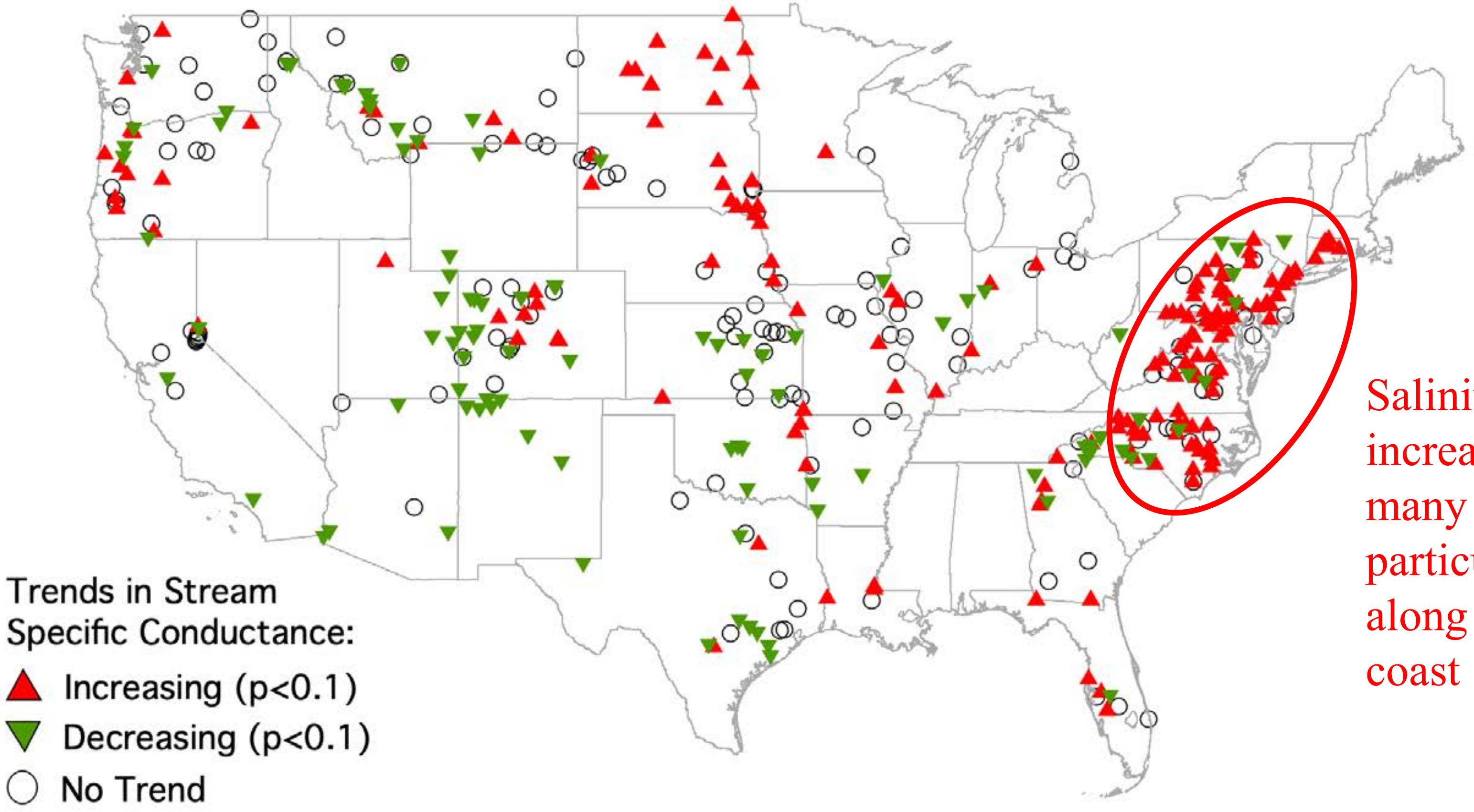
Characterizing the Impact of Deicers on Engineered Ecosystems:

Implications for Performance, Resilience and Self-Repair through Phytoremediation

Professor Megan Rippy, Virginia Tech

Many of the nation's freshwaters are salinizing



Salinity is increasing in many regions, particularly along the east coast

A USGS assessment of trends in specific conductance, a measure of salinity, from 1992 to 2012, in 422 streams across the US

Stets, E.G.; et al., Landscape drivers of dynamic change in water quality of US rivers. *Environ. Sci. Technol*. **2020** *54*(7), 4336-4343.

Salinization threatens freshwater ecosystem health, agricultural productivity, and the sustainability, reliability, and safety of drinking water supplies

It may also decrease the design lifetime of urban infrastructure

- <u>Traditional grey infrastructure</u>: pipe networks, pavement, and the steel components used to reinforce bridges and tunnels

