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University of Maryland

Keynote Speaker

*Freshwater Salinization Syndrome: From
Emerging Global Problem to Managing Risks*



Freshwater Salinization Syndrome: from Emerging Global Problem to Managing Risks

Sujay S. Kaushal

University of Maryland, Department of Geology
& Earth System Science Interdisciplinary Center

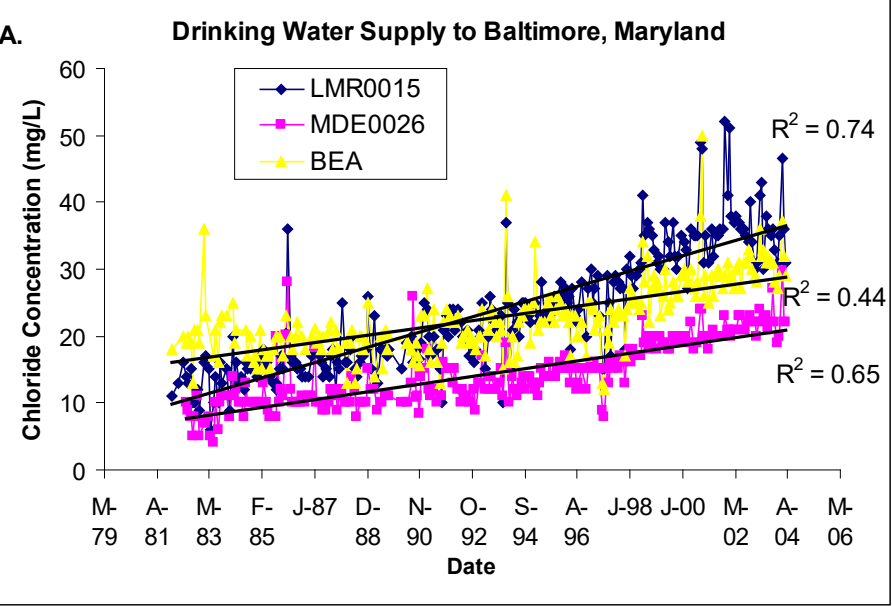


Outline

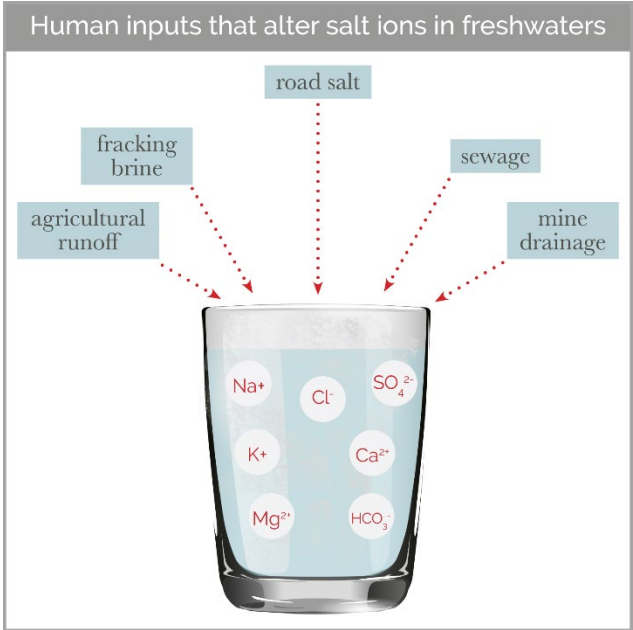
1. Freshwater Salinization Syndrome
2. Risks of Freshwater Salinization Syndrome
3. Managing Freshwater Salinization Syndrome

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1. Freshwater Salinization Syndrome
2. Risks of Freshwater Salinization Syndrome
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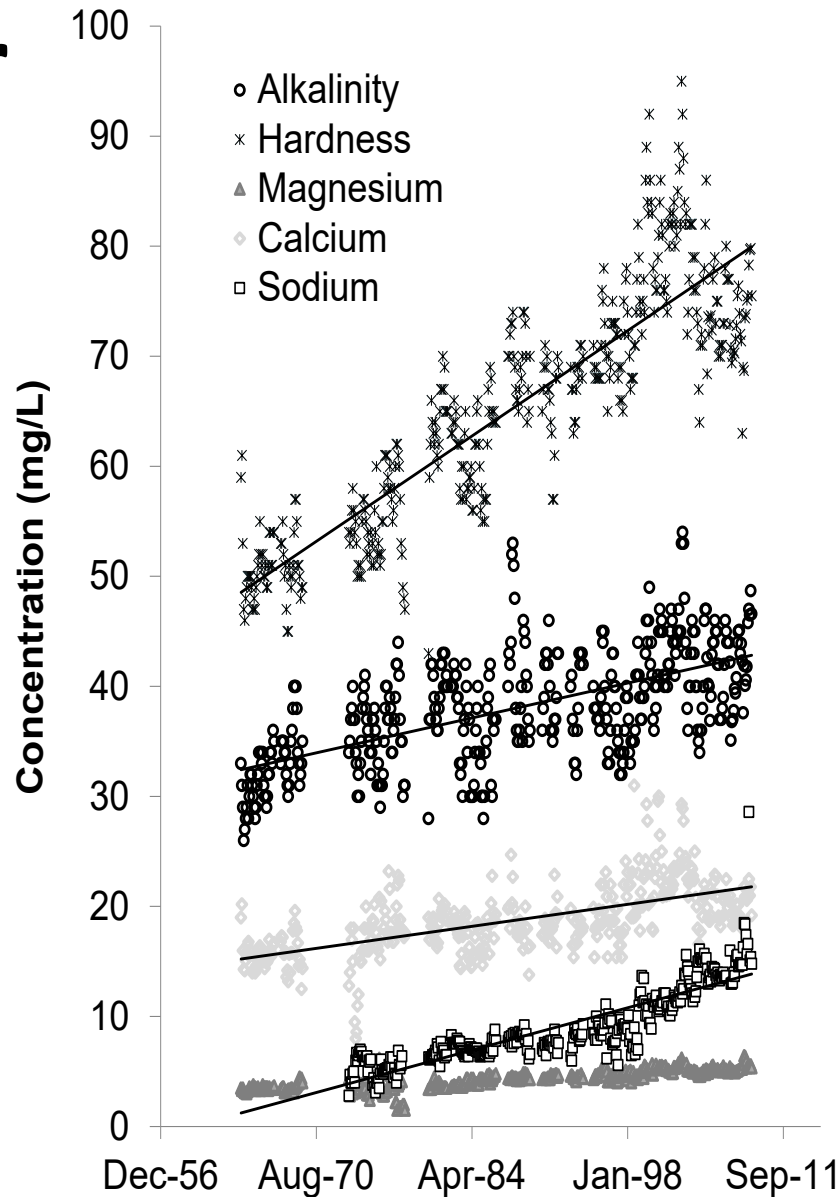


