Microbial water quality
~ wildlife and livestock contributions ~

Rob Atwill, D.V.M., M.P.V.M., Ph.D.
University of California-Davis

UCDAVIS School of Veterinary Medicine

WESTERN INSTITUTE for FOOD SAFETY & SECURITY

UNIVERSITY of CALIFORNIA Agriculture & Natural Resources

To all our cooperators from across California

be they ranchers, growers, or regulators, activists, resource managers, or the public

THANK YOU!

Access to working ranches and farms helps insure that solutions are practical, effective, & adoptable

Waterborne zoonotic pathogens

Drinking water safety

Recreational exposure

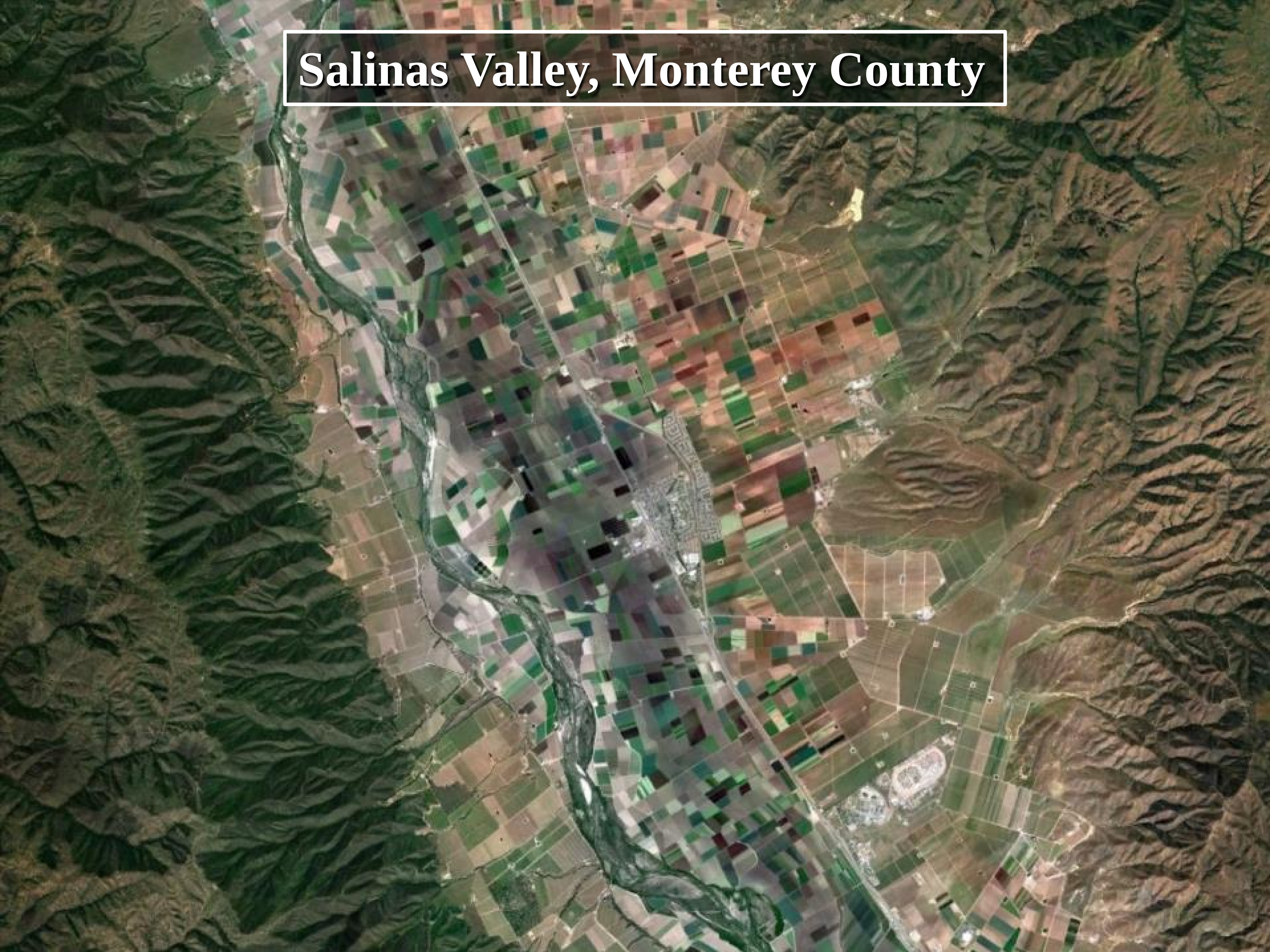
Irrigation water quality
produce food safety

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

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

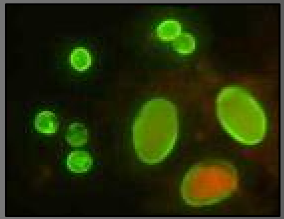
E. coli O157:H7		
Feral pig	10/200	(5%)
Coyote	2/95	(2%)
Am. crow	5/93	(5%)
Cowbird	2/60	(3%)
Rabbit	0/108	(0%)
Skunk	0/63	(0%)
Tule elk	3/150	(2%)
Deer	0/447	(0%)
Rodents	2/1043	(0.2%)
Beef cattle	68/2715	(2.5%)

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

wildlife shedding was 30 times higher compared to cattle (*P*<0.001)

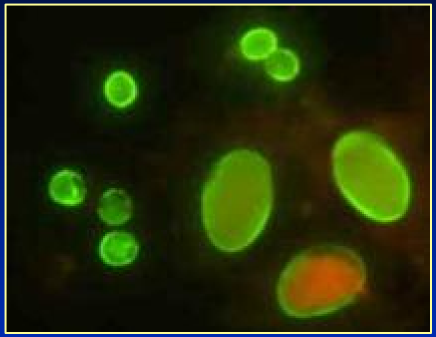
Prevalence of pathogens in wild rodents from produce fields and cattle ranches, central California

