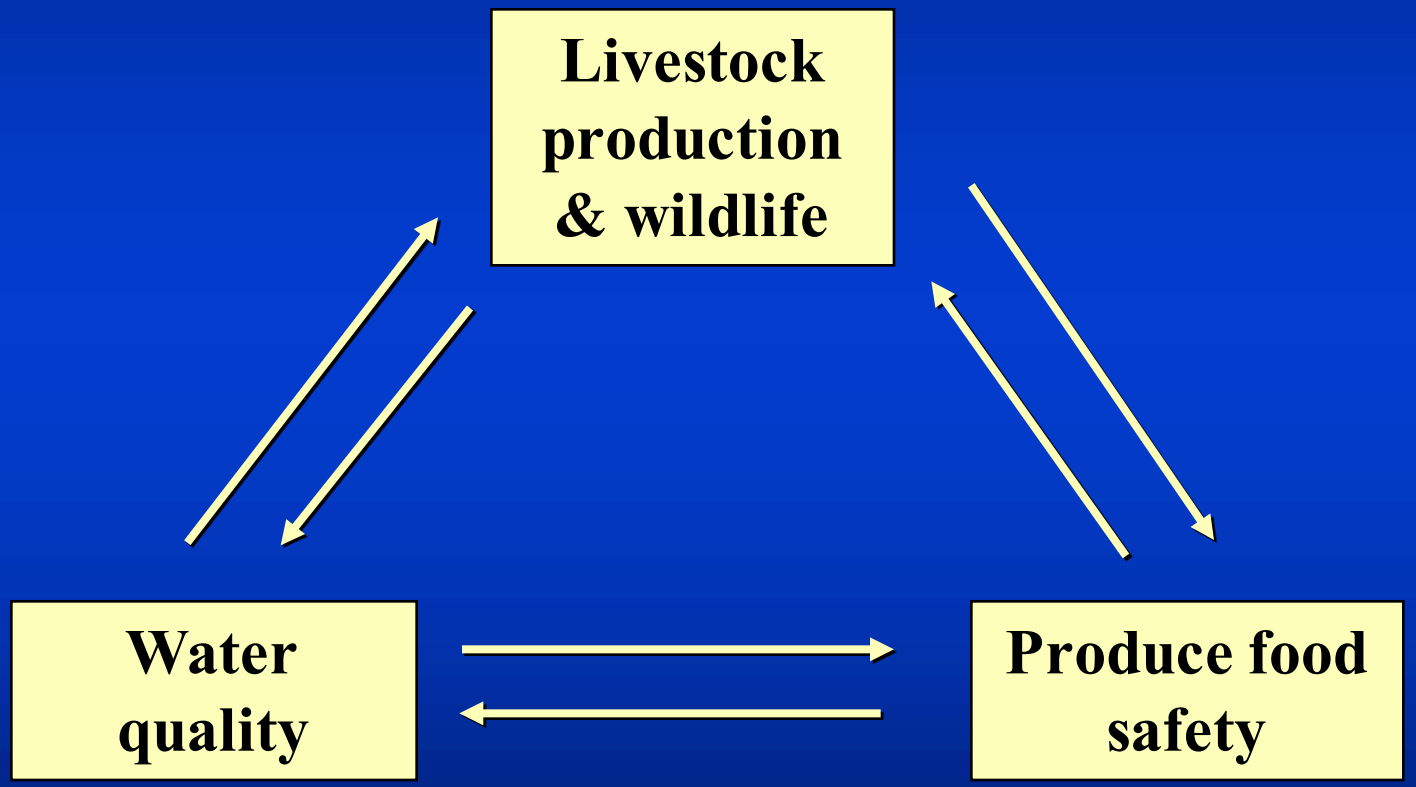


Outbreak occurred in *August* and *September*



Are these produce outbreaks the result of irrigation water, winter runoff, livestock grazing and/or wildlife?
What is the biological source of pathogens and process of contamination?
Many outbreaks in late summer or fall, so how does contamination occur?

