Management Approaches to Reduce Stressors of Stream Health

CENTER FOR WATERSHED PROTECTION

Preliminary Results

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Research Question

- Which of the key stressors affecting stream health in the Chesapeake Bay watershed can be changed through management activities being implemented by jurisdictions to meet total maximum daily load (TMDL) goals?

Background – 2nd Phase of 3-Phased Work Plan

1. Identify stressors (e.g., flow, salinity) most affecting stream health → USGS
2. **Understand how management actions (BMPs) may reduce stressors beyond their intended goal of nutrient and/or sediment reduction → CWP (present study)**
3. Determine how to characterize and monitor the stream health response to management efforts → Not Started Yet

Background – Steps Taken to Date

- Narrowed key stressors to those identified by USGS as affecting stream health in >50% of studies
- Selected BMPs from Chesapeake Assessment and Scenario Tool (CAST) credited 2015-2019; Narrowed by TAG priorities, potential for co-benefits, limited use
- Literature review to identify capacity of selected BMPs to address key stressors

		Stressors Important to Stream Health						
		Urban			Both		Agricultural	
	Coarse BMP	Toxics _Other	Flow	Salinity _Ions	Toxics _Pesticides	Geomorph _Habitat	DO	Riparian
Urban/ Suburban BMPs	Wet Ponds and Wetlands							
	Dry Ponds							
	(Bio)(in)filtration							
	Urban Forest Buffers							
	Urban Tree Planting							
	Urban Stream Restoration							
Agricultural BMPs	No Till and Cover Crops							
	Pasture Management							
	Vegetated Buffers							
	Ag Drainage Management							
	Ag Stream Restoration							
	Wetlands							

Literature Review Metrics

- 185 total papers found
- 71 excluded
  - Duplicate or data reported in other studies
  - Did not provide information on target BMP/Stressors
  - Not peer reviewed (e.g., report, guidance document, or conference proceeding)
  - Impact factor < 2.0
  - Too many papers on subject
- 70 included for Categorical analysis
  - Data could not be directly compared between studies using a single efficiency value due to metrics used (e.g., embeddedness & habitat score)
  - BMP affected stressor through direct alteration (e.g., Vegetated Buffer & Riparian)
  - BMP affected stressor indirectly via an intermediate (e.g., DO via nutrient reduction)
- 44 included for Quantitative analysis
  - In/out or control/treatment stressor parameter comparable across studies
  - 468 data points
  - Some data points are composites of review articles

Effectiveness and Data Source Characterization

- Developing a method for classifying BMP performance based on effectiveness and data richness

	Data Richness			Effectiveness	
	# of Studies	# of Data Points	Type of Study	Mean Efficiency	% of Studies w/ Benefit
High	≥ 4	≥ 20	Review	>50	>50
Medium	2-3	10-19	Field	25-50	25-50
Low	0-1	0-9	Model	<25	<25

Results

“Quantitative” Stressors

Other Toxics

Flow

Pesticides

Efficiency

- Urban **Wet Ponds and Wetlands** & **Bioinfiltration** highly effective for **Other Toxics** and **Pesticides**
- **Urban Tree Planting** only BMP highly effective for **Flow**
- Agricultural **Vegetated Buffers** and **Wetlands** highly effective for **Pesticides**

Stressors Important to Stream Health

	Sector	Urban										Both				
	Coarse BMP	Other Toxics					Flow					Pesticides				
	Metric	# studies	# data pts.	median eff.	Q1 eff.	Q3 eff.	# studies	# data pts.	median eff.	Q1 eff.	Q3 eff.	# studies	# data pts.	median eff.	Q1 eff.	Q3 eff.
Urban/ Suburban BMPs	Wet Ponds and Wetlands	2	4	96	83	98	1	1	44	44	44	1	3	57	54	59
	Dry Ponds	2	4	26	15	40	2	2	22	11	33	1	1	12	12	12
	(Bio)(in)filtration	4	13	89	75	96	3	4	18	8	44	1	4	72	40	98
	Urban Forest Buffers	1	1	40	40	40	0	0	N/A	N/A	N/A	1	1	25	25	25
	Urban Tree Planting	0	0	N/A	N/A	N/A	5	10	57	33	64	0	0	N/A	N/A	N/A
Agricultural BMPs	No Till and Cover Crops	[redacted]										5	38	51	-25	76
	Pasture Management	[redacted]										1	1	10	10	10
	Vegetated Buffers	[redacted]										8	94	83	37	97
	Ag Drainage Management	[redacted]										2	17	36	30	57
	Wetlands	[redacted]										2	40	92	66	97