Kaushal et al. (2005) *PNAS*



L. Quillen (2018) FSS Press Release

1. Freshwater Salinization Syndrome Impacts Drinking Water

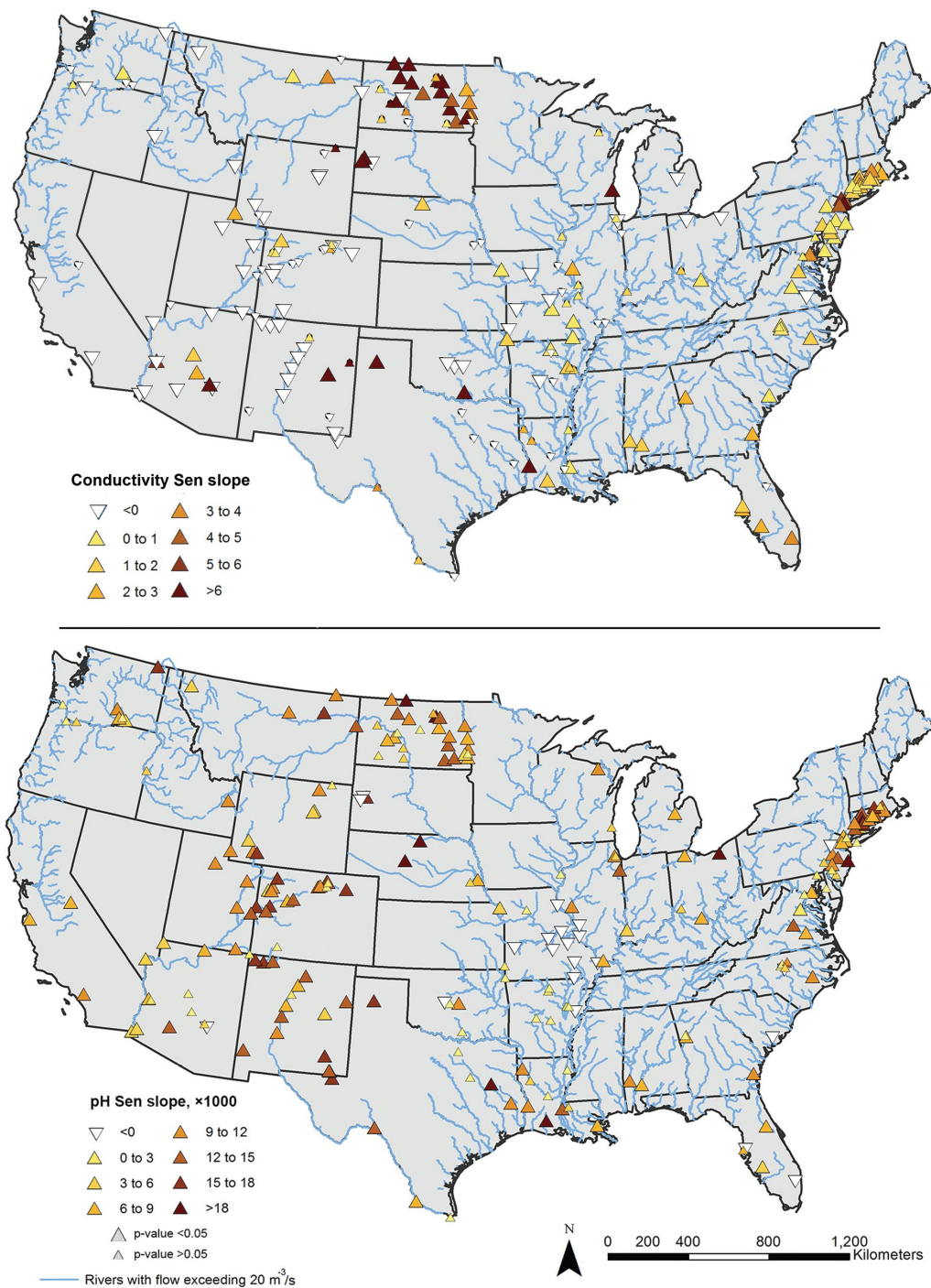


Kaushal et al. (2017) *Appl. Geochem*

Thank You to Early Mentor: Bill Stack

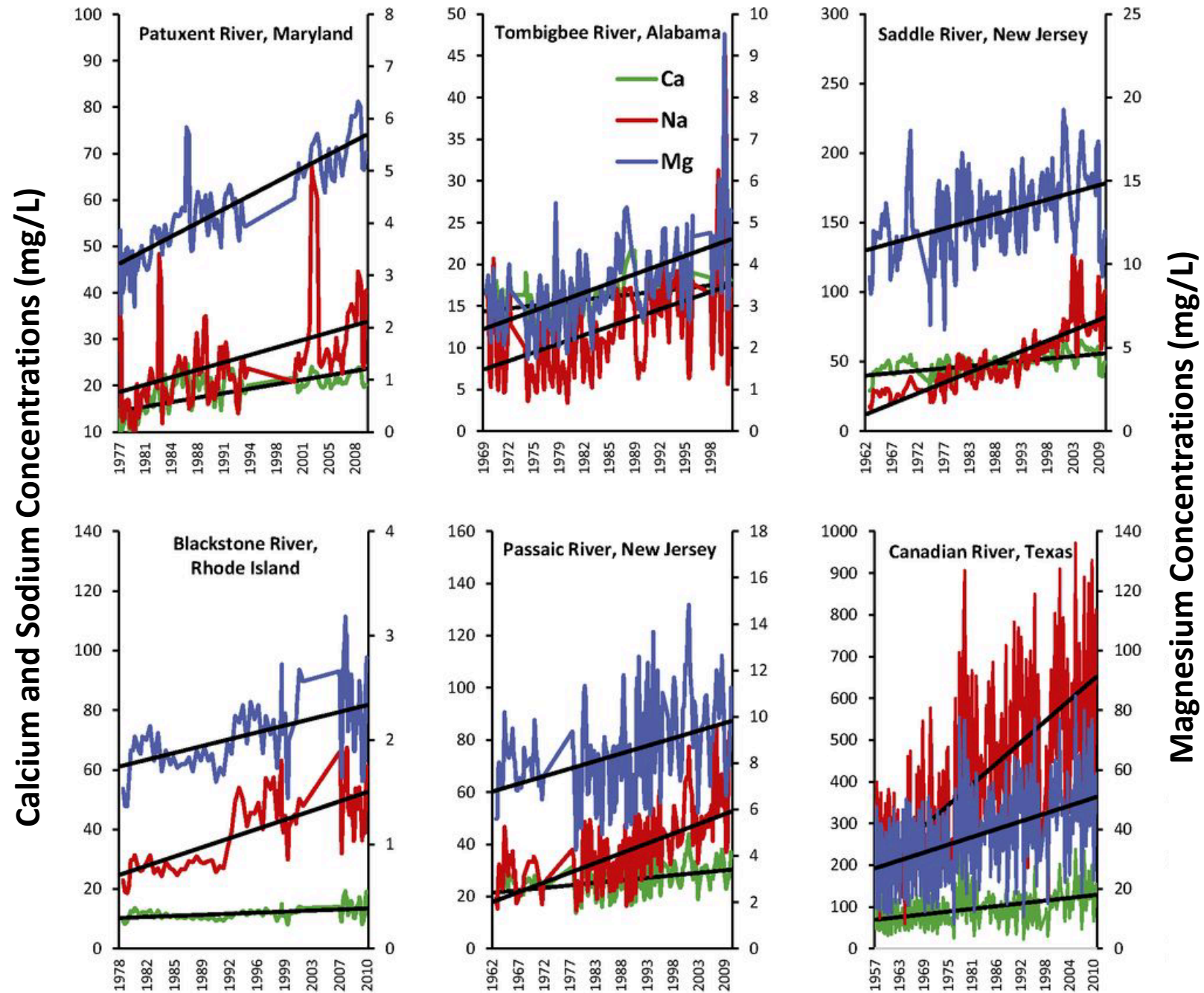
Freshwater Salinization Syndrome on a Continental Scale?

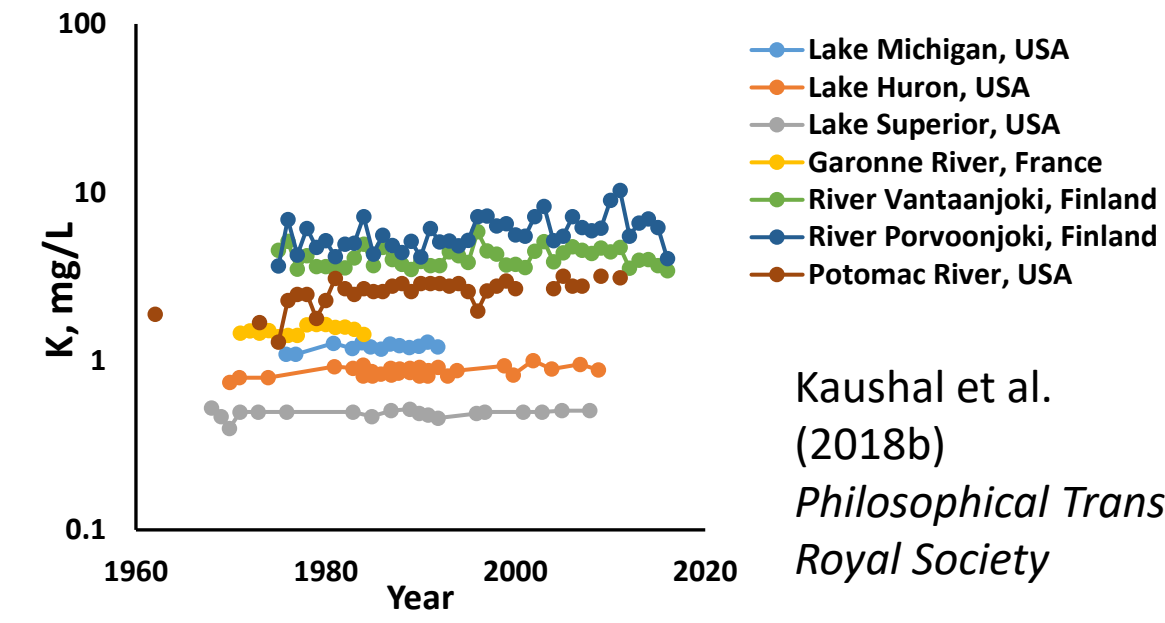
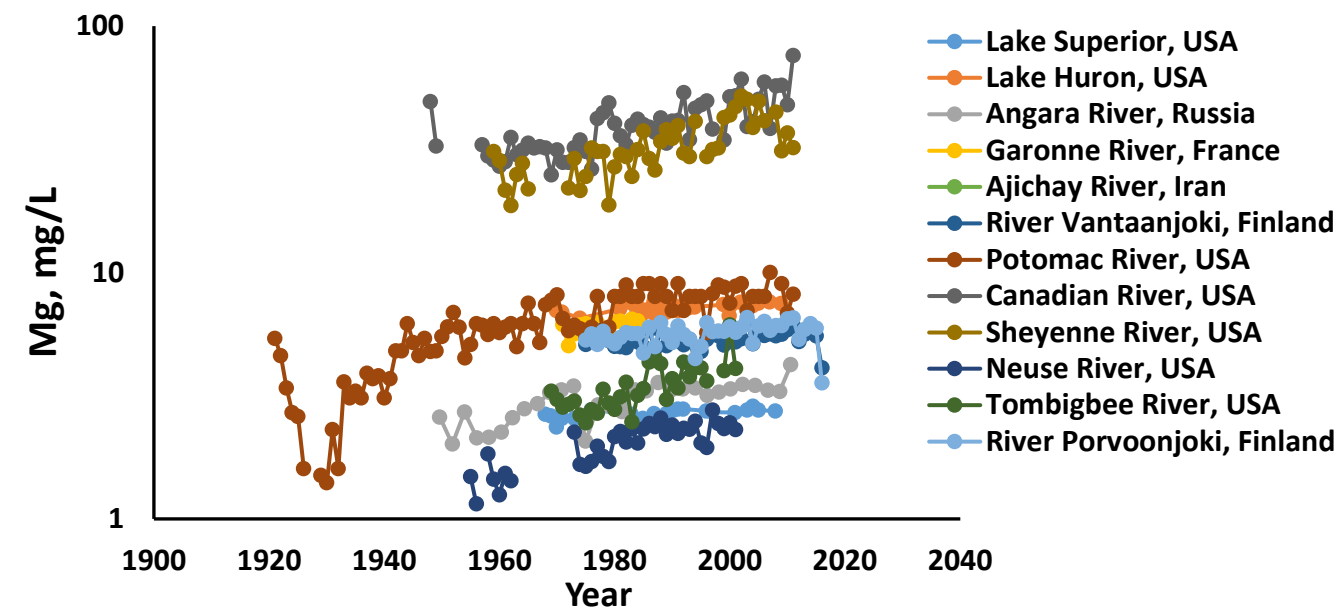
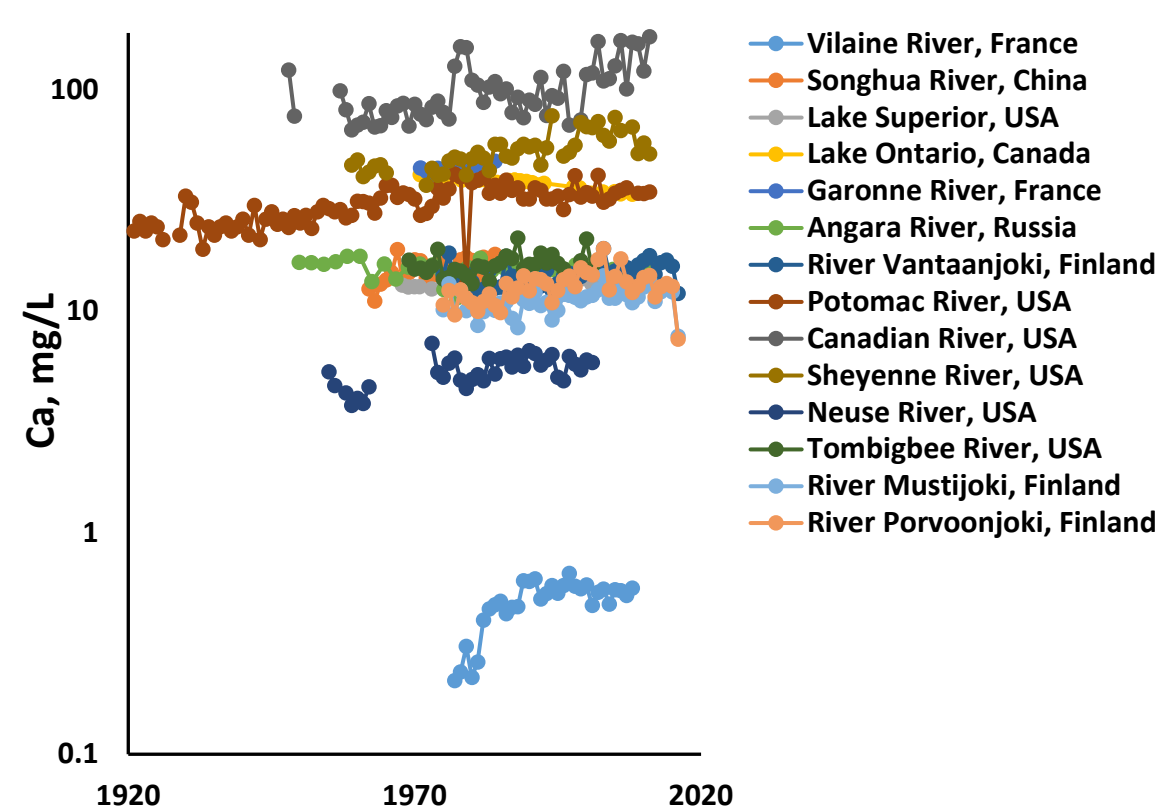
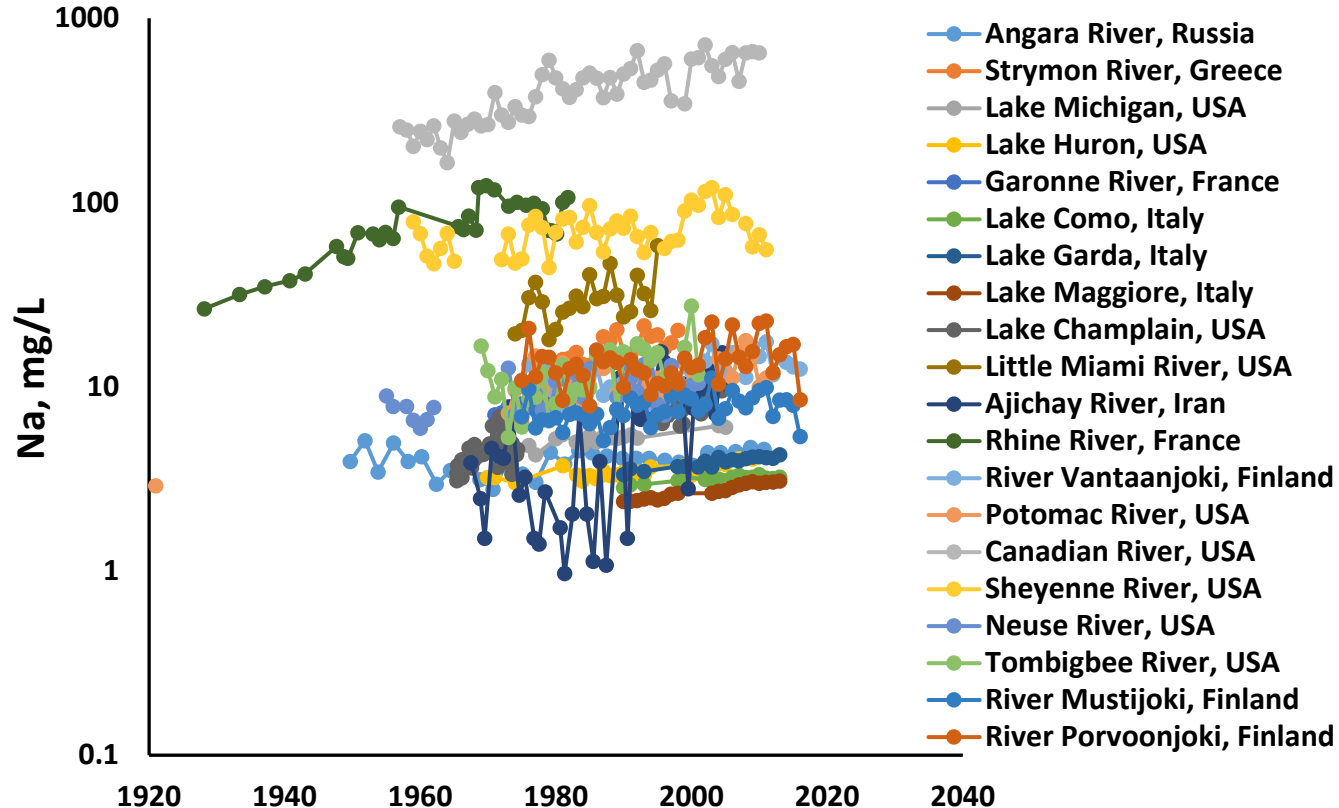
Increased pH and specific
conductance over 50 years