Minimizing pathogen movement from livestock & wildlife to food and water



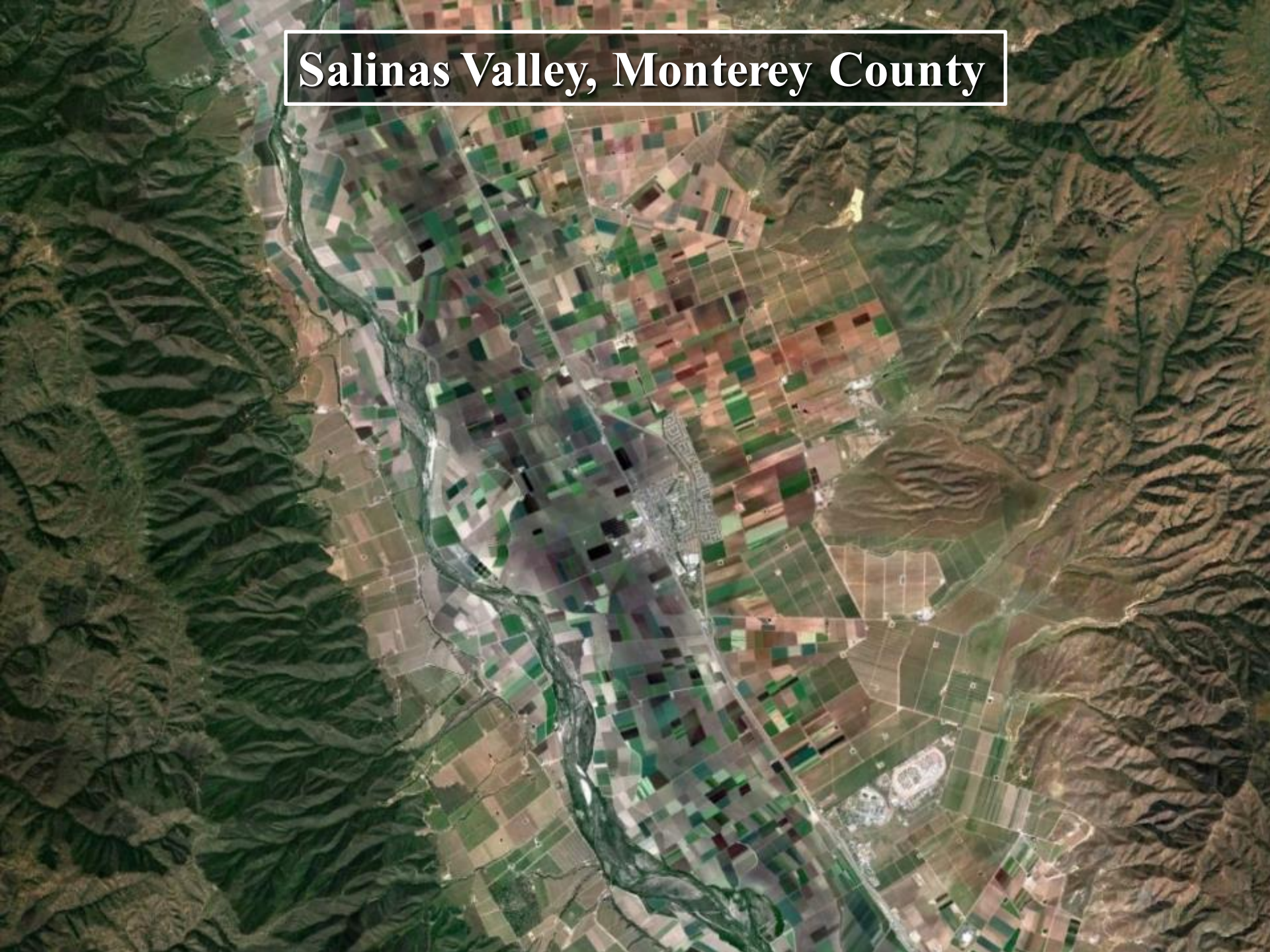
irrigation water, rangeland runoff

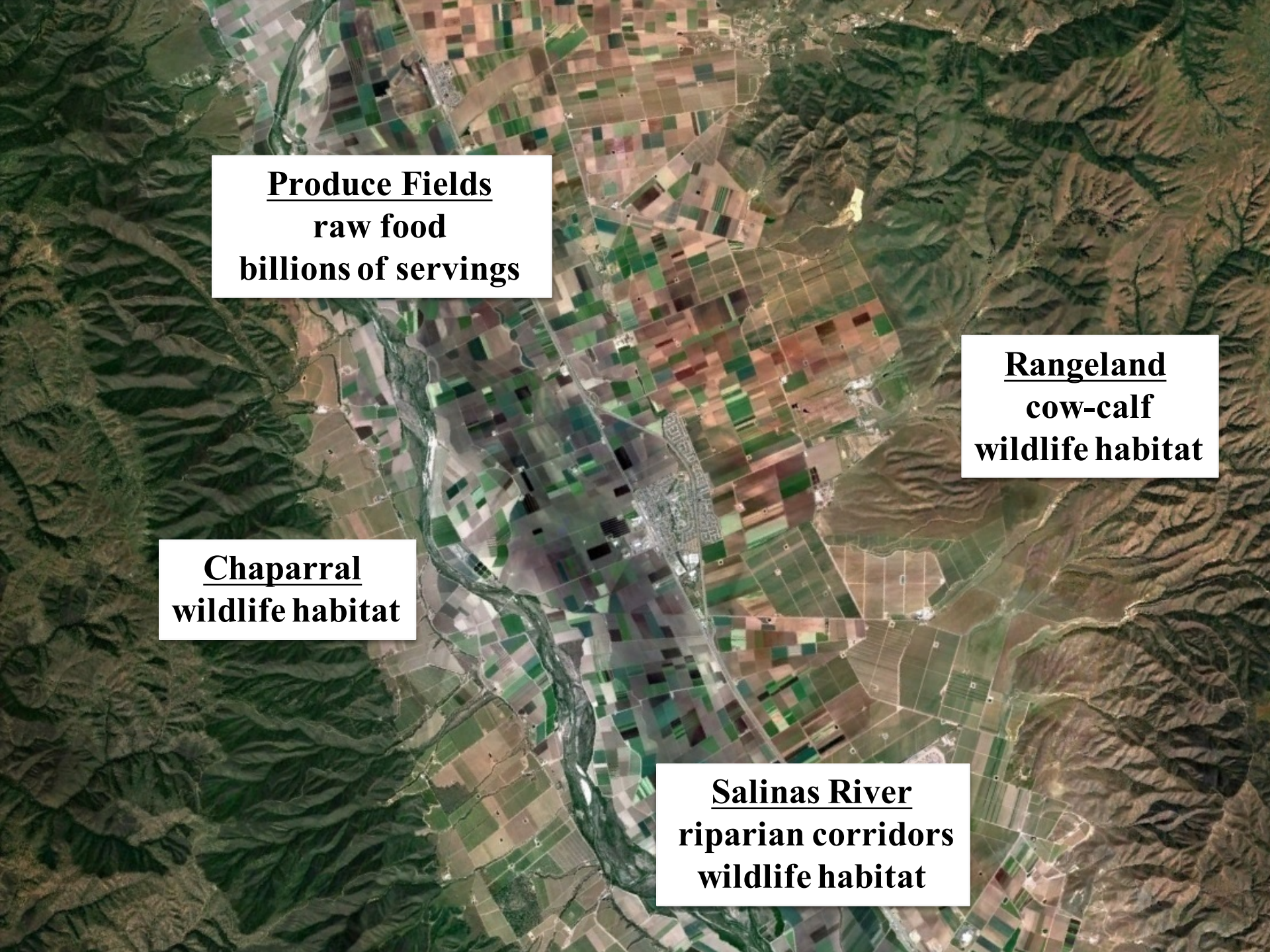
Developing beneficial management practices (BMPs):
1° goal is to match pathogen flux with local BMP efficacy

