Assessing microbial quality in irrigation water sources

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Project: "Design and Implementation of Monitoring and Modeling Methods to Evaluate Microbial Quality of Surface Water Sources Used for Irrigation"

Ponds and Streams

The produce rule uses generic *E. coli* concentrations to derive metrics of irrigation water quality.

- The produce rule does not specify <u>where, when and how</u> water samples have to be taken. Does this matter?
- Do *E. coli* concentrations in streams reflect <u>current</u> fecal contamination?
- The produce rule allows for 2 to 4 years to collect 20 samples to characterize microbial water quality of the irrigation water source. How <u>representative</u> is this characterization?

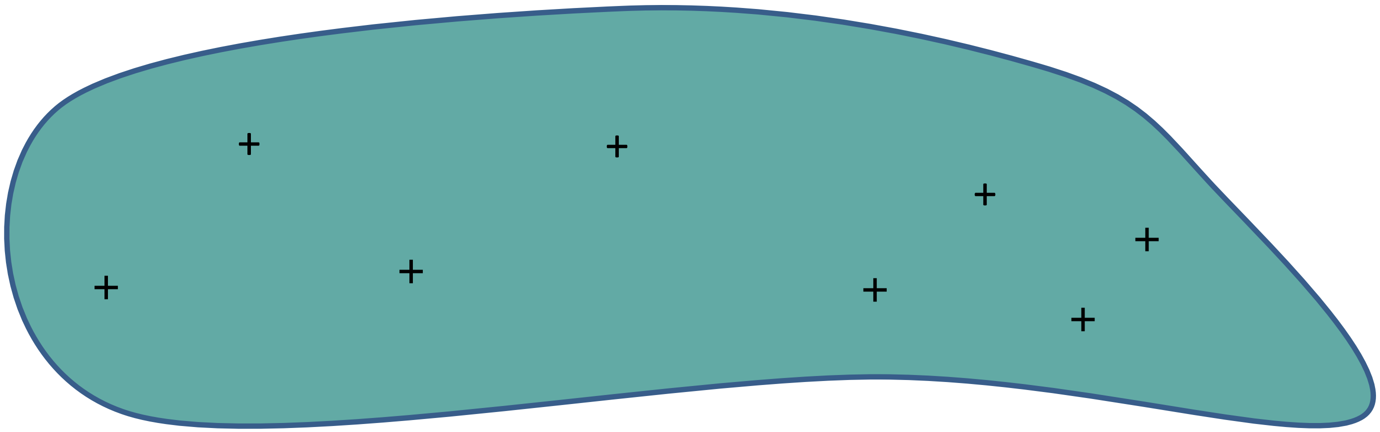
Spatial patterns of *E. coli* concentrations in farm ponds

Wye Center pond

Butler Orchard pond

JEQ (in prep.)