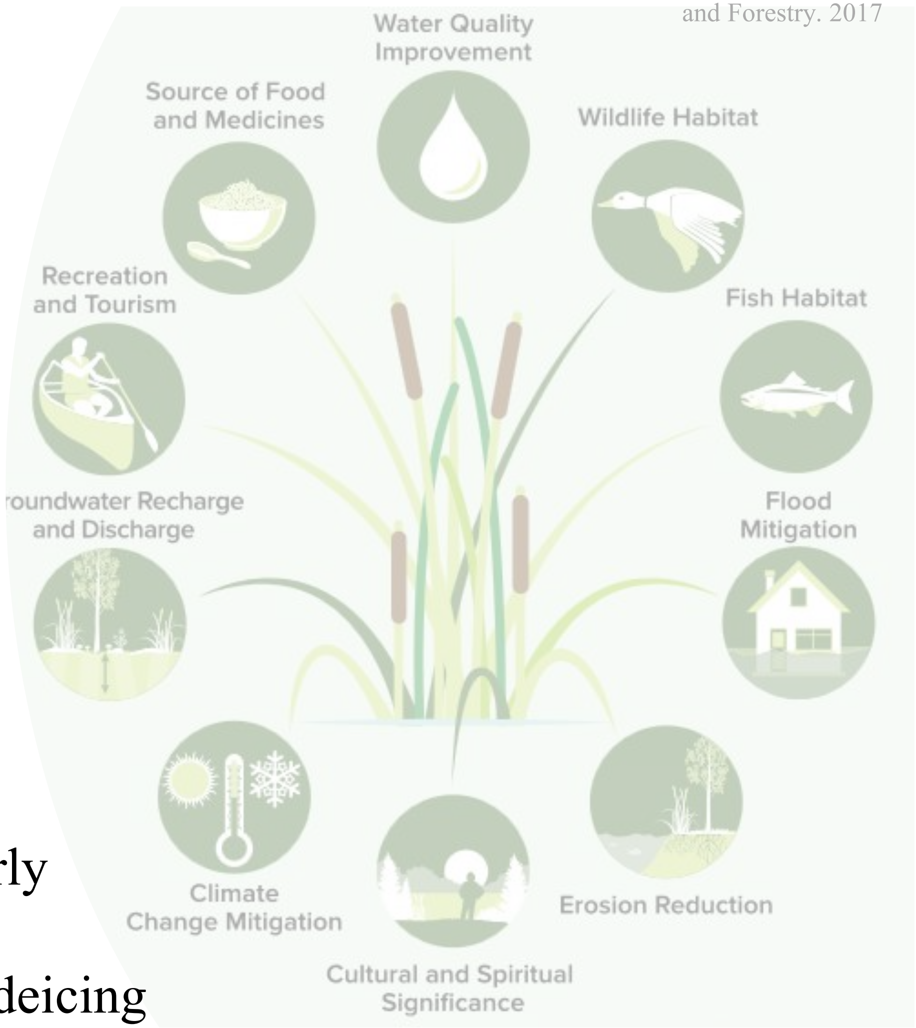
- <u>Green infrastructure elements</u> used to manage urban stormwater such as detention basins and bioretention

Green infrastructure relies on vegetation for many of the services it provides

Ontario Ministry of Natural Resources and Forestry. 2017

Traditional and non-traditional services:

- Nutrient removal
- Stormwater infiltration
- Habitat provisioning
- Aesthetics
- Sense of place



Most plant species are salt sensitive
(only 1% are salt tolerant halophytes)

This makes salinization a credible threat to green infrastructure performance, particularly in regions with cold climates (like VA) where it receives seasonal salt inputs from deicing and anti-icing activities that improve public safety during winter storms

How big of a problem is it?

<u>We don't really know…</u>

We recognize that sodium from road salts can compete with other base cations for exchange sites in soils. This facilitates a slow release of sodium throughout the growing season when plants are most active [Baraza and Hassenmeuller, 2021]

We know that sodic soils *(Exchangeable Sodium Percentage > 7 for clays or 15 for other soil types)* tend to have poor soil structure, which adversely affects plant growth by reducing the permeability of water, nutrients, and oxygen

Saline soils induce ionic and osmotic stress, reducing the capacity of vegetation to provide key water quality and hydrologic services (*slightly saline: conductivity > 2 dS/m, saline: conductivity > 4 dS/m*)

THE PROBLEM: We have limited understanding of both the amount of salt retained in green infrastructure soils and the level of stress it poses to established plant communities

OUR SOLUTION

1) Characterize plant-available salts in green infrastructure soils to determine the level of salt stress presently experienced by vegetation over the course of a year (***how bad is it?***)

2) Survey established green infrastructure plant communities and determine the fraction that are salt tolerant vs sensitive (***what salt tolerant species are present & how vulnerable are these systems?***)

3) Quantify salt accumulation in the tissues of salt tolerant species to estimate their potential to phytoremediate salts and reduce system-wide stress ***(Might phytoremediation mitigate the problem?)***

Where to do this?

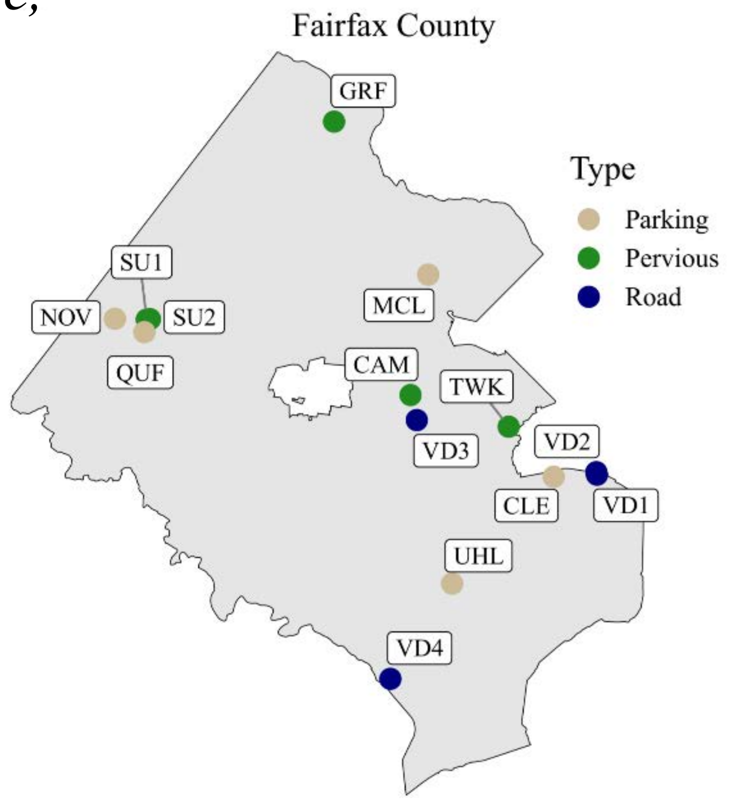
We compiled *(with assistance from Fairfax County and the Virginia Department of Transportation)* information about 1,495 stormwater detention basins within Fairfax County, Virginia