Key processes driving waterborne zoonotic transmission

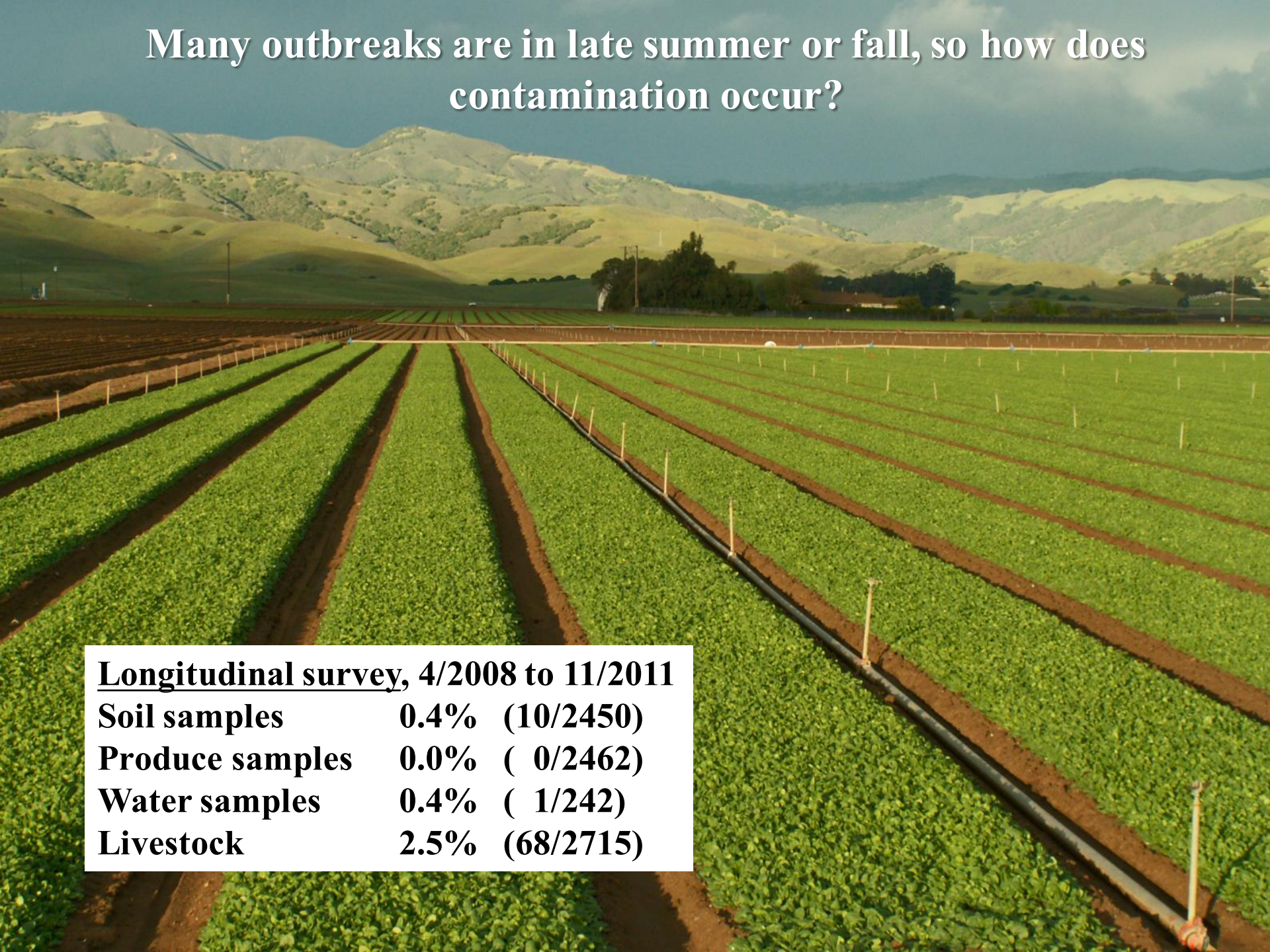
A. Vertebrate pathogen loading: *who sheds the pathogen?*
B. Hydrological transport: *how are pathogens reaching water?*
C. Inactivation kinetics: *can the pathogen survive long enough?*
D. Inter-species infectivity: *is the pathogen infectious for humans?*

Comparing livestock to wildlife shedding of key waterborne zoonotic pathogens


Salinas Valley, Monterey County


Produce Fields
raw food
billions of servings
Rangeland
cow-calf
wildlife habitat
Chaparral
wildlife habitat
Salinas River
riparian corridors
wildlife habitat

Many outbreaks are in late summer or fall, so how does contamination occur?



Longitudinal survey, 4/2008 to 11/2011		
Soil samples	0.4%	(10/2450)
Produce samples	0.0%	(0/2462)
Water samples	0.4%	(1/242)
Livestock	2.5%	(68/2715)

Wildlife and beef cattle from central coastal CA, 2008-10

***E. coli* O157:H7**

Feral pig	10/200	(5%)
Coyote	2/95	(2%)
Am. crow	5/93	(5%)
Cowbird	2/60	(3%)
Rabbit	0/108	(0%)
Skunk	0/63	(0%)
Tule elk	3/150	(2%)
Deer	0/447	(0%)
Rodents	2/1043	(0.2%)

Beef cattle 68/2715 (2.5%)

Salmonella enterica

wildlife	17/449	(3.8%)
cattle	1/795	(0.13%)

wildlife risk 30 times higher compared to cattle ($P<0.001$)

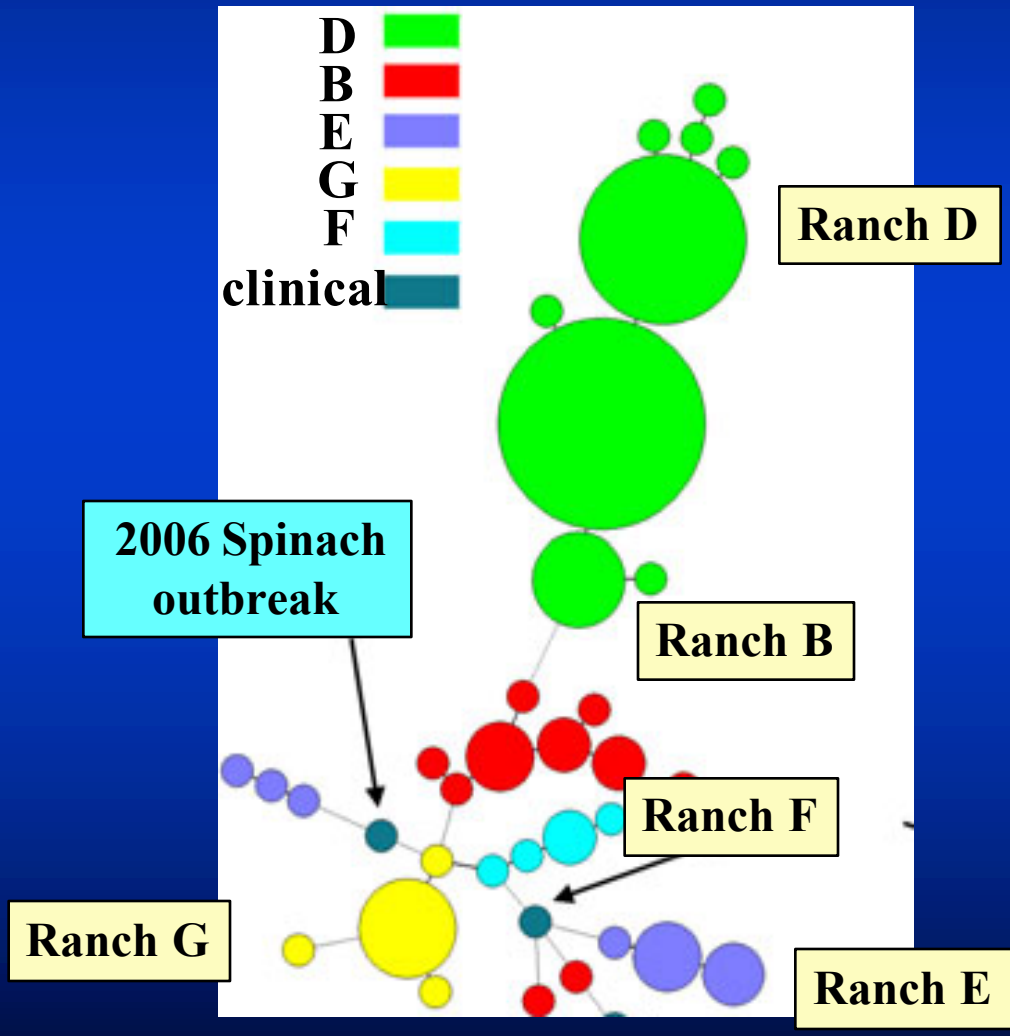
Cow-calf herds, central coastal CA, 2008-2010