Simple pattern recognition method – analysis of relative differences



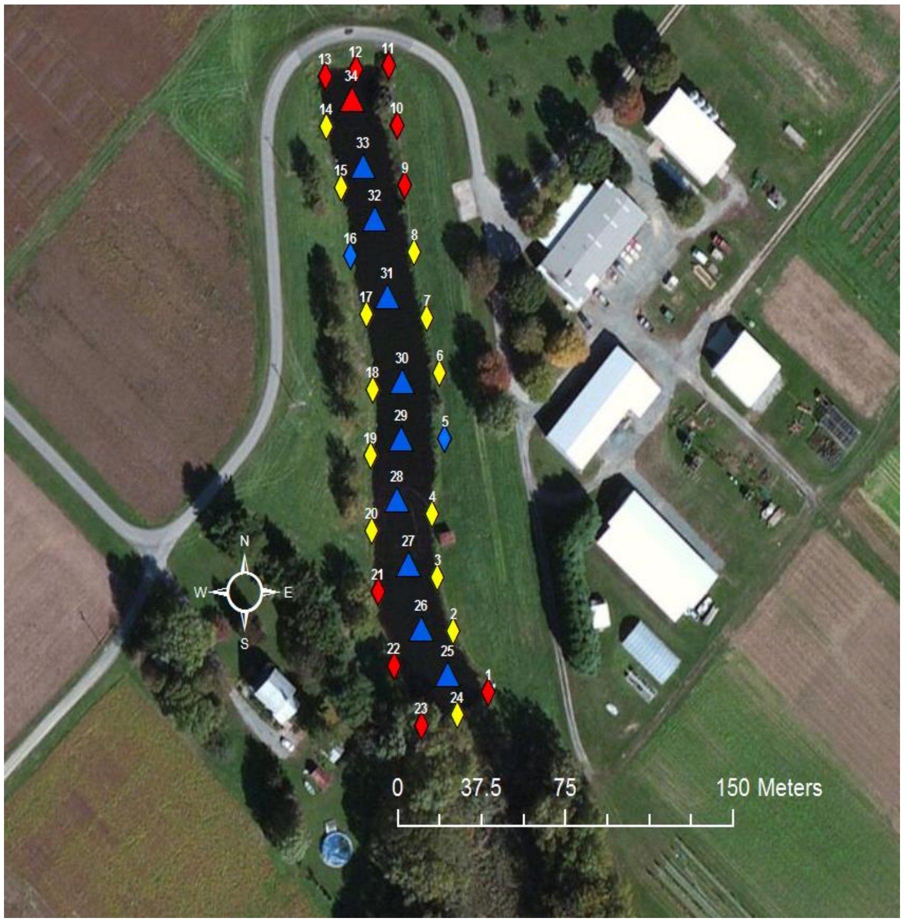
$$\text{Relative difference} = \frac{C - \text{average}(C)}{\text{average}(C)}$$

Make several sampling site visits over time

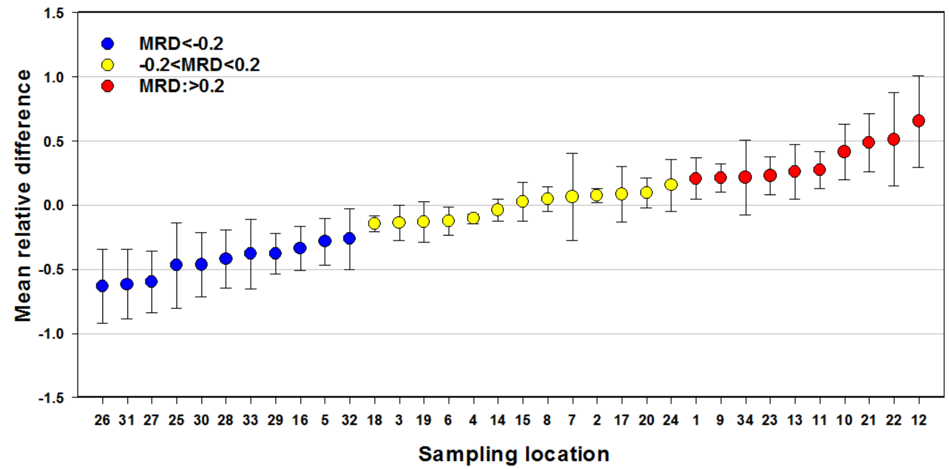
We have a pattern if the relative difference in some locations is consistently less than zero, and in other locations it is consistently greater than zero.