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



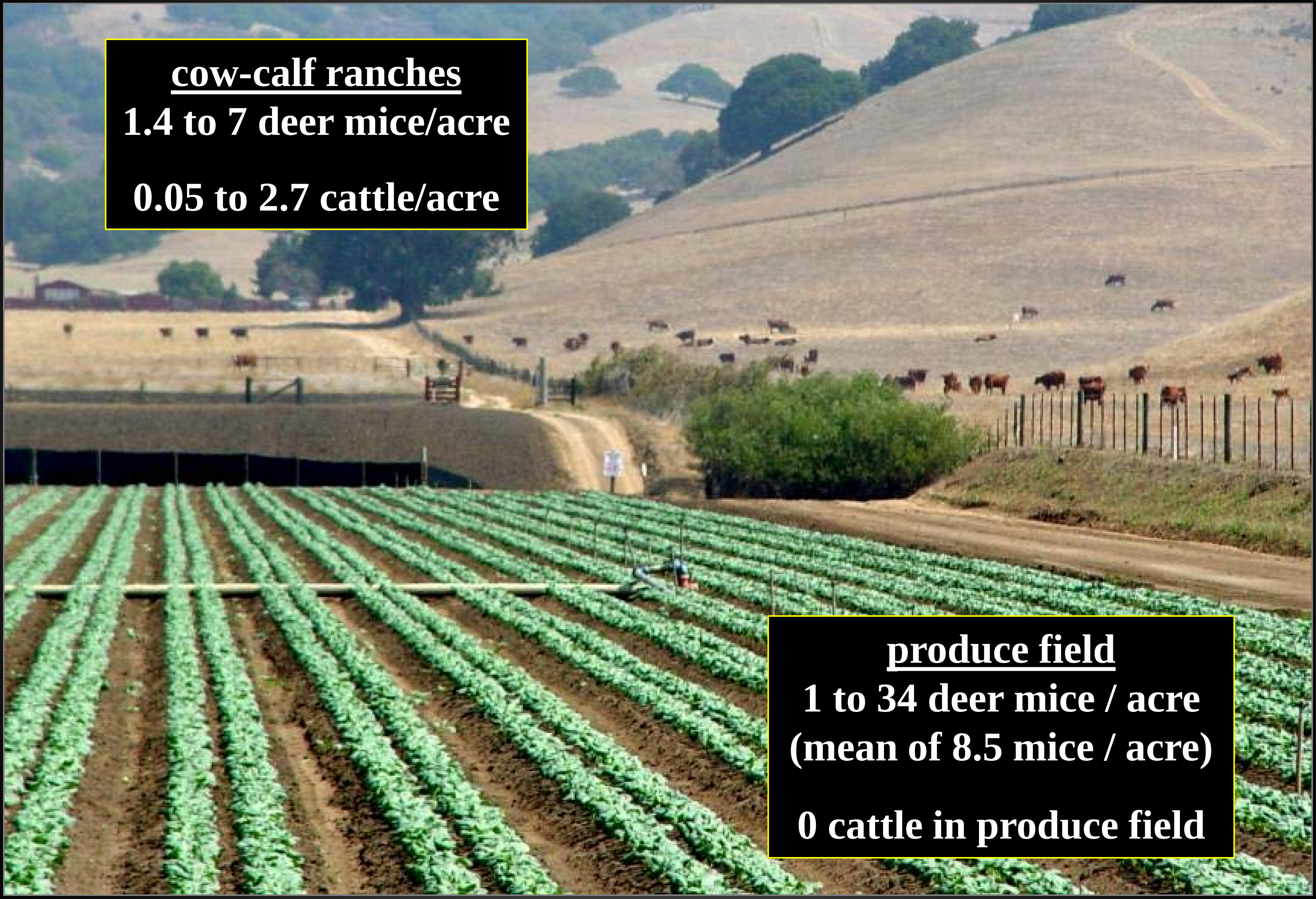
Concentration of *Cryptosporidium* in infected deer mice

over 50 million oocysts / gram of feces

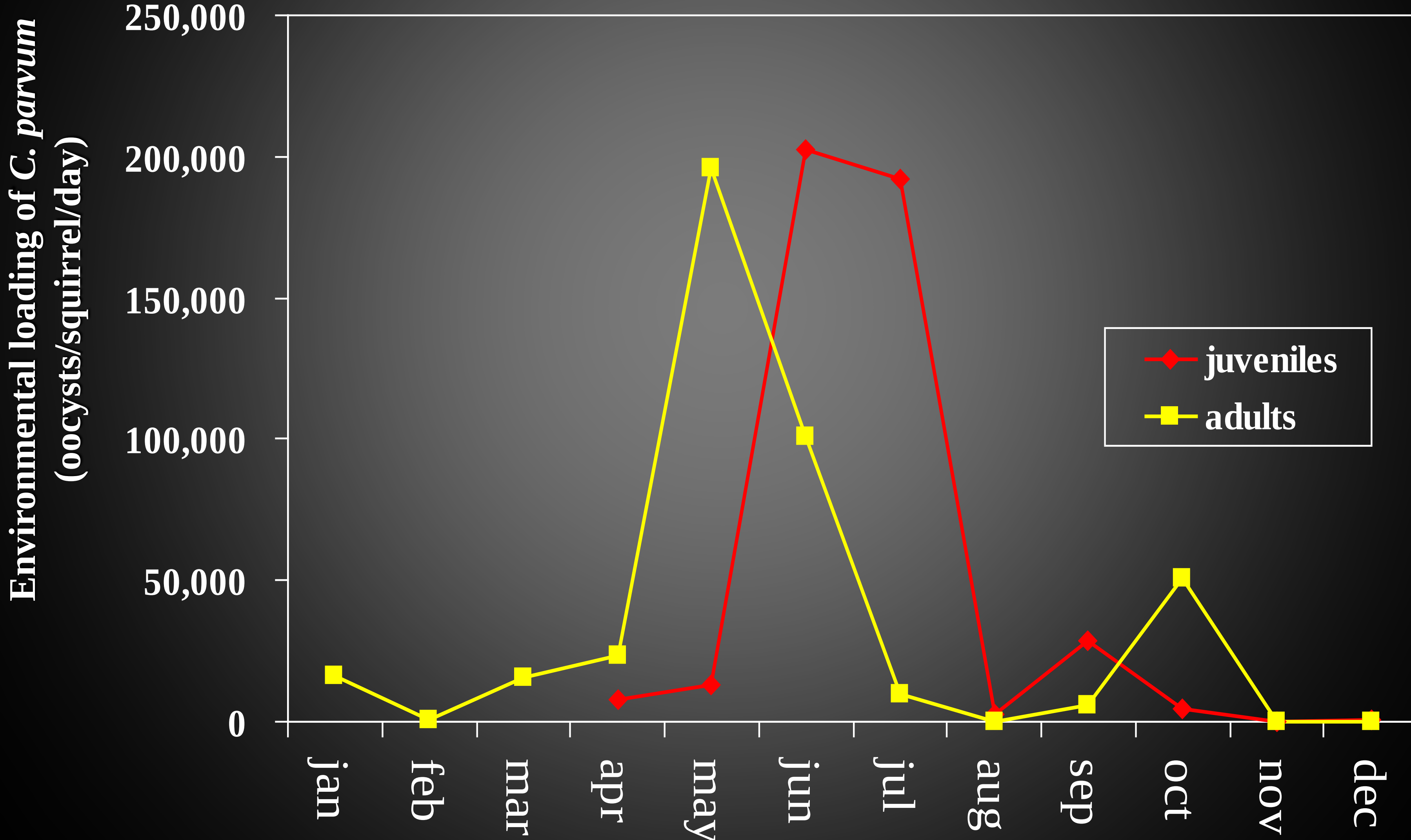
or

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

Winter precipitation runoff versus summer tail-water flows



Environmental loading of *Cryptosporidium* by California ground squirrels on rangeland, Kern County, CA



Belding's ground squirrels, or picket pins (*Spermophilus beldingi*) up in Yosemite

Cryptosporidium infection in Belding's ground squirrels

Tuolumne and Dana Meadows, 2003

	Prevalence	Oocysts / g feces
Adults	15% (42/284)	140,000
Juveniles	42% (84/199)	2,200,000
Overall	26% (126/483)	880,000

1º new species of *Cryptosporidium* with no history of human infection, but 5 to 6% appear similar to *C. parvum*

Packstock, picket pins, and *Cryptosporidium* parasites in Dana and Tuolumne Meadows, YNP

Marmots (*Marmota flaviventris*) and *Cryptosporidium* parasites in the high Sierras, 2012

1 Yosemite NP
2 Little Lakes Valley
3 Courtright Reservoir
4 Chocolate Lakes
5 Clover Creek
6 Gilbert Lake
7 Mineral King
8 Cottonwood Lakes

33/224 (15%) fecals test positive
mean of 1500 to 5000 oocysts / g
only 2 isolates DNA confirmed – *C. parvum*