E. coli O157 infection ranged from 0% to 10%

Herd	pos	n	prev (%)
A	0	489	0.0
B	7	480	1.5
C	0	200	0.0
D	44	434	10.1
E	0	61	0.0
F	6	386	1.6
G	2	271	0.7
H	9	256	3.5
I	0	138	0.0
Total	68	2715	2.5

Phylogenetic tree of *E. coli* O157:H7 spinach outbreak and cattle isolates from outbreak region, central California

Ranch location



CA statewide survey of 20 cow-calf herds, 2012-2013

Butte, Contra Costa, Humboldt, Kern, Lassen, Madera, Modoc, Mono, San Joaquin, San Luis Obispo, Solano, Stanislaus, Tulare and Yuba County (14 counties),

1412 cows and calves

Prevalence (%) of fecal shedding (positive/total)

	Salmonella	*E. coli* O157	*Cryptosporidium*	*Giardia duodenalis*
Cow	0.4% (3/726)	5% (37/726)	9% (67/726)	23% (168/726)
Calf	0.15% (1/686)	5% (35/686)	20% (136/686)	42% (286/686)
TOTAL	0.3% (4/1412)	5.1% (72/1412)	14.4% (203/1412)	32% (454/1412)

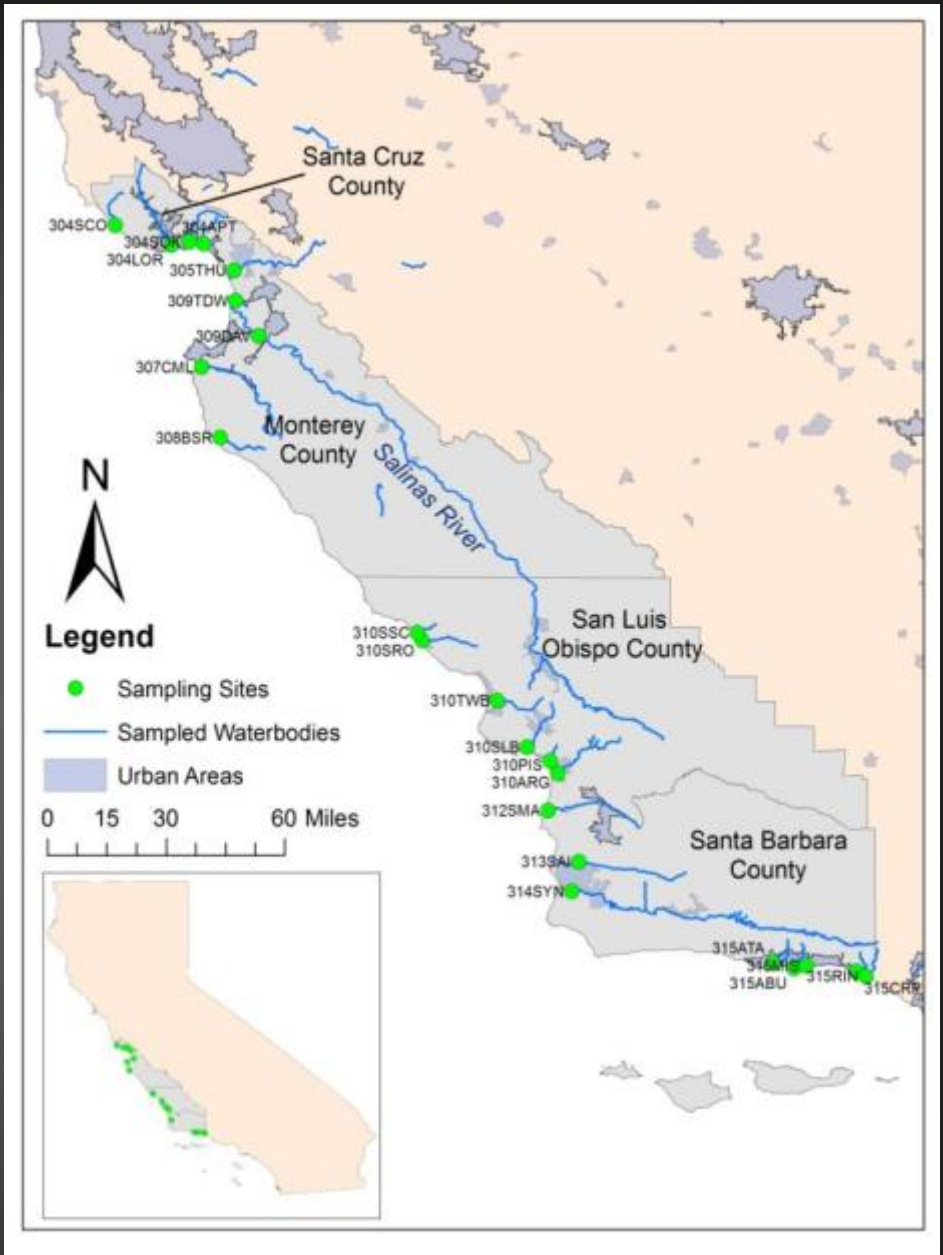
CCRWQCB

From Rincon Creek up to Aptos Creek
23 rivers, creeks or their estuaries

April 2009 to April 2010

***E. coli* O157**
6/251 = 2.4%

Salmonella
78/251 = 35%
1.3 MPN/100 ml



Recall <<1% cow-calf shed *Salmonella*; 2-4% in wildlife

Cryptosporidium from CA beef cattle in this study appear to have low to no infectivity for humans

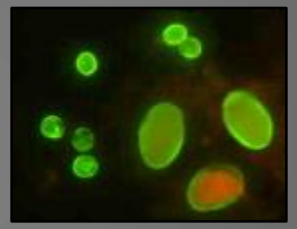
	C. andersoni	*C. bovis*	*C. ryanae*	*C. parvum*
Cow	0	1	18	0
Calf	1	18	43	0
Total	1 (1.2%)	19 (23.5%)	61 (75.3%)	0 (0%)