Wye Center Pond

Colors of symbols are the same in the map and the figure



Mean relative differences of log *E. coli conc.*

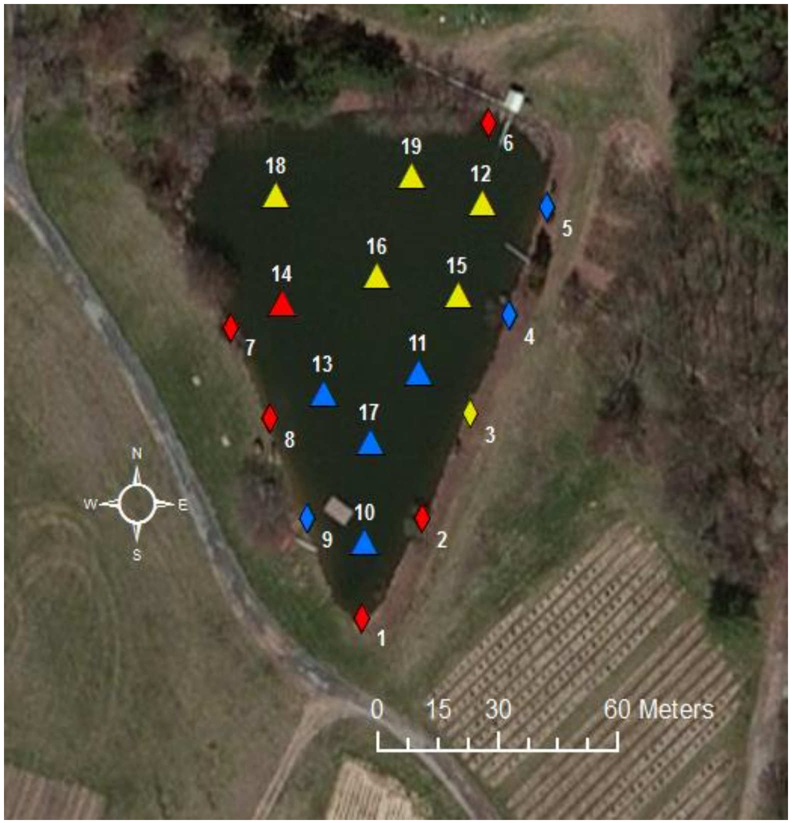


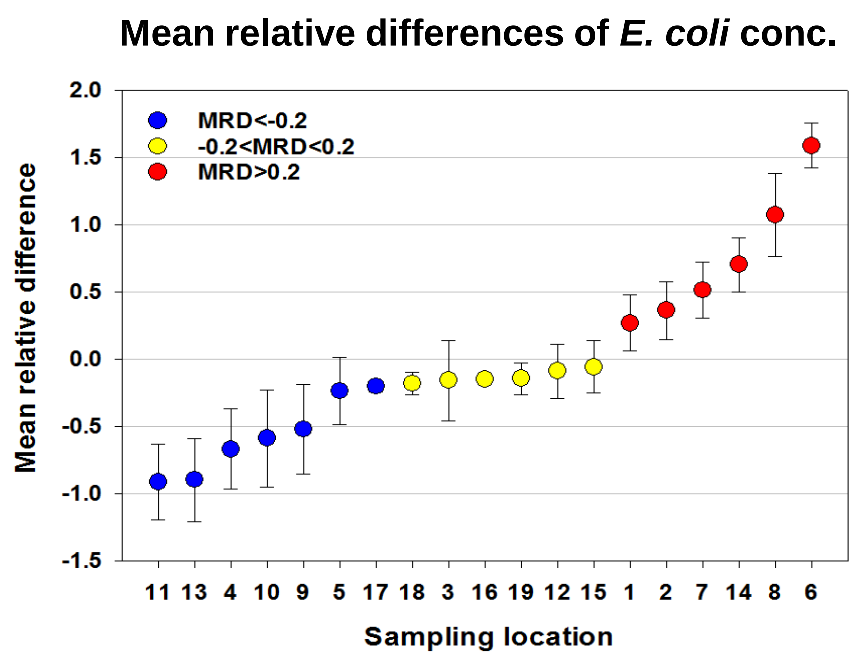
6 sampling sorties

Spatial pattern is well defined
Interior concentrations are mostly lower than close to banks
Banks mostly show the geometric mean concentration (but not at inlet and outlet)

