



The Role of Fungi and Plants in Bioretention Treatment of Stormwater Runoff



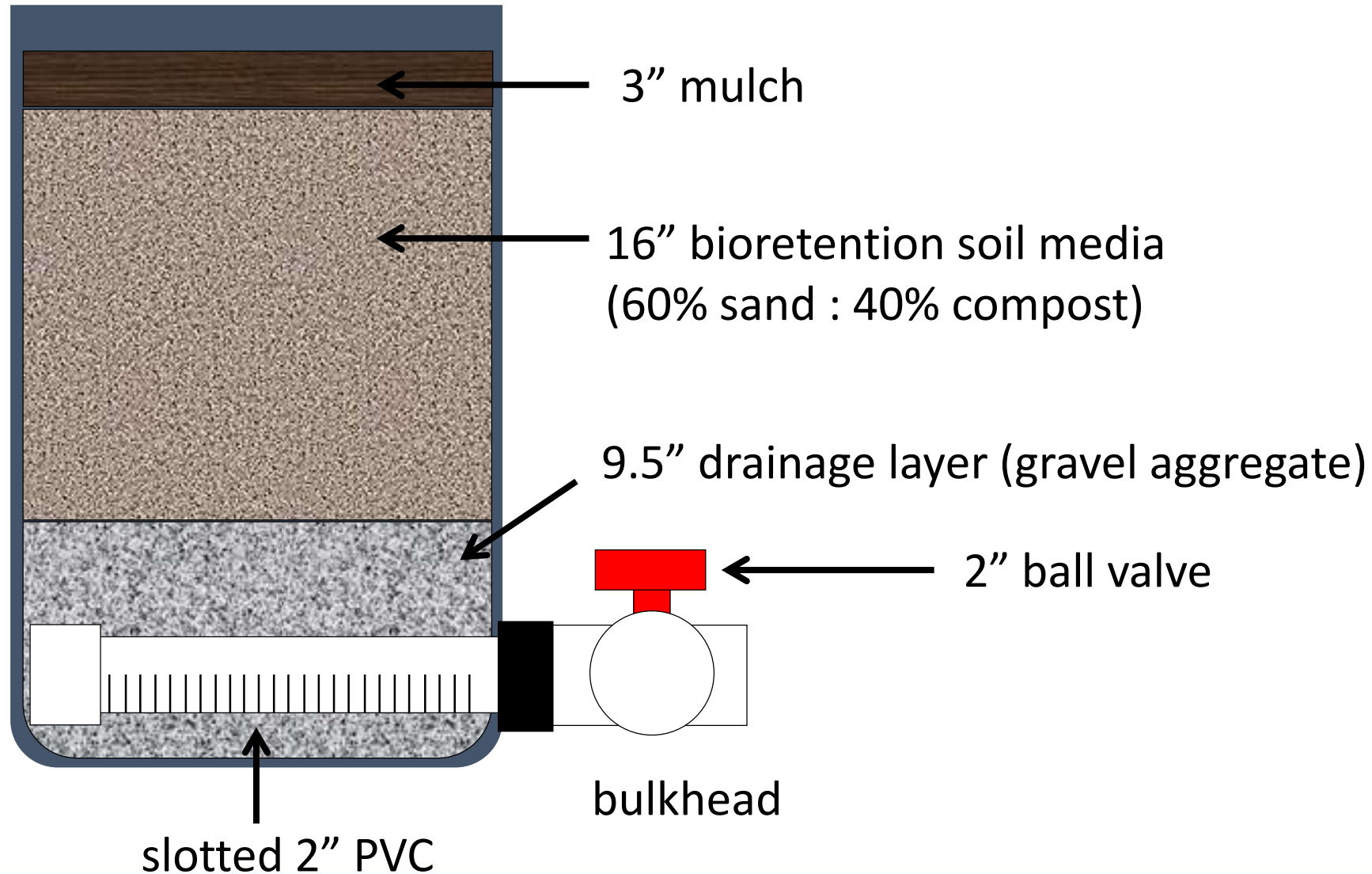
USFWS (Jay Davis) / WSU (Jen McIntyre)



Study Question

- What is the role of plants?
- Do fungi provide additional benefits?
- How long does bioretention treat runoff?

Bioretention Cells



Treatments

Treatment	N	Description
BSM	3	Bioretention soil medium with mulch
BSM + P	3	BSM with mulch and plants
BSM + F	3	BSM with fungi-inoculated mulch
BSM + P + F	3	BSM with plants and fungi-inoculated mulch



Pacific ninebark

Physocarpus capitatus



Winecap

Stropharia rugosoannulata

Installed at WSDOT 'Ultra-Urban Testing Site'
Under the I-5 Ship Canal Bridge
Feb 2017-May 2019



Installation



Treating Stormwater Runoff

Surrounded by clean fill for thermal inertia

When runoff flowing through catch basin, pumped at 120 mL/min to each cell



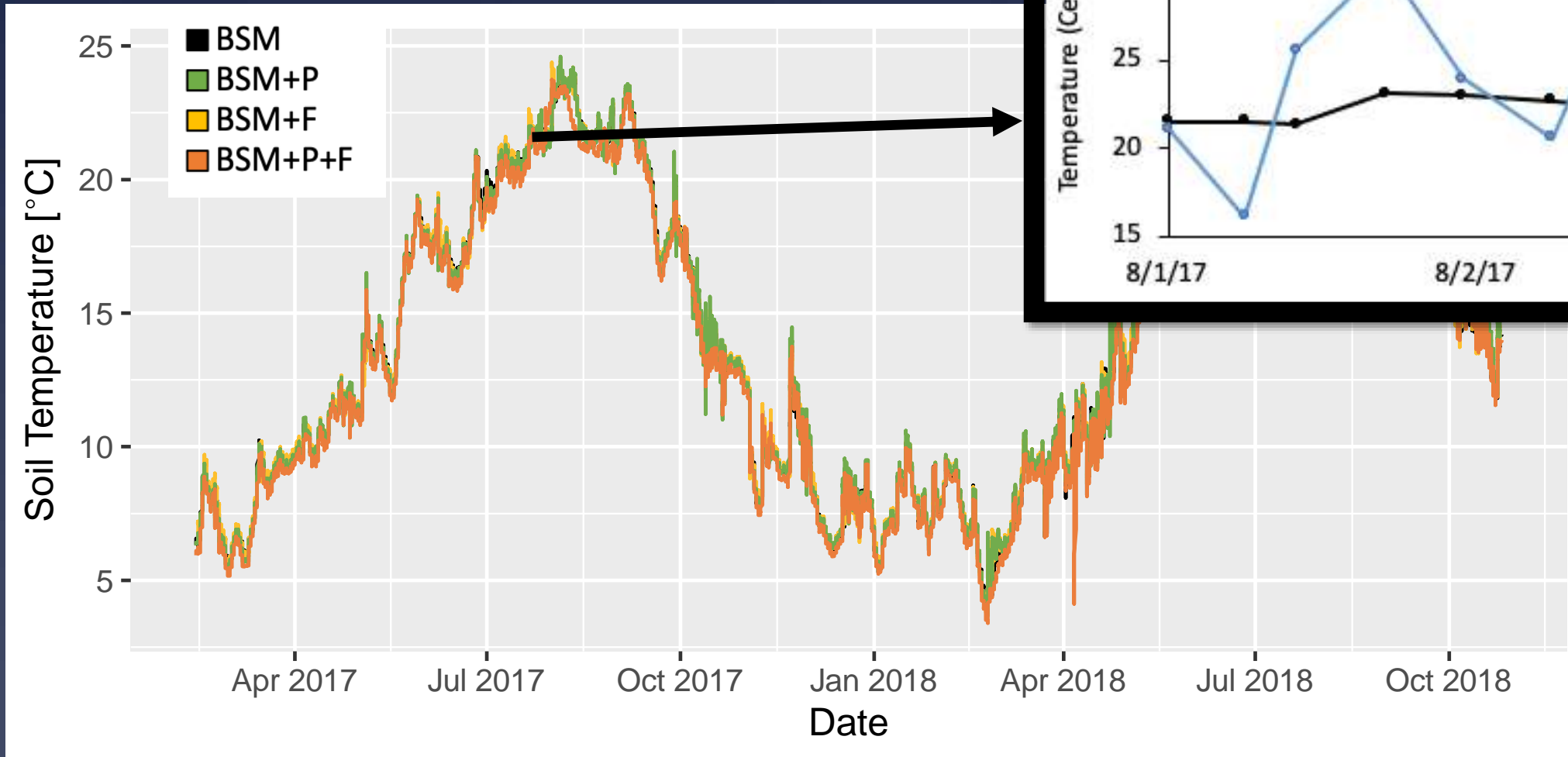
Results Outline

Continuous	Per Event	Per Quarter	Start-End
Soil temperature (Soil moisture)	Water chemistry Toxicology	Ksat	Soil chemistry (In Progress)
Plants			
Fungi			