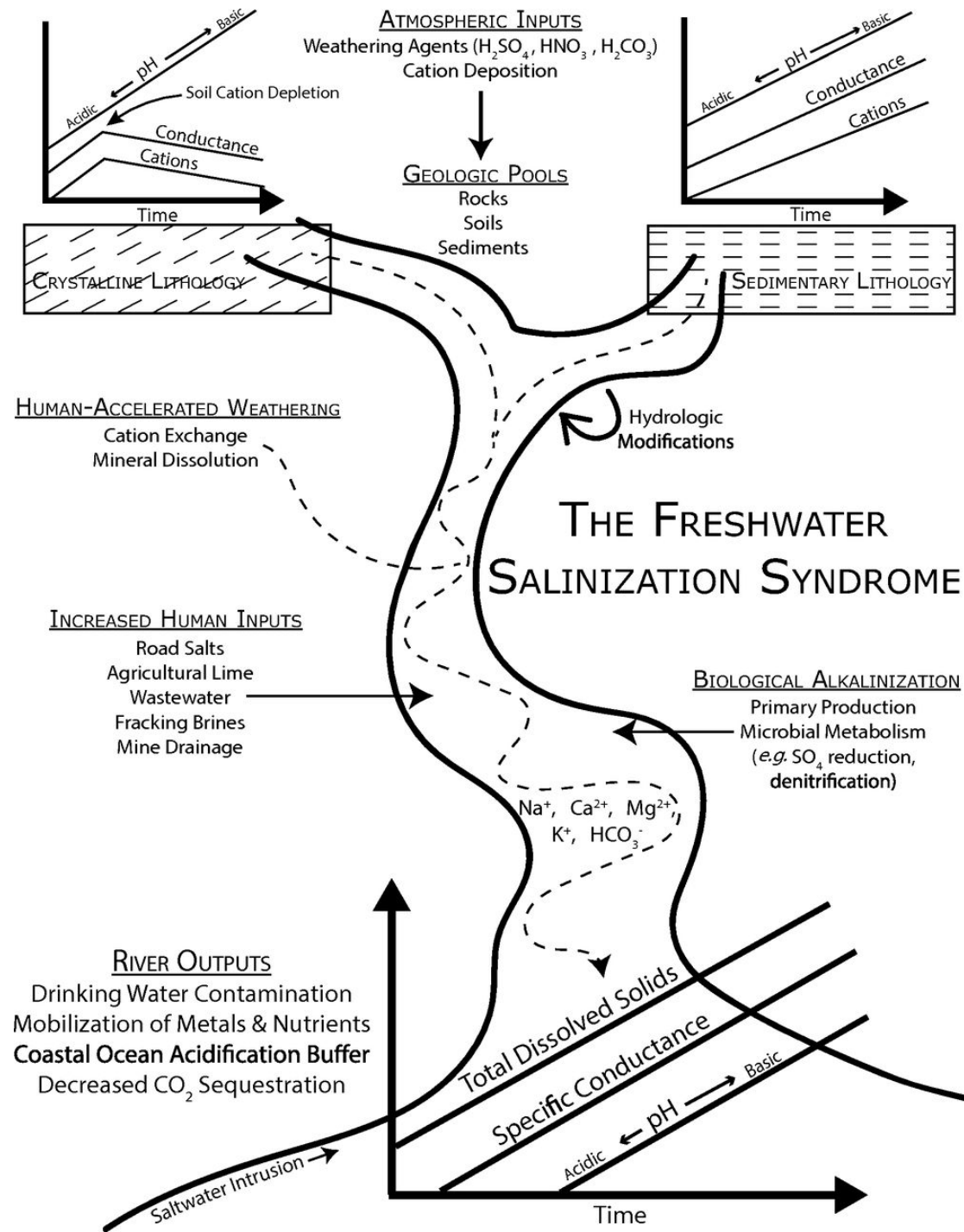
Freshwater Salinization Syndrome- Major Ions on a Continental Scale

Kaushal et al. (2018a) *PNAS*





Kaushal et al.
(2018b)
*Philosophical Trans.
Royal Society*



Outline

1. Freshwater Salinization Syndrome
2. Risks of Freshwater Salinization Syndrome
3. Managing Freshwater Salinization Syndrome