lowest — 50th percentile — highest

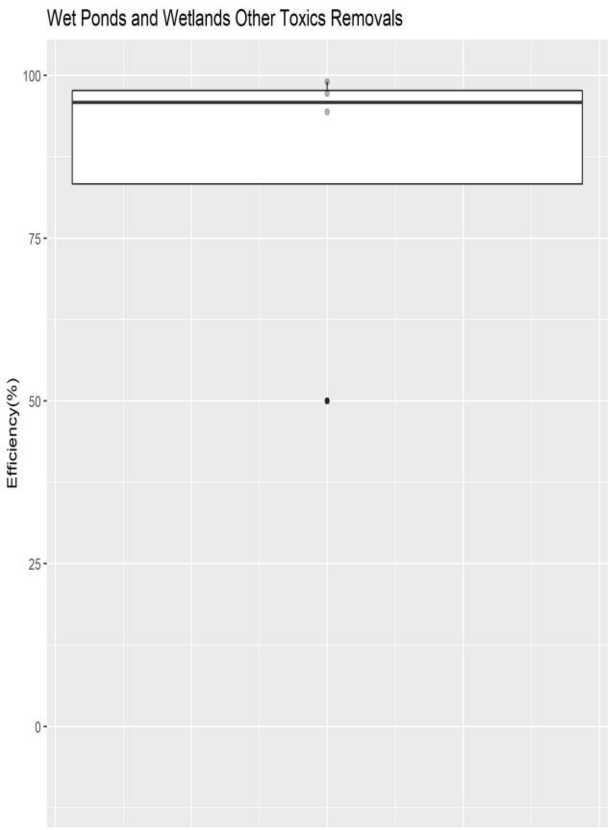
Other Toxics

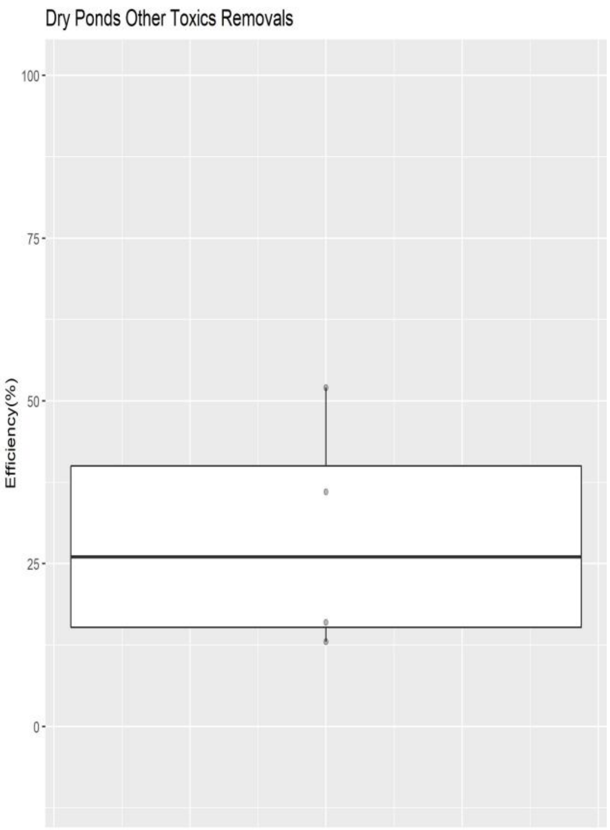
Organic compounds
PAHs
SWTU (toxics, surfactants)
SW TOC (water quality)
Sediment organic contaminant
Total PAH sediment
Organic Compounds