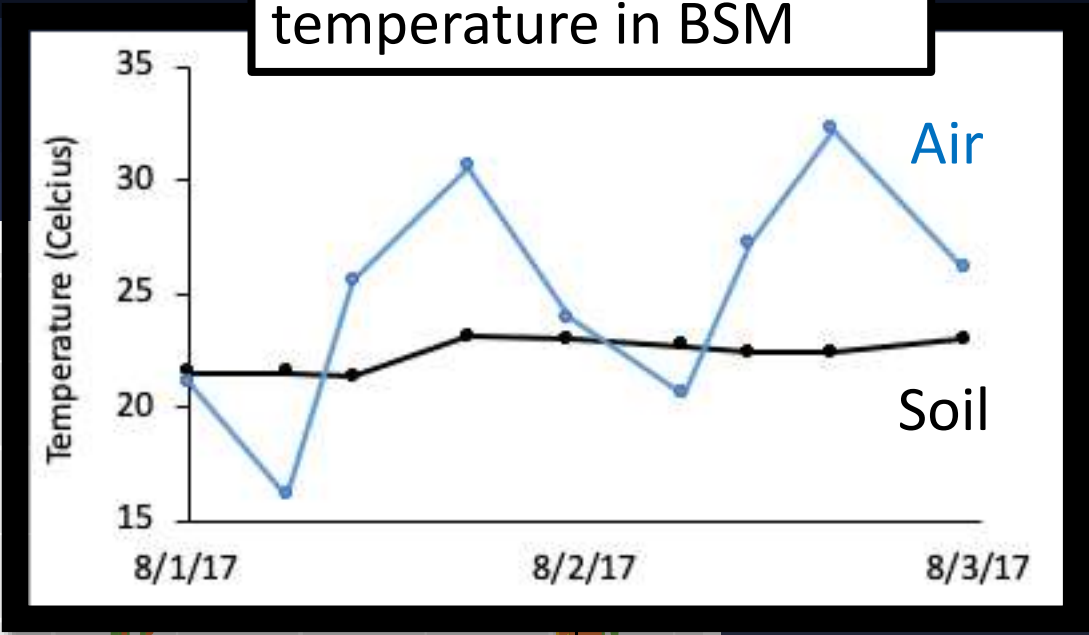
- INF
- BSM
- BSM+P
- BSM+F
- BSM+P+F

Thermal Profile of BSM Treatments

No differences among treatments



Moderation of ambient temperature in BSM



It's official: Seattle breaks record for most consecutive days without rain

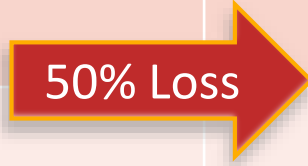


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Plants

Plants per Replicate

Treatment	Start 2017	End 2017
BSM	0/0/0	0/0/0
BSM+F	0/0/0	0/0/0
BSM+P	3/3/3	1/2/2
BSM+F+P	3/3/3	1/3/0

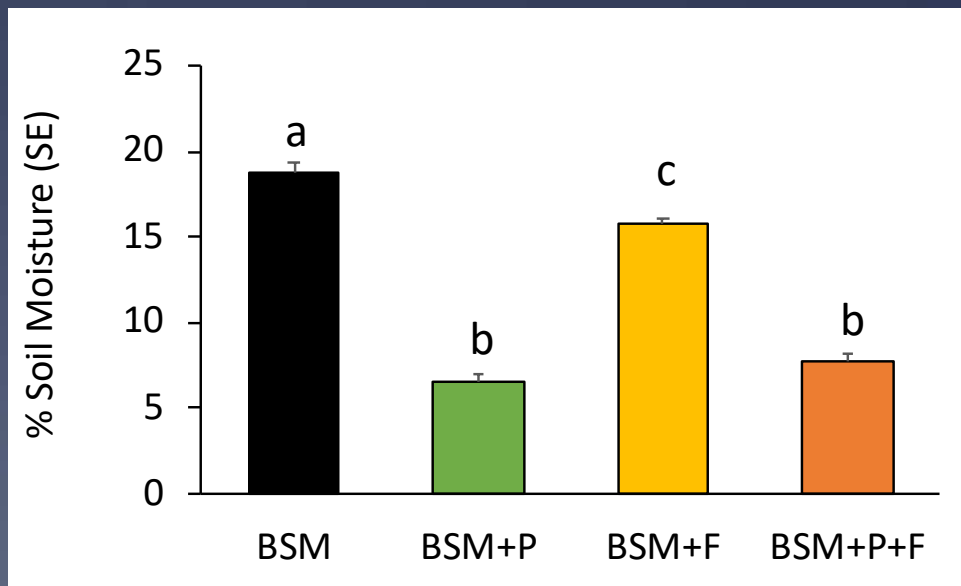
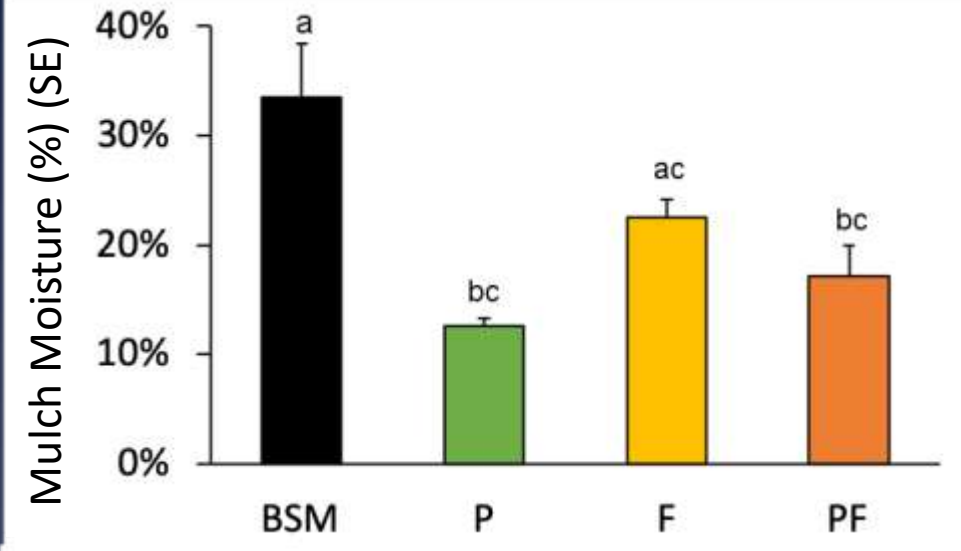


- 50% of plants died during summer drought
- Plants replaced Feb 2018



Plants (May 2019)

- Mulch & soil in plant treatments was drier than mulch in BSM treatment
- Intermediate for treatment with fungi



Fungi



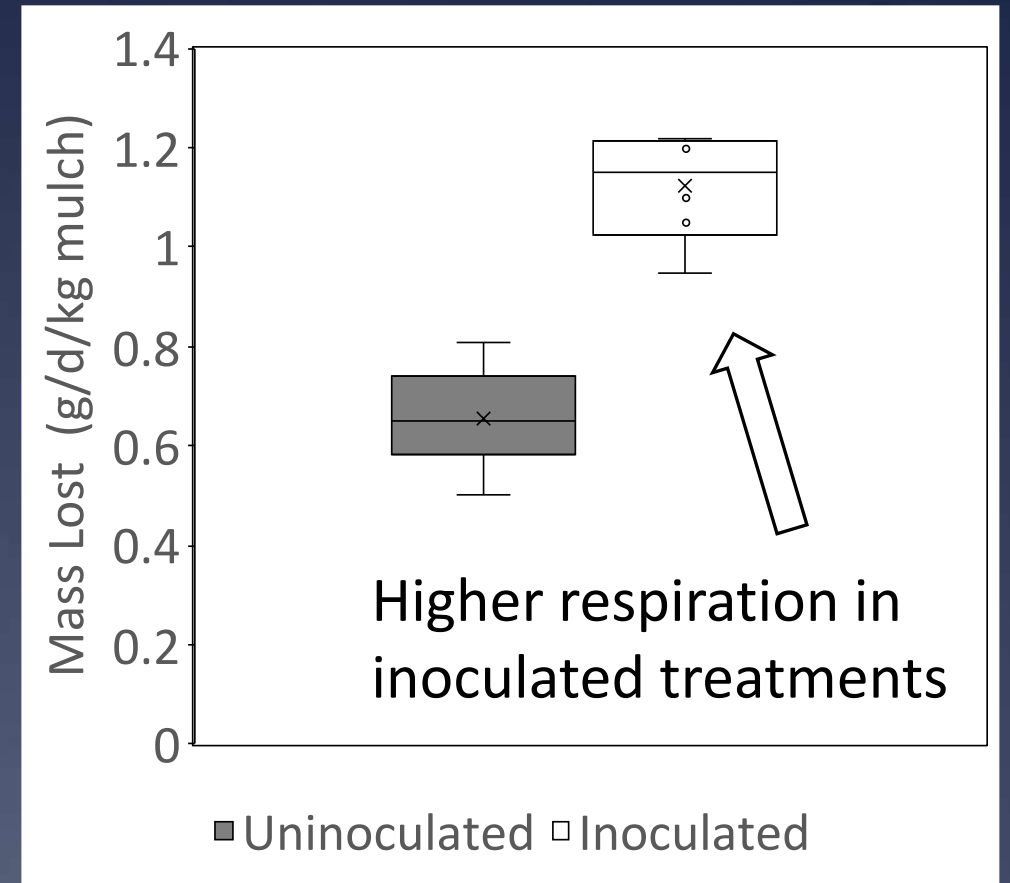
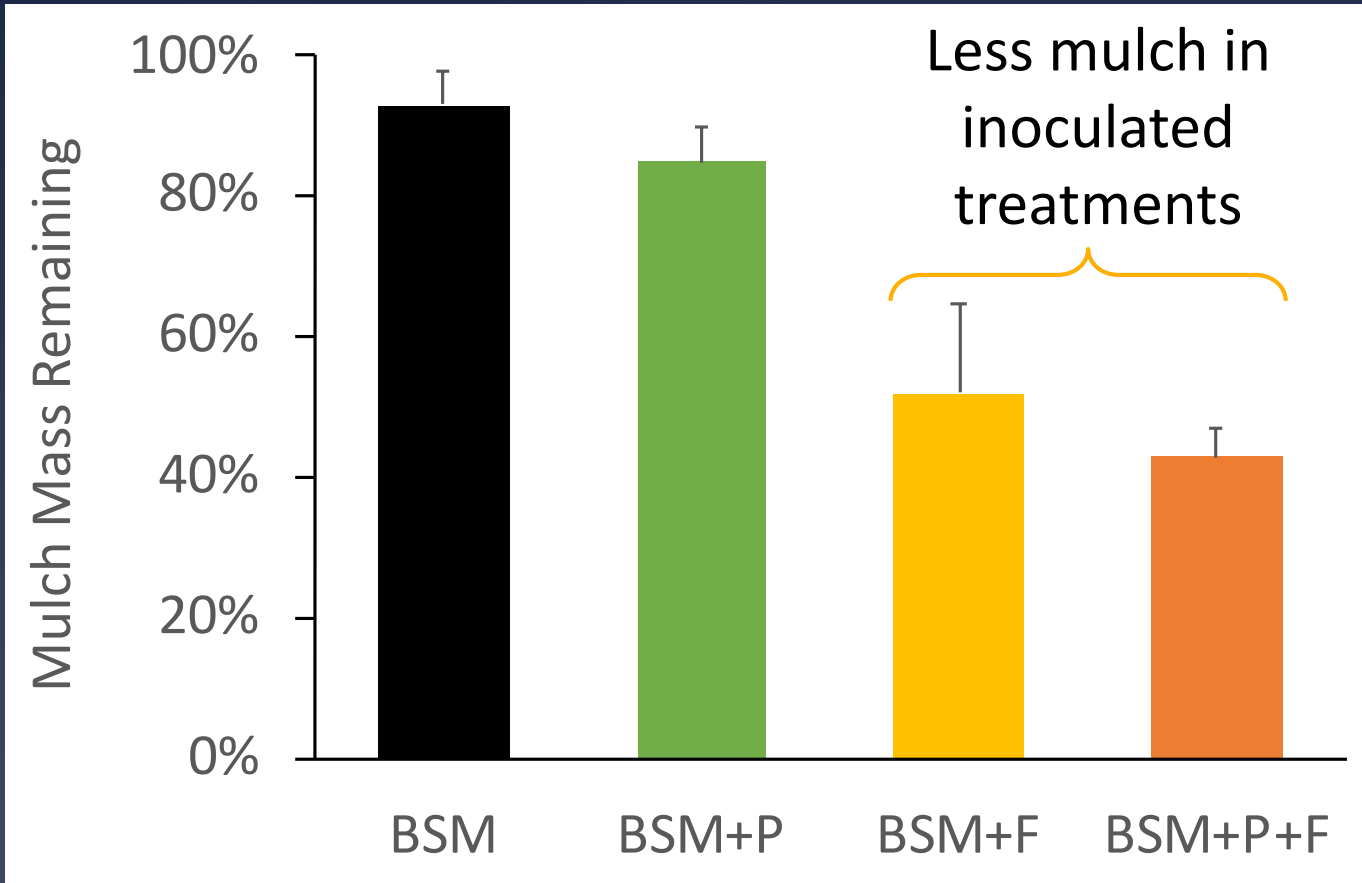
Winecap