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),

<u>1412 cows and calves</u>

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

	Salmonella	*E. coli* O157	*Cryptosporidium* sp.	*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)

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

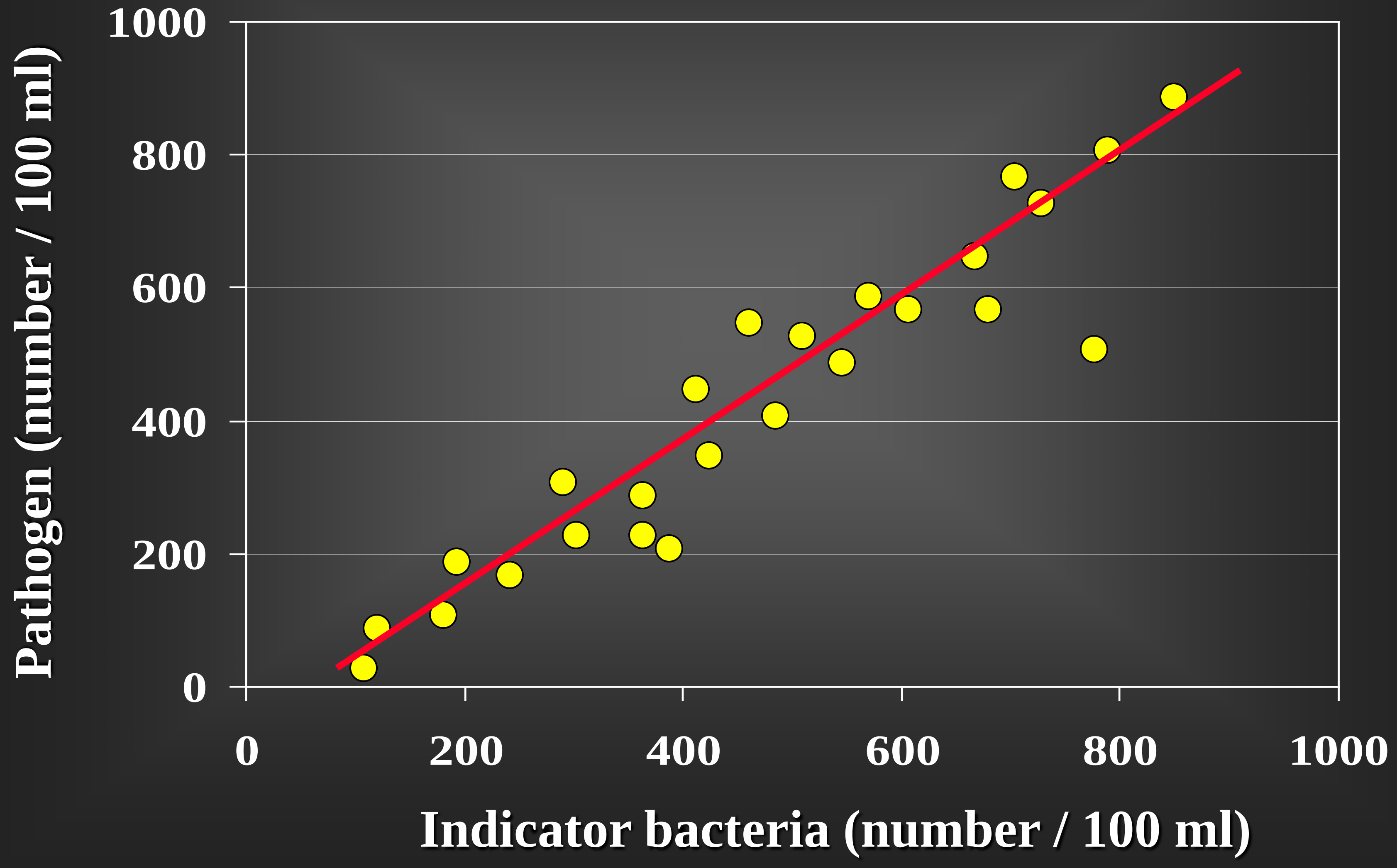
	Assemblage E	Assemblage C	Unknown
Cow	56	8	2
Calf	128	7	4
Total	184 (90%)	15 (7%)	6 (3%)

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

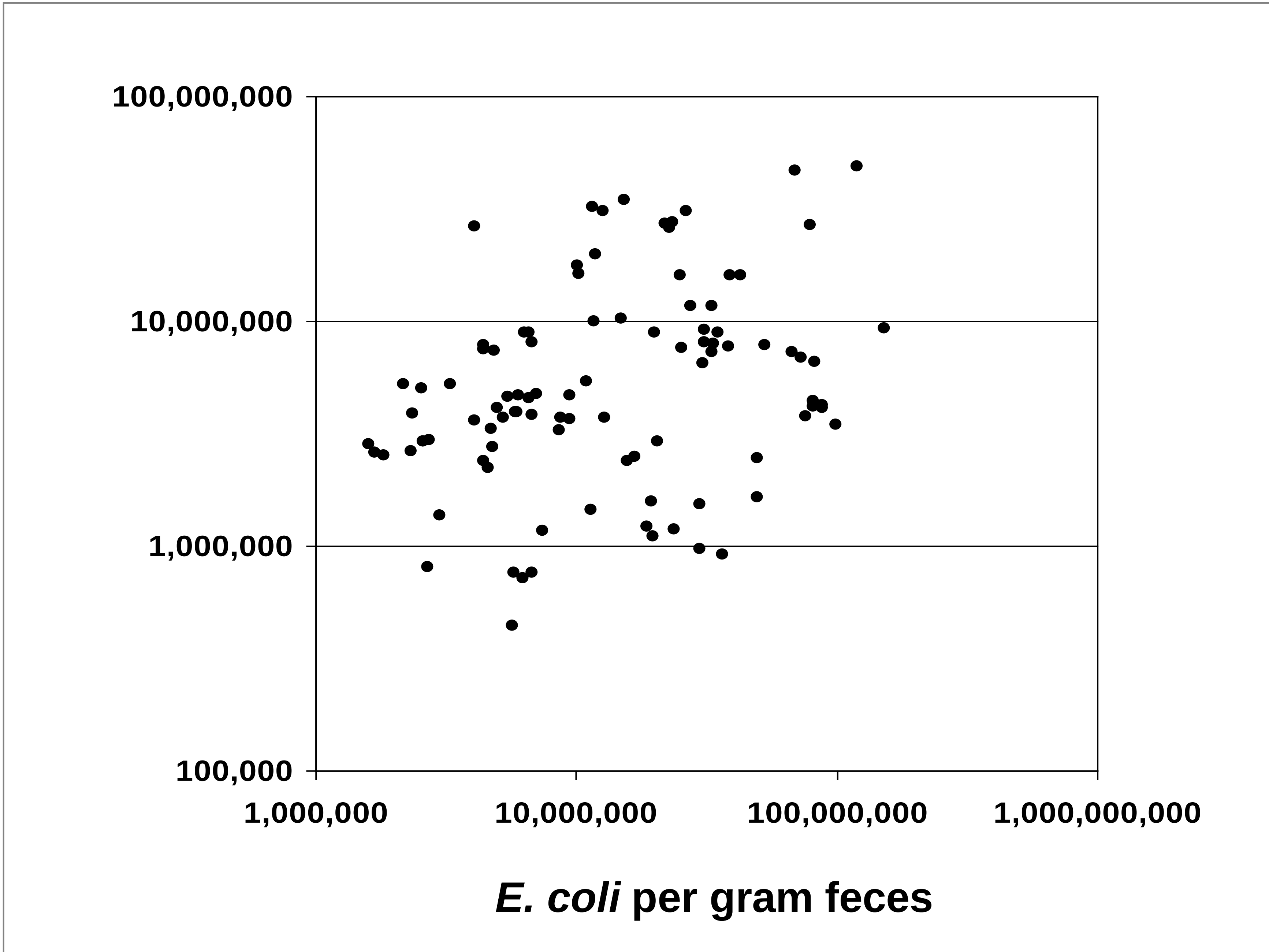
Key processes driving waterborne zoonotic transmission

