



Remediating Salt-Contaminated Sites in Canada Using Phytotechnologies

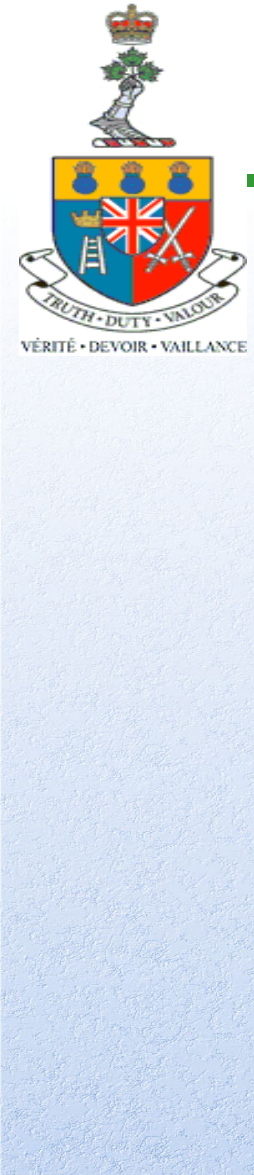
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Royal Military College of Canada
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Battelle 2019 Bioremediation Symposium
Session: D3. Phytoremediation/Mycoremediation
Baltimore, Maryland
April 15-18, 2019



How Canada's addiction to road salt is ruining everything

(Feb 21, 2018; National Post)





Road Salting in Canada

- >7 million tons road salt applied annually (Envt. Canada 2009)
 - NaCl remains most cost efficient deicing agent



1. billions of dollars damage to cars
 - salt corrosion culprit in 1000's of vehicle brake accidents



2. ravaging bridges & highways
 - salt brine seeps into concrete speeding up corrosion of rebar

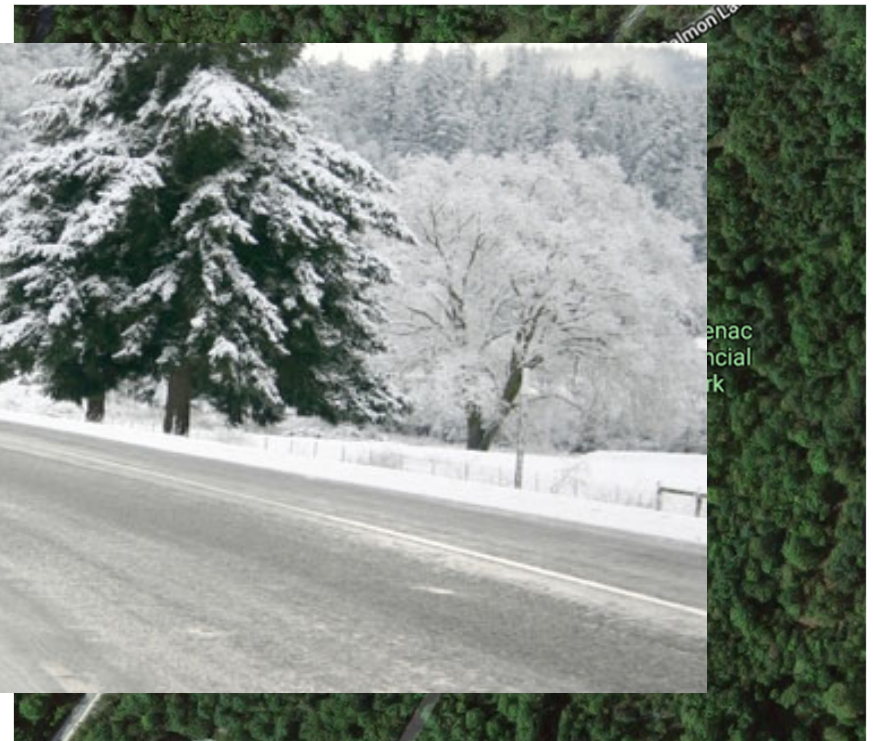
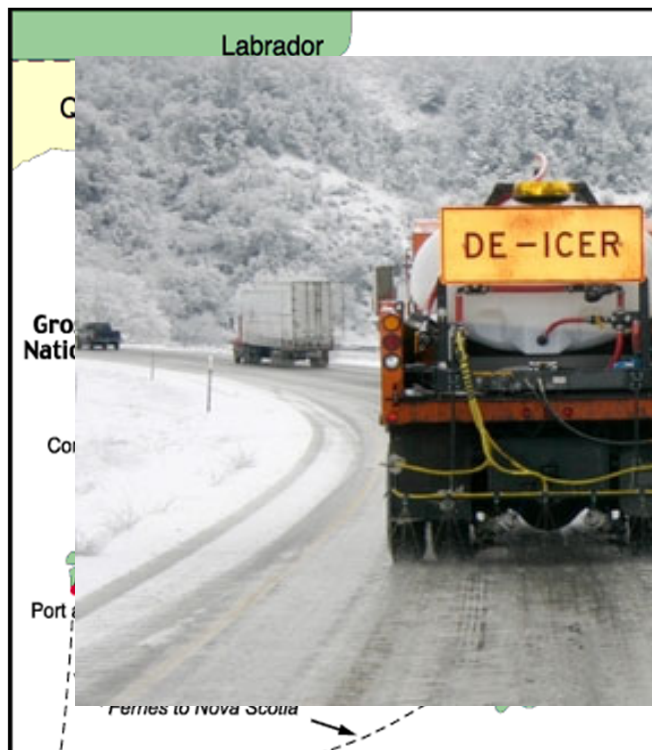


3. causing buildings to collapse
 - shopping mall in Ontario's Elliot Lake in 2012

National and Provincial Parks

Gros Morne National Park, NFLD

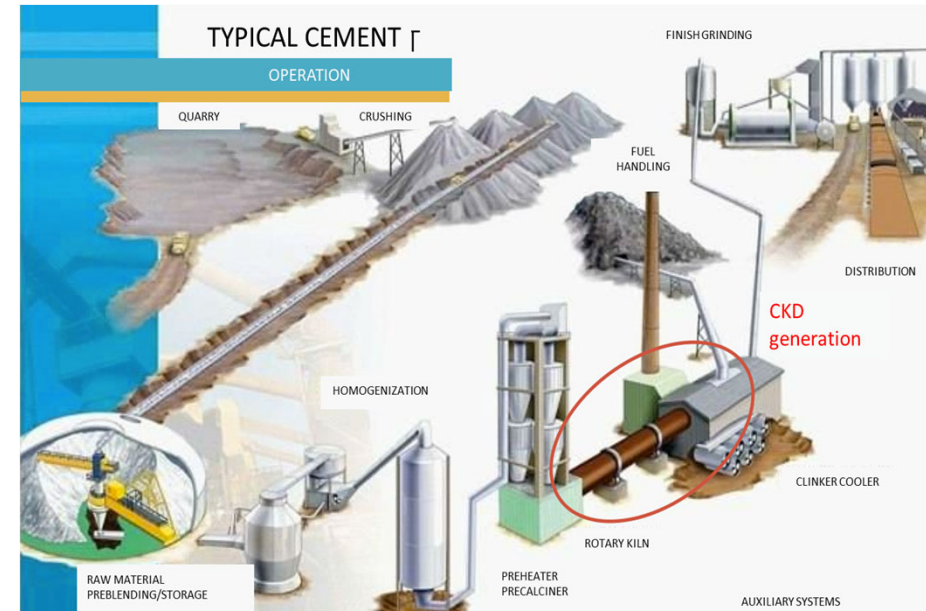
Frontenac Provincial Park, ON



Landfilling of High Salt Content Waste



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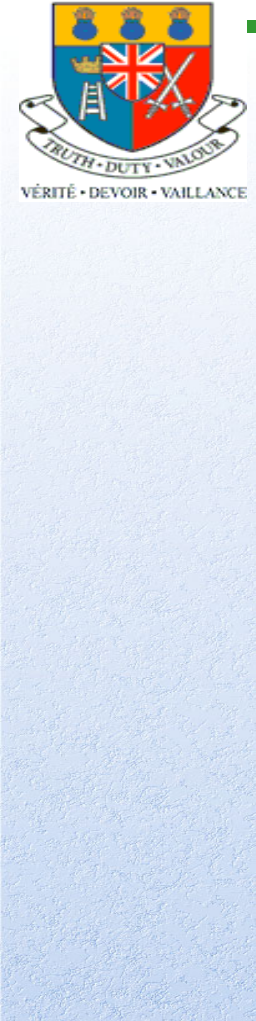
Cement Kiln Dust (CKD)

- generated at ~4-20% of cement production rate
- worldwide generation ~560 million tonnes/year



CKD Site in Bath, ON

- CKD landfilled over ~30 years at ~30000 tonnes/yr
- highly saline (KCl)
- Cl⁻ levels: **>10000 ug/g** (bkgd levels in Canada ~100 ug/g)
- Electrical Conductivity: **11-20 dS/m** (<0.7 dS/m)
- SAR: **15.4** (5)