Stropharia rugosoannulata

Winecap mushrooms found in all treatments by Fall 2017

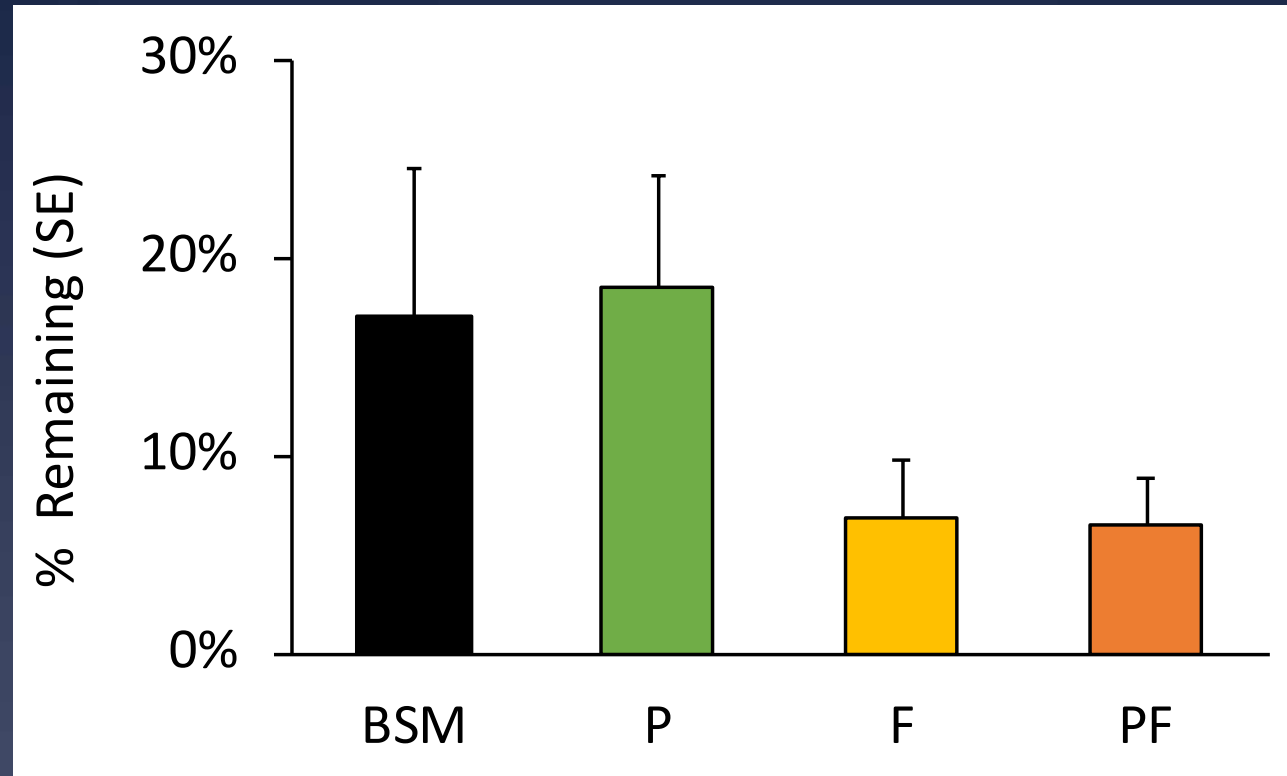
Fungi at end of Year 1

Mulch collected at Year 1 (Jan 2018): mulch mass and microbial respiration measured



Still more fungi in inoculated treatments

Fungi at end of Year 2

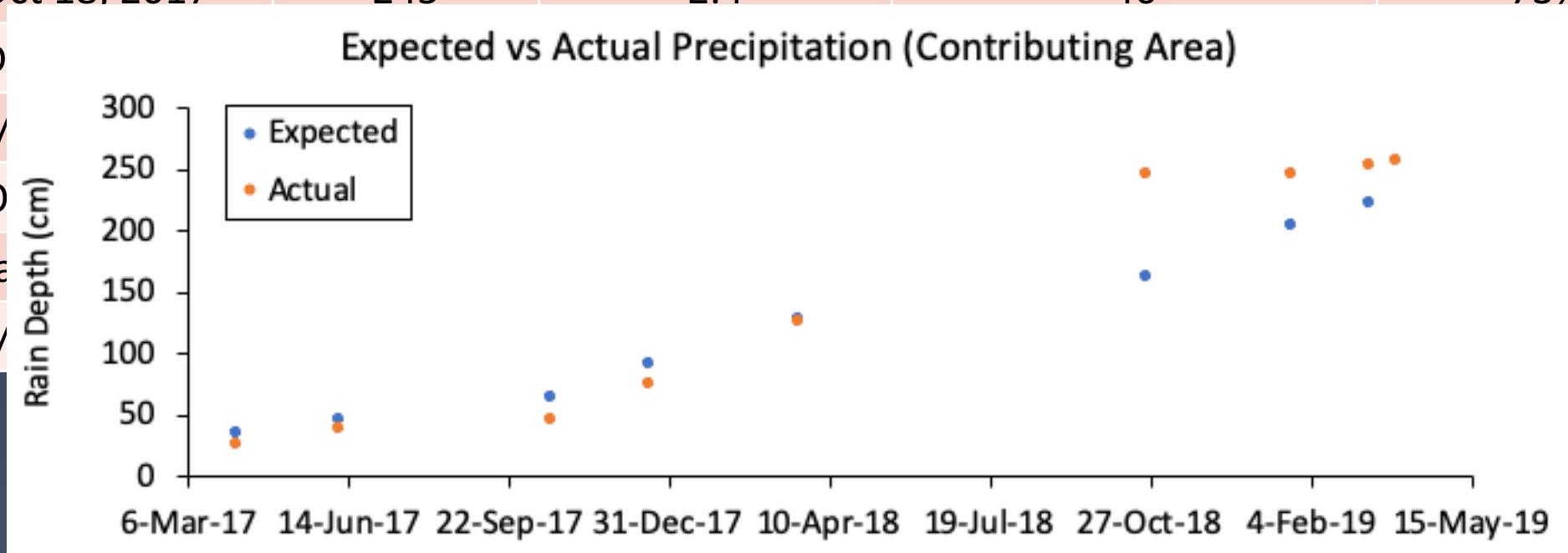


Initially 6.5 kg
dry weight
mulch per drum

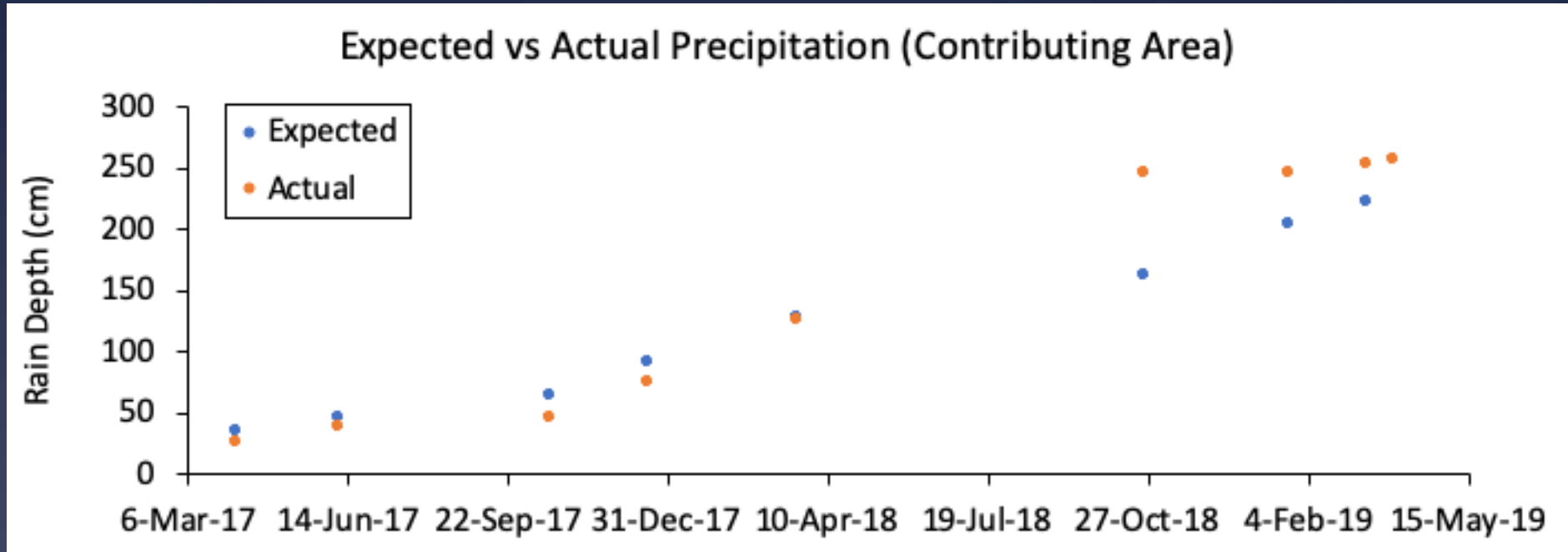
- By end of Year 2, nearly all mulch degraded
- Less mulch in fungi treatments (not statistically different)
- Cannot conclude whether fungi still more abundant in F, PF