Difference between max and min more than 10 times

Butler Orchard farm pond



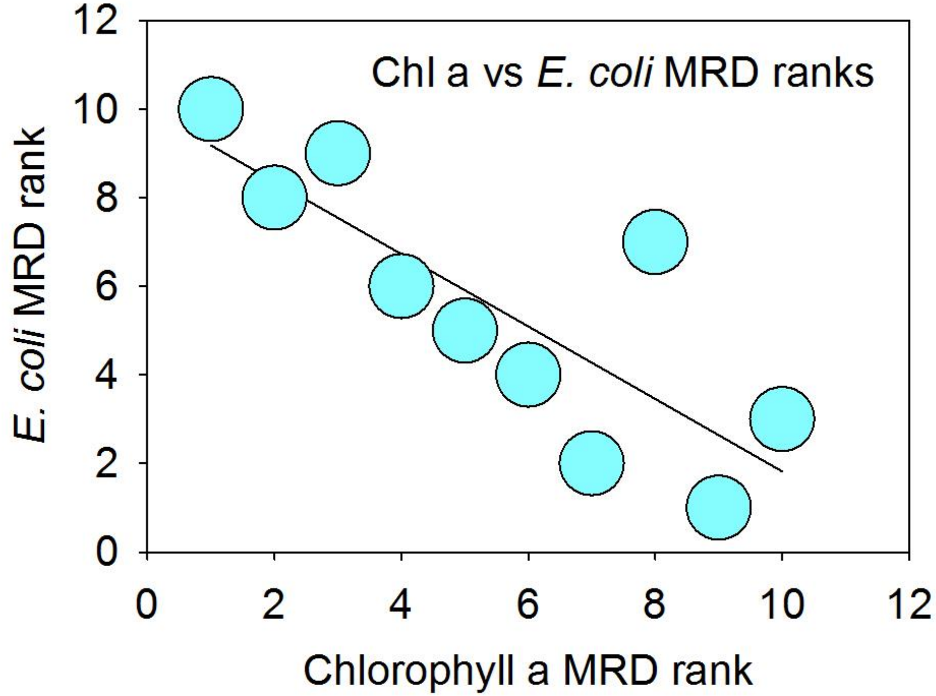


Highest concentrations are in the bathing and inlet-outlet zones

Interior concentrations are mostly lower or close to the mean

max is on average 25 times larger than min

E. coli and algae



***E. coli* do not have spectral signature. Chlorophyll a does**.

With the group of Dr. Moon Kim and collaborators from Ulsan, Korea, we improved the algorithm for sensing low concentrations of Chlorophyll a in water

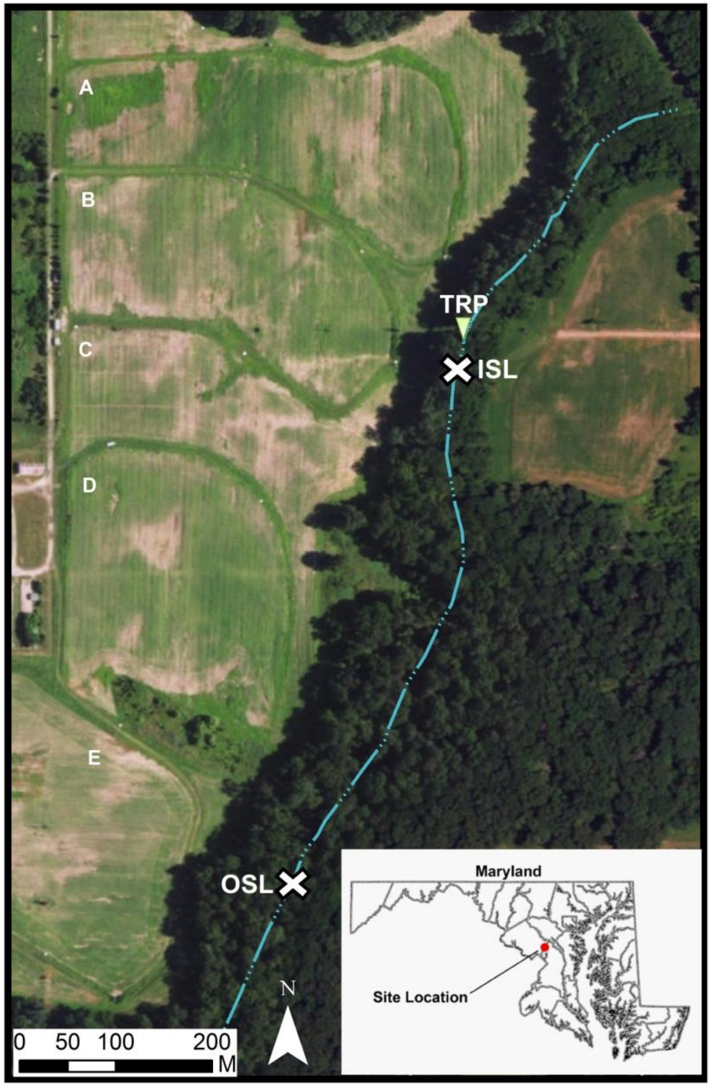
What does the presence of patterns mean?