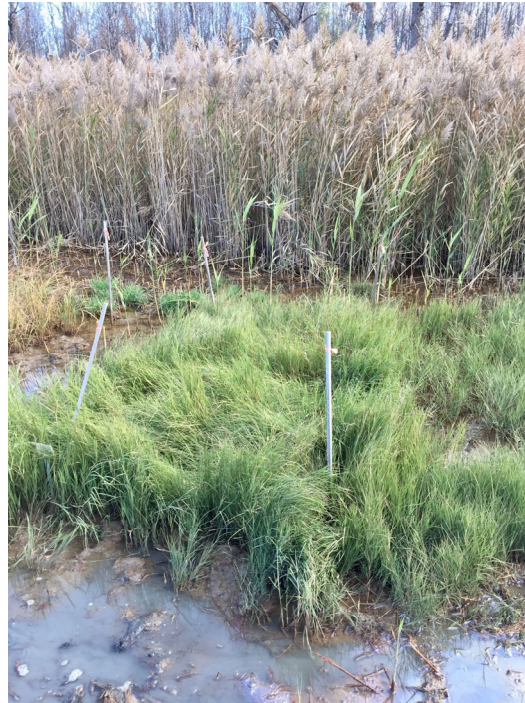




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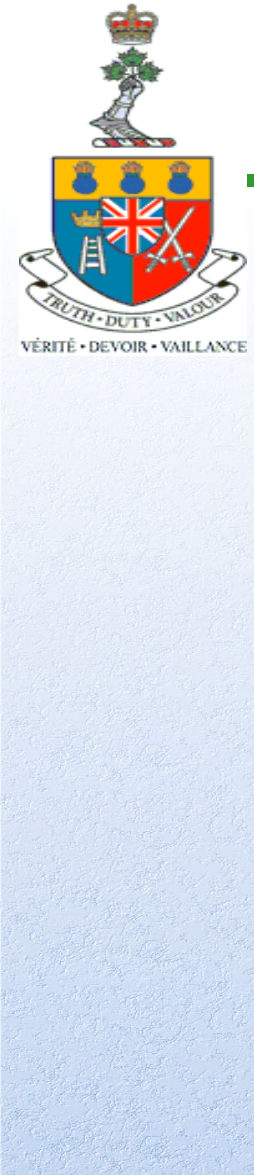
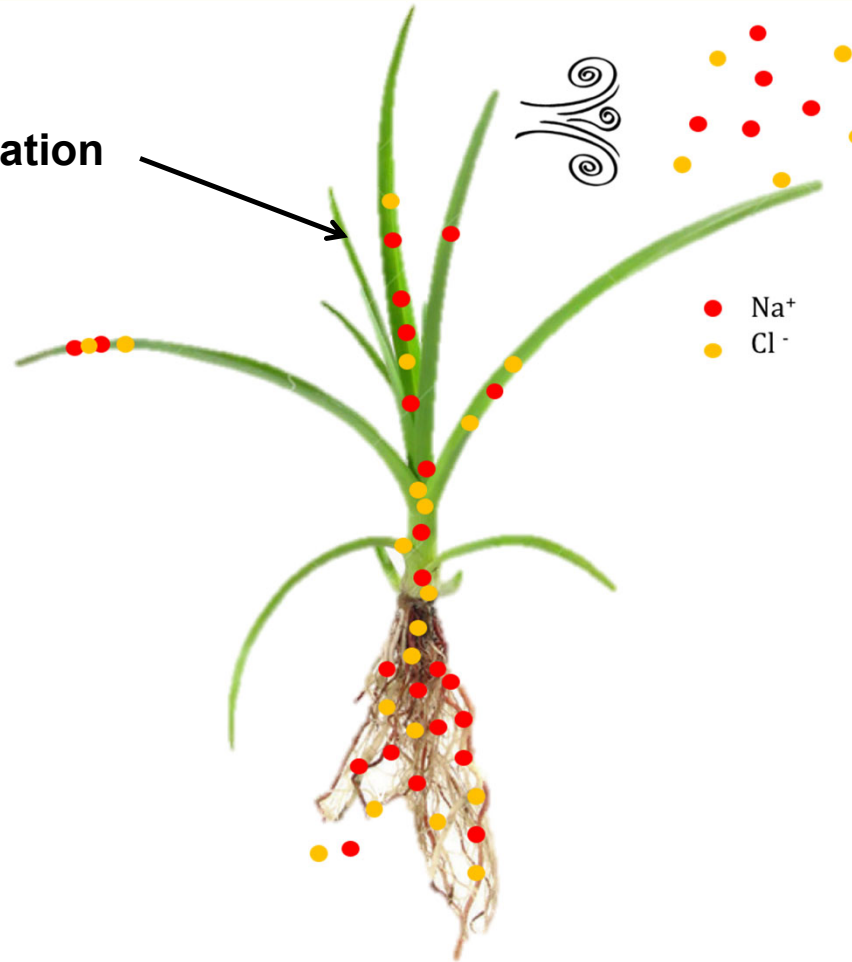
Halophytes (salt-tolerant plants)

- thrive in saline environments
- represent ~1% of all known terrestrial plant species



Salt Tolerance Mechanism I

1. Accumulation



Accumulator Halophytes

Uptake of Salt by Species Native to Canada

Atriplex spp.



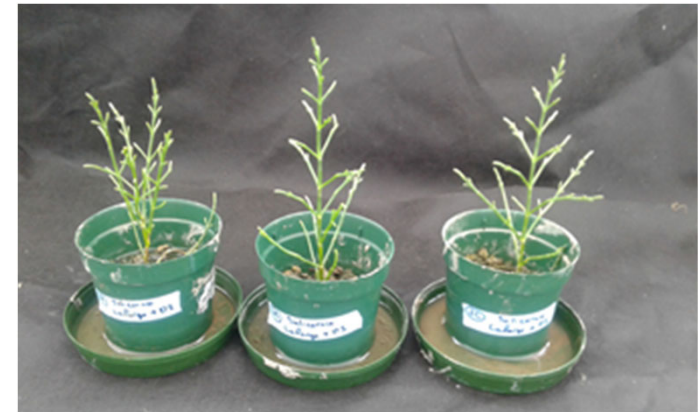
A. hortensis

13-15% salt when grown in roadside Provincial Park soil



A. patula

Salicornia spp.



up to 23% salt when fed with CKD landfill leachate



Invasive Accumulator – P. australis

Community members asked to look out for fast invading plant working its way into Kingston and surrounding areas

BY MANDY MARCINIAK
mandymarciniak@metroland.com

Beach season is just around the corner, but in some parts of Ontario, beaches and

waterfronts are being threatened by a fast invading plant that has the potential to take over the valuable waterfront areas. Phragmites are a perennial that typical-

ly grow in wetland areas. The plant looks like a common reed, and in most cases the native species is harmless, but a new more invasive species of phragmite is quickly spreading across the province. According to Erling Armson, head of land securement, invasive and northern programs at Ducks Unlimited Canada, the species is now making its way into eastern Ontario.

“The plant came to North America about a century ago and it has gradually worked its way across the continent from

east to west,” he explained. “It has really spread and invaded wet and even dry areas where it can live. Now it covers millions of acres across the continental United States and Canada.”

The plant can be easily found in ditches or areas with lower water levels, but according to Armson, it has been popping up more and more over the past few decades along waterfronts and in wetland areas of lakes.

Continued on page 20



Phragmites are threatening waterfront and wetland properties throughout Ontario.

Submitted photo



Plant Harvest

- harvesting using existing agronomic machinery
- composting of harvested plant matter to ↓ volume





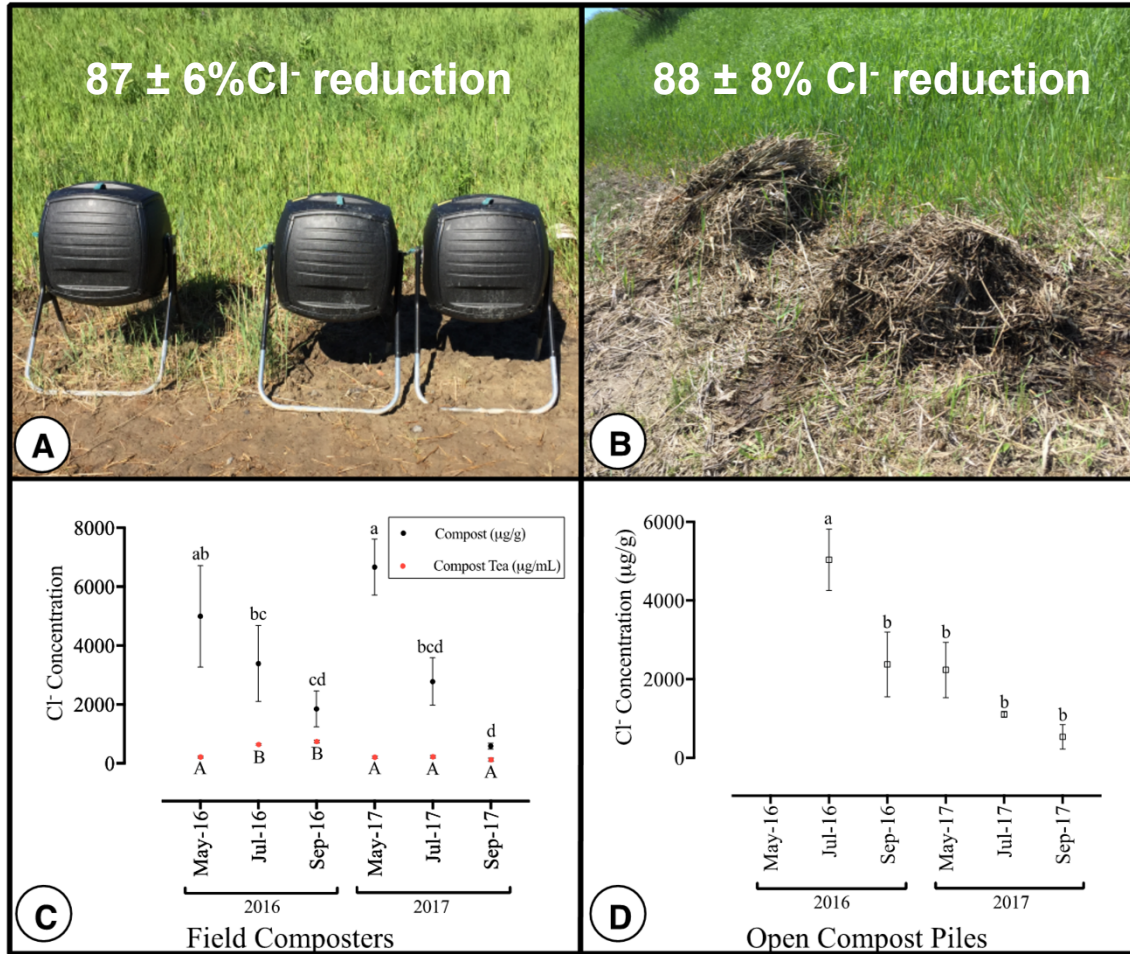
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Composting Phragmites australis