Cluster analysis was used to group these basins based on the land surface area they drained *(pervious open space, parking lot, or road)*

Goal: select five basins at random from each category for inclusion in our study

Reality: adjust selection a bit based on accessibility and other real-world concerns

- 4 basins draining roads
- 6 basins draining parking lots
- 4 basins draining pervious open space



Study Sites: Field sampling occurred from Fall 2021 – Fall 2022

<u>Sample collection was timed to capture deicing events and their aftermath:</u>

- 1 set prior to winter snowfall (*initial condition*),
- 3 during winter, immediately following snow events (*max salt loading*), and
- 4 during the spring/summer growing season that followed *(max plant impact)*

We sampled soils, plant communities, and plant tissues *(to evaluate salt assimilation capacity)* at each site

Soils *(year round)*

- Collected composite soil samples from detention basin bottoms (10-30 samples per composite)
- Samples were air dried, ground, and analyzed for plant-available salts (Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-) and electrical conductivity using saturated paste analysis

Plant Communities *(spring/summer)*

- Vegetation was surveyed using the point intercept transect method
- Plants were identified to the species level and classified as native, exotic, or invasive based on the VA Department of Conservation & Recreation's Invasive Plant Species List, and salt tolerant or salt sensitive using the eHALOPH database

Plant Tissues *(spring and fall)*

- Above-ground plant tissues from 4 common species were harvested
- Samples were dried, ground and analyzed for within-tissue Cl^- and Na^- conc.

Each sampling approach helps us answer 1 of our 3 questions

Soils

1) Characterize plant-available salts in green infrastructure soils to determine the level of salt stress presently experienced by vegetation over the course of a year (***how bad is salinization?***)