Giardia duodenalis from CA beef cattle in this study appear to have low to no infectivity for humans

	Assemblage E	Assemblage C	Unknown
Cow	56	8	2
Calf	128	7	4
Total	184 (90%)	15 (7%)	6 (3%)

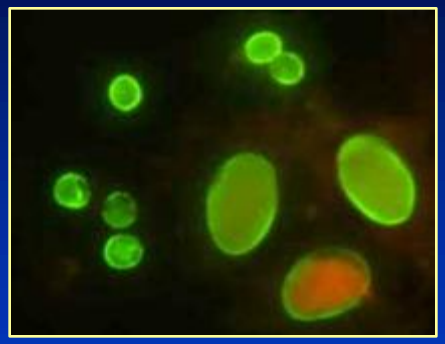
Prevalence of pathogens in wild rodents from produce fields and cattle ranches, central California

E. coli O157:H7 2/1043 (0.2%)
Salmonella 30/1043 (3.0%)



Rodent species	*Cryptosporidium*	*Giardia*
CA parasitic mouse	11%	13%
Deer mouse	33%	27%
Dusky-footed wood rat	17%	17%
TOTAL	30%	26%

Crypto appears human infectious, *Giardia* appears not



Concentration of *Cryptosporidium* in infected deer mice

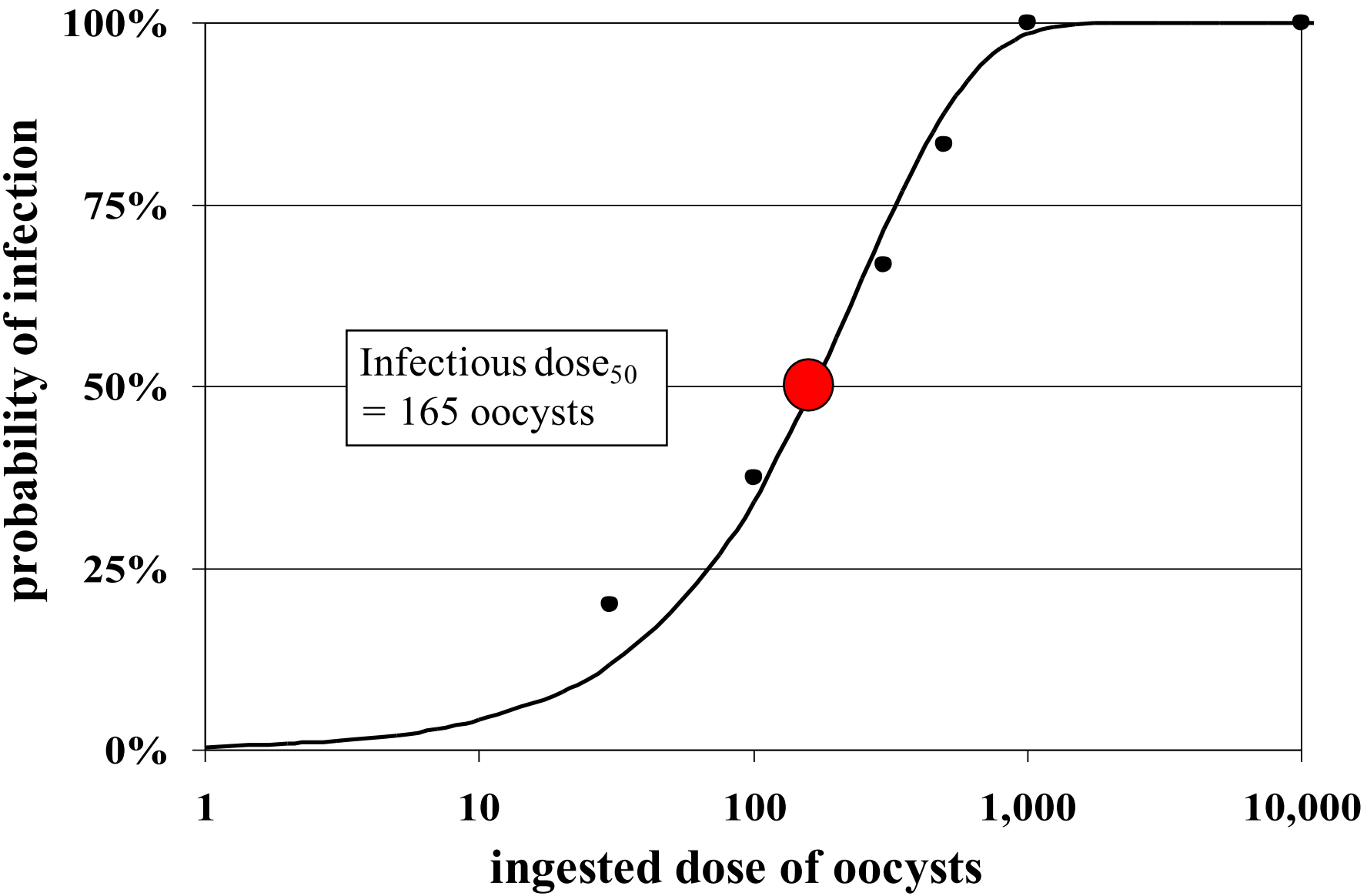
over 50 million oocysts / gram of feces

or

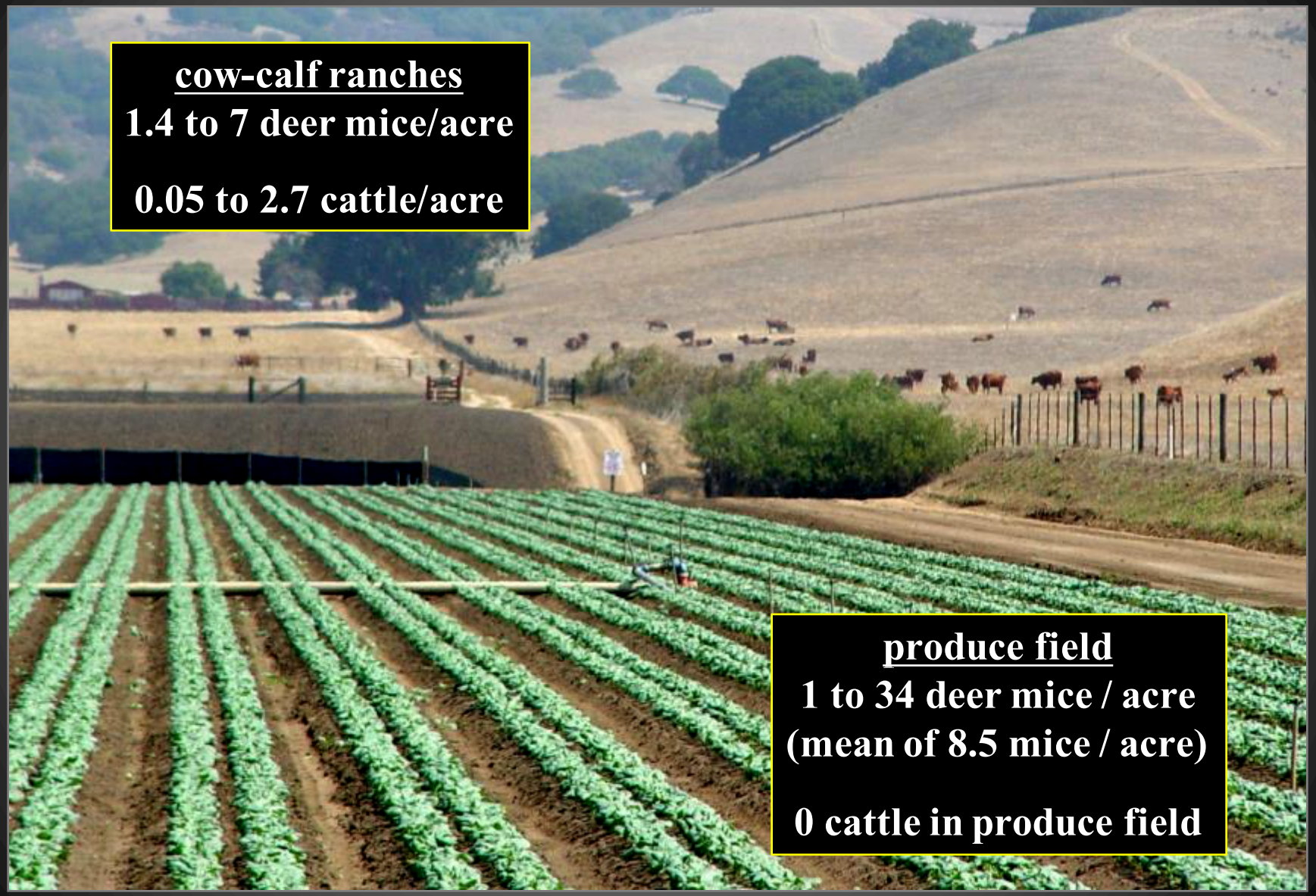