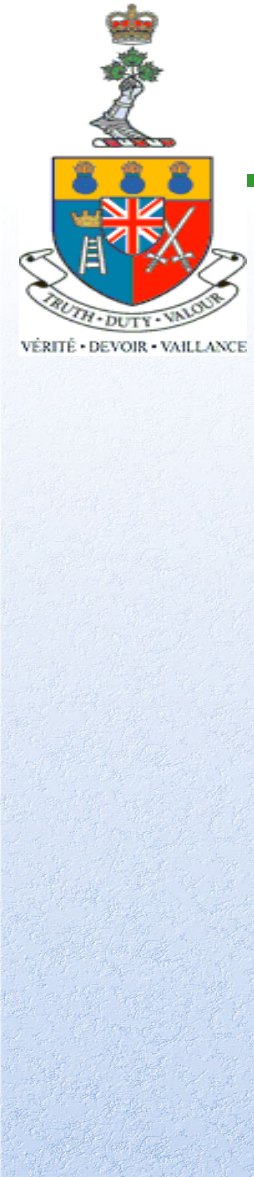
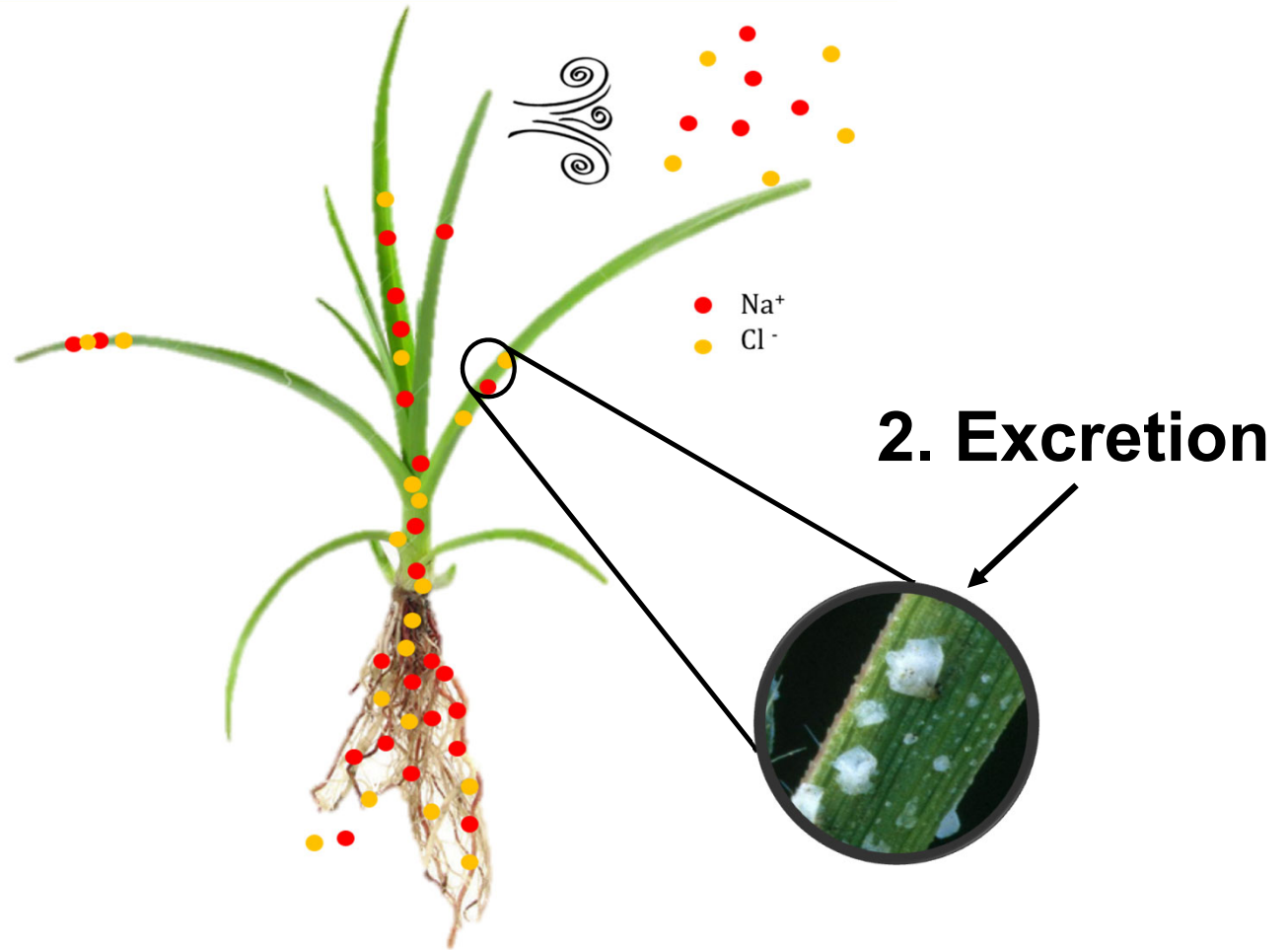




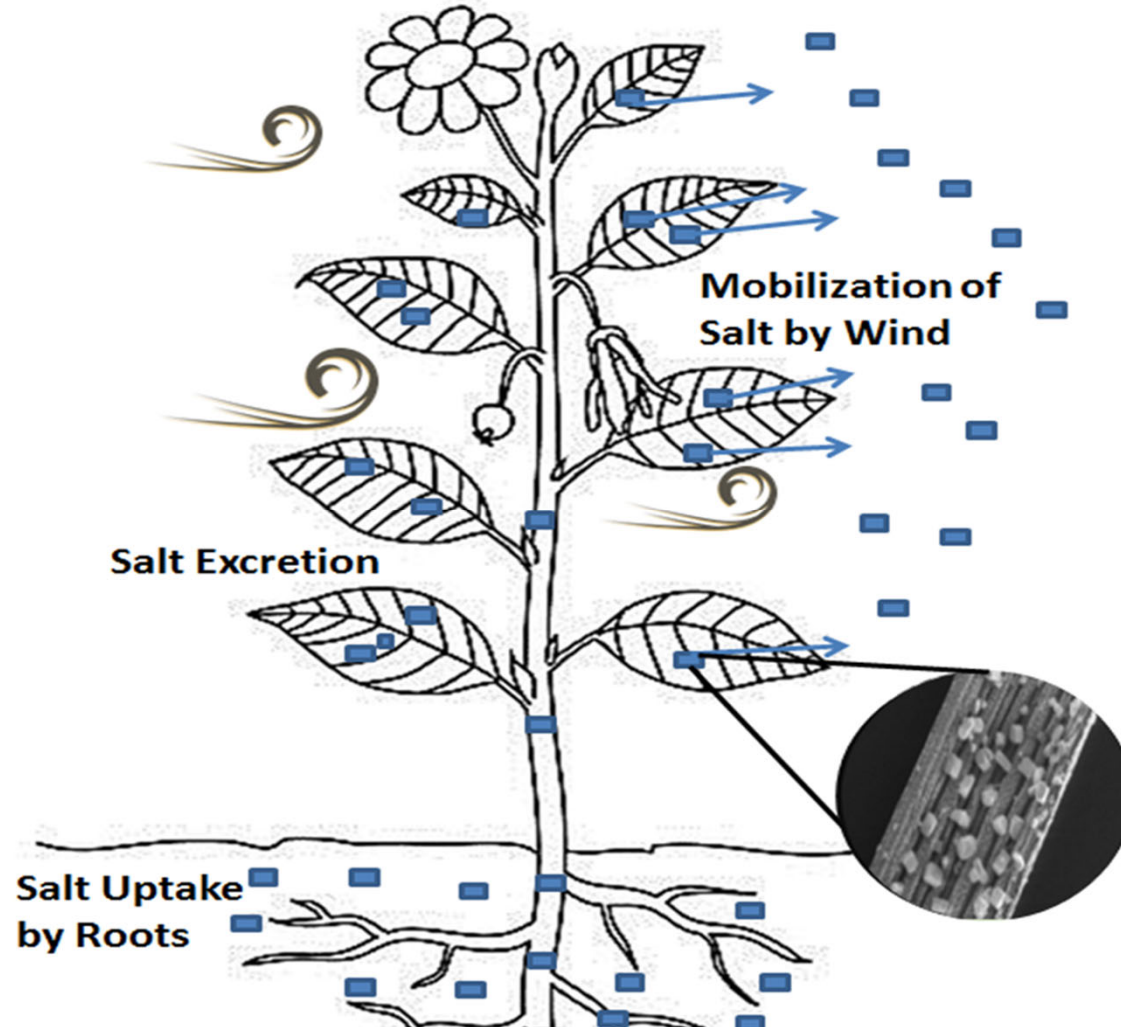
Composting in the Field



Salt Tolerance Mechanism II



Haloconduction





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Recretohalophytes (salt excretors)