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?*

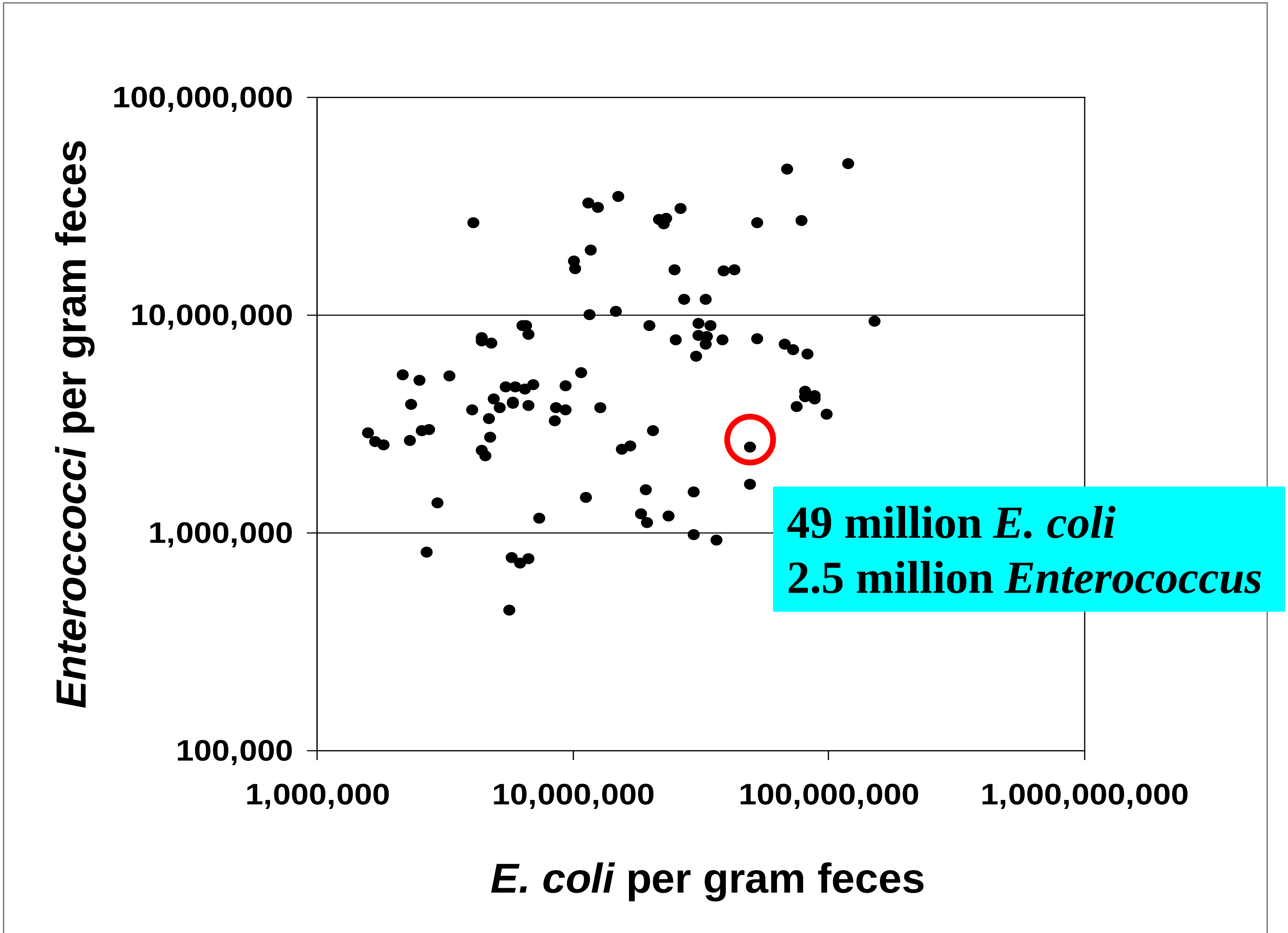
Potential correlation between indicator bacteria like generic *E. coli* and pathogens in water



Indicator bacteria from 90 beef cattle, SJER, Madera Co.



Indicator bacteria from 90 beef cattle, SJER, Madera Co.



POOR CORRELATION BETWEEN INDICATORS AND LIVESTOCK PATHOGENS

~100% of cattle shed millions of generic *E. coli* / g feces

BUT

infrequent shedding of many human pathogens on any day,

so <u>bacterial indicators can't reliably indicate</u> the presence of human pathogens

Poor correlation between indicators and *Cryptosporidium* from cattle

Cattle shed ~50 million *E. coli* / g feces

<u>Adults</u>: <10 Crypto / g feces

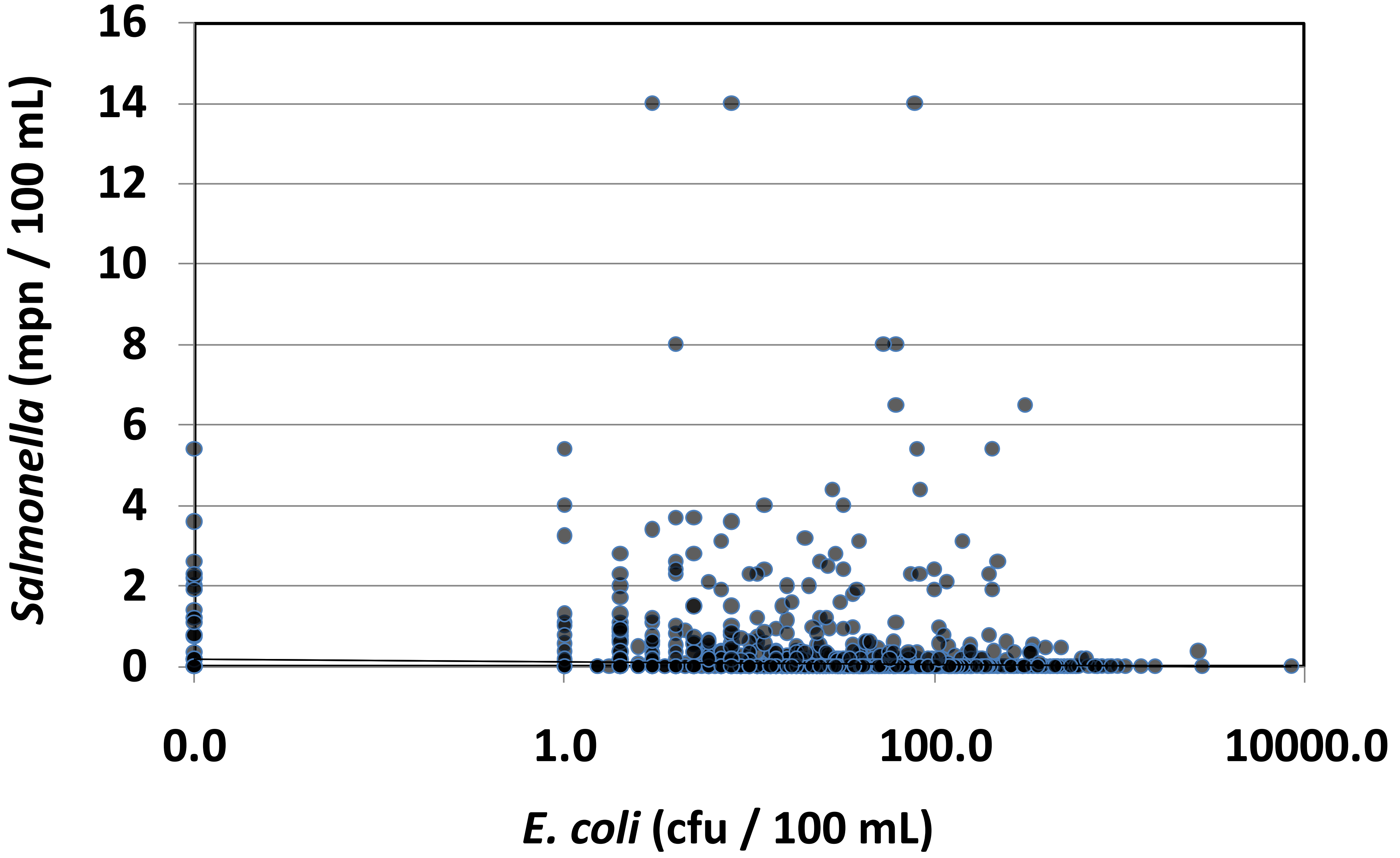
5 million *E. coli* for every Crypto oocyst