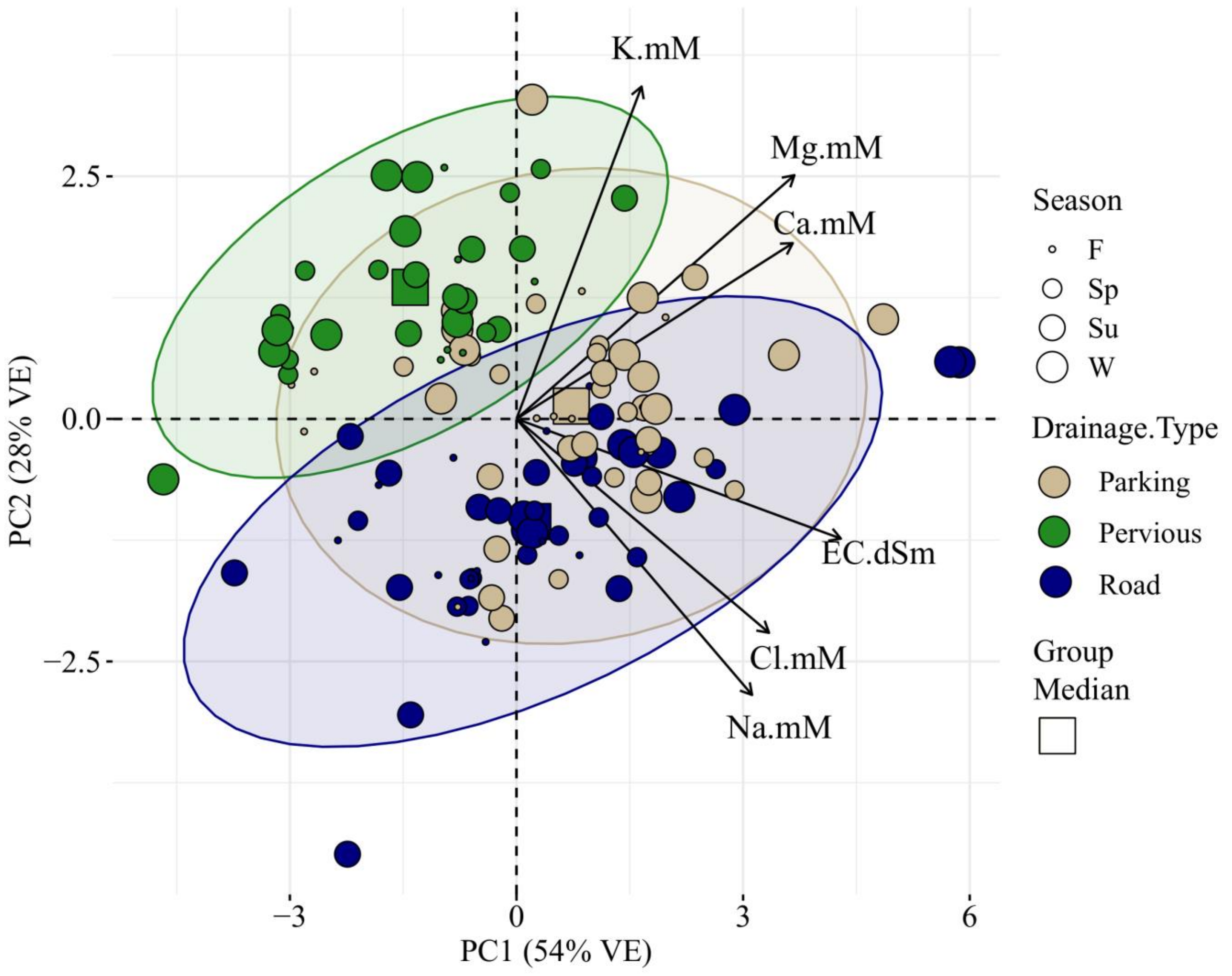
Plant Community

2) Survey established green infrastructure plant communities and determine the fraction that are salt tolerant vs sensitive (***what salt tolerant species are present & how much stress can they handle?***)

Plant Tissue

3) Quantify salt accumulation in the tissues of salt tolerant species to estimate their potential to phytoremediate salts and reduce system-wide stress ***(Might phytoremediation mitigate the problem?)***

How bad is it?: Characterizing plant-available salts in green infrastructure soils



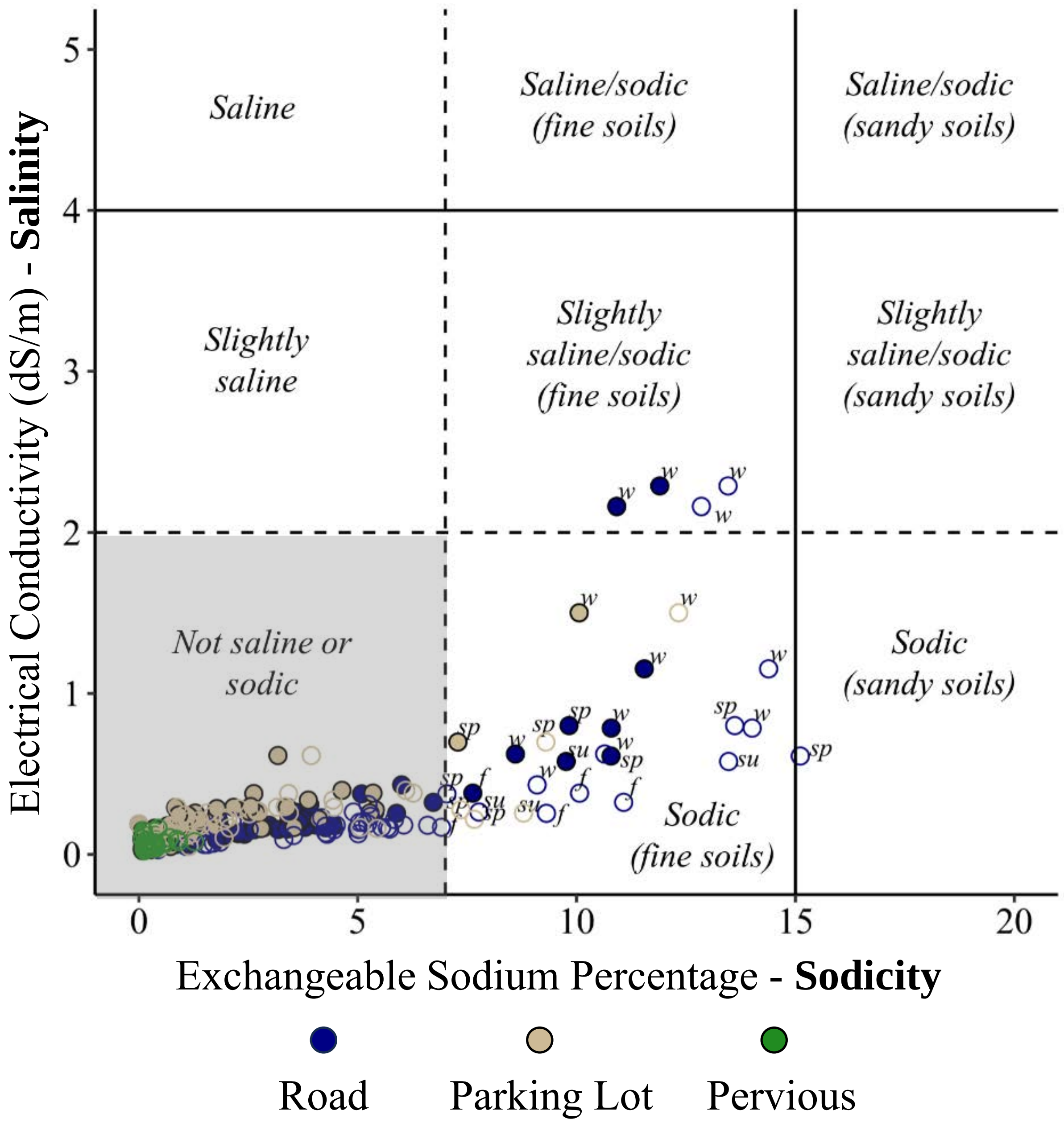
The answer to this question depends on the primary land use a system drains

Road sites (blue) have higher conductivity and sodium and chloride concentrations