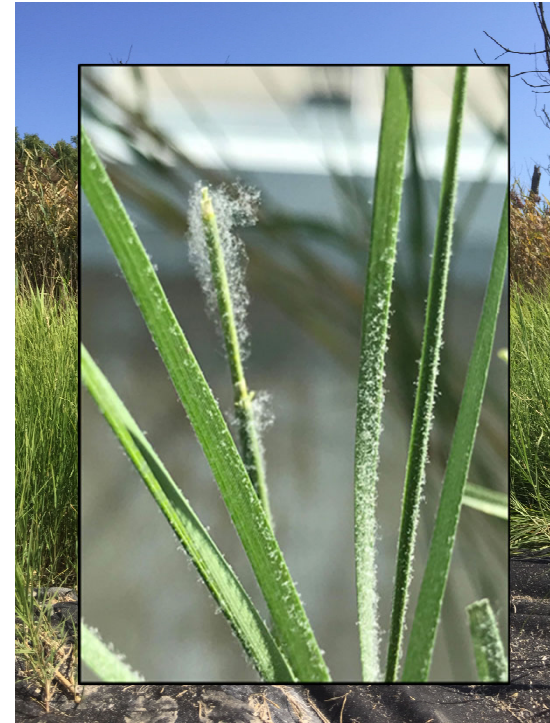


- salt tolerant
- water tolerant
- native to Ontario/Canada

Spartina pectinata
(Prairie Cordgrass)



Distichlis spicata
(Inland Salt Grass)



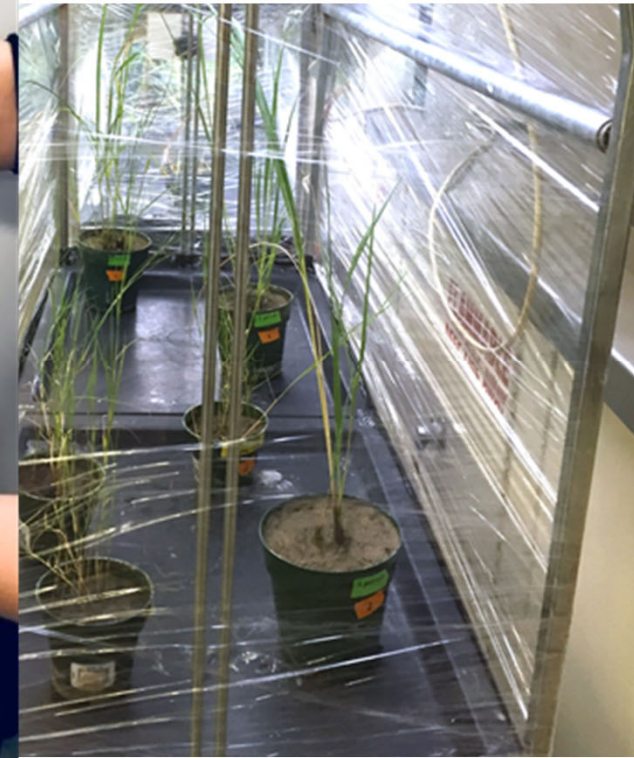


Proving Haloconduction Theory

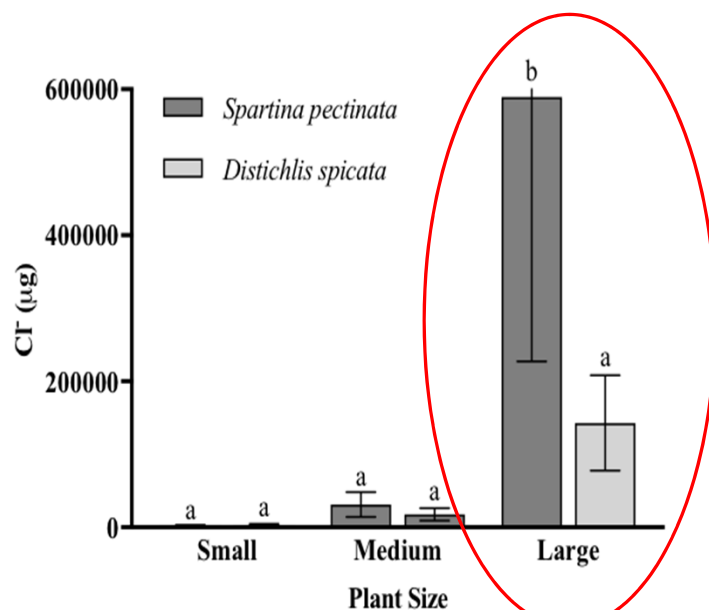
1. How much salt is excreted?
2. What does the excreted salt look like?
3. How much excreted salt is actually dispersed...and where is it going?



1. Quantification of Salt



Measured Salt Excretion



Size Parameters

Small: <5 shoots of ~15 cm in height

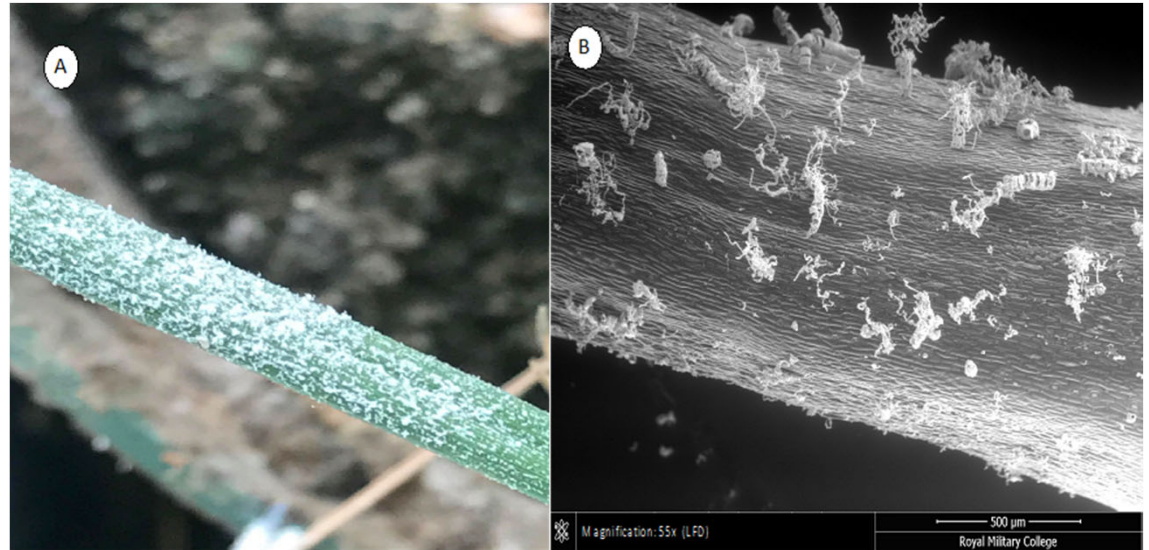
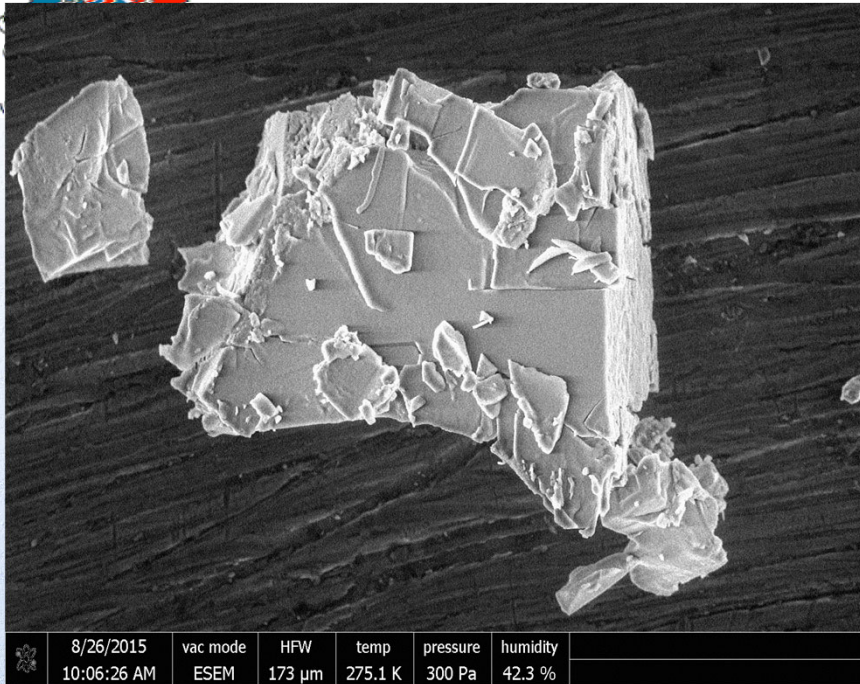
Medium: 6-15 shoots of ~30 cm in height