Points to ponder

- ❖ It matters where the samples are taken.
- ❖ It matters where in the pond water is taken for irrigation.
- ❖ How do different pond locations contribute to irrigation water quality?
- ❖ Blooms, cyanobacteria, seasonally present algae – how do they affect *E. coli* concentrations?
- ❖ How do algaecides impact *E. coli* populations?

Streams

Why do we have high *E. coli* concentrations during low-flow periods?

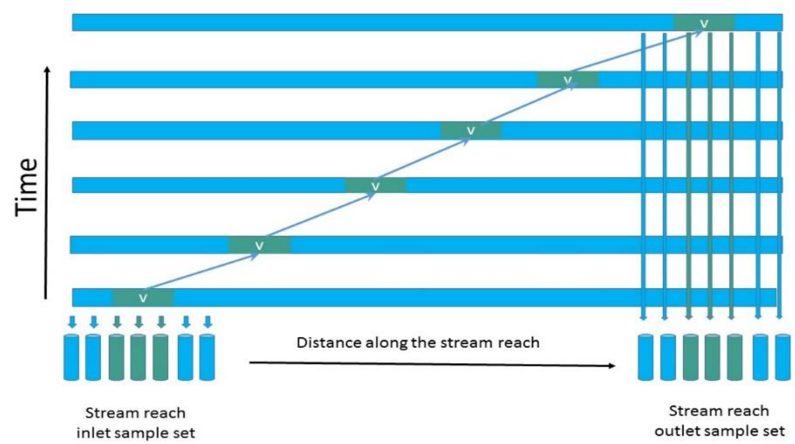


Measuring changes in *E. coli* during the low-flow periods

Experimental design

Mass balance volume (slug) created by labeling water.

Water sampled at the inlet and at the outlet locations.



Environmental Monitoring and Assessment (2017) 189:51

Average concentrations of FIO in tracer slugs (CFU/100 mL) and sediment (CFU/100 gdw)

	E. coli			Enterococci		
	Inlet	Outlet	Sediment	Inlet	Outlet	Sediment
Rep 1	148	610	5872	327	1402	7630
Rep 2	83	1231	6075	563	1196	5386
Rep 3	462	1187	7613	1238	1329	7743
Mean	231	1009	6520	709	1309	6920