Sampling Events

Sampling Event	Sampling Date	Days since Installation	Cumulative Volume Treated (m ³)	Equivalent Cumulative Precipitation (1:20) (cm)	% of Expected Seasonal Treatment
1	Apr 5, 2017	49	1.2	23	73%
2	Jun 8, 2017	113	2.0	38	85%
3	Oct 18, 2017	245	2.4	46	73%
4	D				%
5	M				%
6	O				%
7	Ja				%
8	M				%



Sampling Events



Clean Water Conditioning of BSM

Following conditioning, clean water influent and effluent assessed for baseline water chemistry

Analyte	Units	Influent	Effluent	BSM Source?
TSS	mg/L	1	10	YES
DOC	mg/L	1	28.3	YES
Nitrates	mg/L	2.55	2.30	(YES)
Ortho-P	mg/L	0.037	0.447	YES
dAs	µg/L	1.01	2.30	YES
dCd	µg/L	0.14	0.07	
dCr	µg/L	0.36	1.04	YES
dCu	µg/L	1.4	13.6	YES
dPb	µg/L	0.3	0.1	
dNi	µg/L	0.67	5.32	YES
dZn	µg/L	221.5	30.3	(YES)

PAHs and Fecal coliforms not detected in influent or effluent

Bioretention Performance

	Influent < Effluent (Leaching)	Influent > Effluent (Removing)
T	DOC	TSS
	Nitrates	Fecal coliform
T	Ortho-P	Dissolved Cr
	Dissolved As	Dissolved Cu T
	Dissolved Ni	Dissolved Zn

Net concentration

% Removal

Research Questions:

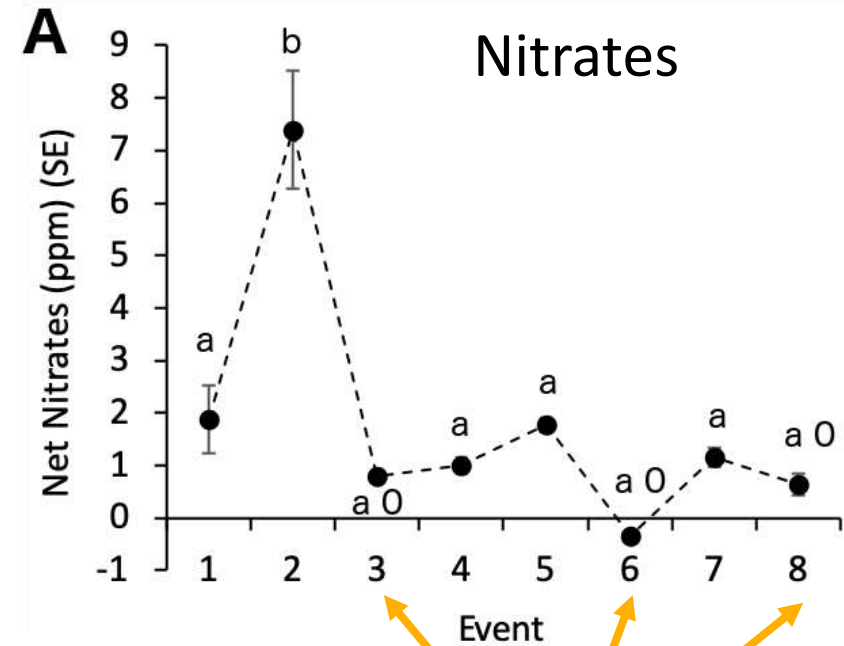
- Did bioretention treatment improve water quality?
- Were there differences among treatments?

Hypotheses:

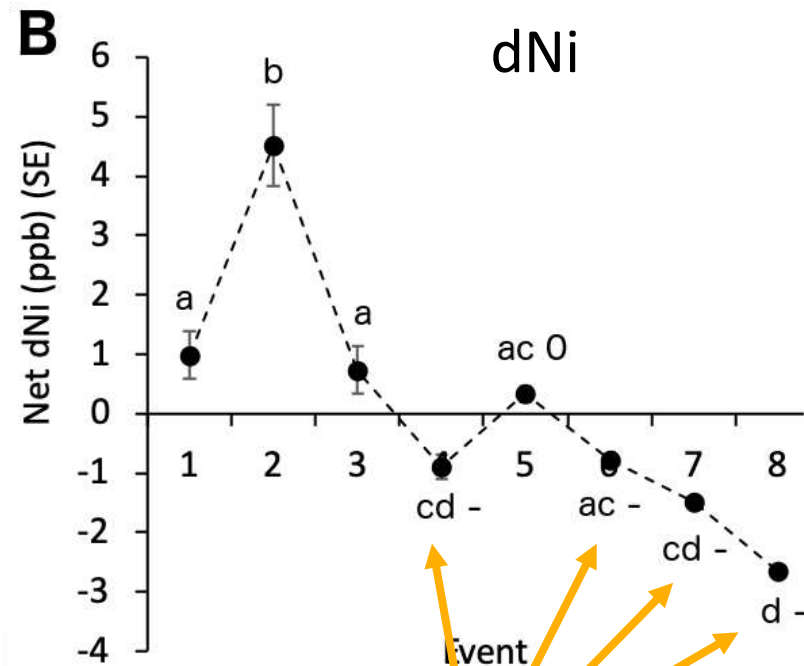
- There would be less leaching over time
- There would be differences among treatments

- All affected by sampling date
- DOC, ortho-P, dCu affected by trmt

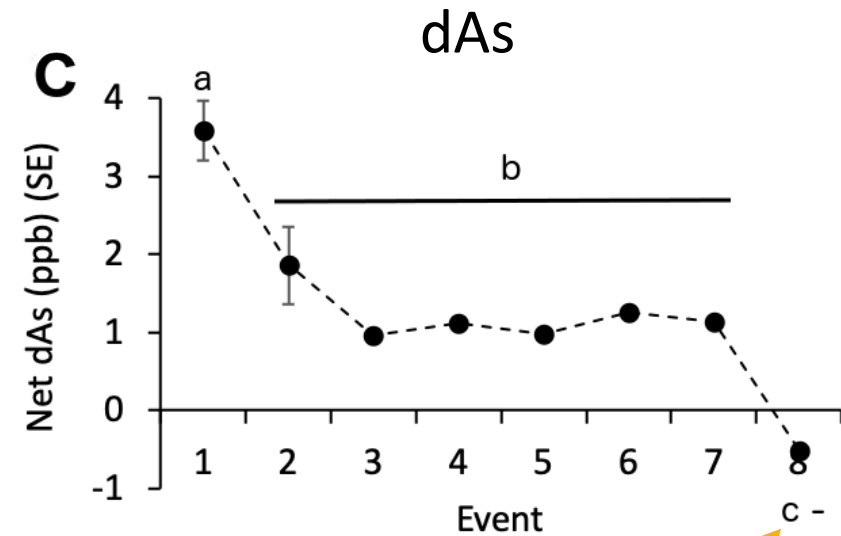
Bioretention Performance: Water Quality Overall