Large: >15 shoots of ~40-50 cm in height

- both species viable excretors
- larger plants excrete more salt (1.4-2.4 yr remediation timeframe)
 - based on conservative 8 weeks excretion (in 16 week growing season)

plants do not
require harvest

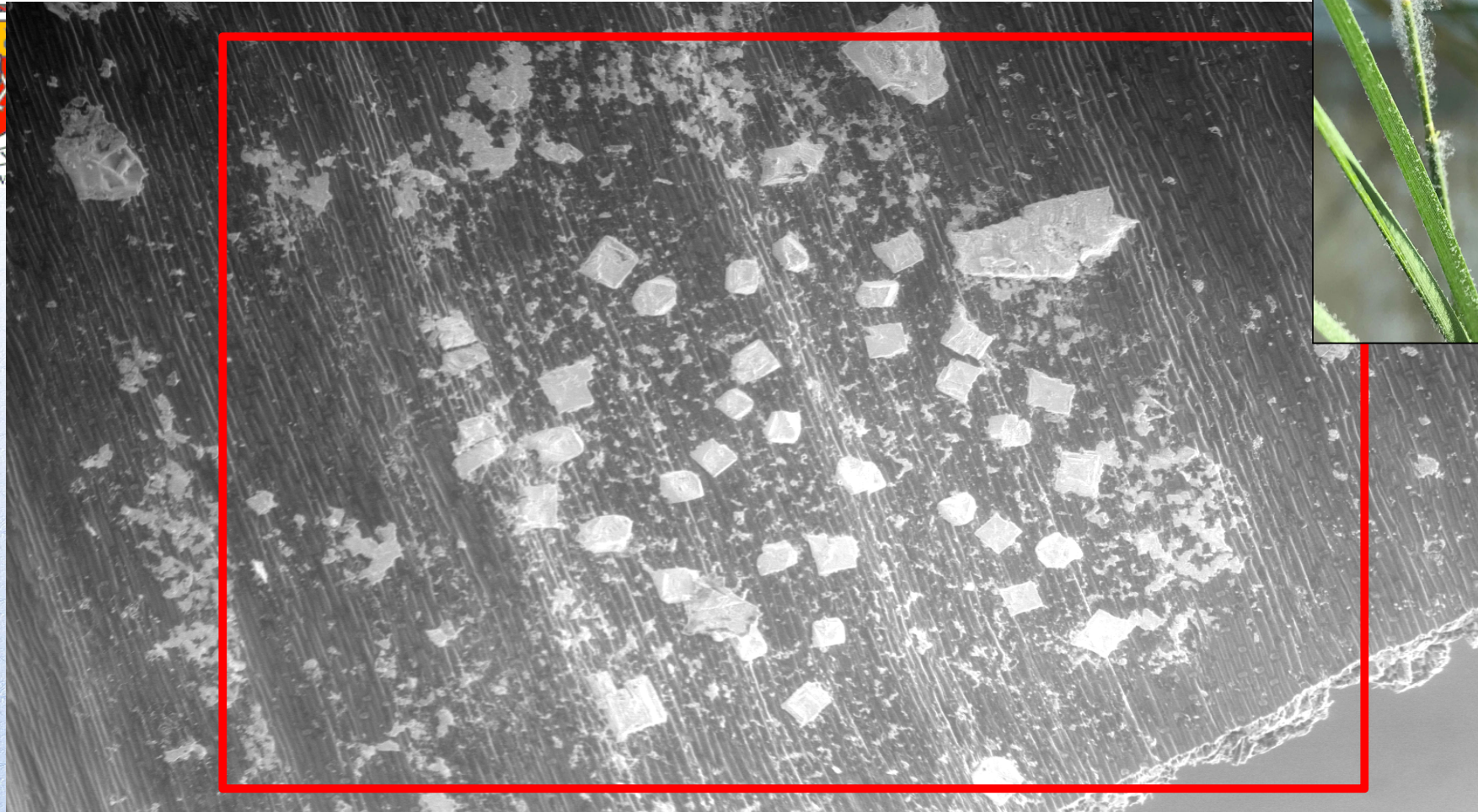
2. Salt Characterization



Salt crystals excreted in suboptimal conditions

Time lapse in SEM chamber with changing humidity

Optimal Conditions; <65% humidity



3/9/2017
2:01:42 PM

HV
10.00 kV

spot
3.0

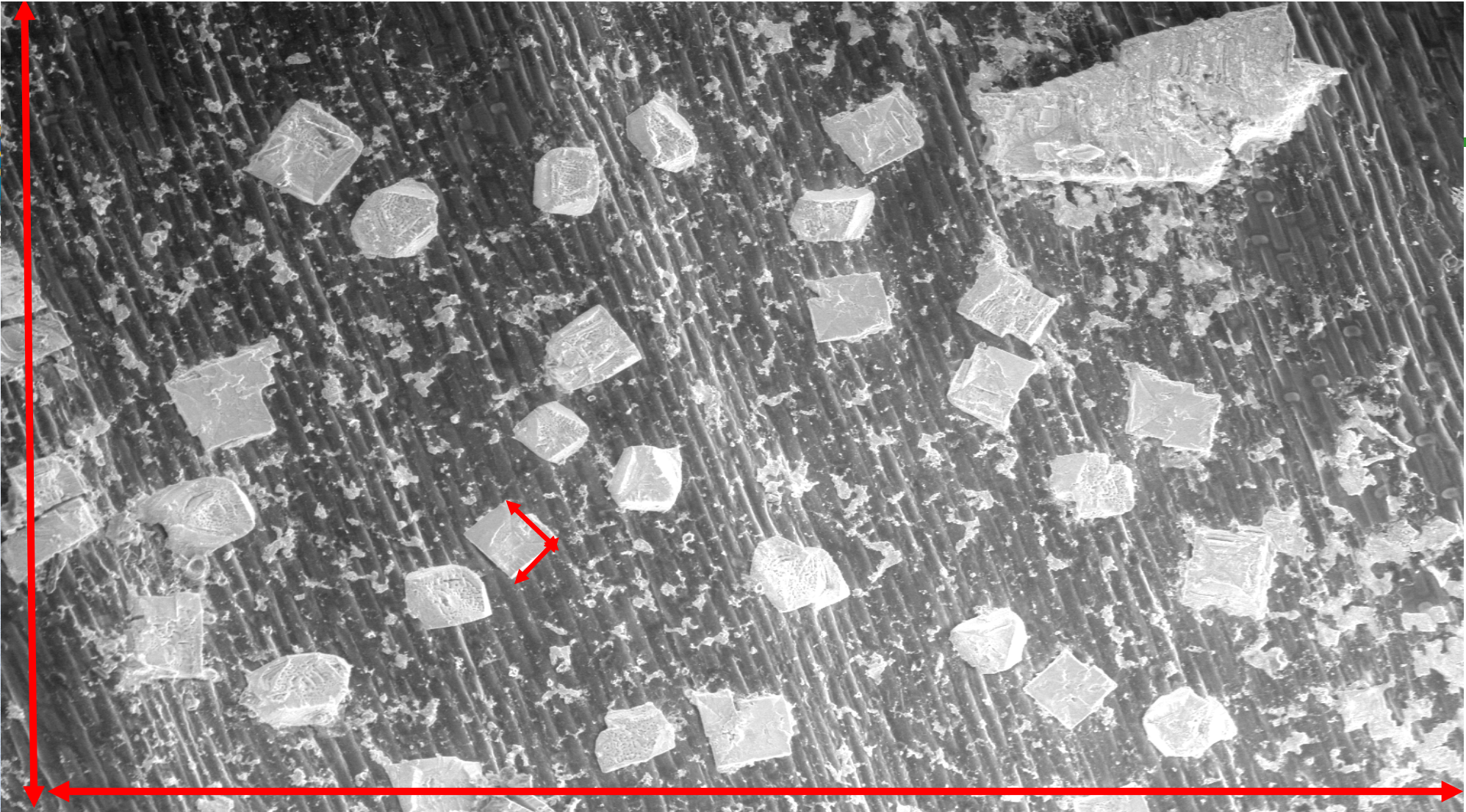
HFW
2.07 mm

det
LFD

WD
11.9 mm

500 μ m

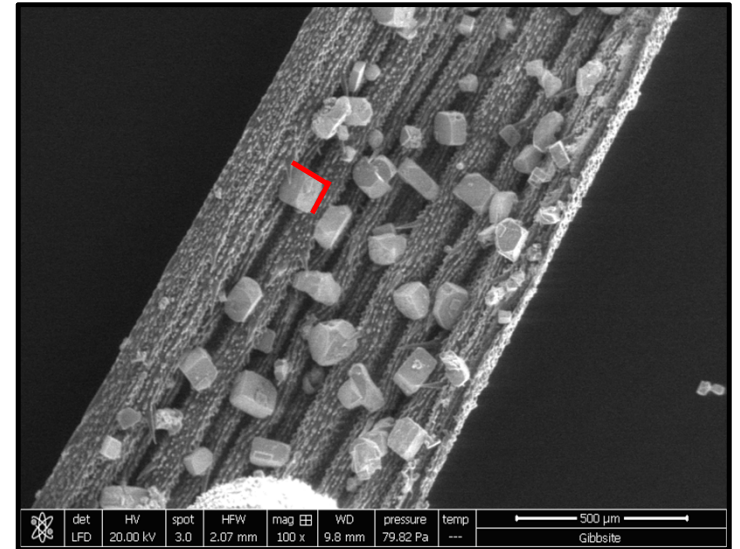
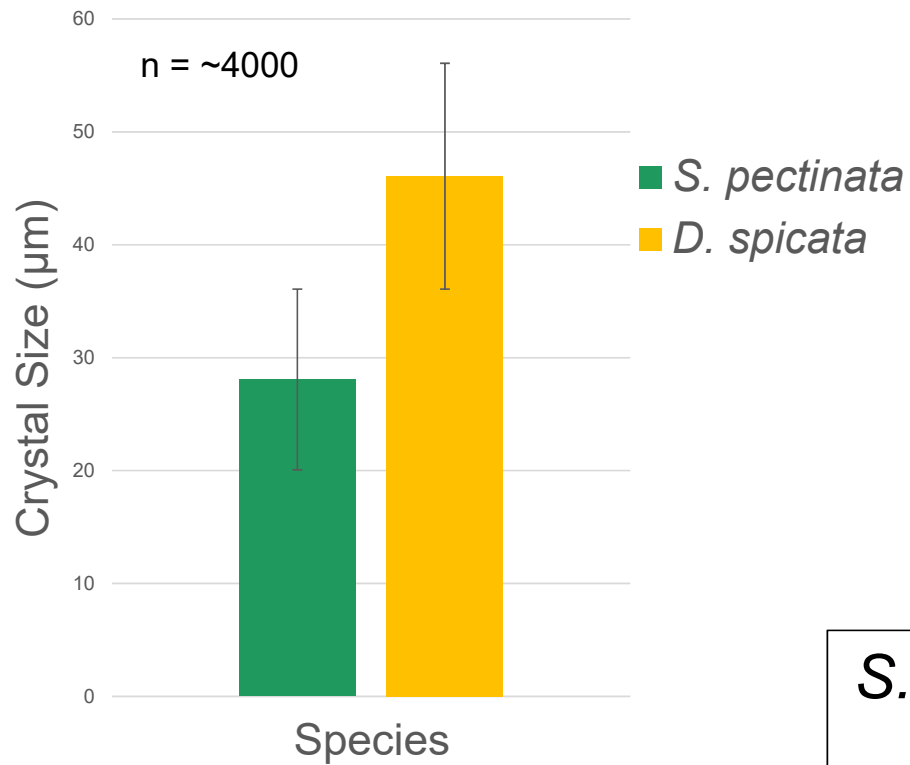
Royal Military College