2,500,000 oocysts per fecal pellet (5 mg)!!

Human dose-response curve for *C. parvum*

$$Probability\ of\ infection = 1 - e^{-\frac{dose\ of\ oocysts}{238.6}}$$



Winter precipitation runoff versus summer tail-water flows



Environmental loading of *Cryptosporidium rubeyi* and other *Cryptosporidium* species by California ground squirrels on rangeland, Kern County, CA

When wildlife congregate then food safety risks are magnified

Prevalence = 5%

What is the probability of ≥1 positive bird in this group of 10 crows?

Prob ($X \geq 1$ positive) for 10 crows

Using the binomial distribution,

$$\binom{n}{x} (p)^{x} (1 - p)^{n - x}$$

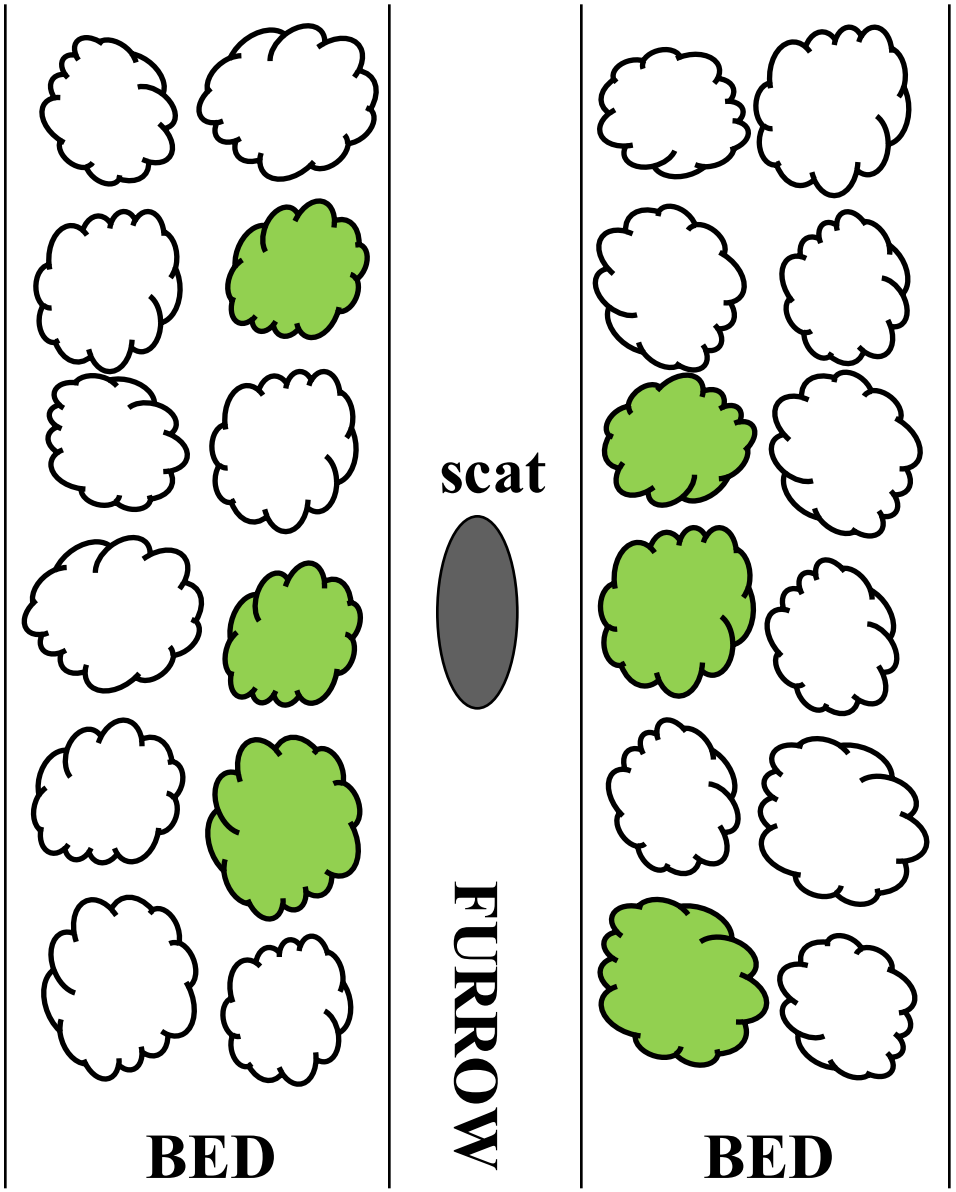
Prob = 40% for ≥ 1 crow with *E. coli* O157, n=10