0 = no net export

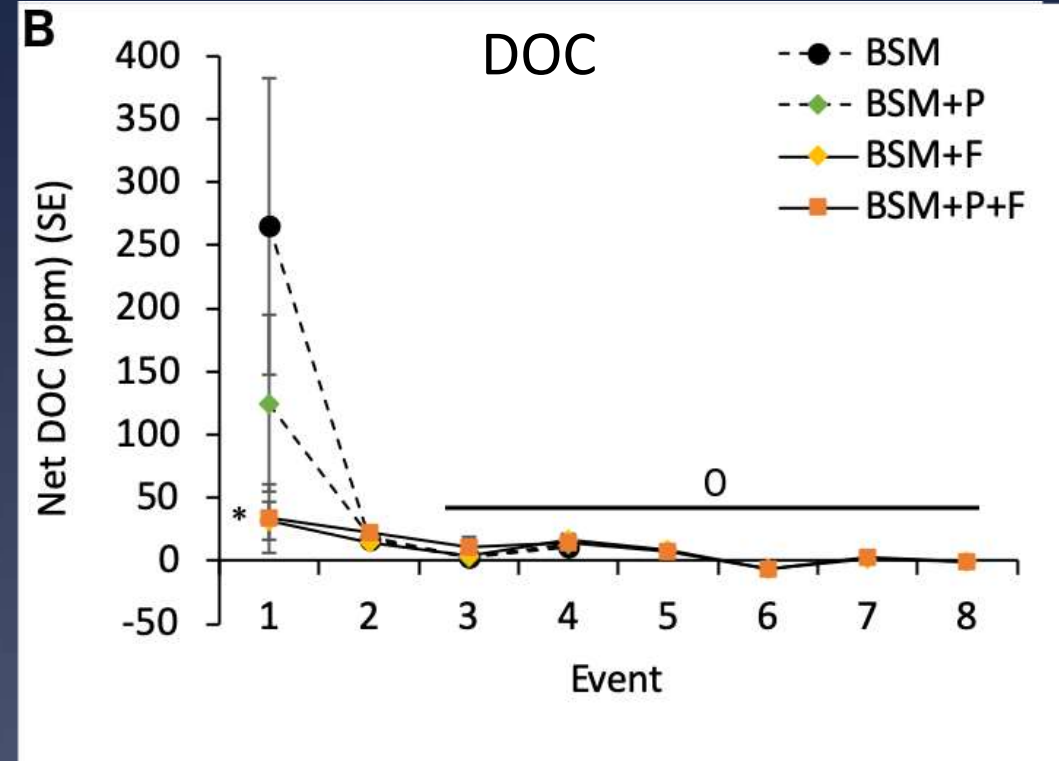
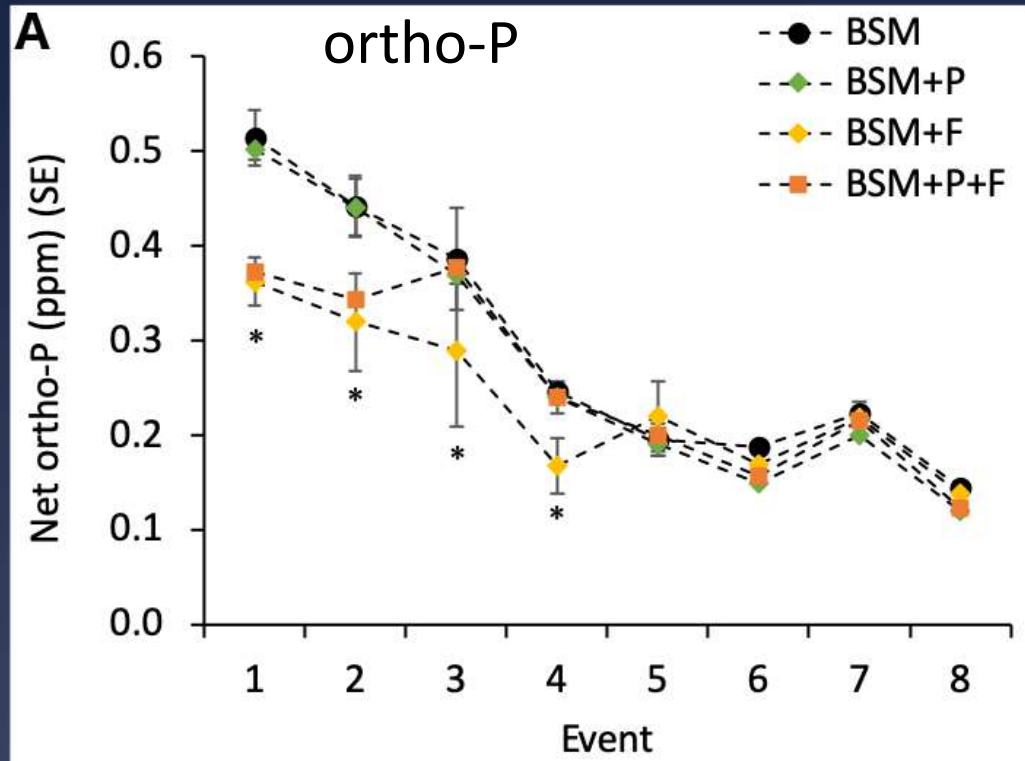


Net removal



Net removal

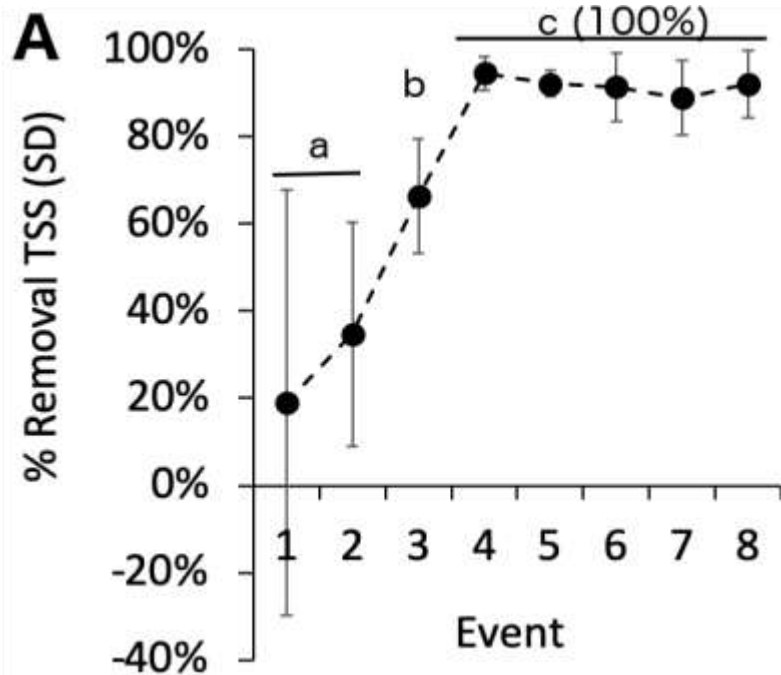
Bioretention Performance: Water Quality



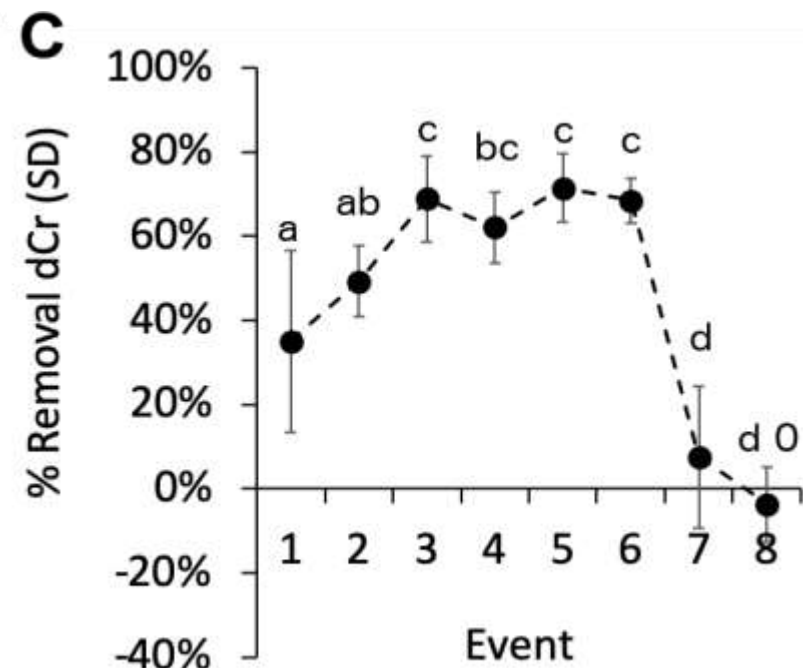
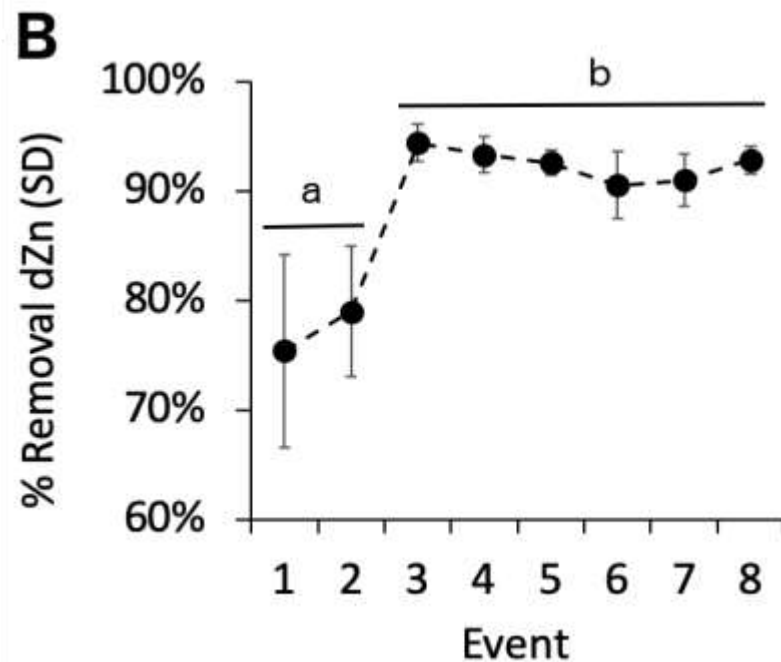
- Declined over time but still exporting at the end of Year 2
- Significantly less export for treatments with fungi during Year 1

- Significantly less DOC export for treatments with fungi Event 1
- No net export after Event 2