<u>Calves</u>: 10,000 Crypto / g feces

5 thousand *E. coli* for every Crypto oocyst

Similar problems with *Salmonella* and *E. coli* O157

Often poor correlation between generic *E. coli* and pathogens
-- Example: Sacramento/San Joaquin Delta--

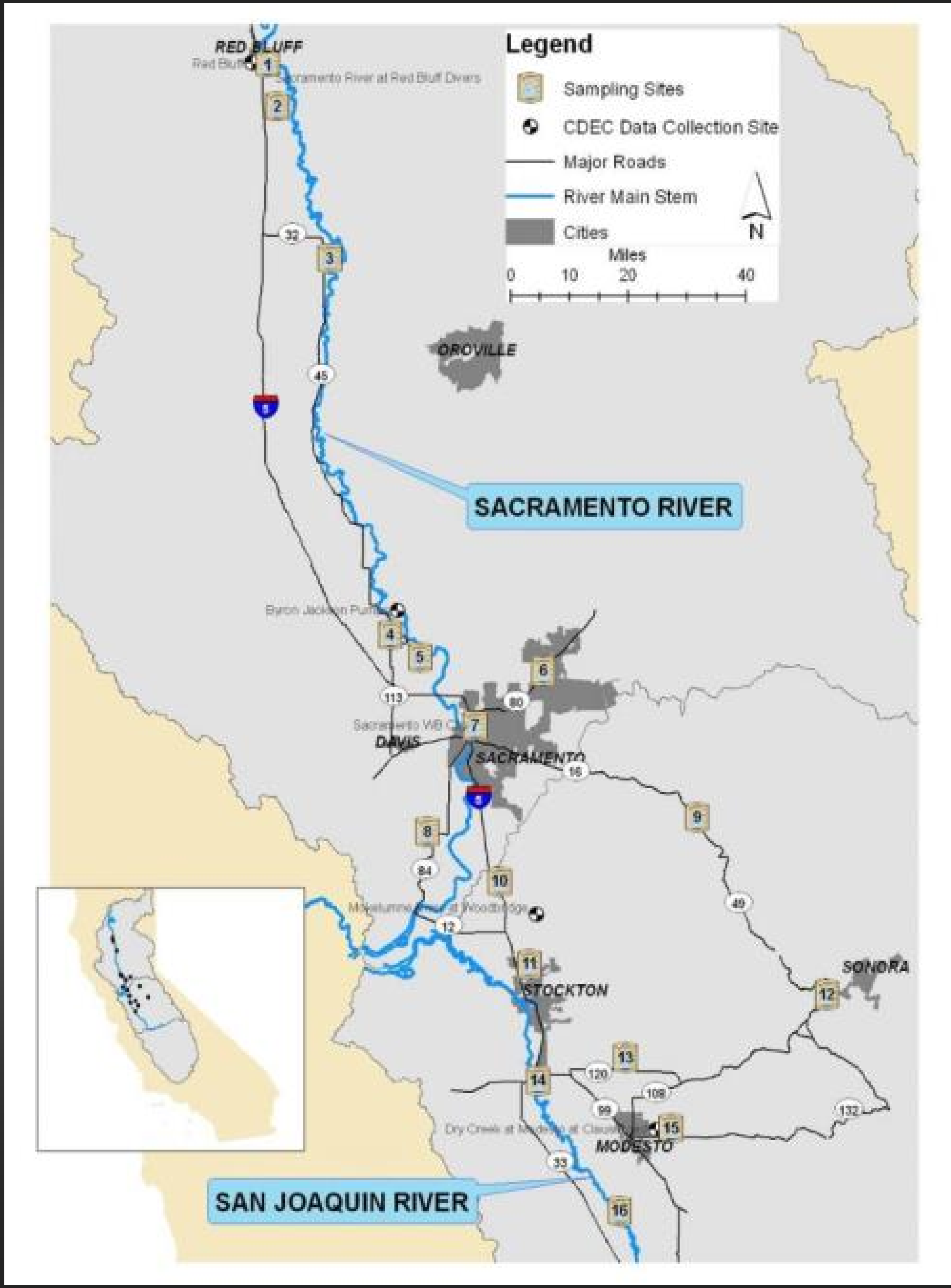


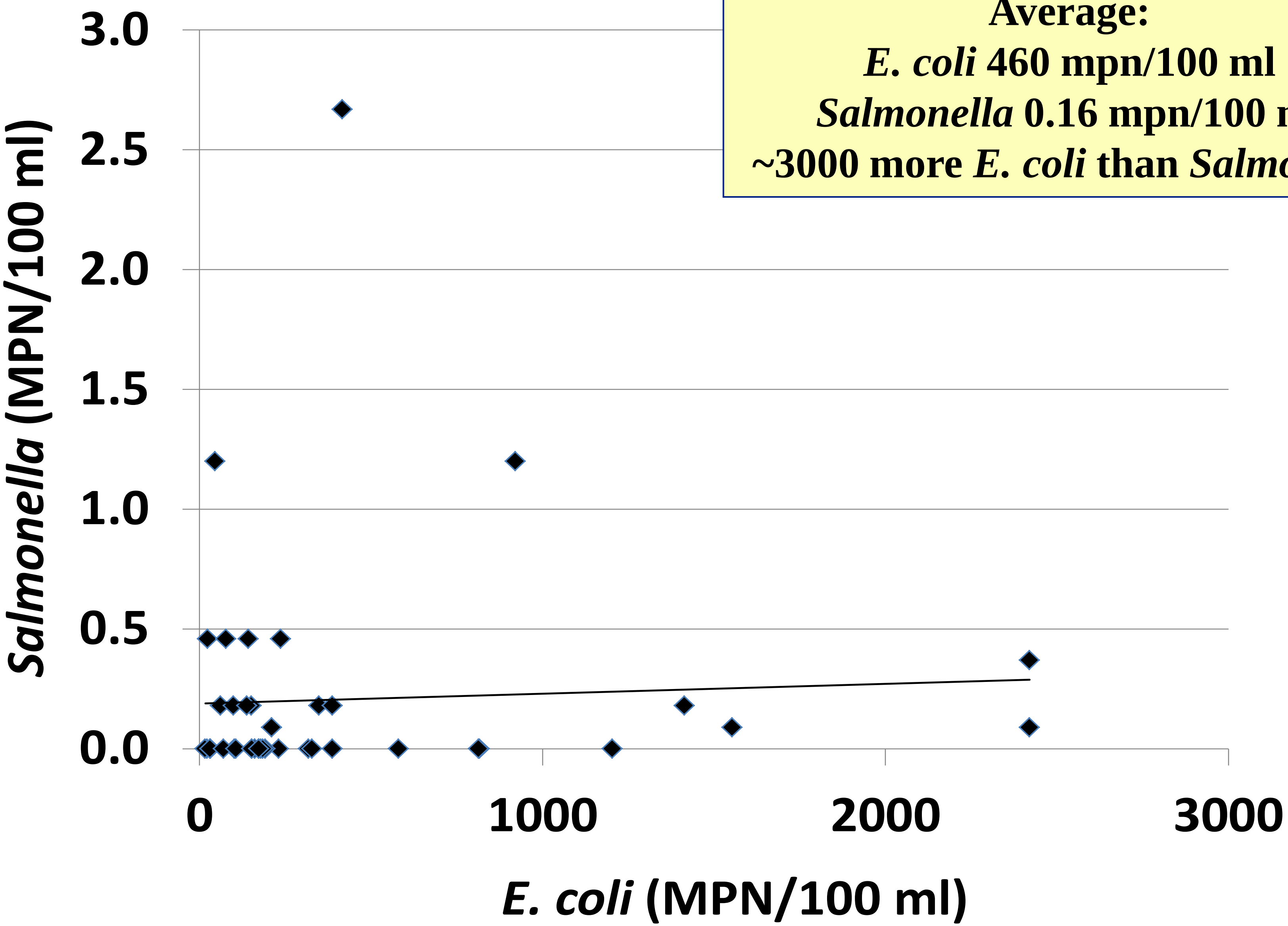
Central Valley RWQCB

From Red Bluff to Sacramento, Sonora to Modesto

E. coli **O157**
2/60 = 3%

Salmonella
21/60 = 35%





Average:
***E. coli* 460 mpn/100 ml**
***Salmonella* 0.16 mpn/100 ml**
~3000 more *E. coli* than *Salmonella*