What if 20 crows visit the field?
64% chance for ≥ 1 bird with *E. coli* O157

n=30, prob=79%
n=40, prob=87%

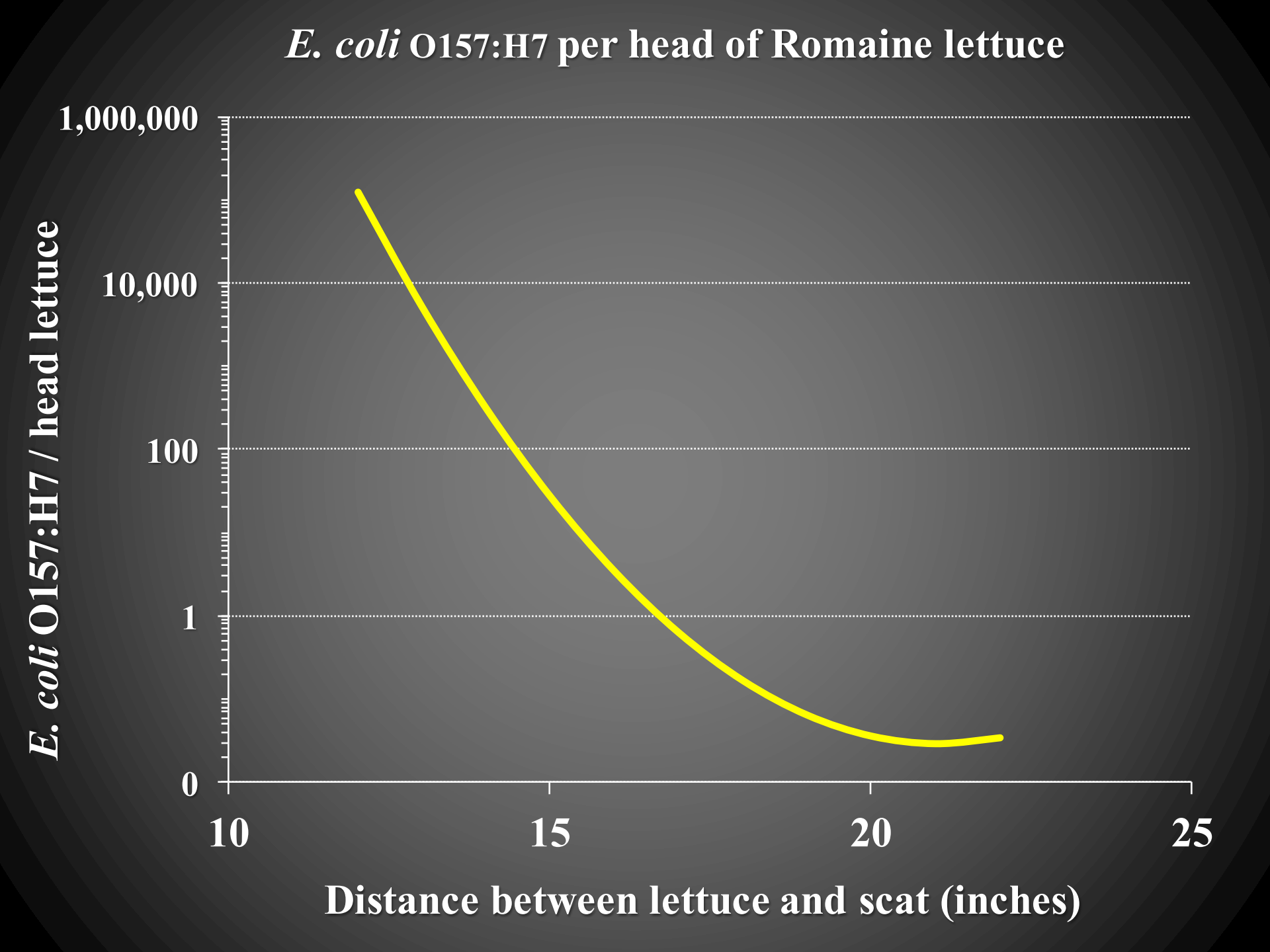

So how did the *E. coli* cross the road and contaminate the produce?

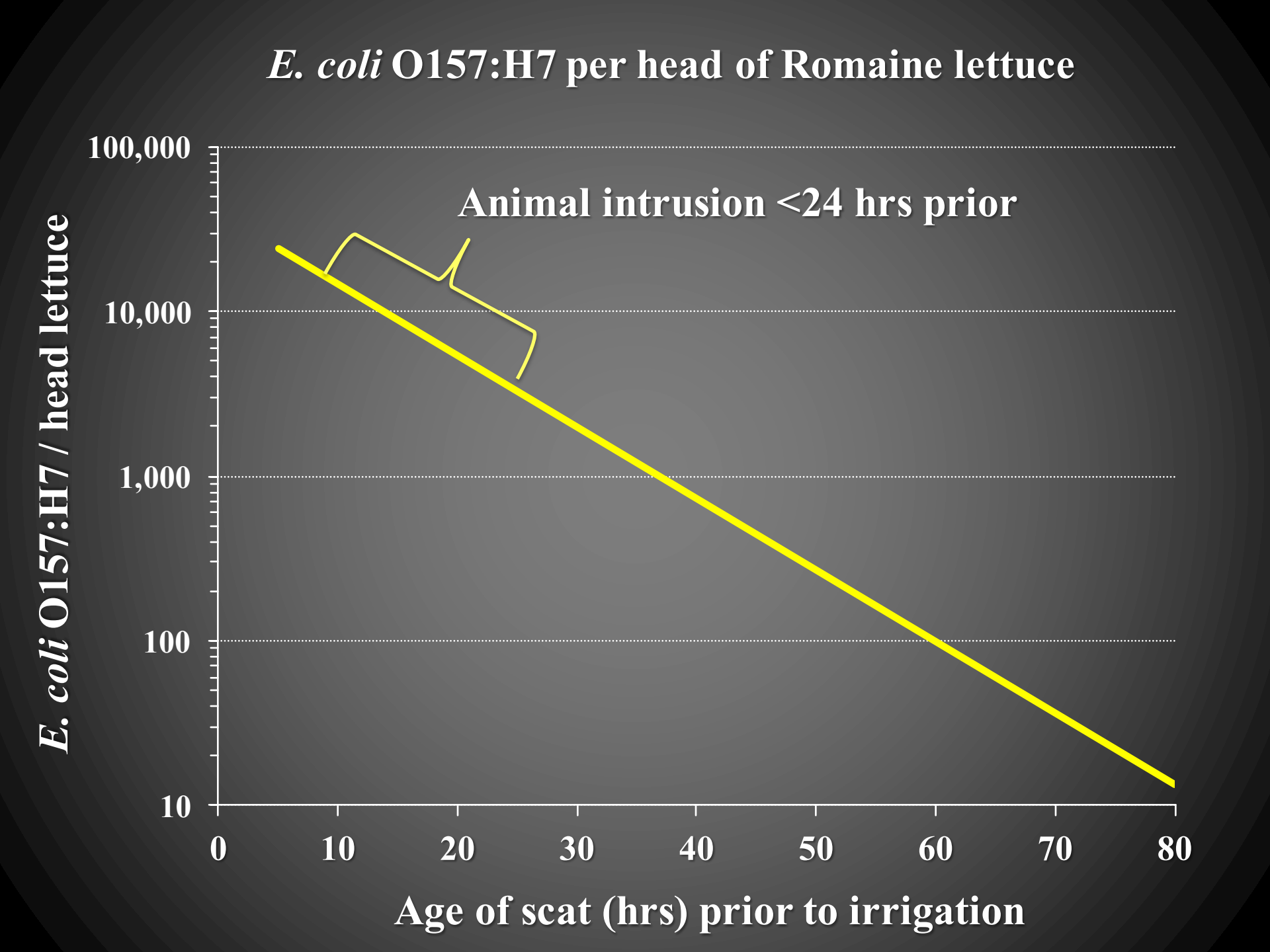
Randomized field trials of romaine lettuce
Salinas Valley, 2011 & 2012