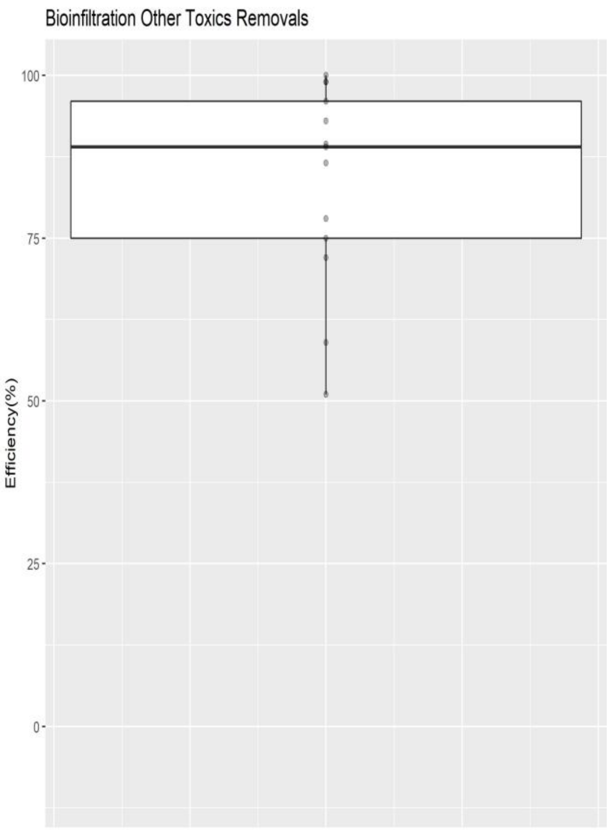
TOXICS_OTH

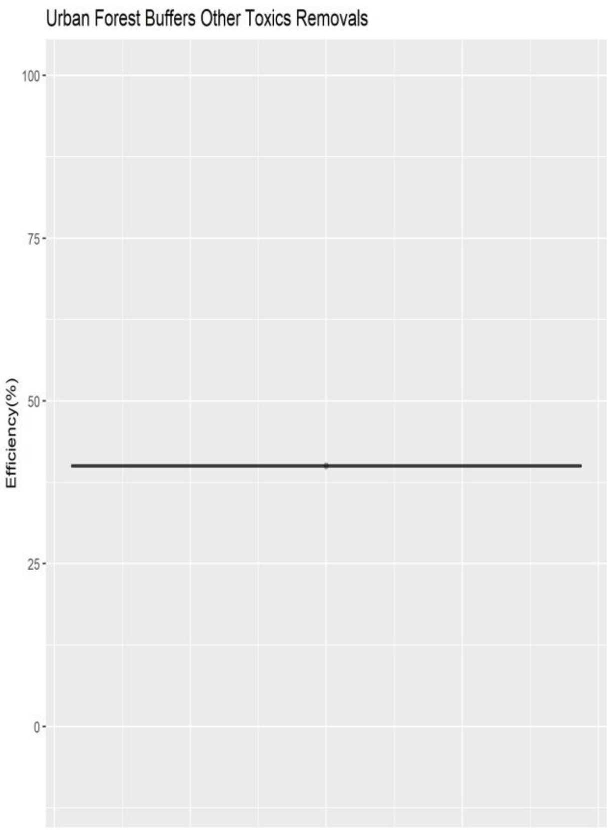
Other Toxics

- Sediment is a vector for toxics and other contaminants (e.g., PAHs, organic compounds) (Noe et al., 2020; Hwang and Foster, 2006)
- Sediment-associated contaminants are effectively trapped in sediment-removing BMPs.
- Retained toxics are not "removed" equally. PAH concentrations were consistently high in the sediments of urban wet ponds but were found to undergo nearly complete mineralization in bioretention (LeFevre et al. 2012).