	3/9/2017	HV	spot	HFV	det	WD	 400 µm Royal Military College
	2:03:20 PM	10.00 kV	3.0	1.04 mm	LFD	11.7 mm	

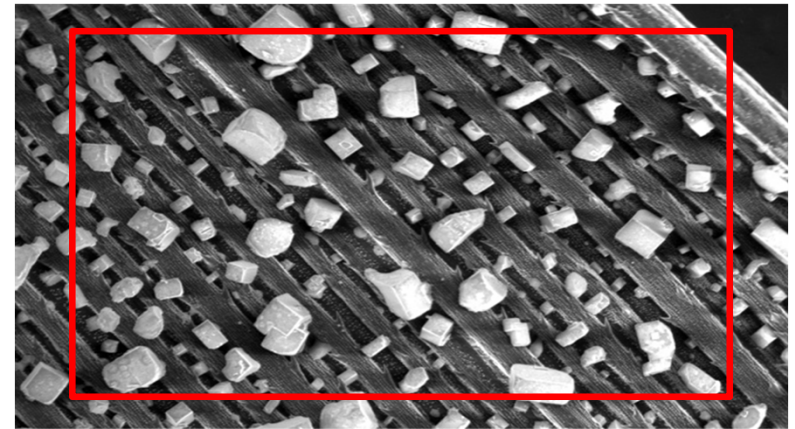
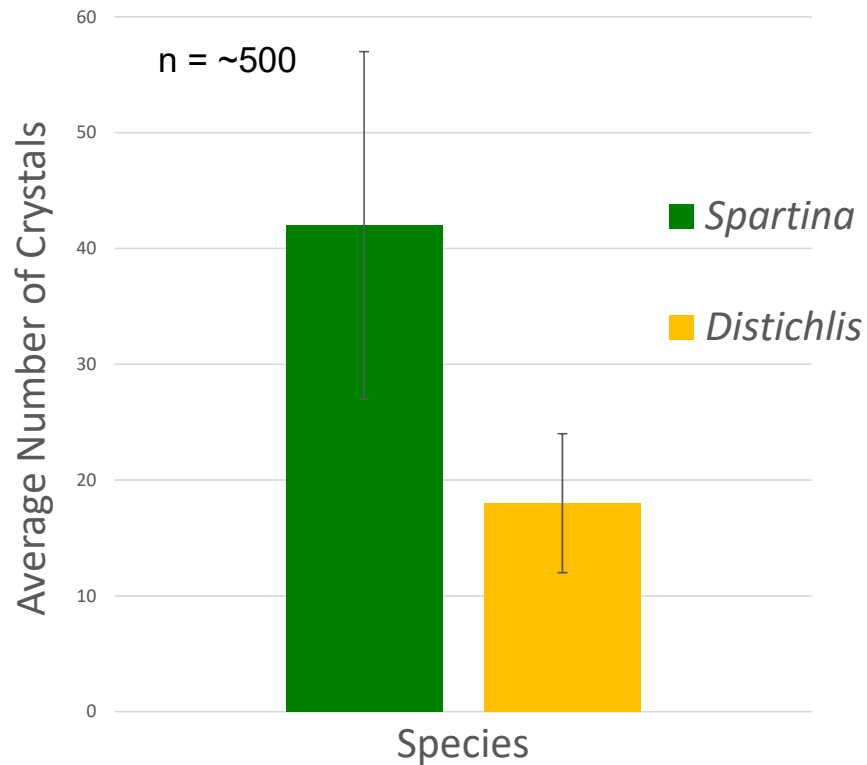


Size of Excreted Salt Crystals



S. pectinata crystals smaller than *D. spicata* crystals

Density of Salt Crystals (per mm²)



significantly higher density of *S. pectinata* crystals per unit area than *D. spicata* crystals



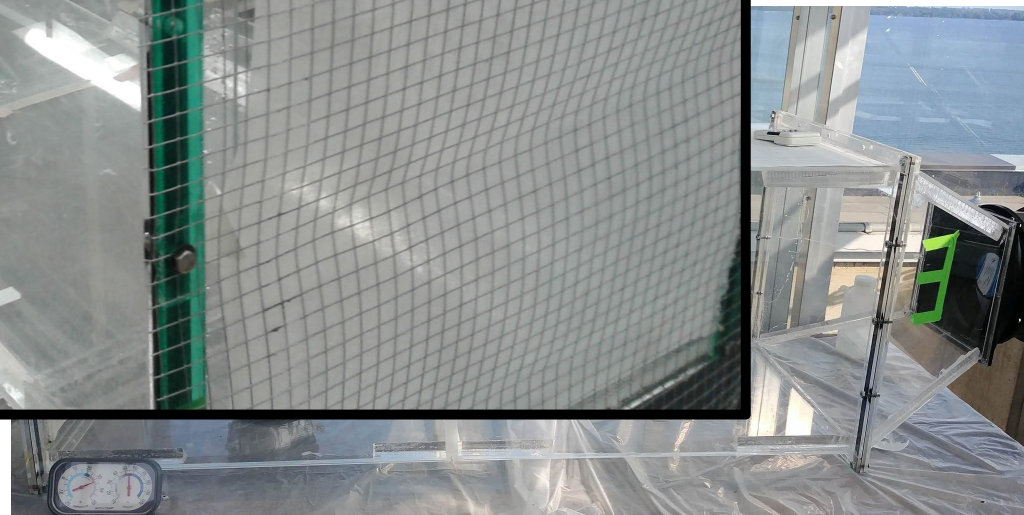
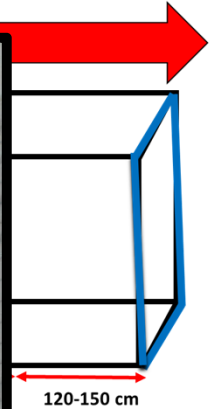
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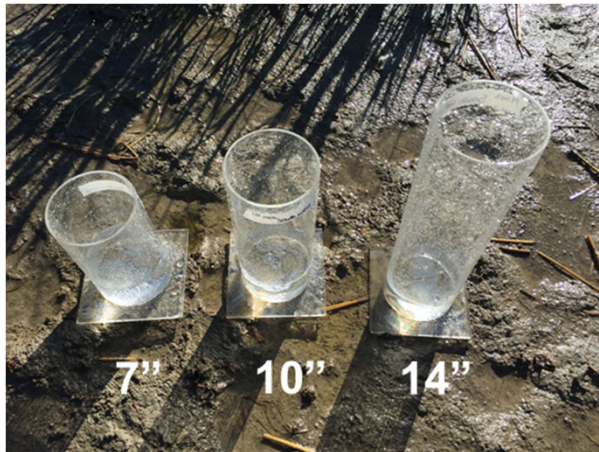
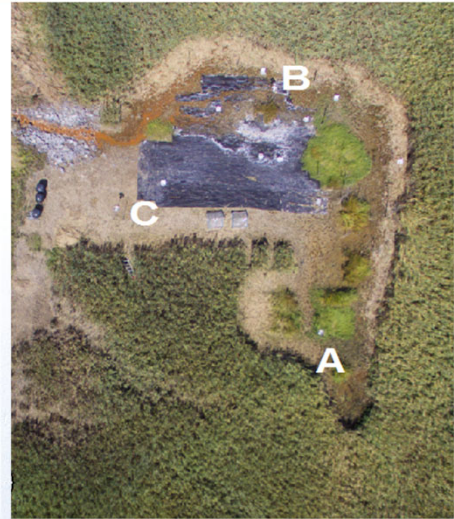
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3. How much salt is mobilized?