Taking environmental and health impacts with a grain of salt

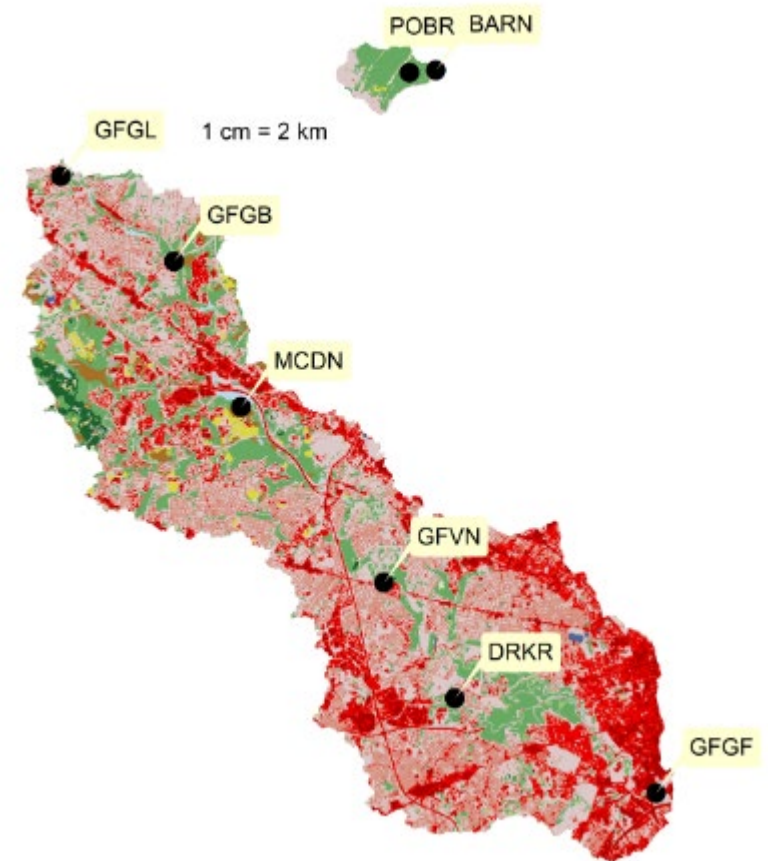
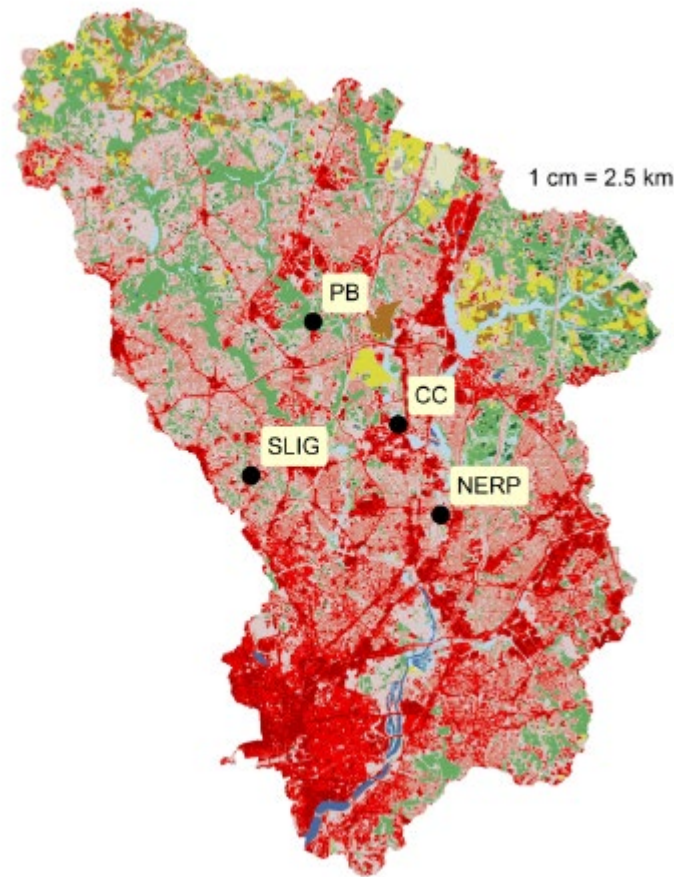
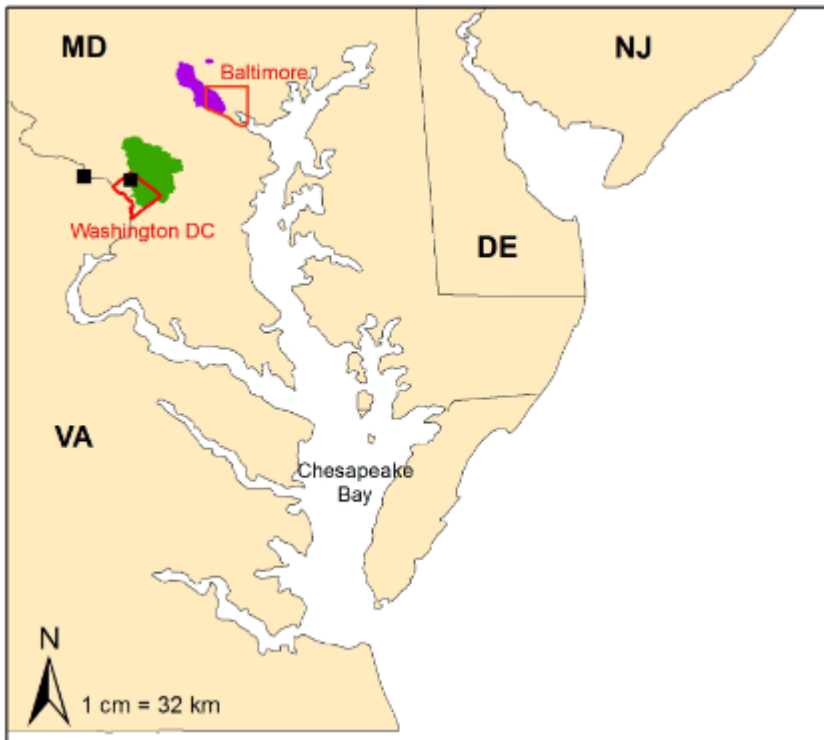