Pervious sites (green) have lower conductivity and sodium and chloride concentrations, but more potassium

Parking lot sites (tan) are more variable

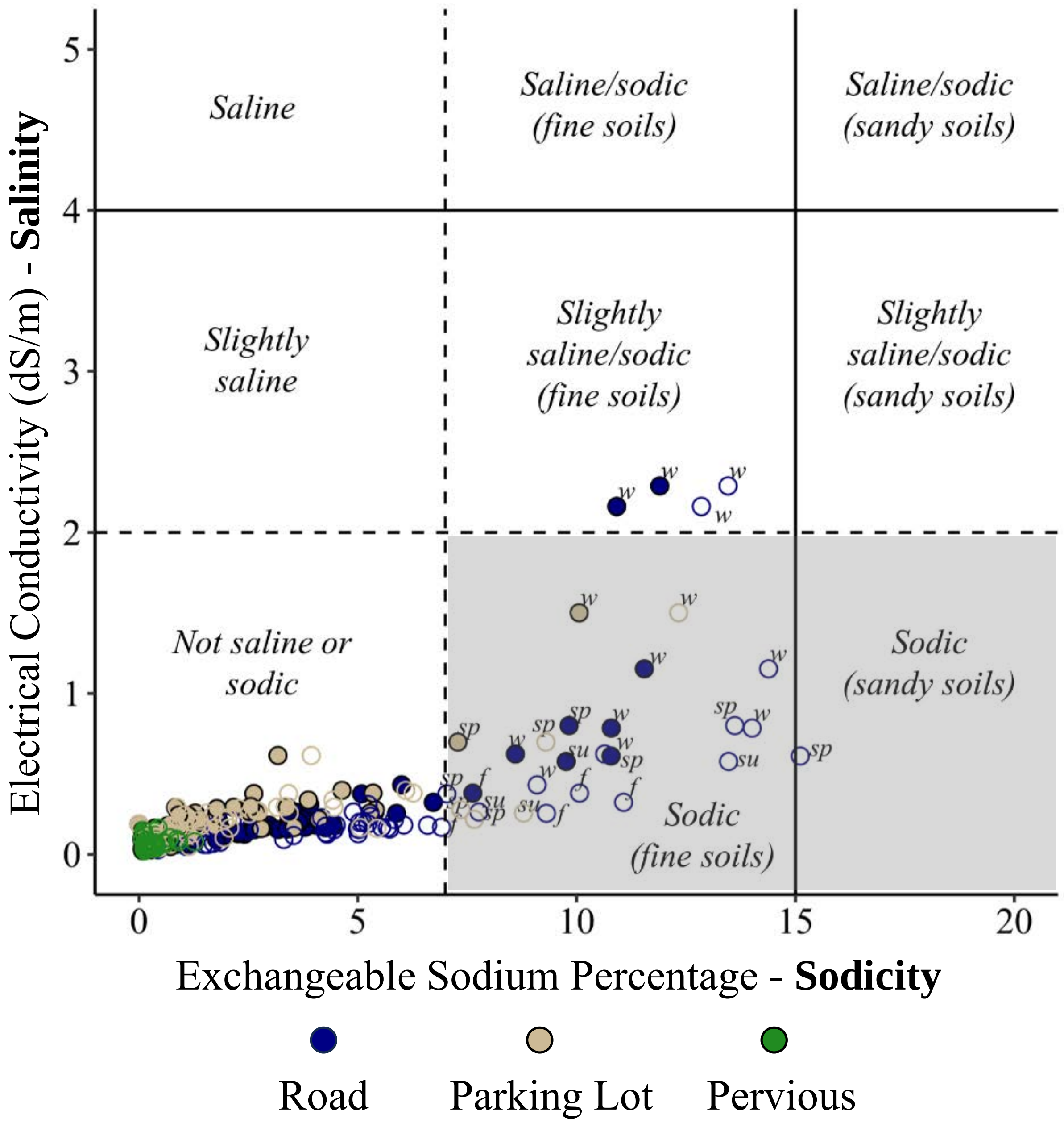
How much stress are we talking about?



Most of the time, the salt ions that accumulate in detention basin soils are not present at levels that are harmful to plants *(grey region)*