Flow

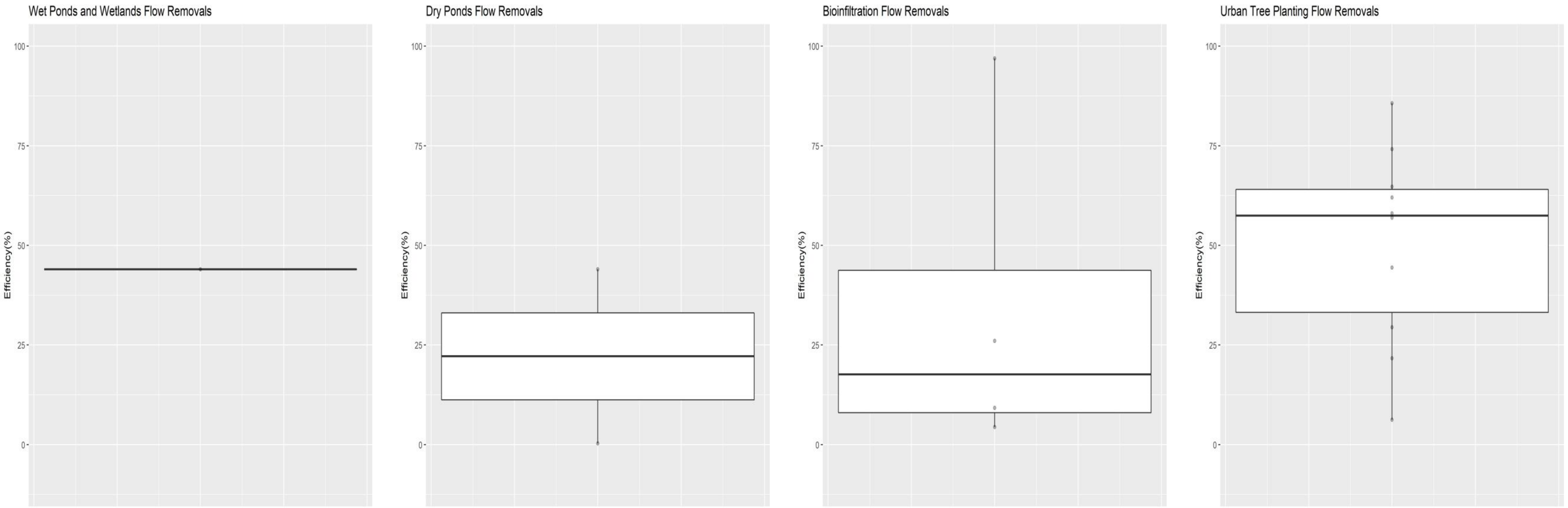
Flow Duration
Flow
Change in Flow
Runoff frequency
flow
Discharge
Flow Peak Interval
Bankfull Flow
Flow frequency

- High-flow event frequency
- Throughfall
- Runoff
- Average annual peak runoff
- Annual flow
- Peak runoff

FLOW

Flow

- Site-scale effects may or may not translate to watershed-scale
- BMPs have limited capacity
- Design matters



Pesticides

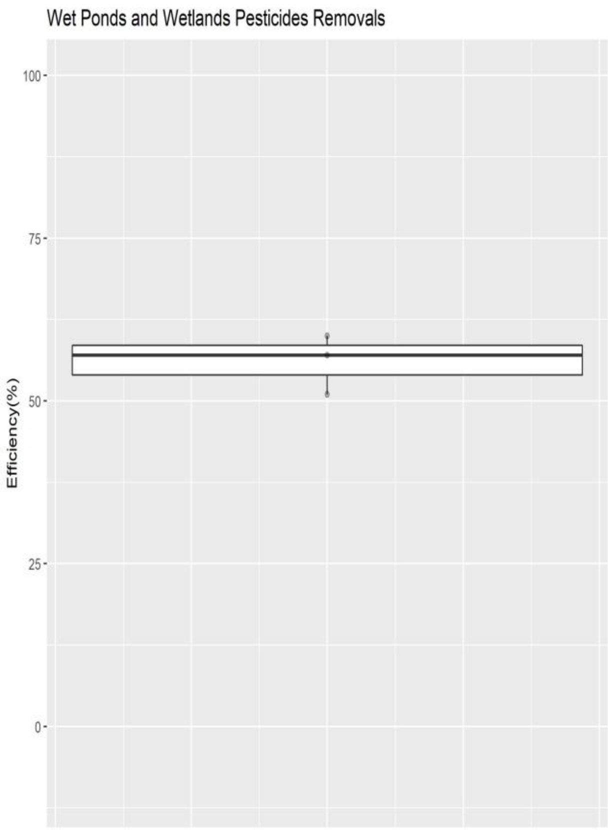
The terms pesticide and herbicide were used interchangeably so we included both