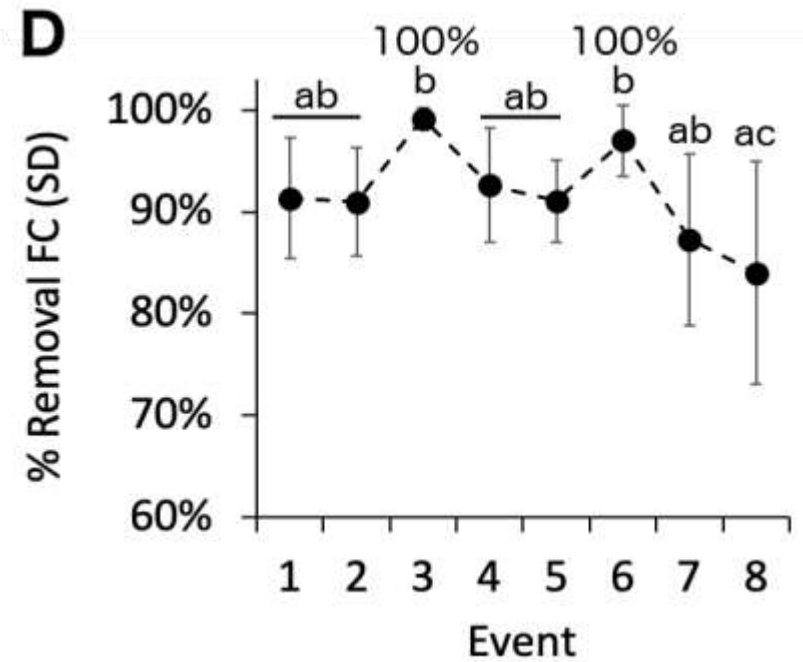
TSS
100% removal
after Event 3



dZn
100% removal
after Event 2

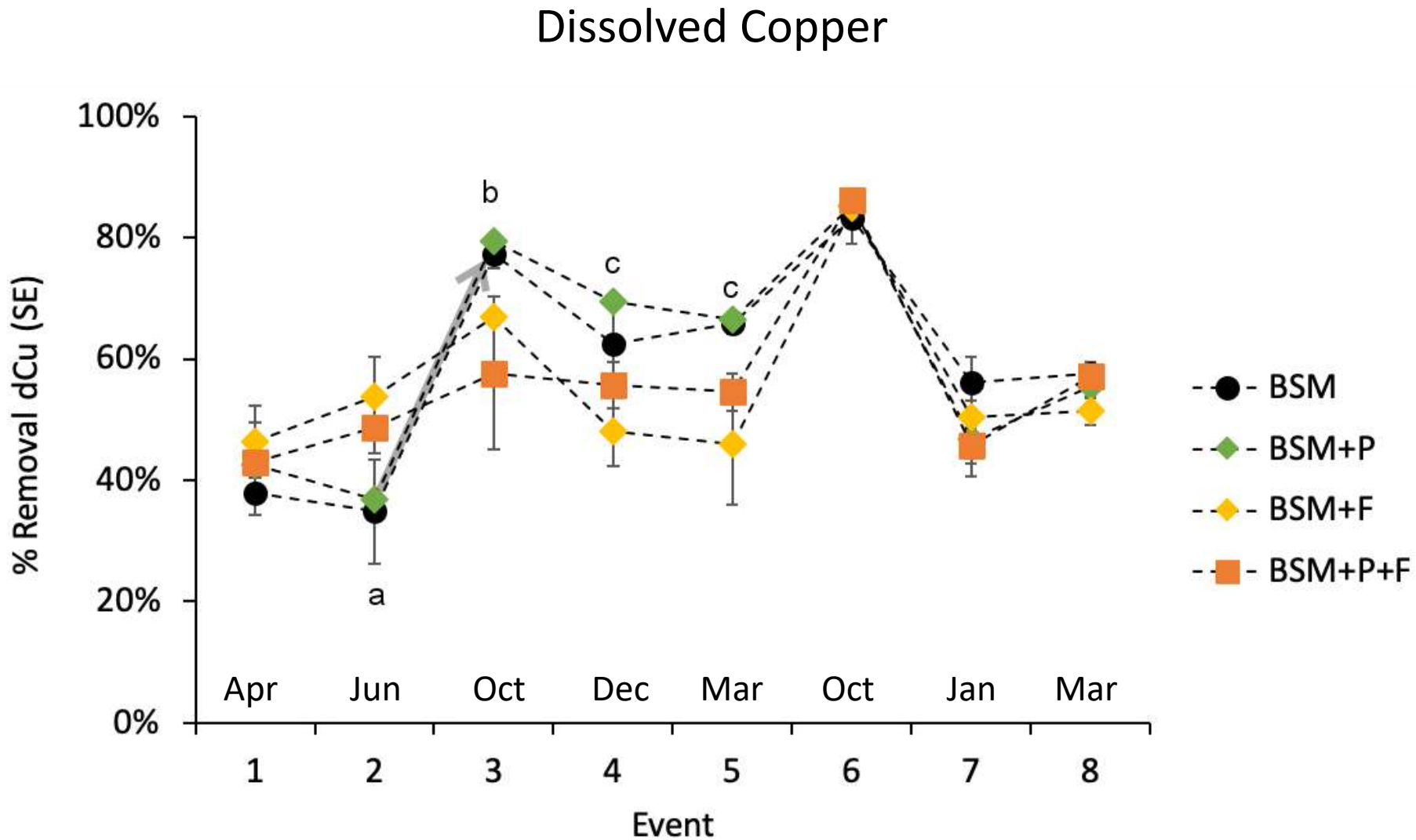


dCr
Removal
improved and
then declined
to zero



Fecal coliform
Good removal
overall
Correlated with
influent

Bioretention Performance: Water Quality



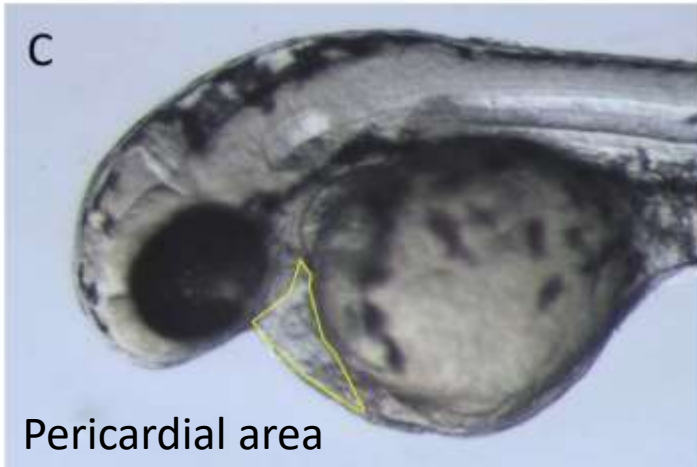
- Event 2: Lower removal of dCu for treatments without fungi
- Event 3-5: Higher removal of dCu for treatments without fungi

Average (2-Yr) Bioretention Performance

Analyte	Unit	Net [X] (SD)	% Removal (SD)
DOC	mg/L	19 (61)	
Nitrates	mg/L	1.8 (2.8)	
dAs	µg/L	1.3 (1.3)	
Ortho-P	mg/L	0.26 (0.12)	
dNi	µg/L	0.1 (2.3)	
Fecal coliform	mg/L		92 (5) %
dZn	µg/L		89 (7) %
TSS	mg/L		72 (30) %
dCu	µg/L		58 (14) %
dCr	µg/L		45 (15) %

Clean Water Conditioning of BSM

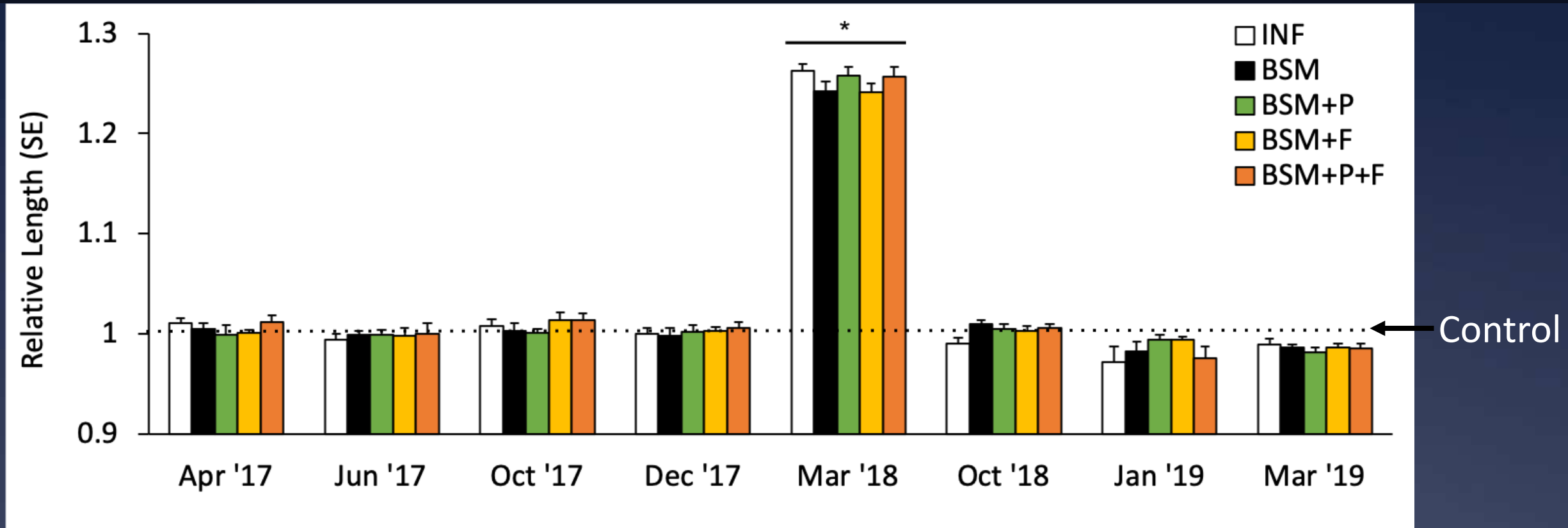
48-h exposure; morphometrics assessed



Metric	Lab Control	Influent	Effluent
Eye Area	0.043 (0.001)	0.042 (0.002)	0.044 (0.001)
PVA	0.023 (0.001)	0.023 (0.001)	0.025 (0.002)
PCA	0.018 (0.001)	0.019 (0.001)	0.019 (0.001)
Length	2.839 (0.011)	2.852 (0.025)	2.834 (0.010)