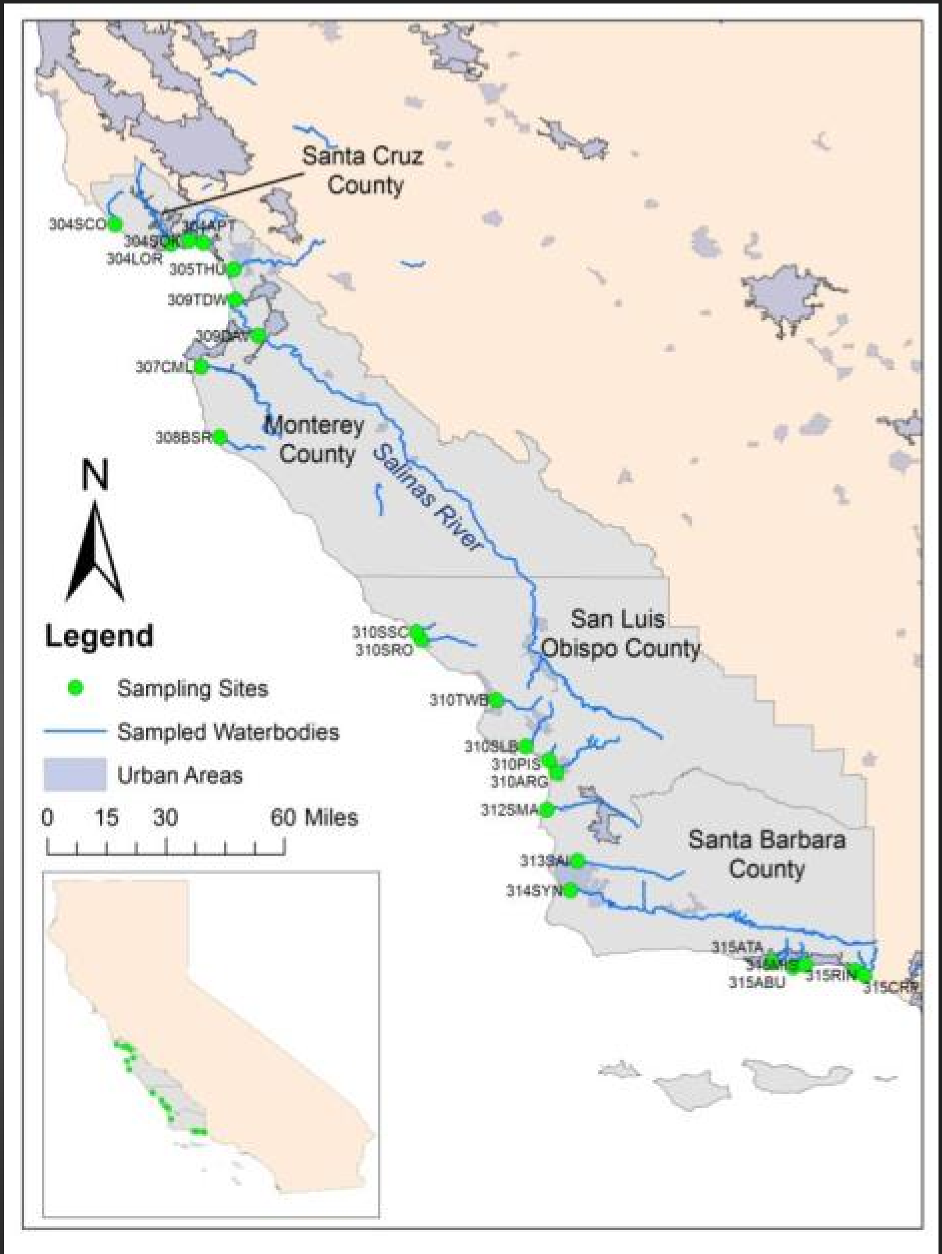
CCRWQCB

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

April 2009 to April 2010

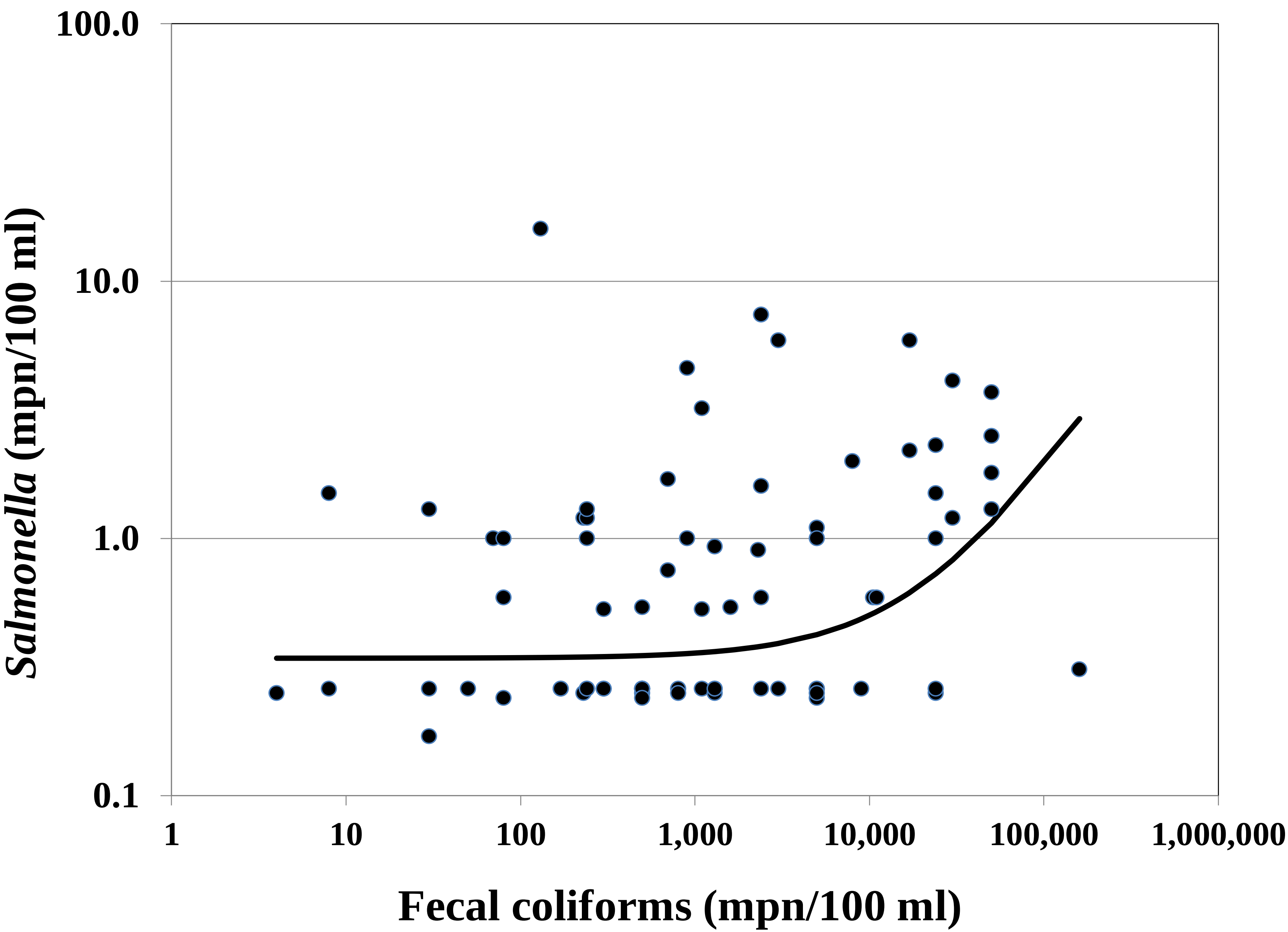
***E. coli* O157**
6/251 = 2.4%

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

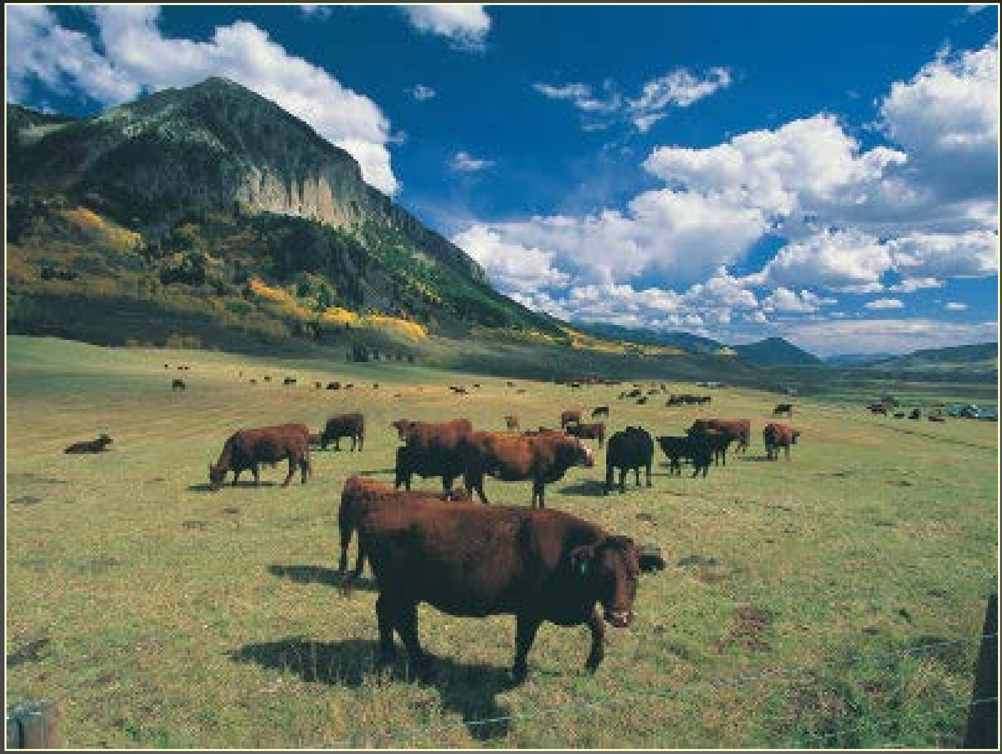


<u>Recall <<1% cow-calf shed *Salmonella*; 2-4% in wildlife</u>