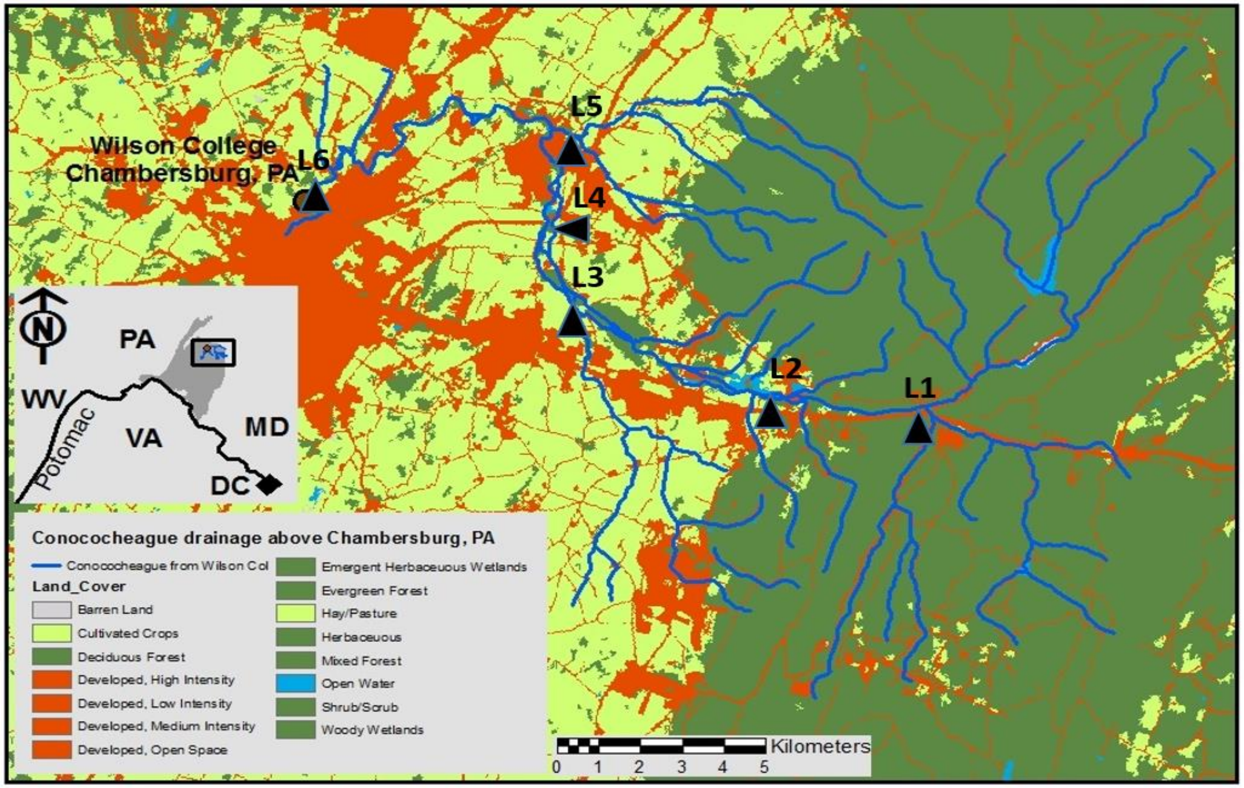
Ratio of the tracer Br mass and total numbers of FIO in the mass balance volume

Rep	Br	*E. coli*	Enterococci
1	0.911	12	15
2	0.942	75	11
3	0.909	15	7

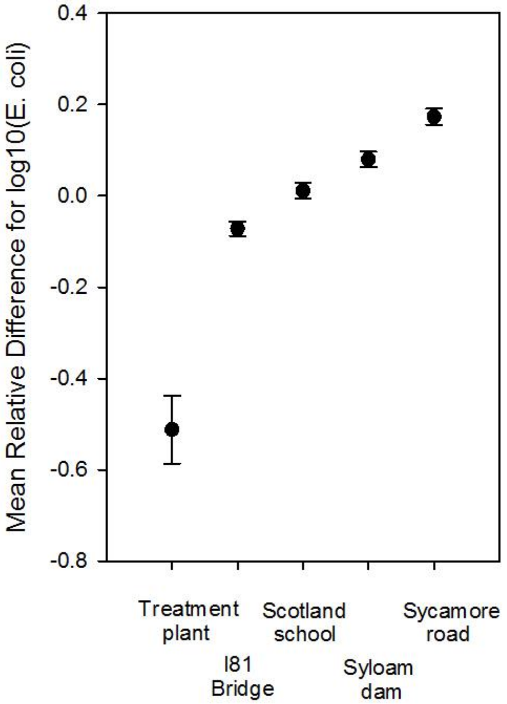
Rates of FIO release from the bottom sediment during the low flow periods, CFU $m^{-2}s^{-1}$

Replication	*E. coli*	Enterococci
1	36	87
2	57	52
3	42	43

(Much) Larger scale: Conococheague creek



Spatial pattern of *E. coli* concentrations
during low flow periods
in 2016



What does the low-flow streambed release of *E. coli* mean?