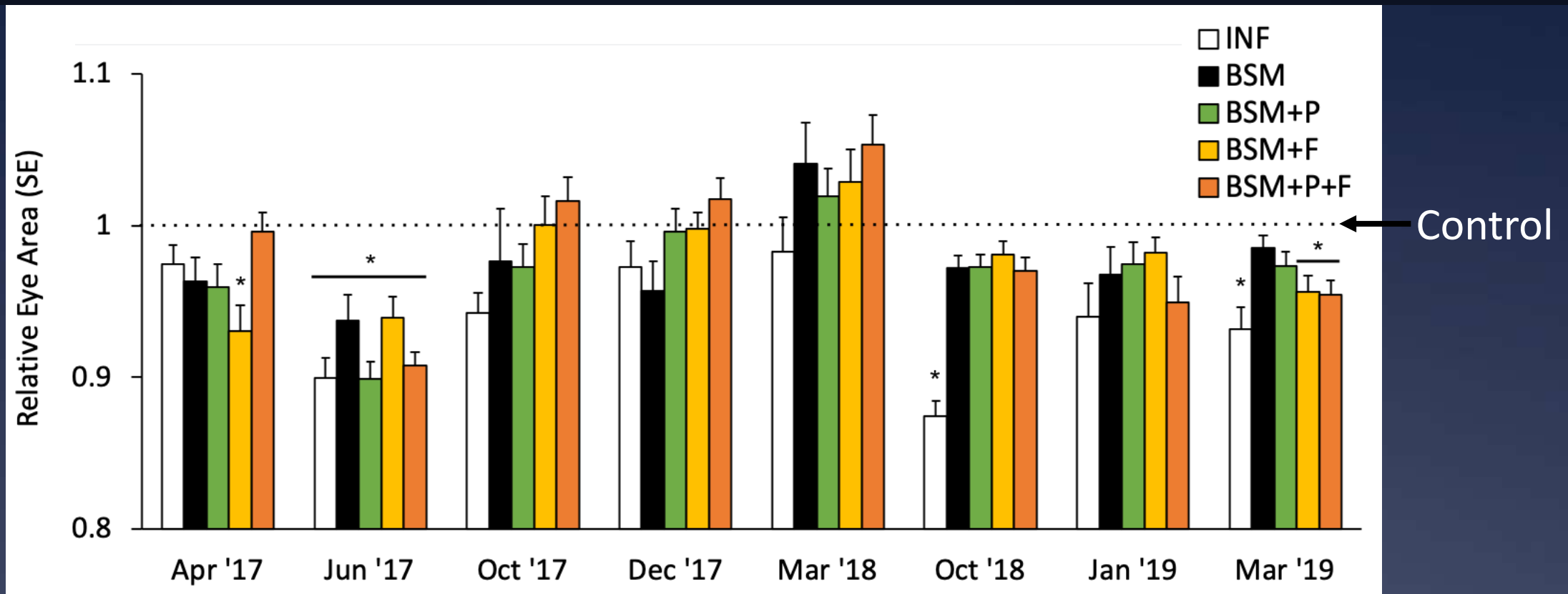
No effect of effluent water on zebrafish embryo development

Bioretention Performance: Toxicology



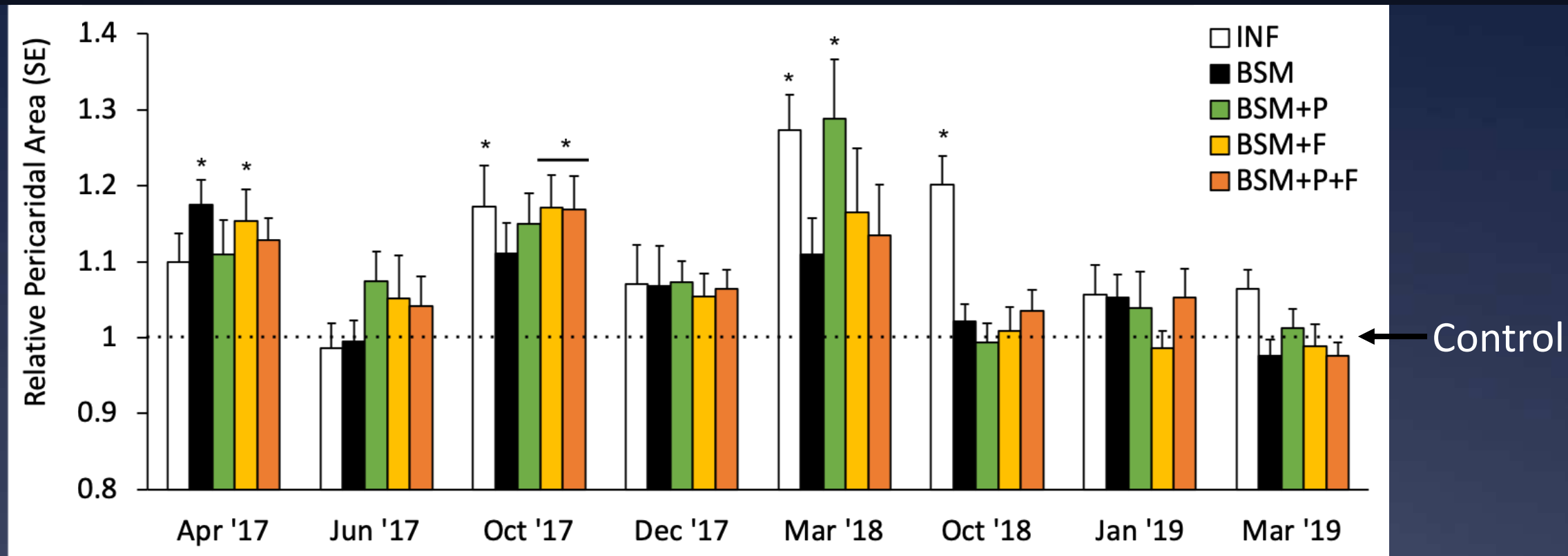
- Zebrafish embryo length was the least sensitive metric (1 event affected)
- Unusual stimulation of growth also present for effluents

Bioretention Performance: Toxicology



- Influent stormwater affected zebrafish eye area for 3 events
- Bioretention treatment prevented impact in some but not all cases
- (Oct 2018: all treatments; Mar 2019: treatment without fungi)

Bioretention Performance: Toxicology



- Influent stormwater from three events caused pericardial edema
- Bioretention treatment inconsistently prevented impacts

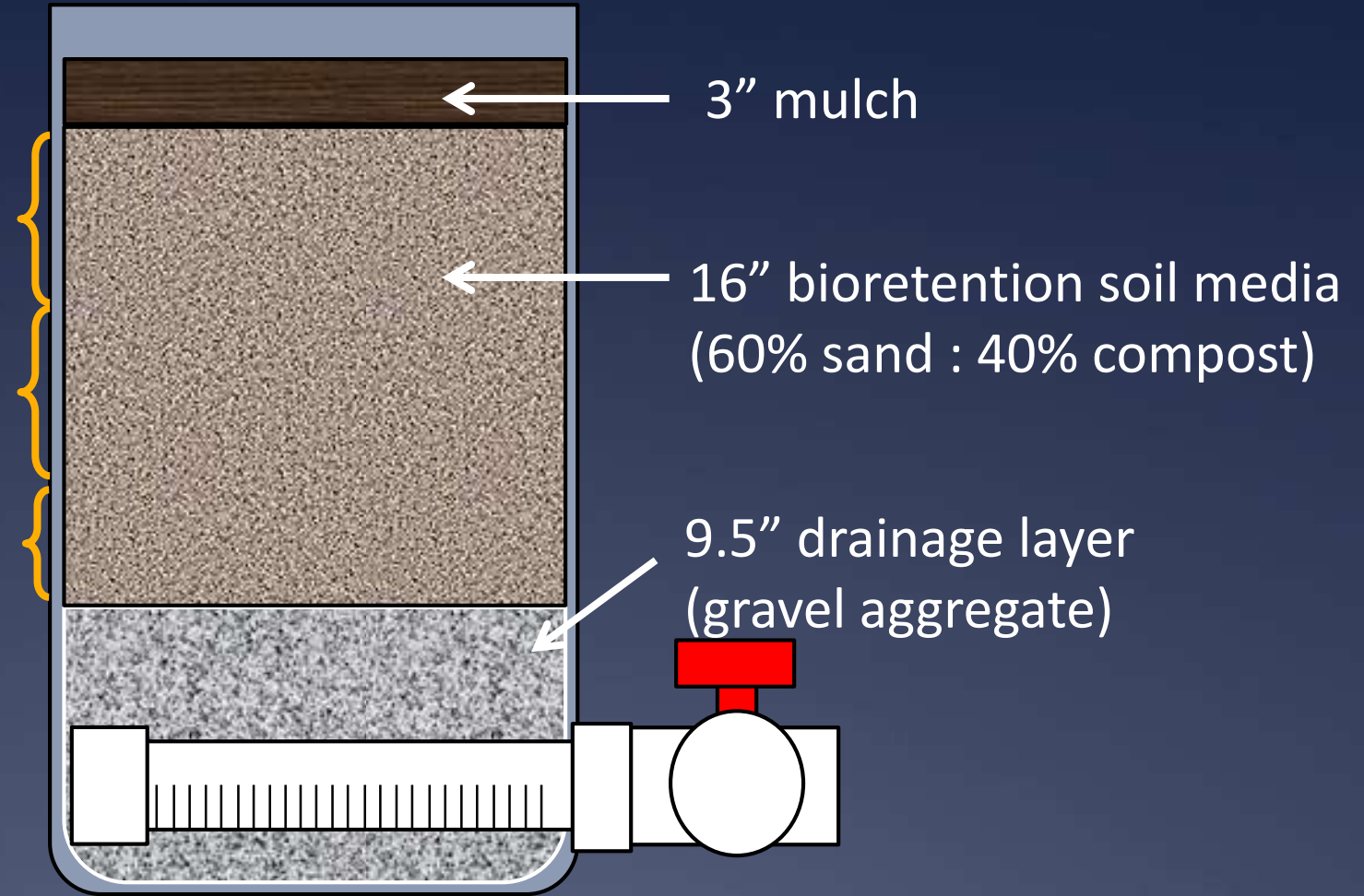
Bioretention Performance: Toxicology

- Influent stormwater from 5 of the 8 events caused sublethal toxicity in zebrafish embryos
- Bioretention tended to prevent toxicity, but amendments performed inconsistently
- Toxicity was mild, therefore less ability to detect differences among treatments
- Among 24 possible cases of toxicity (8 events x 3 endpoints) only 7 observed
- Previously, cardiotoxicity was most commonly observed sublethal effect for stormwater exposure (McIntyre et al. 2014)
- Related to [PAHs] > 1 ppb (McIntyre et al. 2016); this study PAH < 1 ppb
- Fewer fines at this site, related to numerous catch basins 'upstream'
- TSS low compared with Phase I municipal discharges
- Contributing area (12.8 hectares) includes unknown contribution from non-highway land uses