Photos Courtesy: S. Kaushal



Photo Courtesy: J. Galella

2. Emerging Risks of Freshwater Salinization Syndrome are from Chemical Cocktails

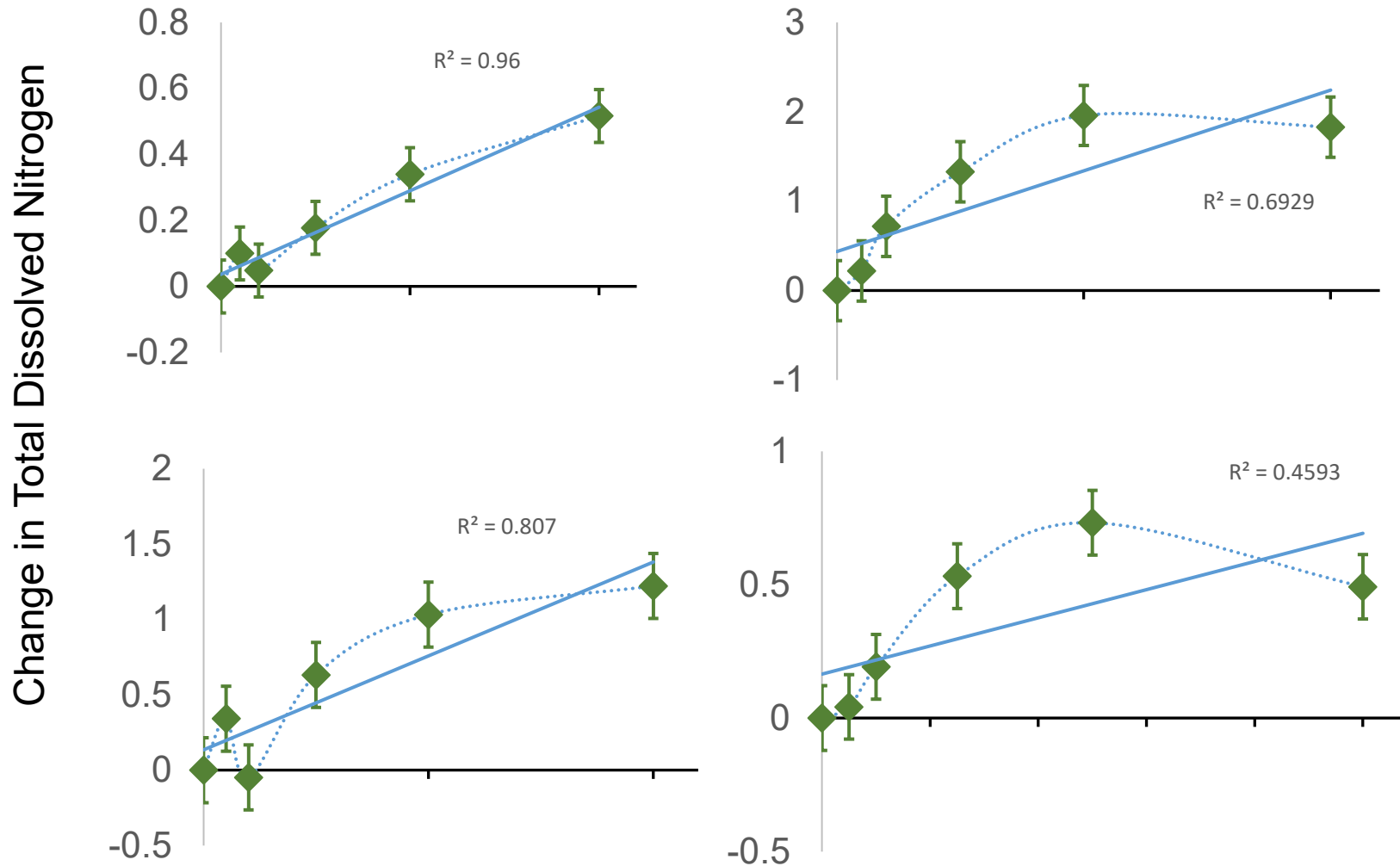


Haq et al. (2018) *Biogeochemistry*

Anacostia River, Washington, DC

Gwynns Falls, Baltimore LTER, MD

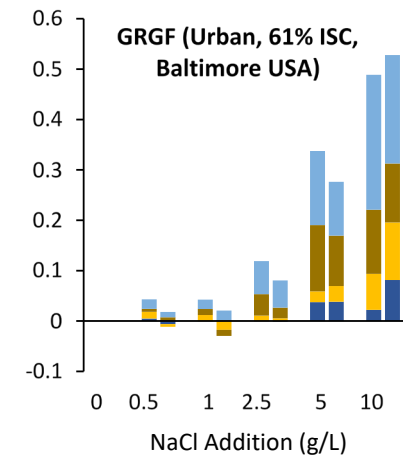
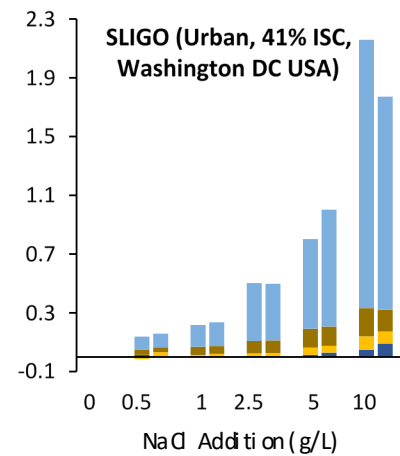
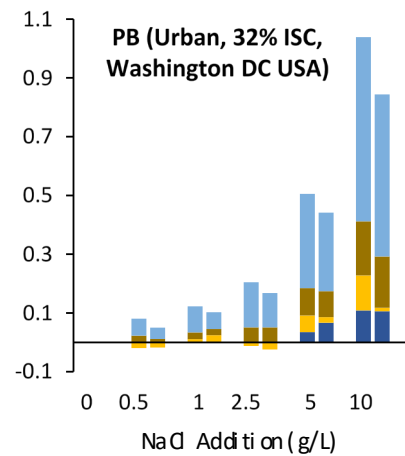
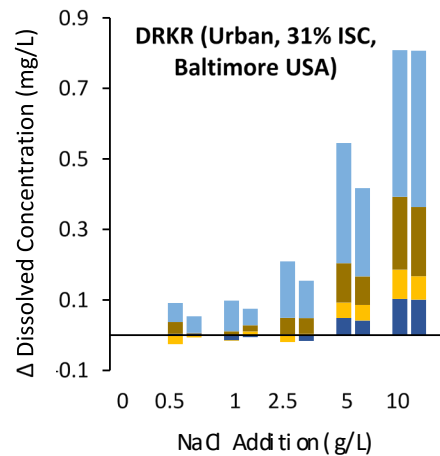
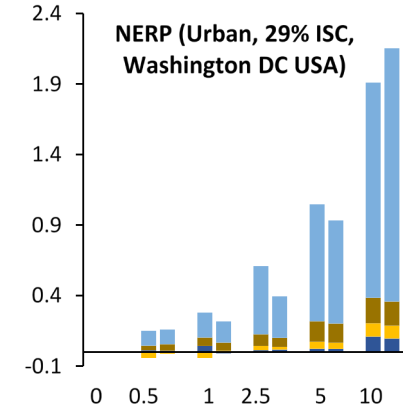
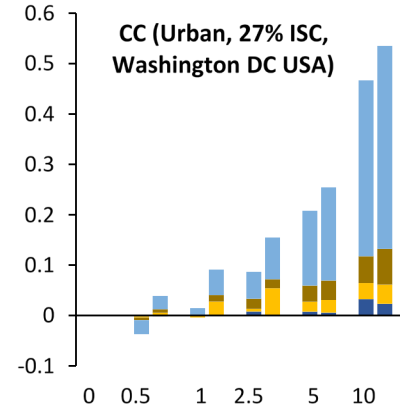
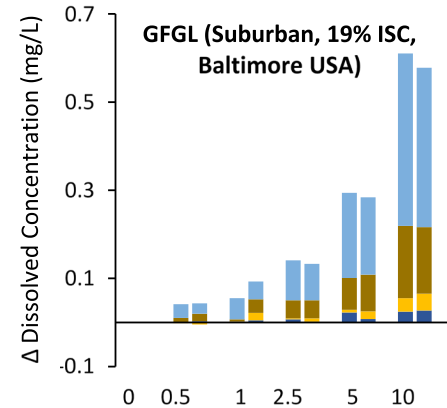
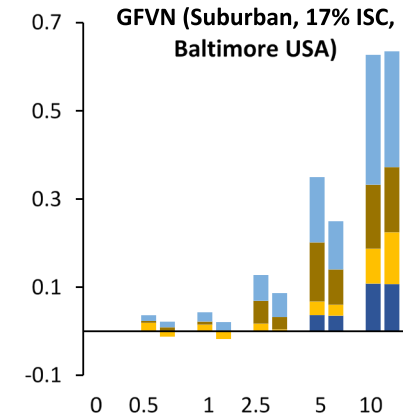
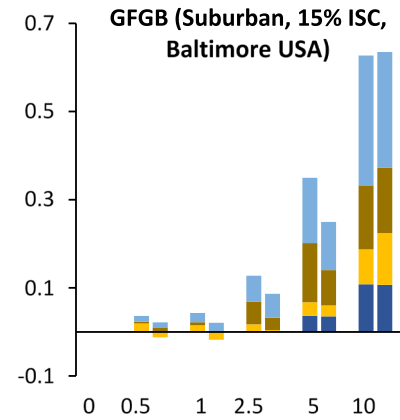
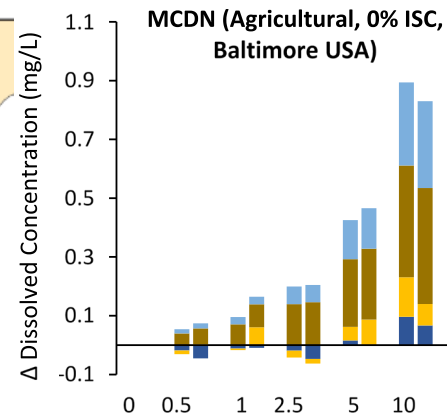
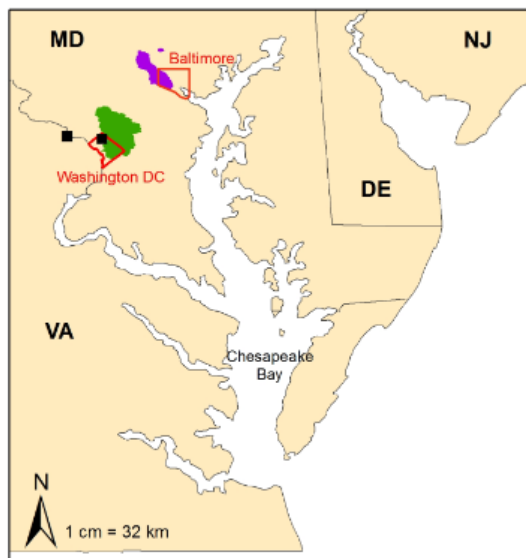
Salinization Mobilizes Nitrogen in Streams



Salt Dosing Experiments: 0 g/L, 0.5 g/L, 1 g/L, 2.5 g/L, 5 g/L, 10 g/L of Na Cl

Haq et al. 2018





Freshwater Salinization Mobilizes Metals and Nutrients to Streamwater

Kaushal et al. (2019)
Philosophical Trans. Royal Society

FSS Has Diverse Human Health Implications

Table 2 A broad synthesis of examples of sources and impacts from common freshwater salinization syndrome ions

From: [Freshwater salinization syndrome: from emerging global problem to managing risks](#)

FSS Ions	Examples of Geologic and Atmospheric Sources	Examples of Anthropogenically Enhanced Sources	Examples of Diverse Environmental Implications	Examples of Diverse Health and Ecotoxicology Implications
Na ⁺	Weathering of Na-bearing silicate minerals (e.g. albite) ^[10, 11] , atmospheric deposition from sea salts ^[10, 12] , evaporation and evaporites ^[13]	Sewage, fertilizer, road salt ^[10] , drinking water treatment additives (e.g. Na hypochlorite) ^[14]	Increase algal production, decrease soil permeability, aeration, increase overland flow ^[15] , displaces metals, cations, organic and inorganic particles in soils ^[16]	Systolic and diastolic blood pressure ^[17] , Impacts sodium restricted diets (i.e. treatment of Miniere's disease), development of heart disorder of high risk groups, hypertension ^[18]
Ca ²⁺	Weathering of sedimentary carbonate rocks, rain ^[10]	Concrete drainage pipes, weathering of impervious surfaces ^[2] , atmospheric inputs ^[10]	Heavy metals ion exchange, damage to vegetation ^[19]	Excess Ca is secreted by the kidney (if no renal impairment), potential issues if have milk alkali syndrome and hypercalcemia ^[20]
Mg ²⁺	Weathering of rocks (e.g. pyroxenes, dolomites) ^[10, 11]	Weathering of impervious surfaces, urban structures ^[2]	Heavy metals ion exchange, damage to vegetation ^[19]	Diarrhea, laxative effect with high sulfate, hypermagnesemia (if abnormal kidney function) ^[20]
K ⁺	Weathering of silicate minerals (e.g. K-feldspar, mica, magnetite) ^[3, 10] , cyclic salt, decomposition of organic matter ^[21]	Concrete drainage pipes ^[2] , biomass burning ^[3] , agricultural land use, fertilizers, industrial, municipal sewage, and treated water discharge ^[21]	Decrease aquatic organism growth and reproduction ^[22]	Unlikely to occur in healthy individuals, large doses cause vomiting, hyperkalemia in high risk groups ^[23]
Cl ⁻	Weathering of rocks	Air pollution ^[1]	More Cl ⁻ tolerant aquatic species, lake	Organoleptic issues (Seigel, 2007); assist in developing

Thanks to Carly Maas!! in Kaushal et al. (2021)

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Managing Salt in Streams and Stormwater