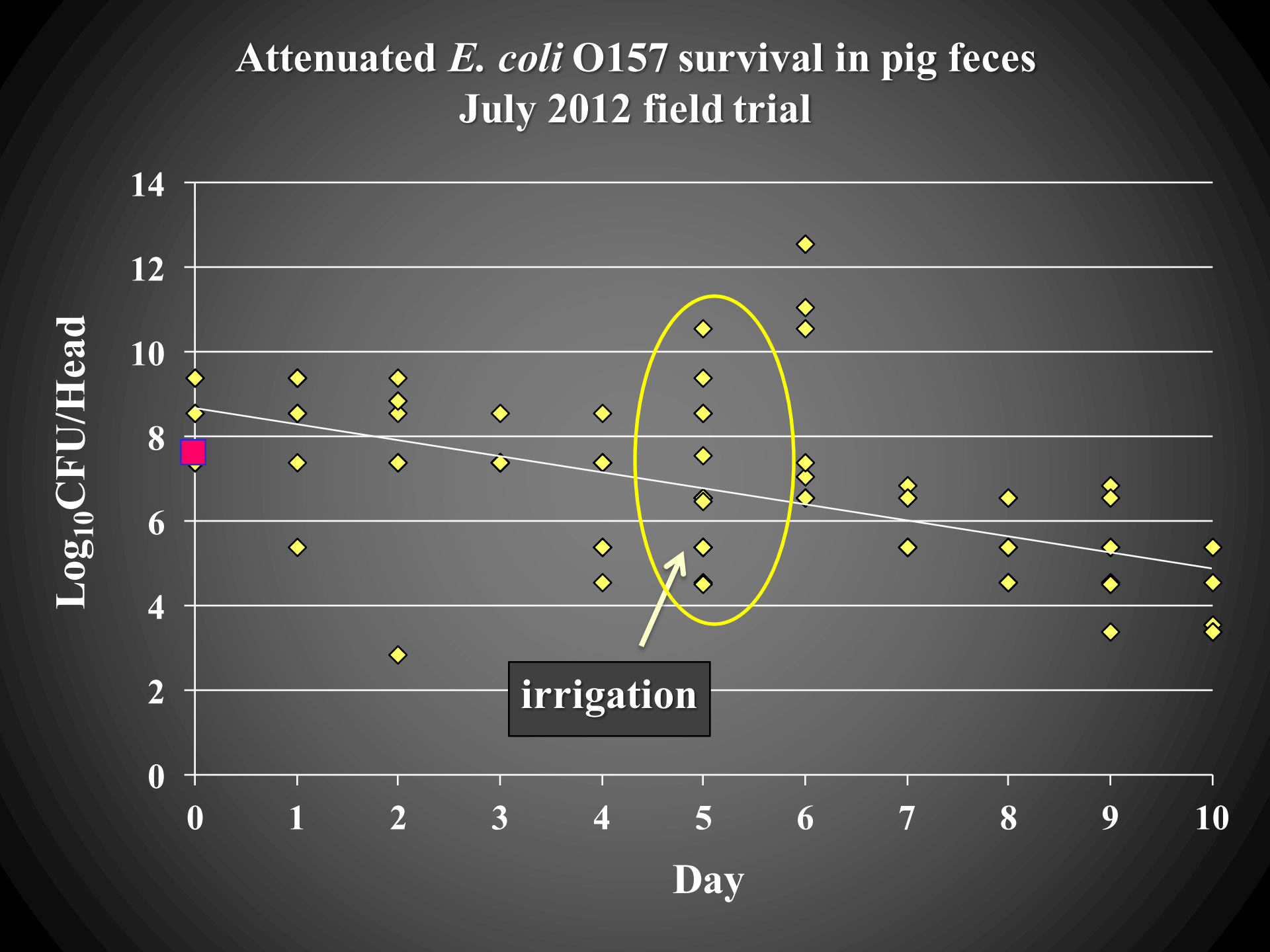

scat
FURROW
BED
BED

Add in 2 hours of irrigation

20 to 30% of nearby heads of lettuce contaminated with *E. coli* O157:H7


E. coli O157:H7 per head of Romaine lettuce
1,000,000
10,000
100
1
0
E. coli O157:H7 / head lettuce
10
15
20
25
Distance between lettuce and scat (inches)


E. coli O157:H7 per head of Romaine lettuce
100,000
10,000
1,000
100
10
E. coli O157:H7 / head lettuce
Animal intrusion <24 hrs prior
0
10
20
30
40
50
60
70
80
Age of scat (hrs) prior to irrigation


Attenuated E. coli O157 survival in pig feces
July 2012 field trial
Log10CFU/Head
14
12
10
8
6
4
2
0
0
1
2
3
4
5
6
7
8
9
10
Day
irrigation

Exclude wildlife by fencing, trapping and habitat modification

Best theory:

- **wildlife intrusion, likely nocturnal**
- **combine with foliar irrigation**
- **combine with difficult biosecurity during harvesting**
- **lack of a kill step during processing**
- **product consumed raw by millions of consumers**

multiple independent variables sporadically combine to create full connectivity

Dr. Ken Tate: developing beneficial management practices:
1° goal is to match pathogen flux with BMP efficacy

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Questions?