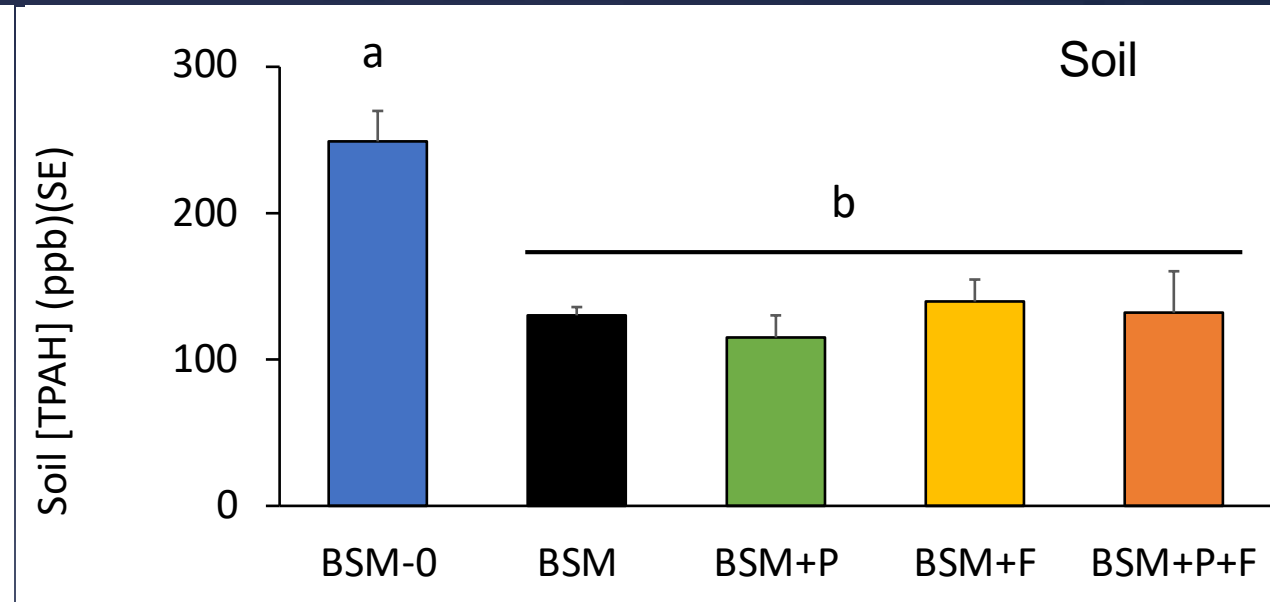
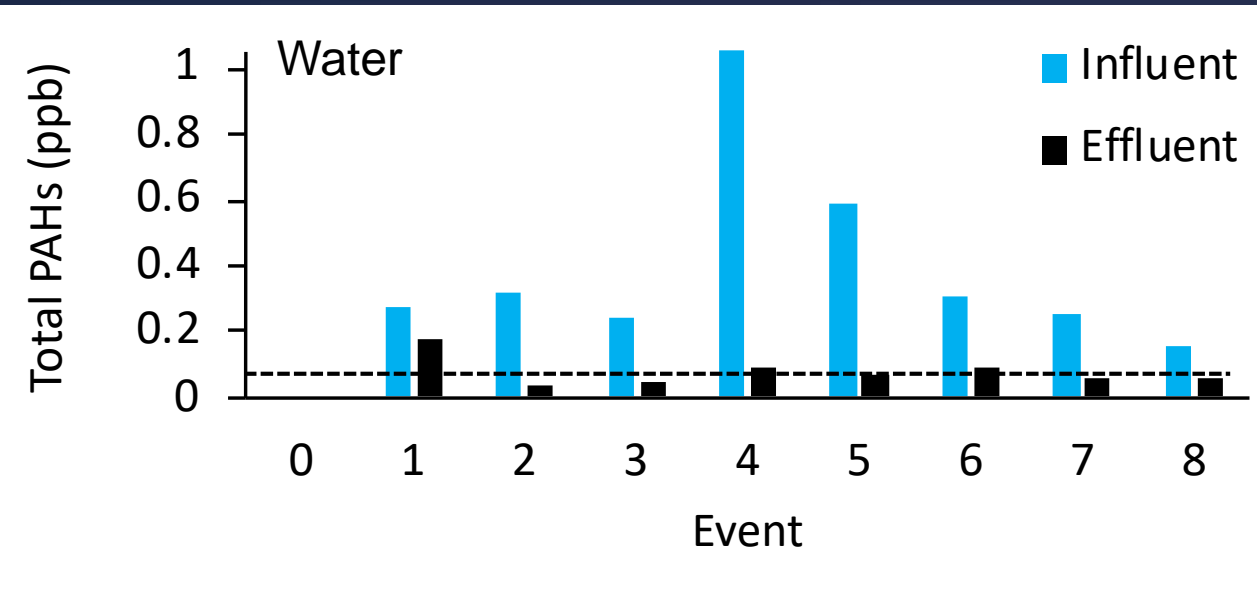
Bioretention Performance: Soil

Yr 0	Yr 2	Depths Assessed
PAH metals	PAH ?	0-15 cm
metals	metals	15-30 cm
metals	metals	30-40 cm

No stratification of soil
contaminants
(Year 0 or Year 2)



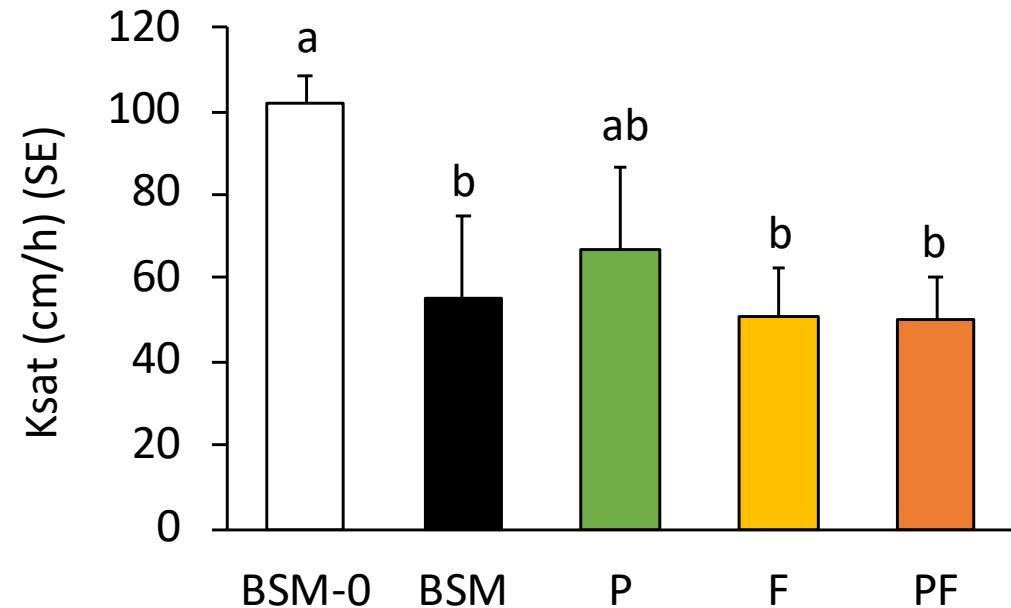
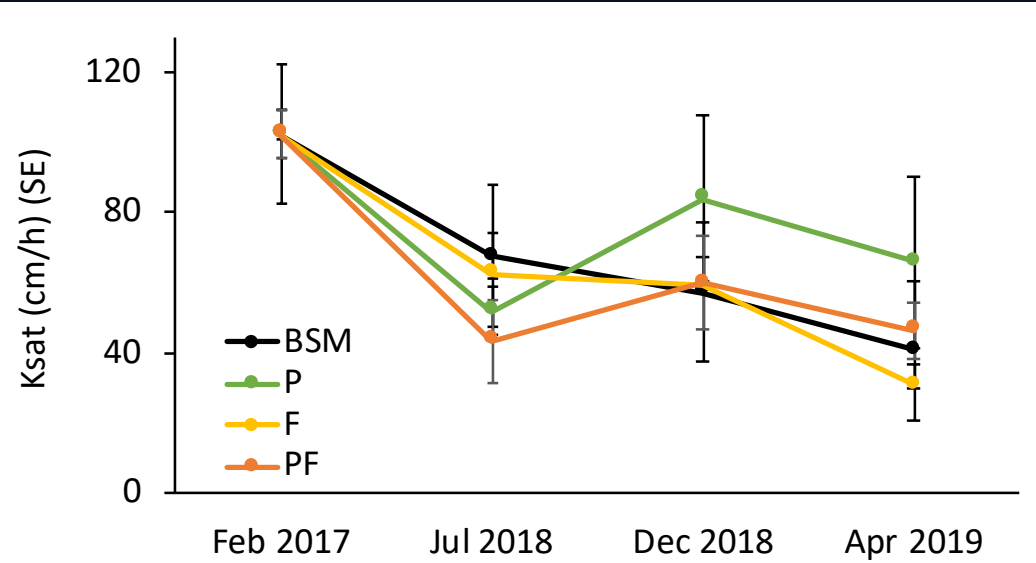
Bioretention Performance: Soil PAHs



- Influent concentrations low (<1 ug/L) but measurable (>0.011 ug/L)
- Effluent almost all below detection limits

- 11% increase in soil TPAH expected
- 47% decrease observed
- Conclusion: microbial degradation

Bioretention Performance: Ksat



Hydraulic conductivity measured after conditioning and during Year 2

No difference among Ksat during Year 2

Ksat decreased 34-51% across treatments

Decrease was significant for all treatments except BSM+P

(Note: New plants added Feb 2018)

Bioretention Performance: Summary

What is the role of plants?

- Less loss of hydraulic conductivity during Year 2
- Very thirsty (summer maintenance, no winter benefit of deciduous)

Do fungi provide additional benefits?

- Initially reduce leaching of DOC and P
- No clear benefit of plants and/or fungi to toxicity prevention (no detriment!)

How long does bioretention treat runoff?

- No decrease in treatment effectiveness over 2 years (dCr?)
- No noticeable increase in toxicity of effluent by end of 2 years

Article

Engineering Analysis of Plant and Fungal Contributions to Bioretention Performance

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The background of the slide is a light gray gradient with several realistic water droplets of various sizes scattered across it. The droplets have highlights and shadows, giving them a three-dimensional appearance. The main text is centered in a large, bold, black font.

SPECIAL THANKS FOR FIELD ASSISTANCE!

JILL WETZEL*

EMMA MUDROCK

CHELSEA MITCHELL

JAMES CAMERON

KEN KING

MICHELLE CHOW

CLAIRE DUCHET