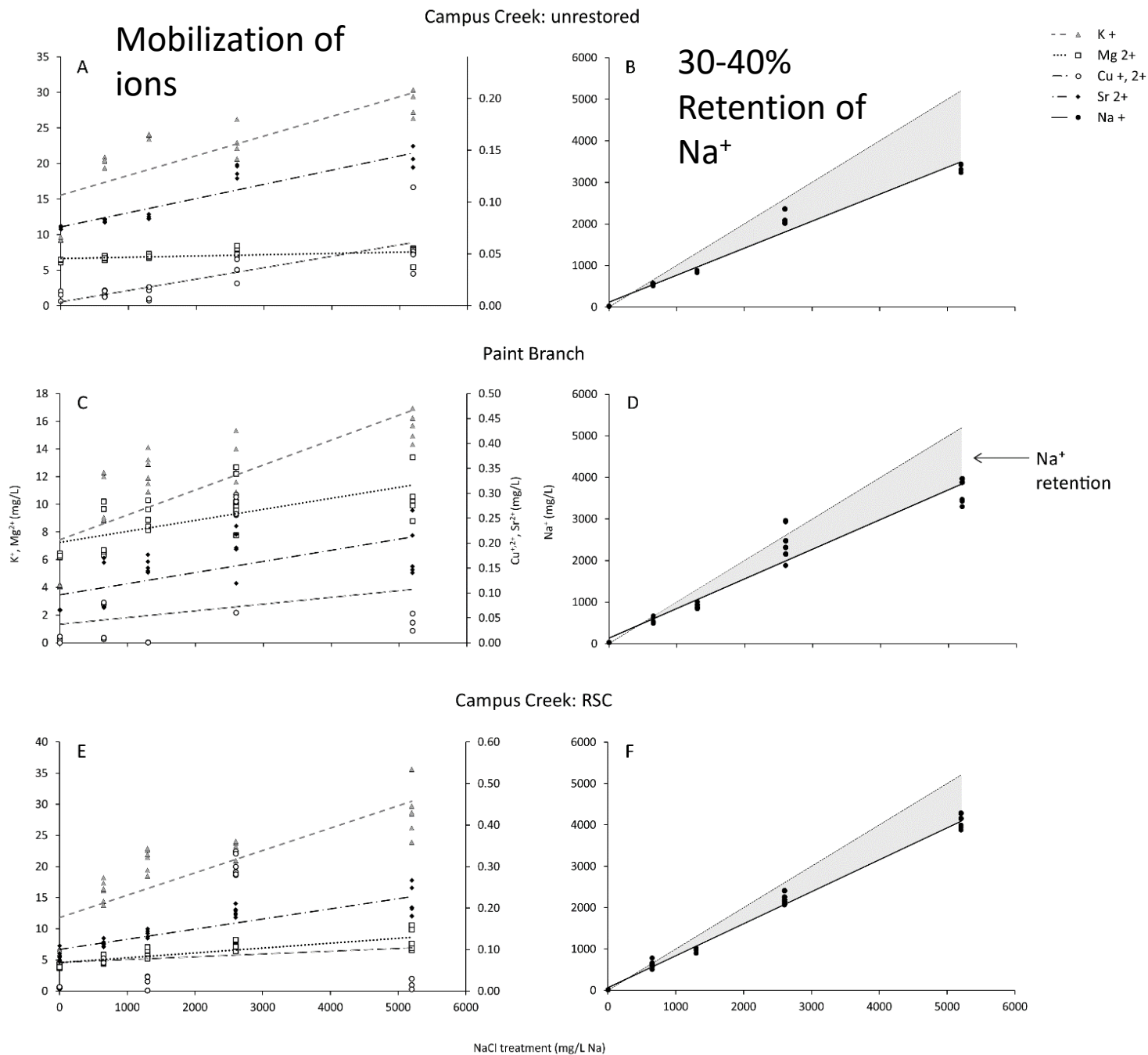
Photos Courtesy: Kelsey Wood

Hold the Salt: How Much Can Be Retained in Stormwater Management Best Management Practices?



**Retention and Release of
Salts, Nutrients, and Metals in
Different Stormwater
Management Features**

Photo courtesy of
Kelsey Wood (2019)



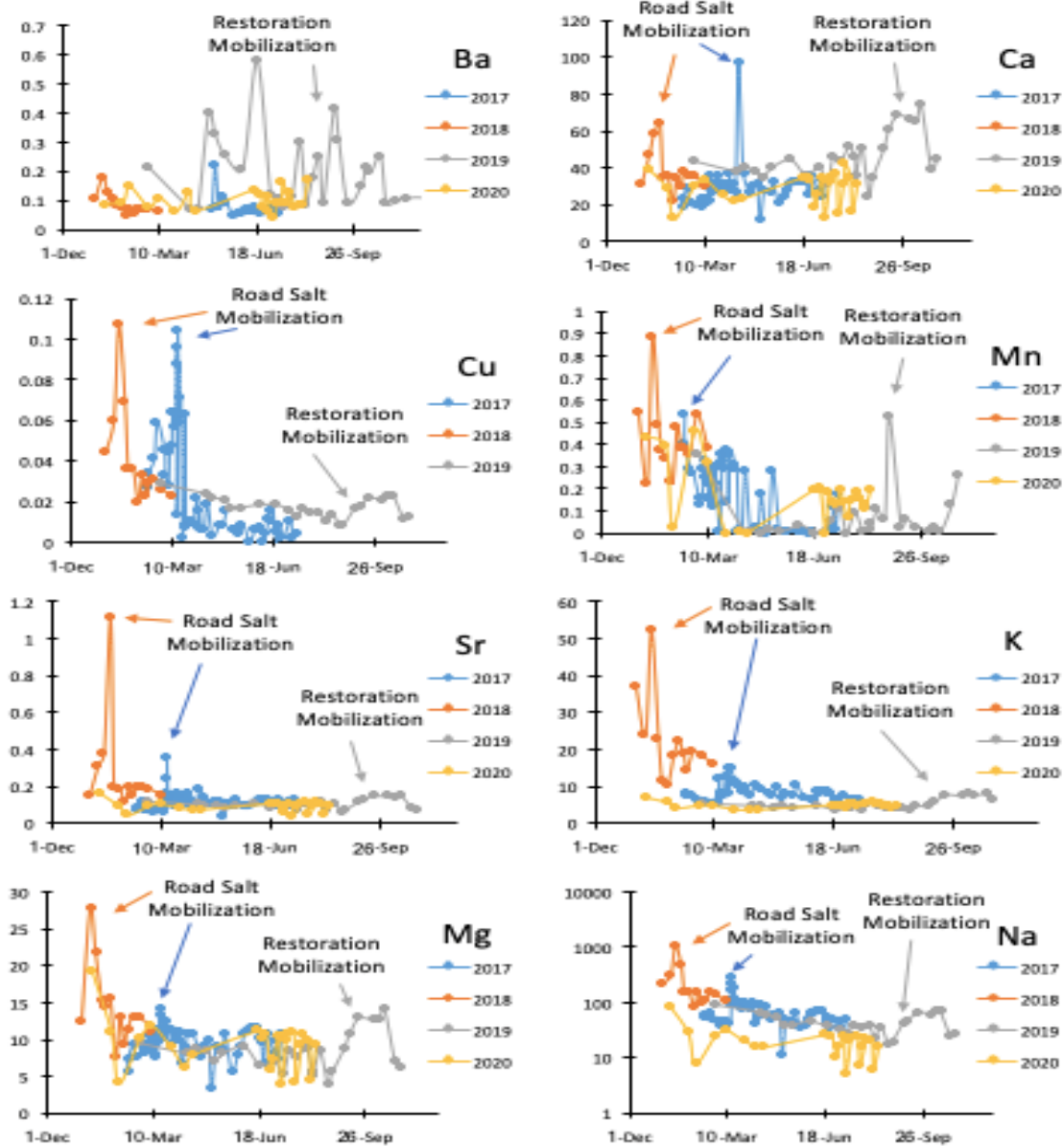
Stormwater Best Management Practices (BMPs) can retain substantial amounts of salt ions

Results: ANOVA Salt type, concentration, and BMP type are significant

- Site type had a significant effect on the concentration of:
 - B, Ba, K, Mn, and Sr
- Salt type was significantly correlated with all major and trace elements save for:
 - B and Fe
- **Salt concentration was statistically correlated with mobilization of ALL major and trace elements**

Variable	Site Type			Salt Type			Salt Concentration		
	N	F-ratio	p-value	N	F-ratio	p-value	N	F-ratio	p-value
B	248	10.675	0.000	248	1.989	0.139	248	2.722	0.021
Ba	248	22.458	0.000	248	10.523	0.000	248	26.294	0.000
Ca	248	0.416	0.868	248	69.988	0.000	248	28.744	0.000
Cu	241	0.318	0.927	241	72.073	0.000	241	25.260	0.000
Fe	182	1.784	0.105	182	2.917	0.057	182	2.771	0.020
K	248	41.476	0.000	248	21.122	0.000	248	176.314	0.000
Mg	248	0.420	0.866	248	73.466	0.000	248	23.883	0.000
Mn	245	53.566	0.000	245	3.889	0.022	245	5.324	0.000
Na	248	0.106	0.996	248	77.882	0.000	248	24.069	0.000
Sr	248	6.264	0.000	248	79.050	0.000	248	66.406	0.000
DIC	X	X	X	36	21.301	0.000	36	4.220	0.006
DOC	X	X	X	36	22.903	0.000	36	12.346	0.000
TDN	X	X	X	36	14.548	0.000	36	21.124	0.000

Mobilizing Chemical Cocktails: Comparison by Year and Season



There can be significant recovery and decreases in ion concentrations over years (>50%) depending on amount of road salt use

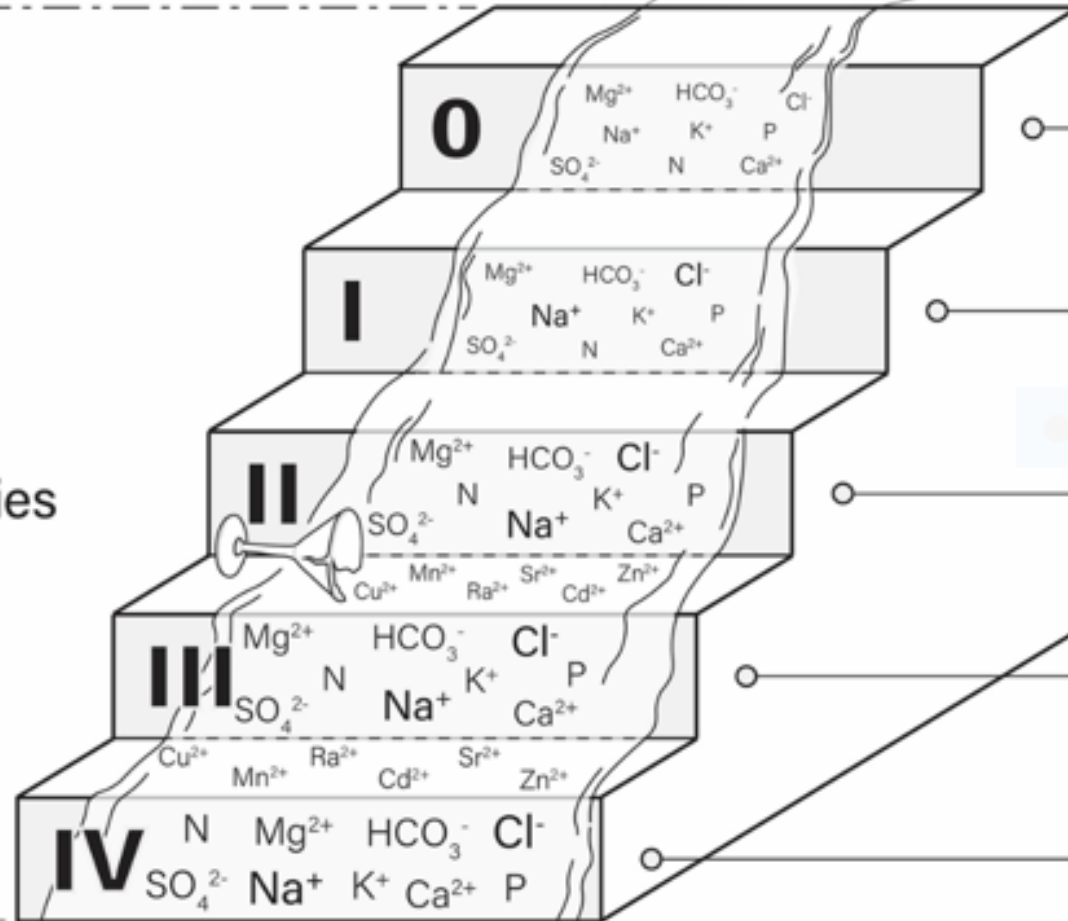
Stages of Freshwater Salinization Syndrome

HIGHEST WATER QUALITY

Driven by
State Factors:

- Climate
- Geology
- Human activities
- Flowpaths
- Time

LOWEST WATER QUALITY



Stage 0. Highest water quality; minimally disturbed.