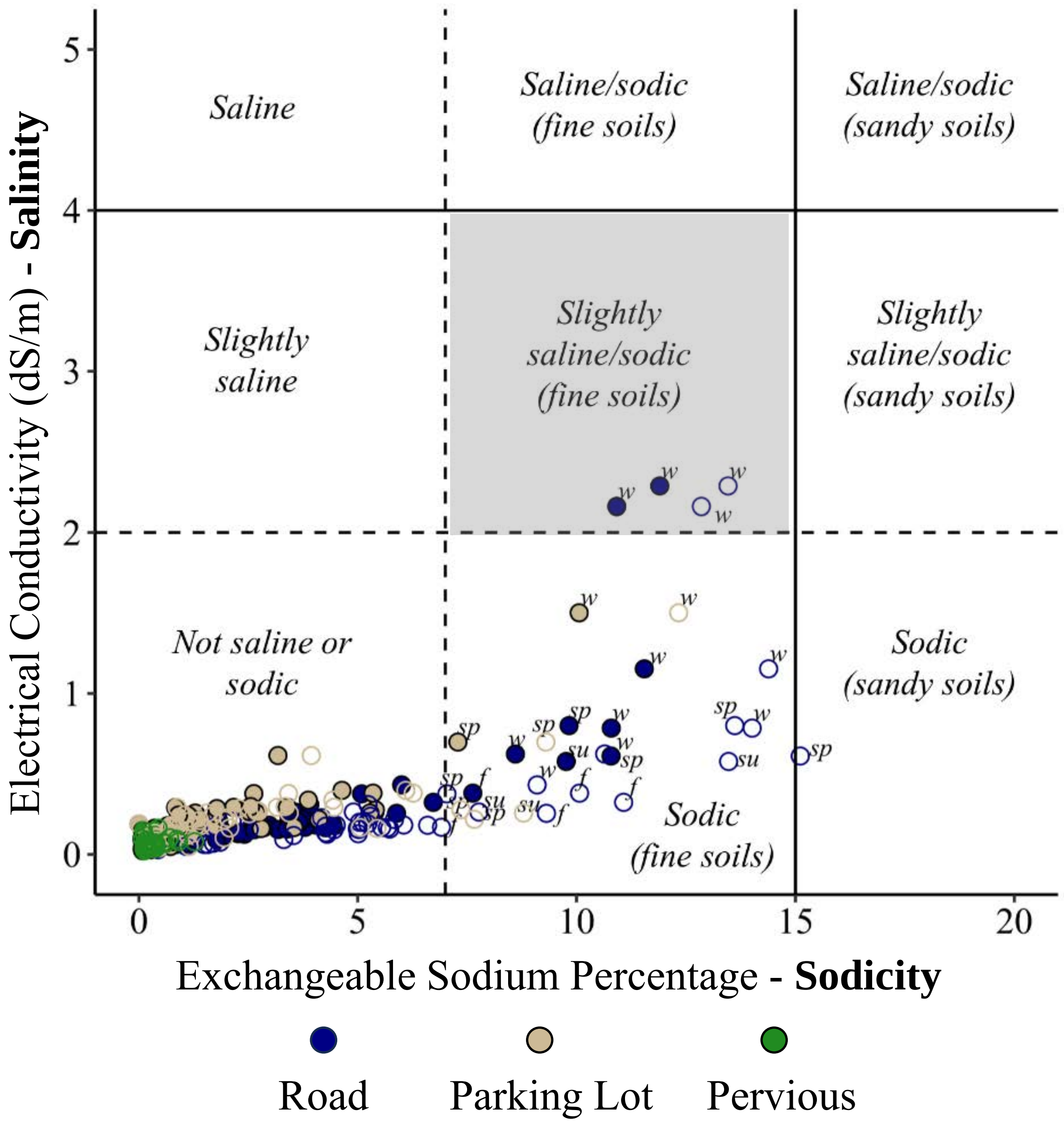
This is always true for sites draining pervious areas (100% of the time)

Often true for sites draining parking lots (88-95% of the time) and roads (77-81% of the time)



Soils do become sodic, particularly at sites draining roads

This occurred primarily during winter and spring, but persisted through to the following fall at certain sites



Soils rarely became both saline and sodic

This occurred only during winter at a single detention basin site that drained a major freeway overpass

Key Takeaways

Salts are not present in green infrastructure soils at levels that are harmful to vegetation all that often, which is really good news

The sites most at risk are those that drain large highways

Risk is primarily due to elevated soil sodicity, which adversely affects plant growth

We aren’t home free either…

Desirable services such as assimilation of nutrients and other pollutants by plants is a function of plant growth rate

It may still be wise to bias towards salt tolerant plant species at sites where sodicity persists throughout the year (basins that drain large highways)

Each sampling approach helps us answer 1 of our 3 questions

Soils	1)	Characterize plant-available salts in green infrastructure soils to determine the level of salt stress presently experienced by vegetation over the course of a year (***how bad is salinization?***)
Plant Community	2)	Survey established green infrastructure plant communities and determine the fraction that are salt tolerant vs sensitive (***what salt tolerant species are available?***)
Plant Tissue	3)	Quantify salt accumulation in the tissues of salt tolerant species to estimate their potential to phytoremediate salts and reduce system-wide stress ***(Might phytoremediation mitigate the problem?)***

What salt tolerant species are available?

Plant community analysis identified 279 unique species across all green infrastructure sites

- 10% were salt tolerant (capable of completing their life cycle when exposed to water containing more than 100 mM NaCl)

- 48% were salt sensitive

- 41% had unknown salt tolerance

What salt tolerant species are available?

Less than half of these salt tolerant species are also native *(we don't have a lot of salt tolerant candidates to choose from if promoting native biodiversity is also one of our end goals)*

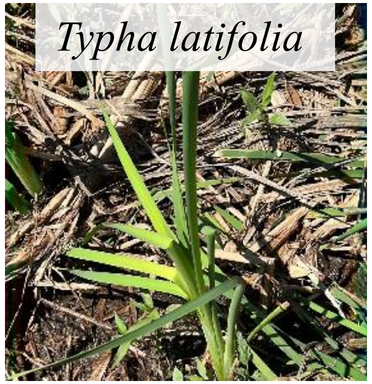
Graminoids
Elocharis palustris
Festuca rubra
Leptochloa fusca
Panicum virgatum
Schoenplectus tabernaemontani

Forbs
Solidago semipervirens
Typha angustifolia
Typha latifolia
Xanthium strumarium

Vine
Calystegia sepium

Shrub
Baccharis halimifolia

Trees
Robena pseudoacacia
Taxodium distichum


Typha latifolia


Festuca rubra

Recognizing that we don't have a lot of salt-tolerant species to choose from, can planting the ones that we have confer any real-world benefit (self-repair)?