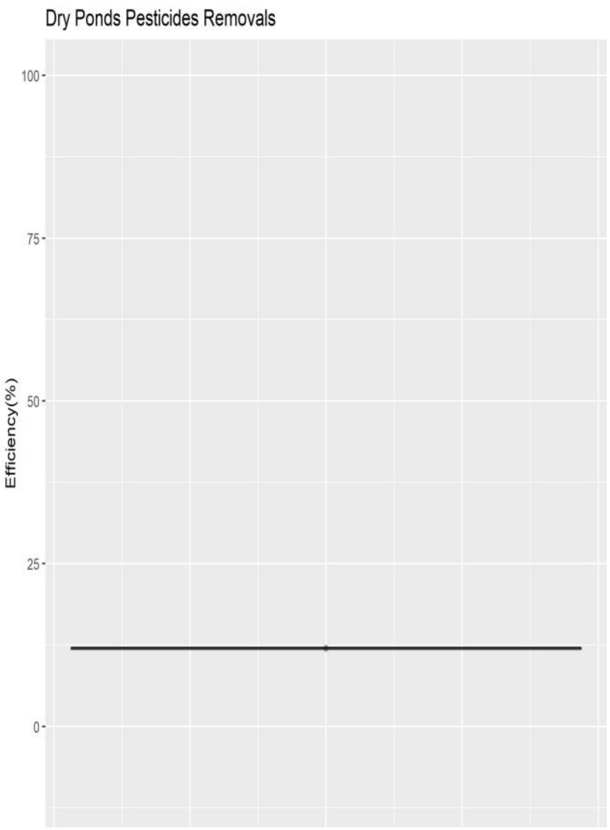
Legacy pesticides
current pesticides
Pesticides
Fungicide
Number of pesticides detected
Number of Pesticides
Insecticides
Insecticide degradates
Fungicides