Stage I. Abnormally elevated concentrations of at least one or more ions across one season.

Stage II. Chronically elevated concentrations of ions across multiple seasons.

Stage III. Formation of harmful chemical cocktails exceeding water quality thresholds.

Stage IV. Systems-level failures in infrastructure and ecosystem functions and services.

Kaushal et al. 2022, *Limnology & Oceanography Letters*

Managing Salinization by the Amounts and Types of Salt Ions along Flowpaths

Management Implications

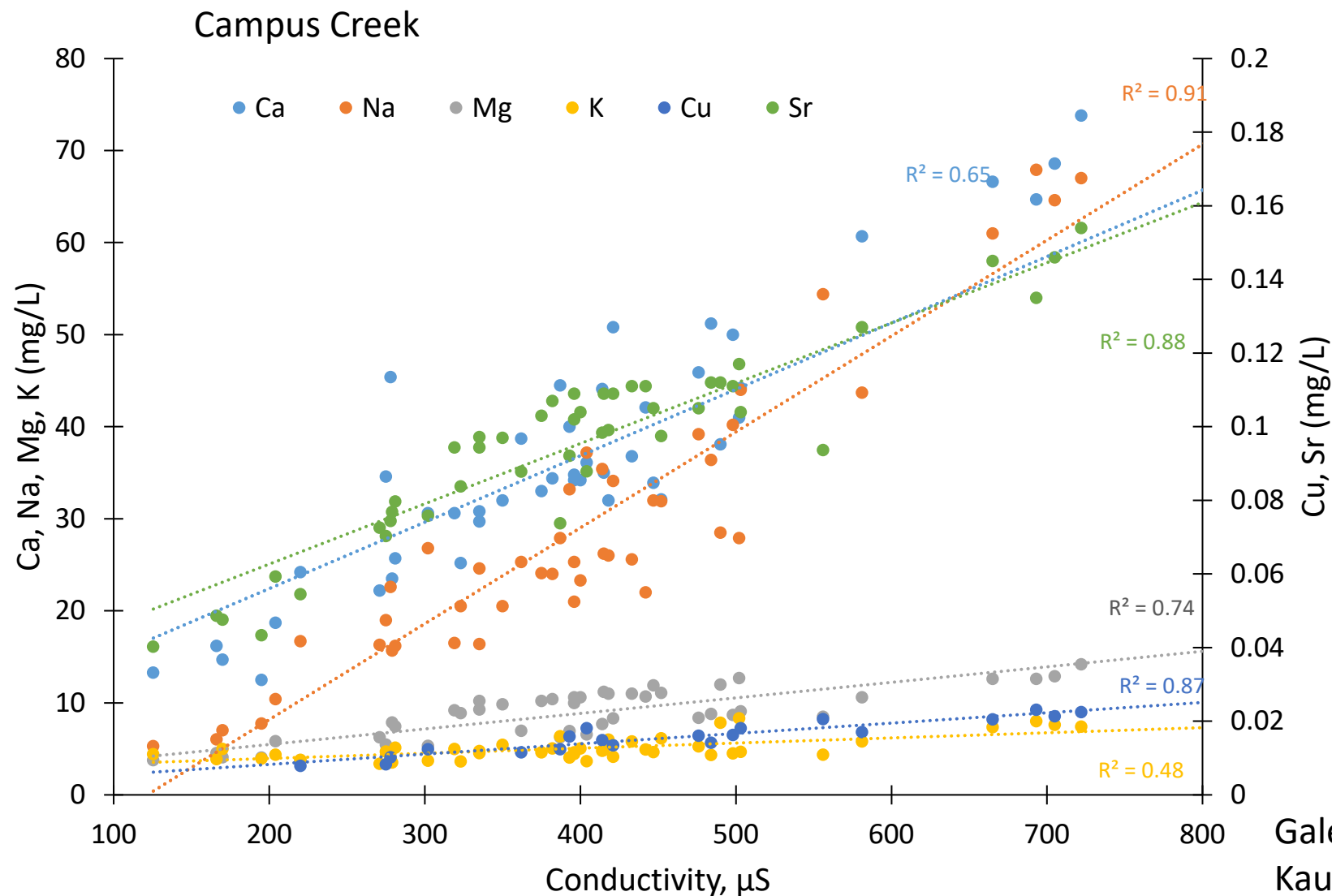
- Freshwater Salinization Syndrome is increasing from local to global scales
- Freshwater Salinization Syndrome poses risks to drinking water and health
- Stormwater management retains salt ions but mobilizes contaminants
- Reducing NaCl inputs leads to rapid and year long recovery in water quality

Acknowledgments

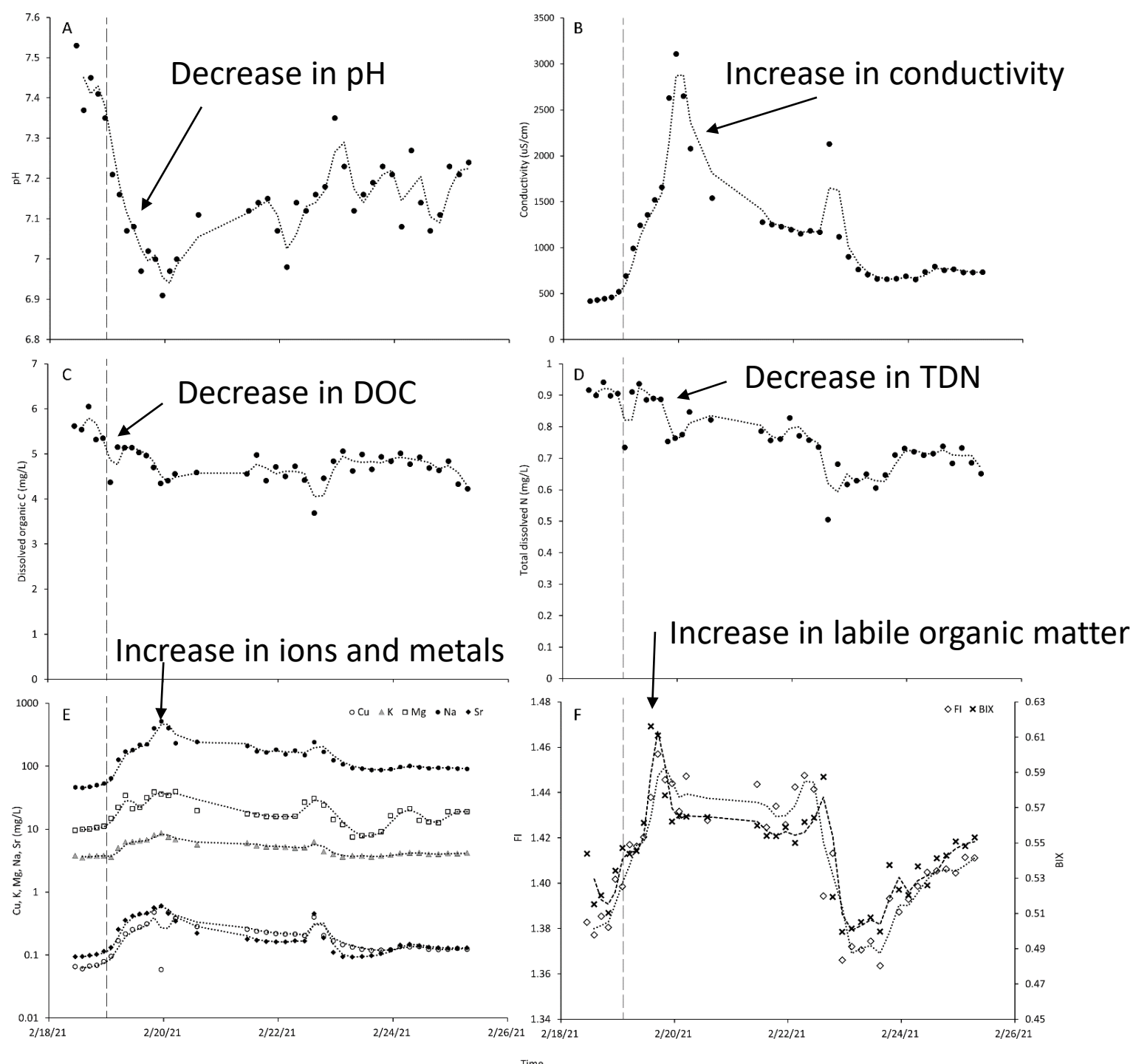
- Thanks to the Maryland Department of Transportation, and Maryland Department of Natural Resources for funding along with all the funding partners below.
- Special thanks to Karl Berger, Steve Bieber, and Washington COG
- Thanks to Maryland Sea Grant and National Science Foundation