Soils

1) Characterize plant-available salts in green infrastructure soils to determine the level of salt stress presently experienced by vegetation over the course of a year (***how bad is salinization?***)

Plant Community

2) Survey established green infrastructure plant communities and determine the fraction that are salt tolerant vs sensitive (***what salt tolerant species are available?***)

Plant Tissue

3) Quantify salt accumulation in the tissues of salt tolerant species to estimate their potential to phytoremediate salts and reduce system-wide stress ***(Might phytoremediation mitigate the problem?)***

Might phytoremediation mitigate the problem?

Relatively common plant species

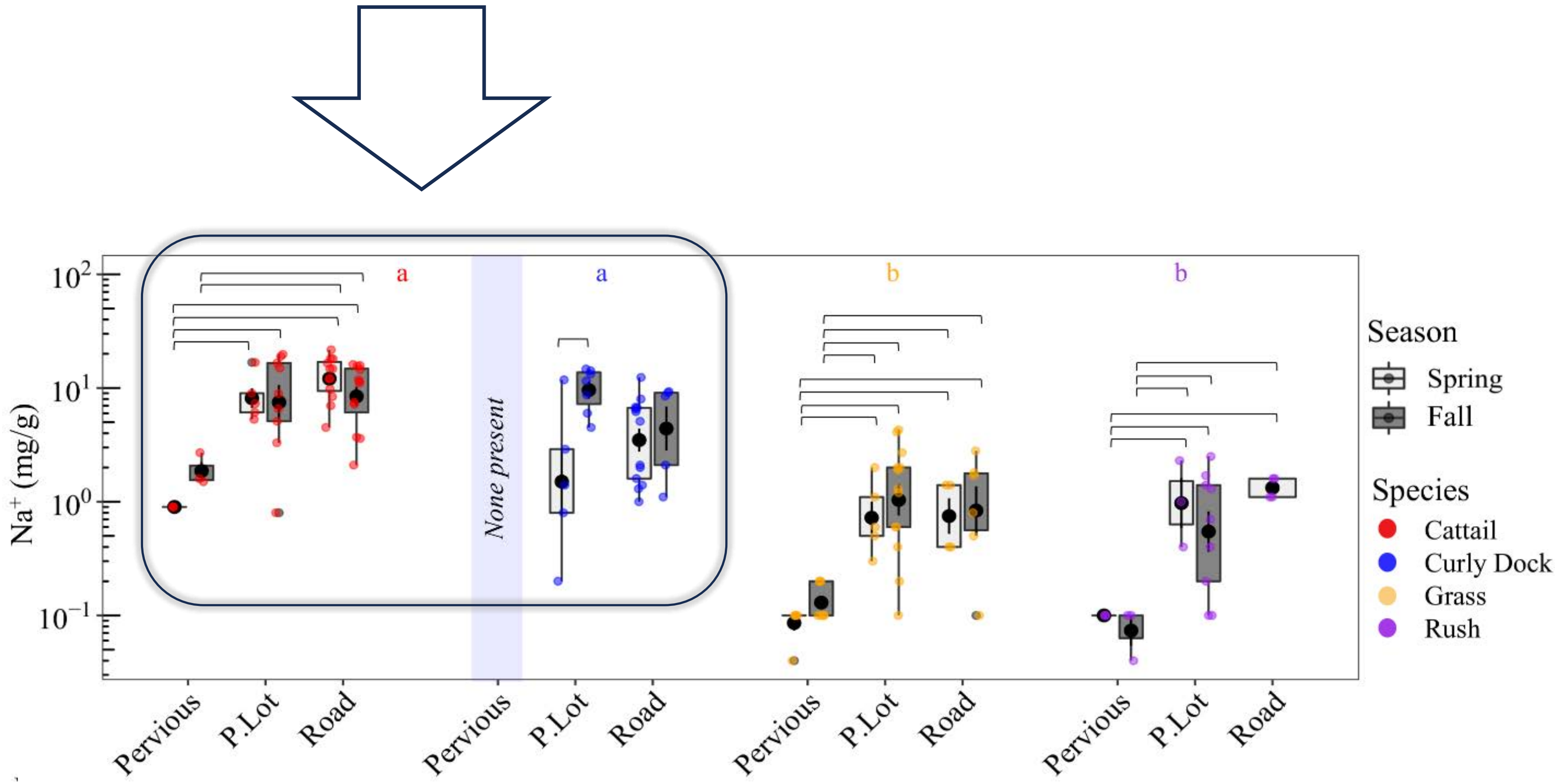
Targeted two native, salt-tolerant species (*Typha latifolia* and *Festuca rubra*)

One native rush with unknown salt tolerance that is a common phytoremediation species (*Juncus effusus*)

One low-level invasive (a nuisance weed) with high salt tolerance (*Rumex crispus*)