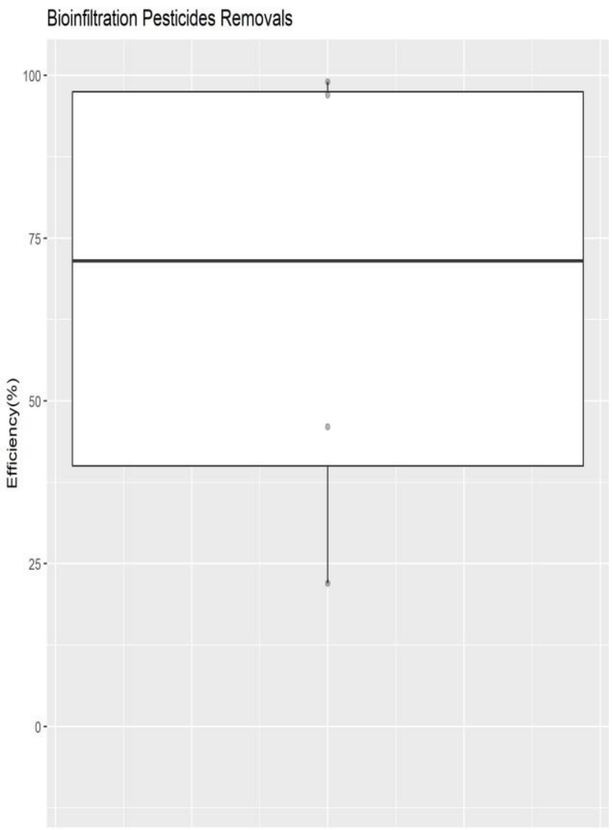
TOXICS_PEST

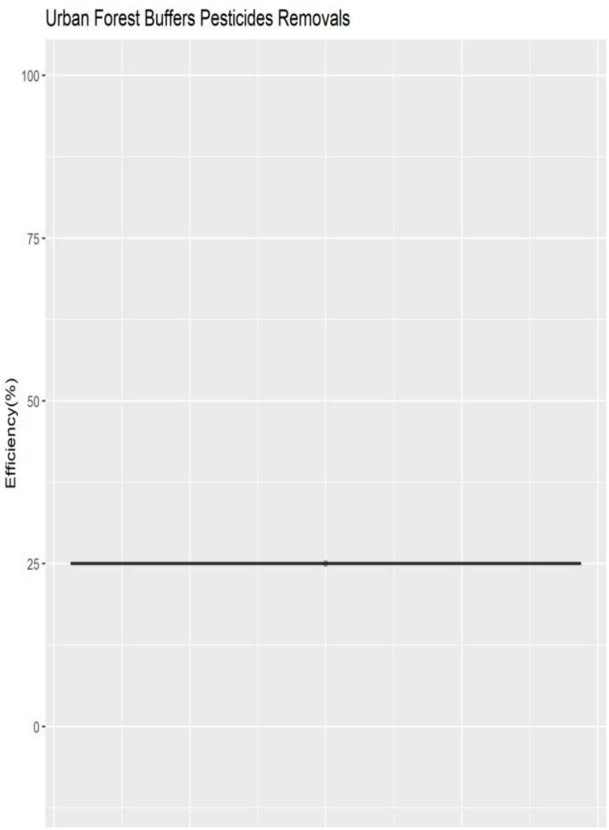
Pesticides - Urban BMPs

- Removal linked to flow reduction and sedimentation
- Efficiency varied by pesticide, atrazine and glyphosate highly removed