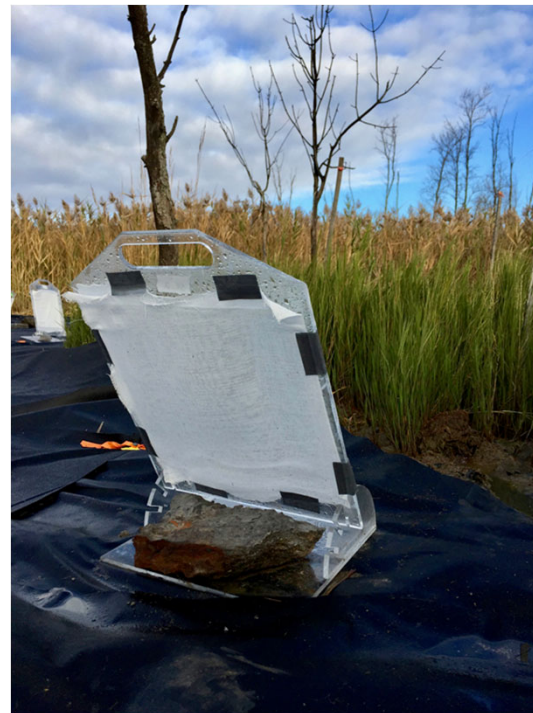
- wind
- dev
- cap
- che
- pla



Field Capture of Salt



plexiglass columns



cheesecloth mounts

ground level



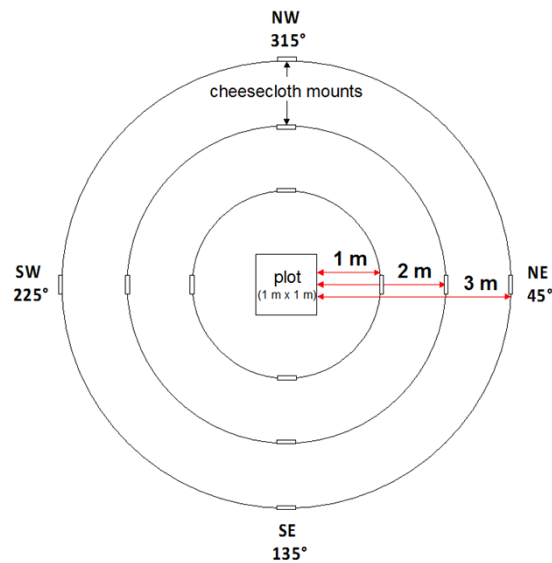
dustfall samplers

2.5 m height

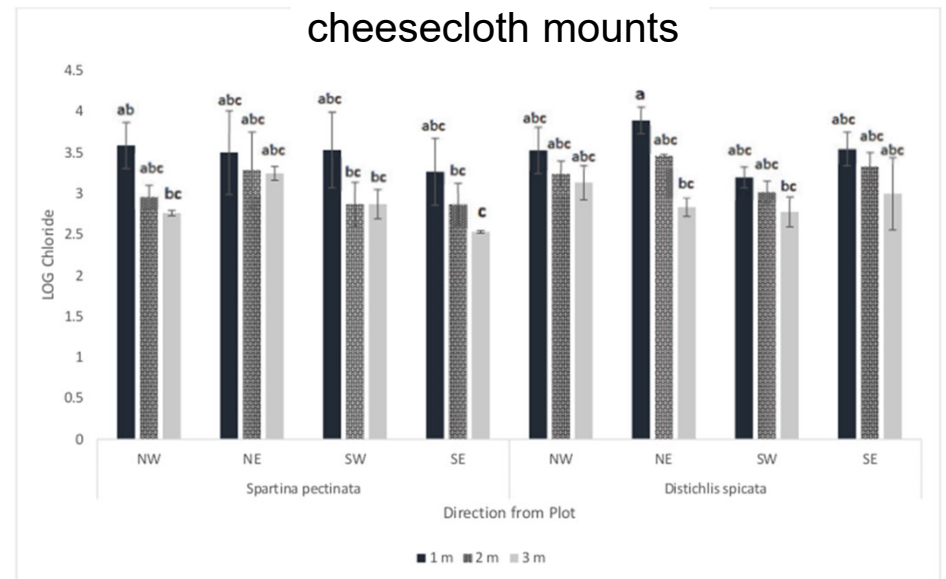


Salt Capture at Ground Level

experimental set-up



cheesecloth mounts

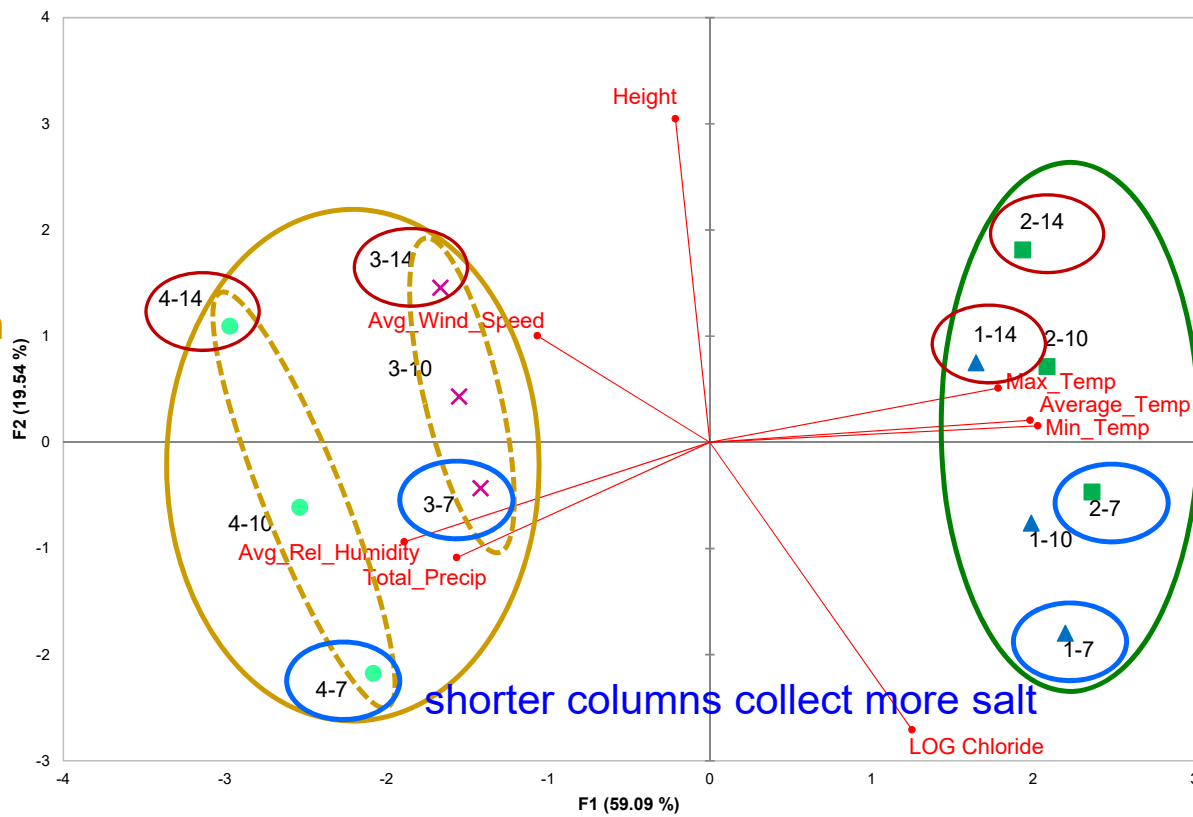


- amt. of salt captured ↓ with ↑ distance
- 2 methods (columns & cheesecloth mounts) are comparable
- 130,000 - 137,000 μg salt dispersed/week

PCA - Field Collection of Salts



samples collected in October correlate with higher wind speeds, humidity, and precipitation



samples collected in June/July correlate with higher temperatures

shorter columns collect more salt

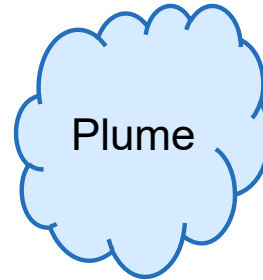
▲ Jun. 23/16 - Jun. 30/16 ■ Jul. 14/16 - Jul. 21/16 ✕ Oct. 06/16 - Oct. 13/16 ● Oct. 13/16 - Oct. 20/16

Basic Haloconduction Model



1.