New approaches are needed to monitor microbial water quality



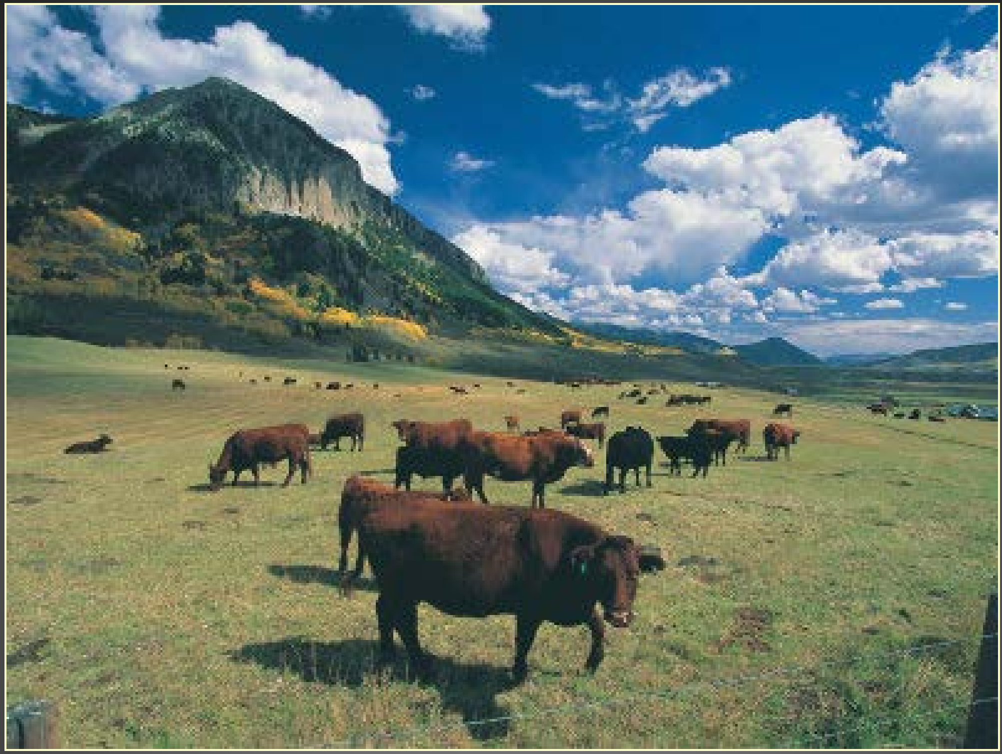
Waterborne pathogen BMPs for grazing



Key processes driving waterborne contamination

1. animal loading (who done it)
2. microbial transport (how did it get there)
3. microbial inactivation (is it still alive)