Cattail and curly dock are promising phytoremediation species

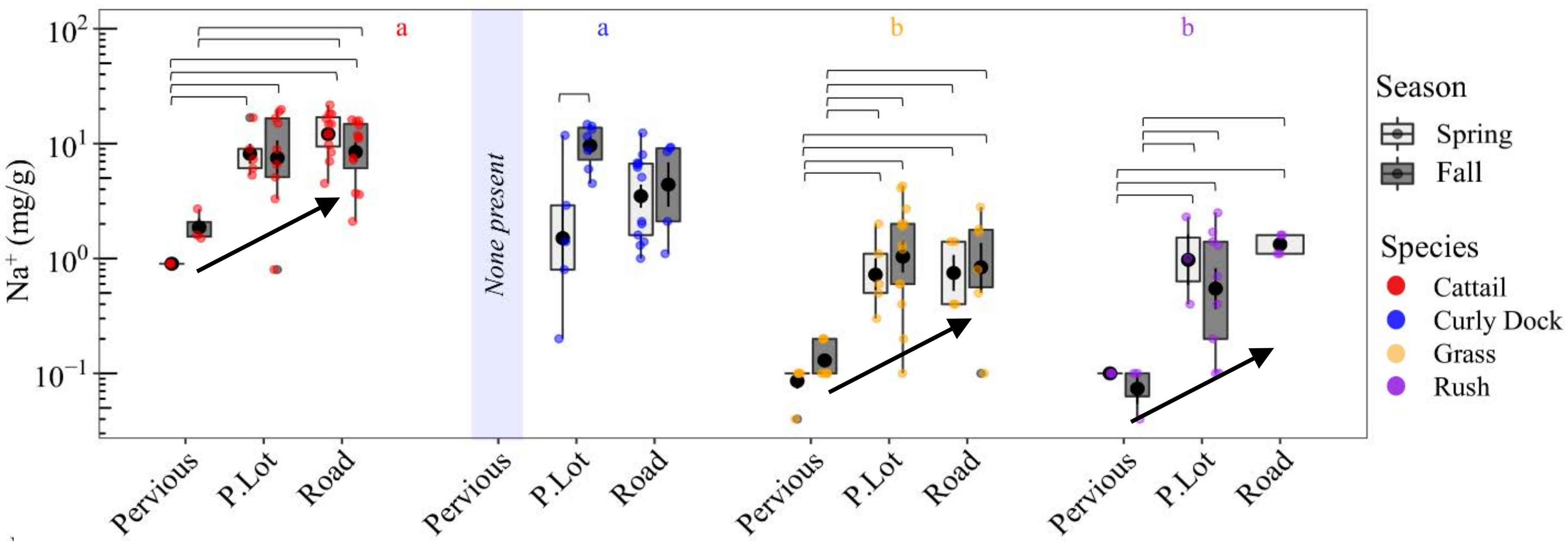
Within-tissue concentrations of sodium and chloride were significantly higher in cattail and curly dock than red fescue and juncus, suggesting that the former two species are most promising for phytoremediating salt



Cattail and curly dock are promising phytoremediation species

Within-tissue concentrations of sodium and chloride were significantly higher in cattail and curly dock than red fescue and juncus, suggesting that the former two species are most promising for phytoremediating salt

Within-tissue concentrations of sodium and chloride were always higher at road and parking lot sites than pervious sites suggesting that all plants have at least some phytoremediation potential



So plants take up salt…is it enough to really matter?

Lets do a little back of the envelope calculation:

The amount of salt that would have been placed on roads that drain to each of our VDOT detention basins can be estimated using recommended application guidelines for road salt from the Salt Management Strategy for Virginia

500 to 3,000 kg of sodium and 800 to 4,500 kg of Cl

2136 kg Na 3273 kg Cl	2889 kg Na 4454 kg Cl	539 kg Na 831 kg Cl	2139 kg Na 3298 kg Cl

Combine with a quick calculation for phytoremediation potential

$$\underbrace{\frac{Ion\ conc\ (mg)}{kg\ dry\ mass}}_{\text{Within-tissue salt conc.}} \times \underbrace{\frac{dry\ mass\ plant}{m^2}}_{\text{Plant dry mass}} \times \underbrace{m^2\ basin}_{\text{Basin area}} = \underbrace{\frac{\text{salt uptake by cattail}}{\text{growing season}}}_{\textbf{Phytoremediation potential for our best native salt accumulator over the growing season}}$$

2136 kg Na
3273 kg Cl

105 kg Na
199 kg Cl

2889 kg Na
4454 kg Cl

14 kg Na
40 kg Cl

539 kg Na
831 kg Cl

21 kg Na
43 kg Cl

2139 kg Na
3298 kg Cl

47 kg Na
87 kg Cl

Road Sites

Could these plants assimilate enough salt to really matter?

Our best salt accumulator could remediate a maximum of 0.5-5% of the sodium and 0.9-6.1% of the chloride each basin received during winter

- The rest of the salt either accumulates in detention basin soils or is discharged to downstream waterbodies

Although 5-6% is not nothing, its safe to say that the majority of salt is not photoremediated over a single winter season

Caveat: We only looked at a single winter season

The winter we studied was particularly snowy and salt application rates were high, which is not always the case. When winters are less severe, the amount of salt plants have to process will be lower, making phytoremediation more viable

Summary and Conclusions

Soils

1) Does salinization of green infrastructure soils pose a threat to their vegetation and the services they provide?

Generally, no for sites draining pervious areas and parking lots. Detention basins that drain highways are more problematic, with some becoming sodic during winter & remaining that way through the growing season. This has the potential to impair nutrient assimilation and other services

Plant Community

2) Do green infrastructure plant communities include salt tolerant species that might perform well under these conditions?

Yes, but not many. Only 10% of the species we identified were salt tolerant (28 total). Of these 13 were native.

Plant Tissue

3) Can any of these species phytoremediate salts, increasing the resilience of green infrastructure to deicing events?

Maybe. Cattail (native) and curly dock (nuisance weed) certainly show promise, but they can only do so much. Phytoremediation is only a partial solution – no substitute for source control

Thank You!

Happy to take questions ☺