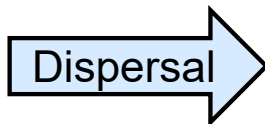
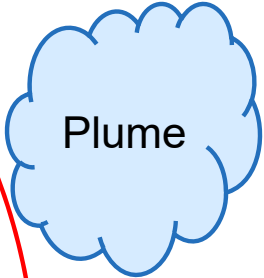
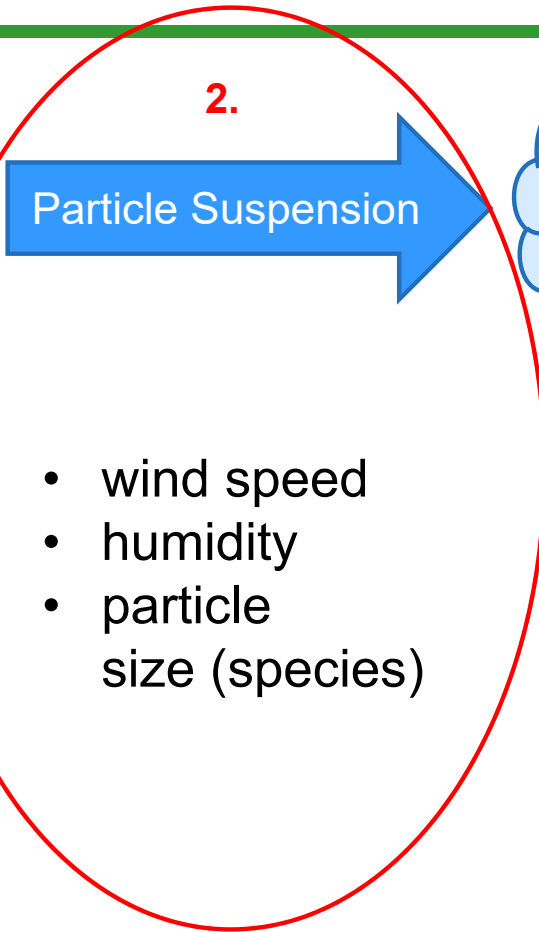
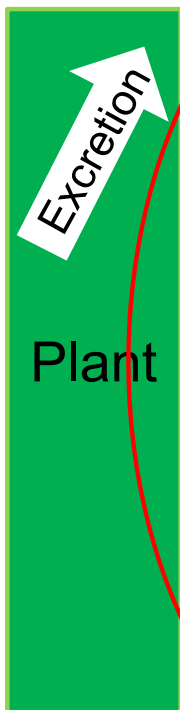
- species-level differences
- [soil]
- time of year



Basic Haloconduction Model



- species level differences
- [soil]
- weather



Basic Haloconduction Model



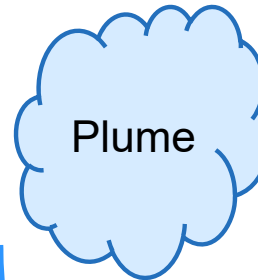
- species level differences
- [soil]
- time of year

Uptake



Particle Suspension

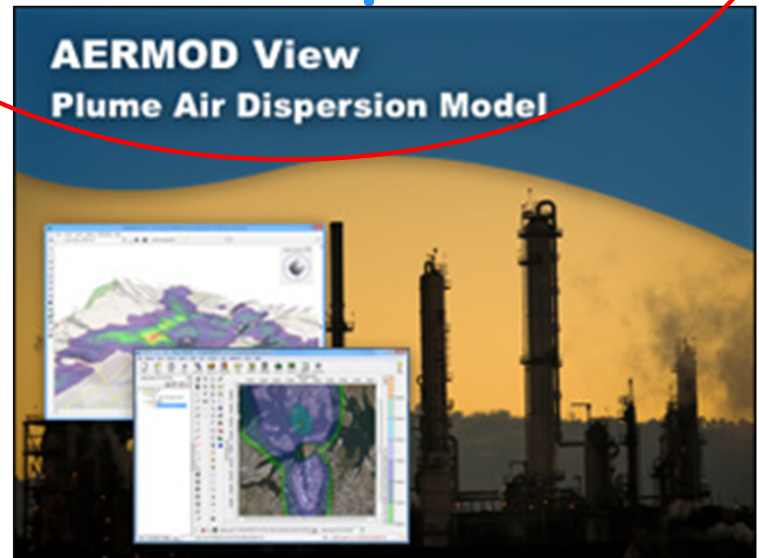
- wind speed
- humidity
- particle size (species)



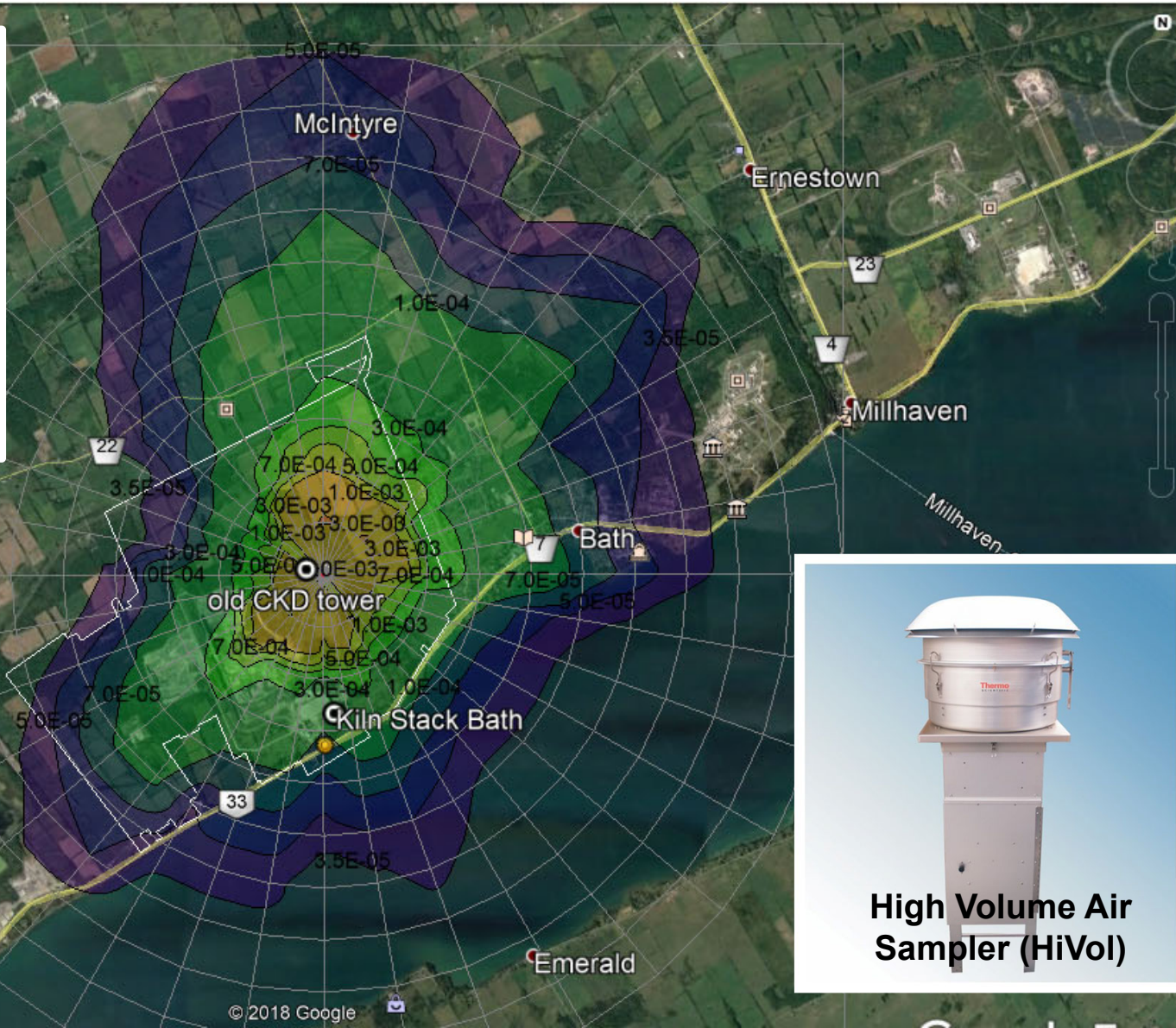
3.

Dispersal

Deposition



PLOT FILE OF PERIOD VALUES AVERAGED ACROSS 0 YEARS FOR SOURCE: (gmp08): A
Max: 3.5E-03 [ugm³] at (356361.54, 4863745.71)



Summary

Phytotechnologies have role to play in remediation of salt-contaminated sites

1. Accumulator halophytes - remediation 3-9 yrs
 - coupled with composting (achieves ~88% [Cl⁻] in plant waste)
2. **First study to demonstrate haloconduction in the field**
 - capture & quantification of salts
 - evidence that haloconduction can work as a remediation strategy
 - modelling studies of dispersed salt underway



S. pectinata growing in RMC lab



Photo: Anita-Daria Andriescu



Acknowledgements



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Queen's
UNIVERSITY

LAFARGE



NSERC
CRSNG

Questions?