New Monitoring Approaches: Specific Conductance as a Proxy for Ions and Metals



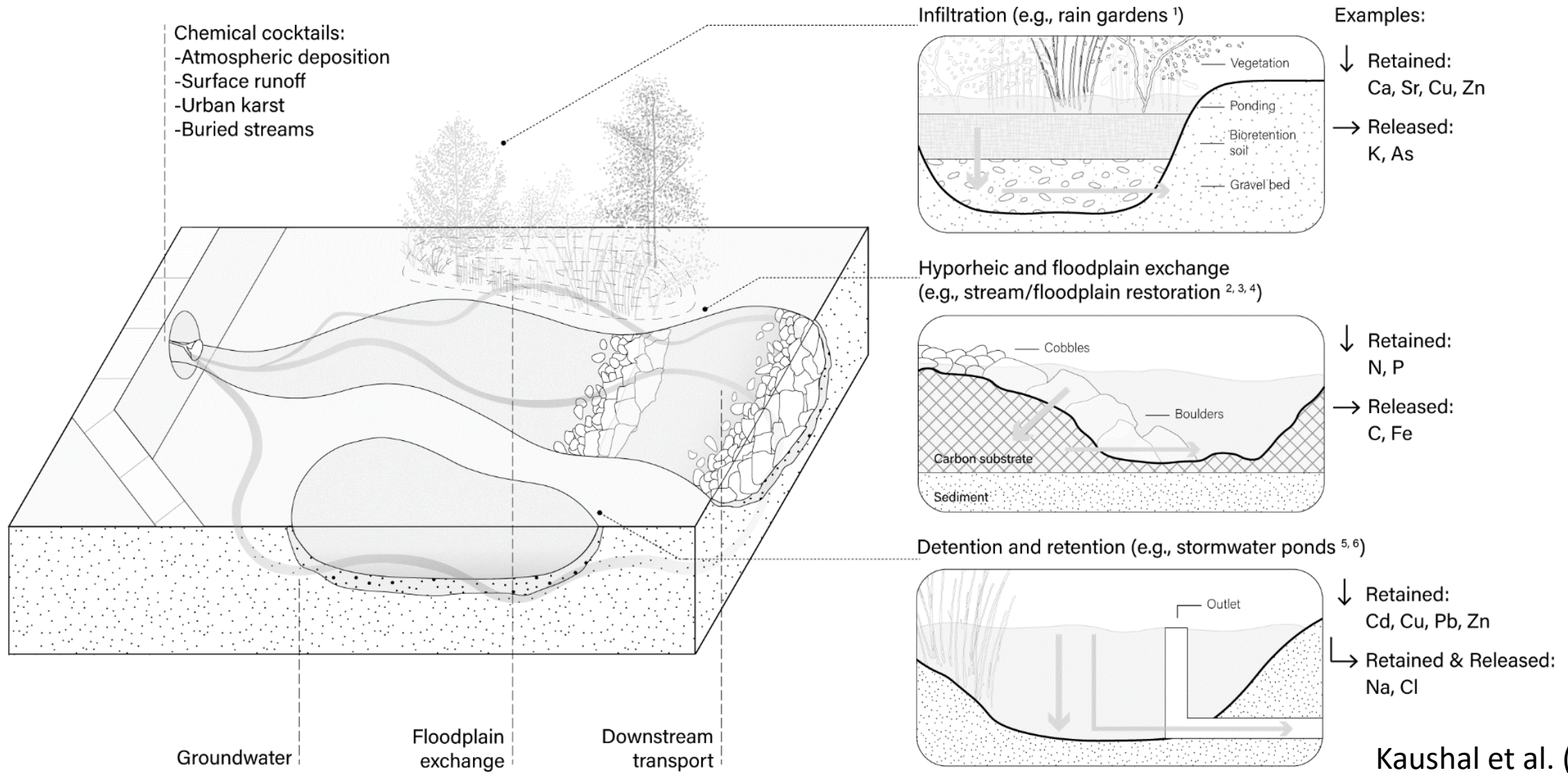
Galella et al. (2021),
Kaushal et al. (2021),
Kaushal et al. (2022),
Kaushal et al. (In Press)



Changes in water quality following road salt events in stormwater BMPs

Kaushal et al. (In Press)
Freshwater Science

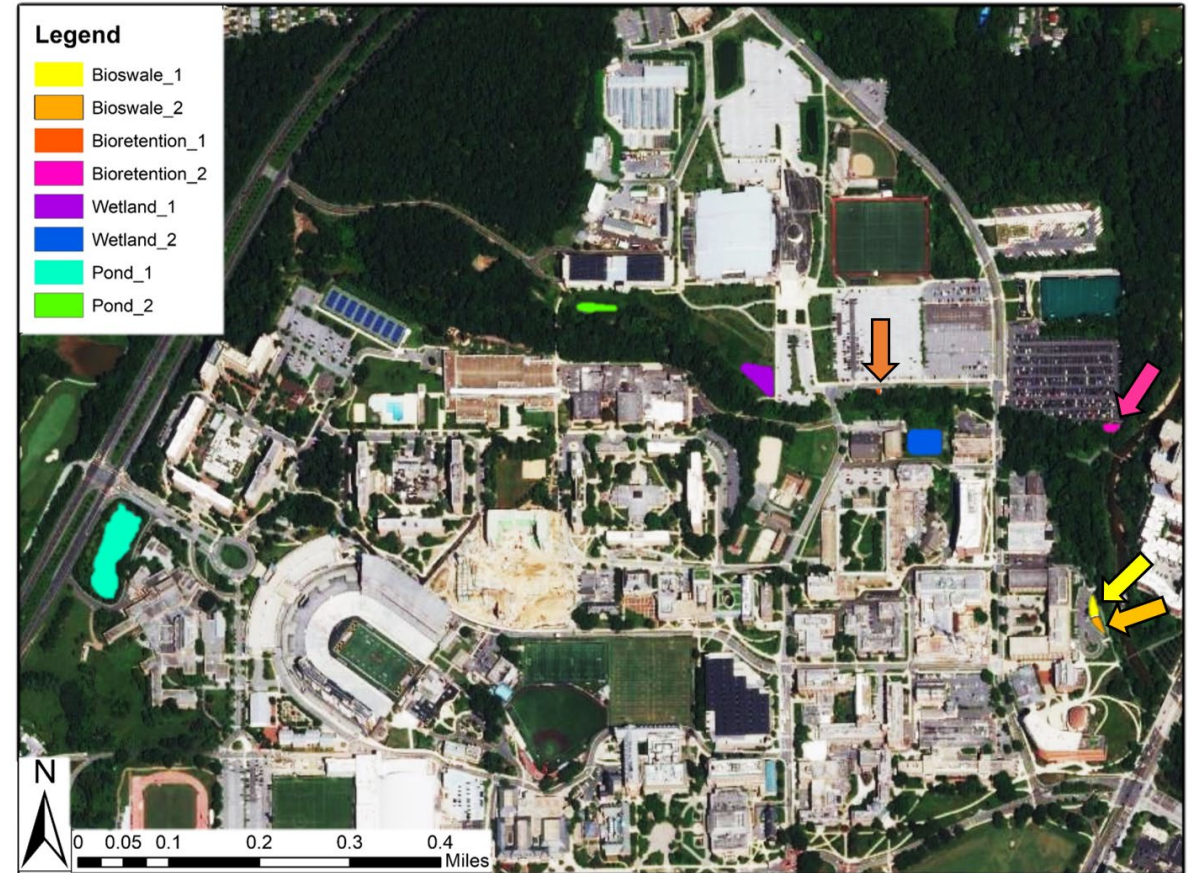
Retention and release of chemical cocktails along stream and stormwater flowpaths



Study Sites:

- 4 different stormwater management features (with replicates)
- Sites range from 5 to 33 years in age and were almost always constructed concurrently with a building or large area of impervious surface coverage
- Stream restoration sites and regenerative stormwater conveyance (RSC) systems

Galella et al. (In Prep)



Bioswale #1



Bioretention #1



Wetland #1



Pond #1



Bioswale #2



Bioretention #2

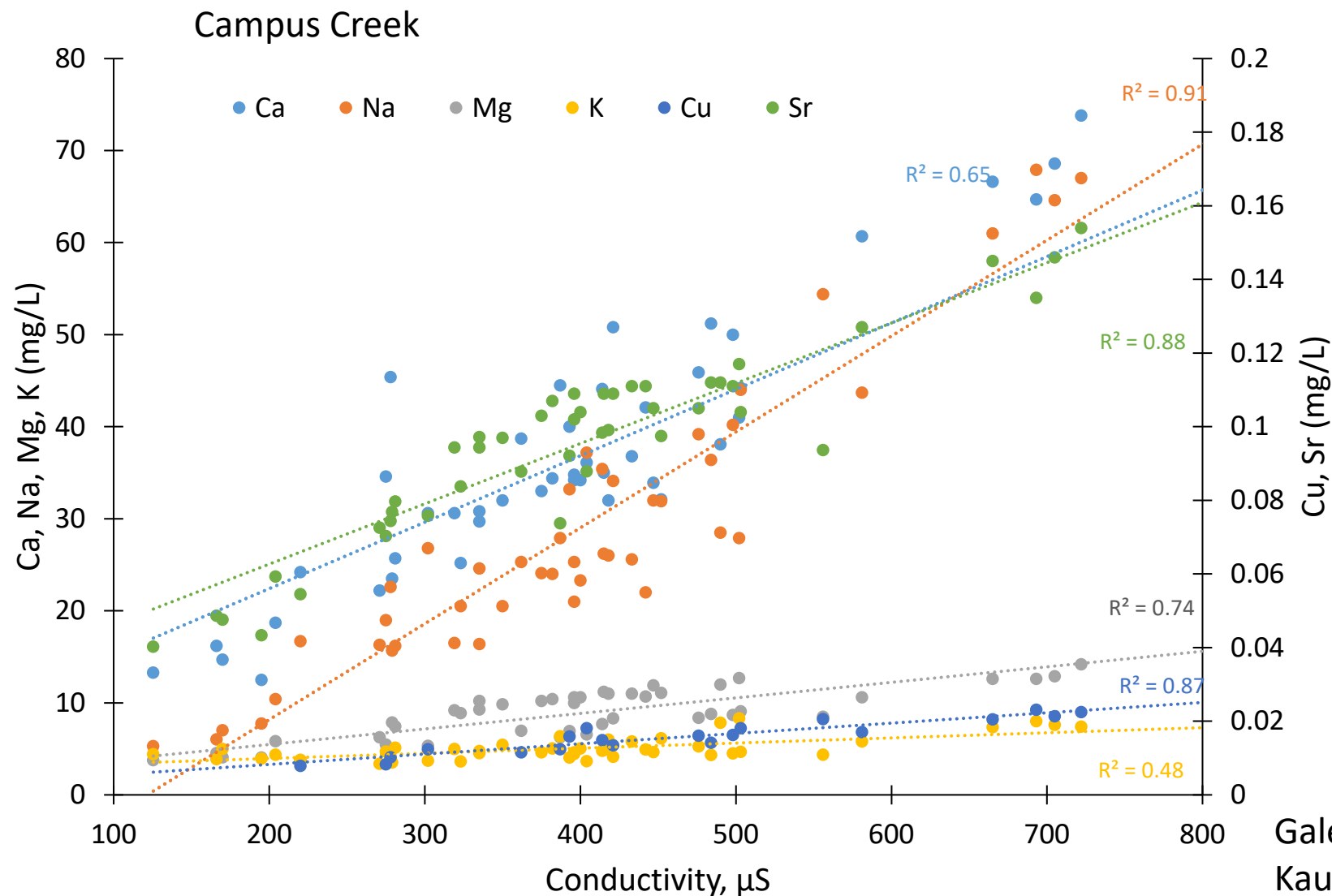


Wetland #2



Pond #2

New Monitoring Approaches: Specific Conductance as a Proxy for Ions and Metals



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