Waterborne pathogen BMPs for grazing



Key processes driving waterborne contamination

1. animal loading (who done it)
2. microbial transport (how did it get there)
3. microbial inactivation (is it still alive)

Sierra Foothill Research & Extension Center, University of California

<u>Buffer width (m)</u>
0.1, 1.1, 2.1

<u>Land slope (%)</u>
5, 20, 35

<u>RDM (kg/ha)</u>
225, 560, 900, 4500

Take advantage of pathogen retention of rangeland and pasture.

Vegetated buffers can retain ≥95% of key pathogens in winter and spring; >99.9% achievable with <u>sufficient infiltration</u>; heavy rain leads to buffer failure

Take advantage of natural pathogen inactivation

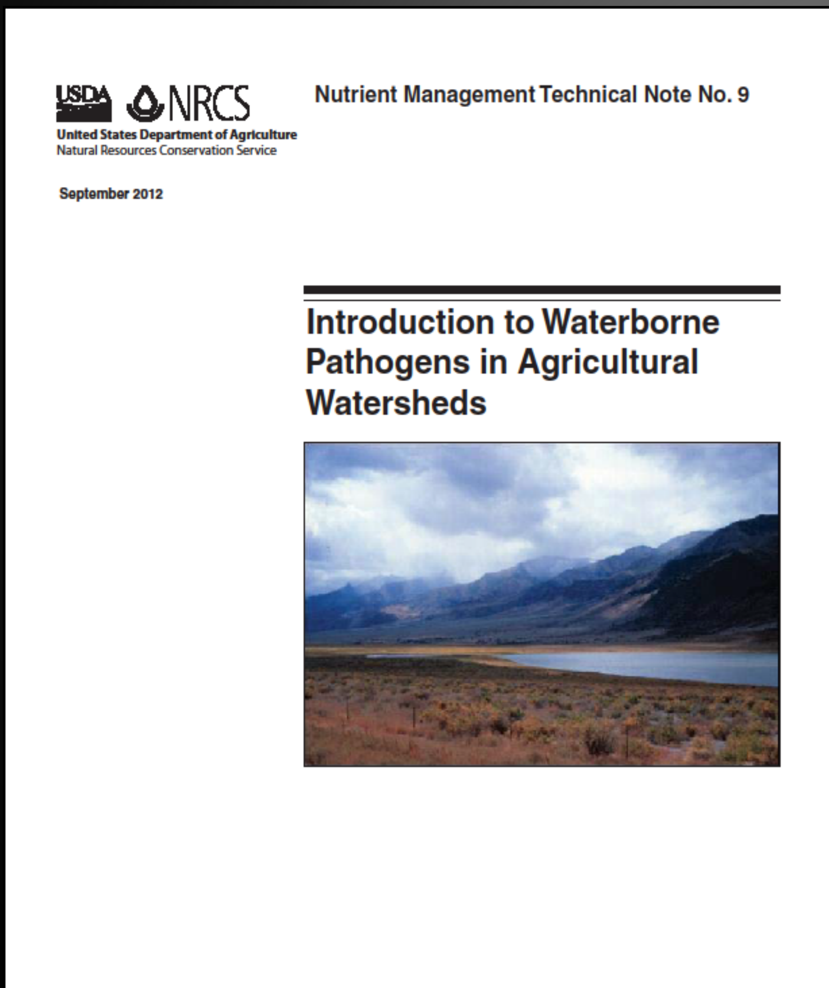
- **Time between exclusion and onset of rainy season**
- **Summer riparian grazing and solar inactivation**
- **Rotational grazing timelines—pathogen die-off**
- **Unpredictable in the mountains due to T-storms**

Irrigated rangeland / pasture BMPs

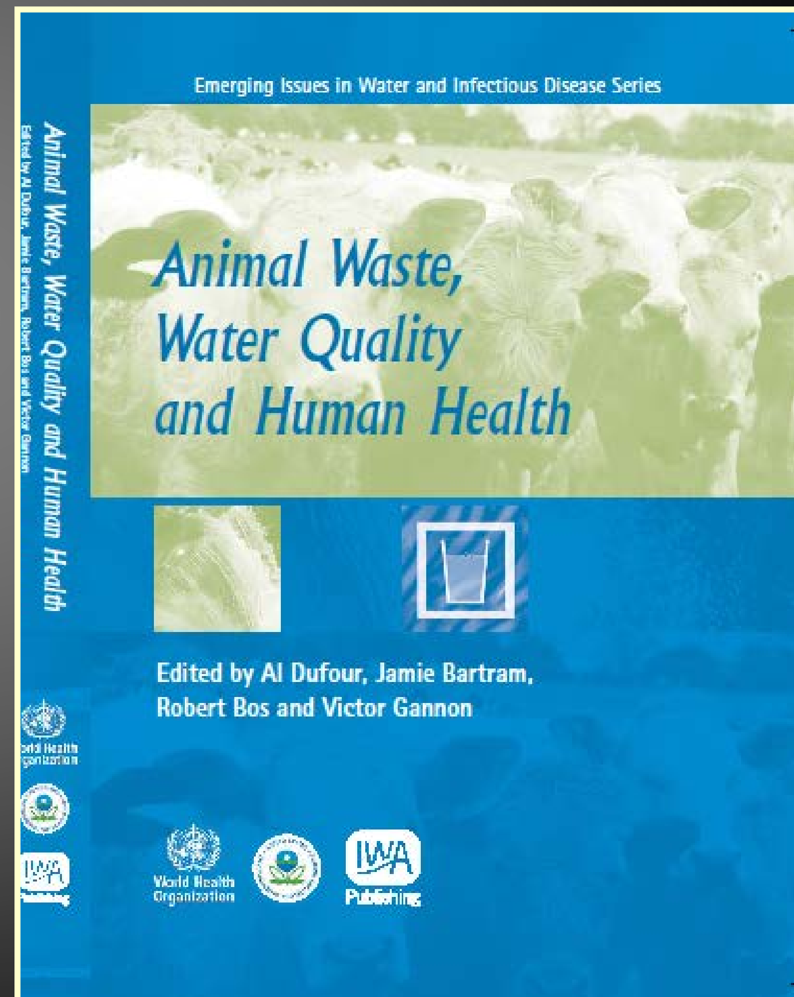
exclude cattle before irrigation, reduced tailwater flows, retention basins, constructed wetlands, etc.

2012 technical reports on waterborne pathogens and BMPs
Dr. Ken Tate's website (California Rangeland Watershed Laboratory)
all are FREE!

NRCS-USDA



EPA, WHO



- **Match BMP efficacy to local conditions and expected pathogen loads;**
- **Modernize microbial monitoring tools**

Questions?