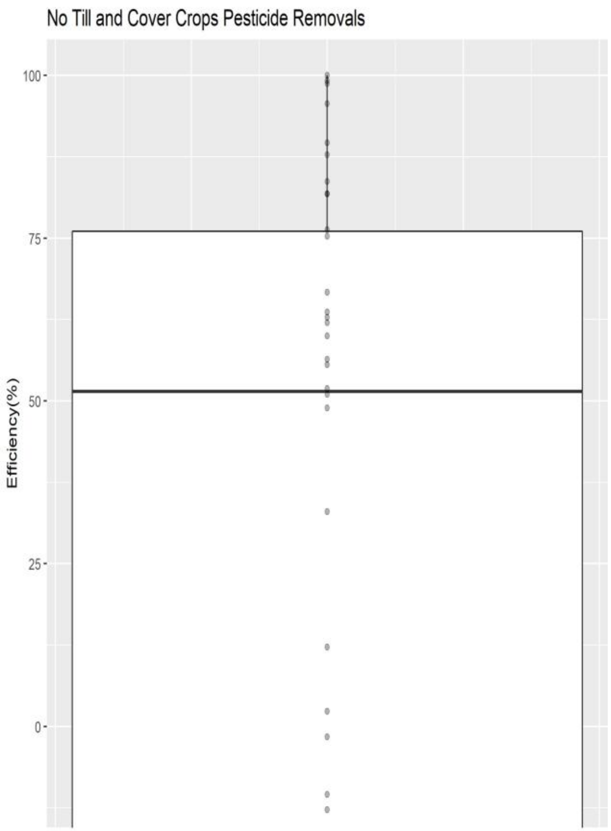


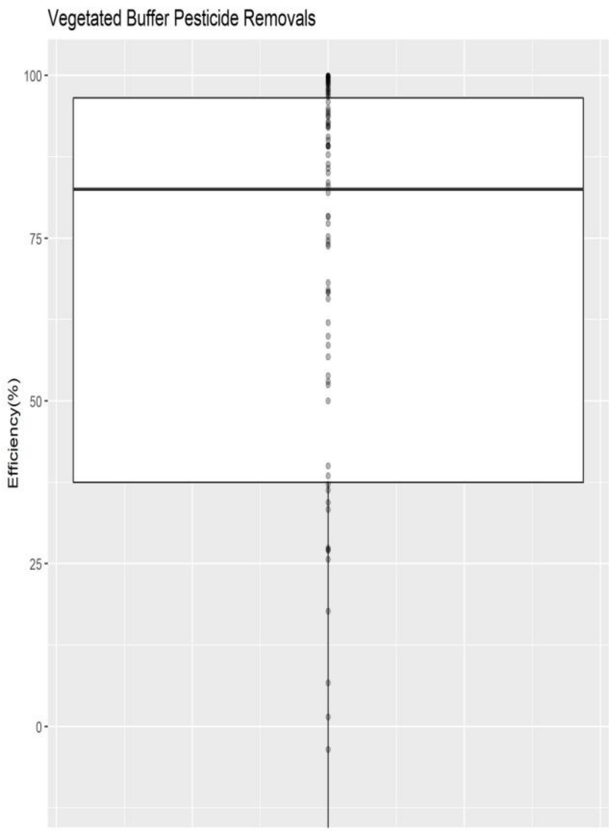


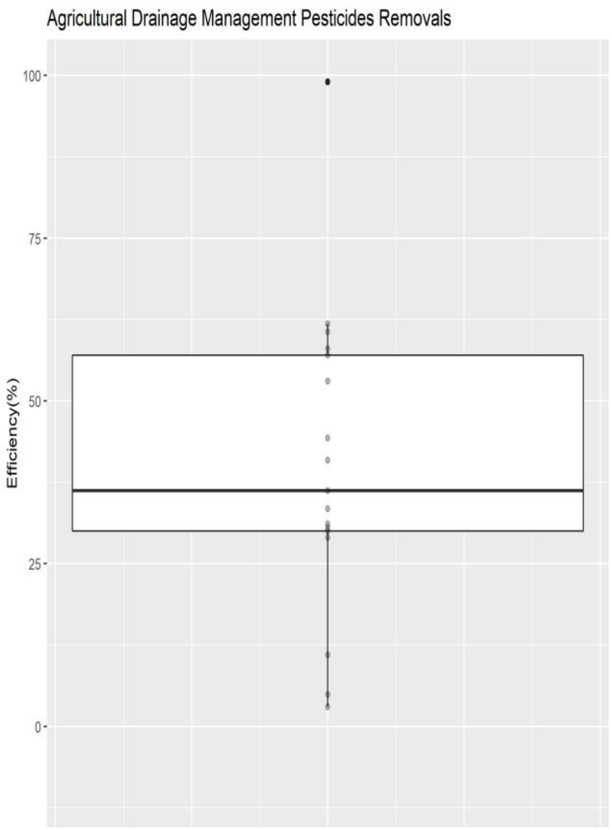


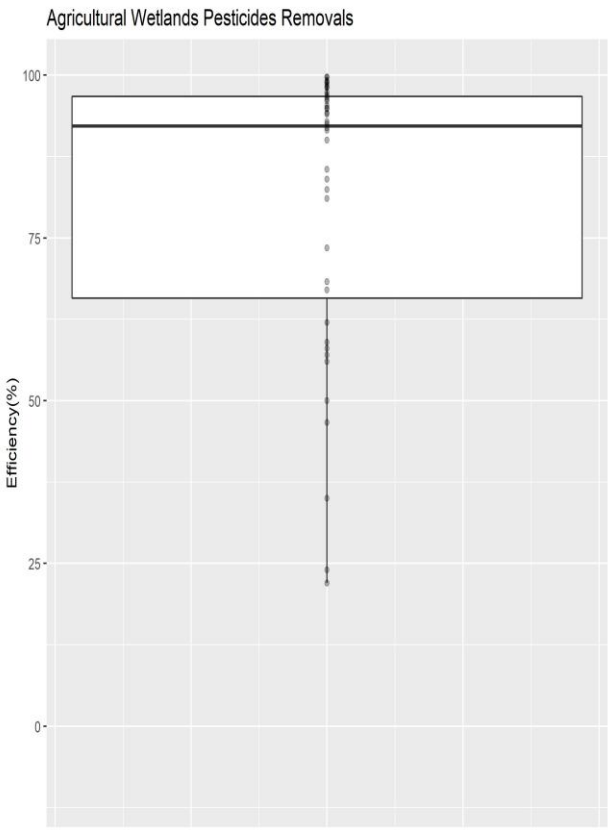
Pesticides - Agricultural BMPs

- Extent and placement of BMPs influences the area/loading they can manage
- Wide range of removal even among the same pesticides
- Agricultural wetlands results may skew high due to a California study









“Categorical” Stressors

Salinity

Geomorphology

DO

Riparian

Salinity

Chloride
conductivity
sulfate
Conductivity
SO4
Calcium
Mg
Magnesium

Sulfate
Hardness
K
Ca
Specific Conductance
Mine drainage (SO4 ion effect)

SAL_IONS

Salinity

- Stormwater BMPs have been shown to slow the pulses of salts and release them slowly (reduces peaks). Salts also “hide” in the stream groundwater (hyporheic zone) and banks.
- Smoothing salinity peaks and prolonging periods of high salinity may not be better for biotic health.

Geomorphology

Deposited fine sediment
Percent fines
Substrate homogeneity
Streambed particle size
large cobble-to-fines ratio

Log relative bed stability
substrate
Cobble substrate riffle
Sediment deposition
Deposited sediment
Bed sediment size

variability (habitat)
Phi Variability
Depth
Habitat Score
Sedimentation
Habitat (substrate)
Ave. silt
Ave. velocity
Habitat (grasses in

streambed, bank, riparian)
RBP (overall habitat score)
Embeddedness
in-stream cover
Habitat cover
Ave silt

GEOMORPH_HABITAT

Geomorphology

- Improving stream geomorphological stressors requires addressing the causes of the system's degradation in addition to the use of effective BMPs.
- Stream Restoration BMPs show positive impacts on stressors impacted by physical stream conditions – water velocity and transient storage (Bukaveckas et al. 2007).
- Rebuilding habitat may not be enough to support the recovery of biotic communities (Violin et al. 2011).

DO

DO
DO conc
DO Minimum