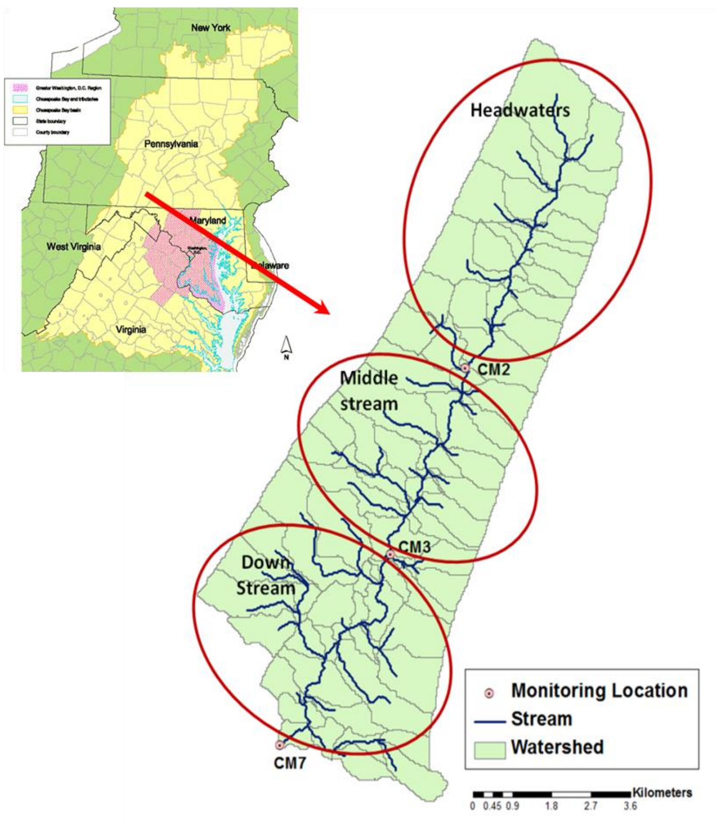
Points to ponder

- Role of sediments as a bacterial source during low flow periods was unknown and appears to be substantial.
- More info about pathogens in sediments is needed for representative sampling.
- Heterogeneity of sediments is a serious issue for sampling .
- Brinkmeyer et al., 2015: " Water quality goals may not be achievable due to an endless supply of fecal indicator bacteria from sediments".

How representative are 5 samples a year/20 samples in 4 years?

We cannot monitor for 1000 years but we can calibrate and validate a model, and then sample modeling results

Cove Mountain watershed, southern PA



USDA ARS model SWAT

Monitoring data 2006-2008

After calibration, the model showed the ability to correctly predicted compliance with produce rule

Produce rule metrics: *E. coli* geometric mean 135 CFU/100 mL
STV 410 CFU/100 mL

90 year of actual weather data

Results of simulations were sampled 5 times a year for 4 consecutive years

Journal of environmental management, 187 (2017): 253-264

Geometric mean (GM) and statistical threshold values (STV) of *E. coli* concentrations in 20 random samples for 4 consecutive years

Produce rule thresholds	126	410

Locations and Months	GM (CFU/100 ml)				STV (CFU/100 ml)			
	avg	std	min	max	avg	std	min	max
CM3								
Apr	155	22	84	229	223	29	129	690
May	164	36	82	466	409	319	121	2706
Jun	156	46	44	534	783	541	86	3913
Jul	108	33	22	354	599	452	56	3725
Aug	90	33	14	360	608	470	28	3475
Sep	83	32	16	397	580	477	35	3818
Growing season	122	36	24	425	513	409	64	3309
CM7								
Apr	202	34	98	320	312	48	135	526
May	201	40	101	564	437	235	145	1959
Jun	180	51	51	515	695	402	95	2833
Jul	121	38	26	366	519	320	62	2692
Aug	99	33	26	357	508	342	45	2595
Sep	91	33	22	343	512	373	52	2950
Growing season	142	41	33	429	490	294	81	2623

How does the interannual variability affect the representativeness?

Points to ponder

- The regulatory threshold was exceeded from 16 % to 70% during the four-year sampling campaign.
- The variations in microbial concentrations and water quality metrics were affected by location, wetness of the hydrological years, and seasonality.
- Long-term assessment of microbial water quality may be quite different from the evaluation based on short-term observations.
- The results of this work demonstrate the value of using modeling to design and evaluate monitoring protocols to assess the microbial quality of water used to irrigate produce.

We are at the first year of the project plan

When, where and how to sample requires serious attention.