DO

DO

- DO influenced by sediment, nutrient, and BOD loadings
- Coupled to carbon and nitrogen biogeochemical cycles (Newcomer et al. 2012; Sivirichi et al. 2010)
- Some unintended changes in DO availability
  - Canopy cover reduction after stream restoration may cause a "restoration effect" temporarily increasing gross primary production and ecosystem respiration (Newcomer et al. 2021)

Riparian

canopy cover
Shade
Riparian forest
Ag riparian buffer
Light (-)
Rip row crop
Veg zone width

RIPARIAN

Riparian

- Improving riparian conditions is only achieved through BMPs, such as vegetated buffers, that directly modify the stressor.
- Parameters:
  - canopy cover
  - Shade
  - Riparian forest
  - Ag riparian buffer
  - Light (-)
  - Rip row crop
  - Veg zone width
- Regular maintenance is needed to maximize BMP effectiveness

“Categorical” BMPs

Urban & Agricultural Stream Restoration

Stream Restoration

- The complexity of stream systems and the multitudinous reasons for project implementation make it difficult to quantitatively determine the effectiveness of this BMP

- Toxics, Pesticides, Salinity
  - may be removed with sediment removed in restoration
- Flow
  - may be spread over floodplain/pool in restored reach
- Geomorphology and Riparian
  - Effects on multitude of geomorphologic parameters (e.g., Bain et al. 2014; Gothe et al. 2016; Larson et al. 2001)
- Stressors can drive long-term success of the BMP
  - “habitat restoration will prove ineffective if urban stormwaters rapidly rehomogenize restored stream segments, as seen in previous urban restorations.” (Violin et al. 2011)

Next Steps

- Improve weighting and data source characterization
- Identify mechanisms influencing effectiveness
- Outline key design parameters and considerations to increase effectiveness
- Clearly identify research gaps

Thank You

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