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Development of soft tailings capping technology – first step towards creating stable and sustainable boreal landscapes

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Background



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Objectives

- Three year study to evaluate wetland and upland species performance on thinly capped treated tailings
 - Assess plant health and development, plant biomass and plant tissue chemistry
 - Monitoring soil moisture, temperatures, and rooting depths
 - Monitor changes in tailings and capping materials (PHCs, NAs and inorganics)
 - Evaluated changes in microbial functional structure in the substrates and transcript level responses of plants



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Tailings Properties

	Centrifuge Tailings	Co-Mix Tailings	Thickened Tailings
Solids (%)	59	66	80
pH	7.8	7.6	8.7
EC (dS/m)	2.0	3.5	1.0
SAR	4.3	5.3	1.9
Dean Stark (% Bitumen)	4.8	0.5	0.6
Sand (%)	18	26	70
Silt (%)	79	37	17
Clay (%)	3	37	13



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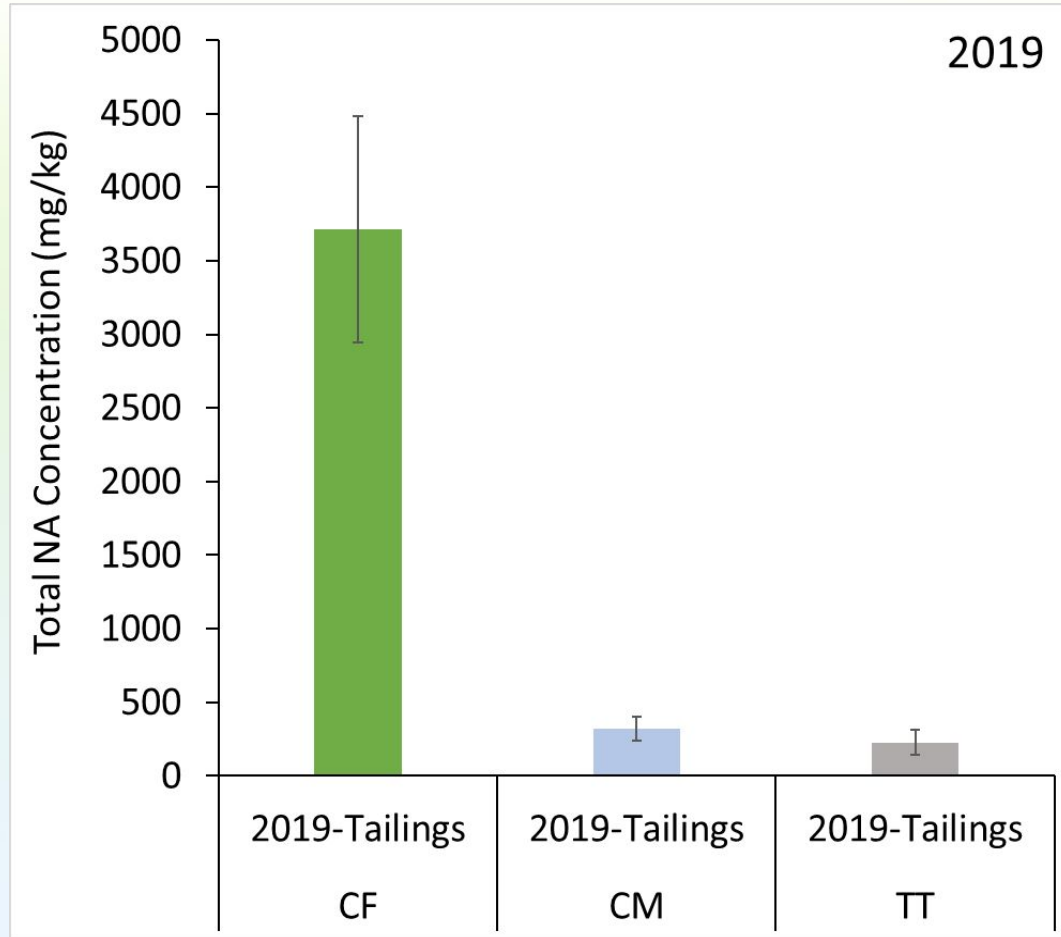


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Tailings Properties: Naphthenic Acid



- We utilize Orbitrap-MS for characterization of the NAFCs
- The most toxic components of AOSR bitumen-derived NAFCs are the O₂ NAFCs
- O2 Class for all three types (>95%) as opposed to the oxidized species of NAFC O4, O5, O6

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Experimental Setup



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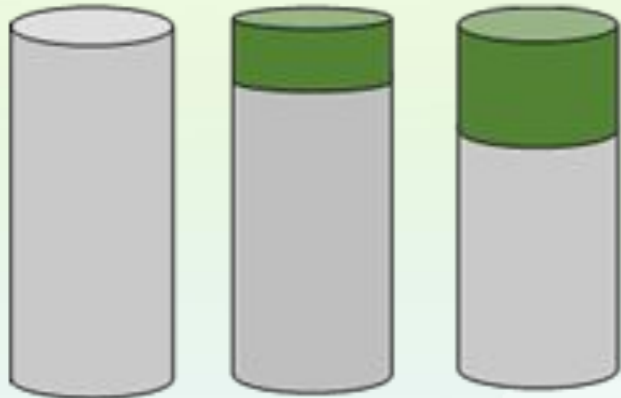
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Tailings Types and Capping Treatments

Centrifuge and Thickened Tailings



Control
90 cm tailings

10 cm PMM
80 cm tailings

30 cm PMM
60 cm tailings

Co-Mix Tailings



90 cm CM Tailings

5 cm PMM
85 cm CM tailings

5 cm PMM
15 cm Till
70 cm CM tailings

5 cm PMM
35 cm Till
50 cm CM tailings

5 cm PMM
85 cm Till

4 reps per each treatments

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Centrifuge Tailings: Shrubby Fen

Salix bebbiana ✓

Scirpus microcarpus ✓

Betula pumila ✓

Rumex occidentalis ✓



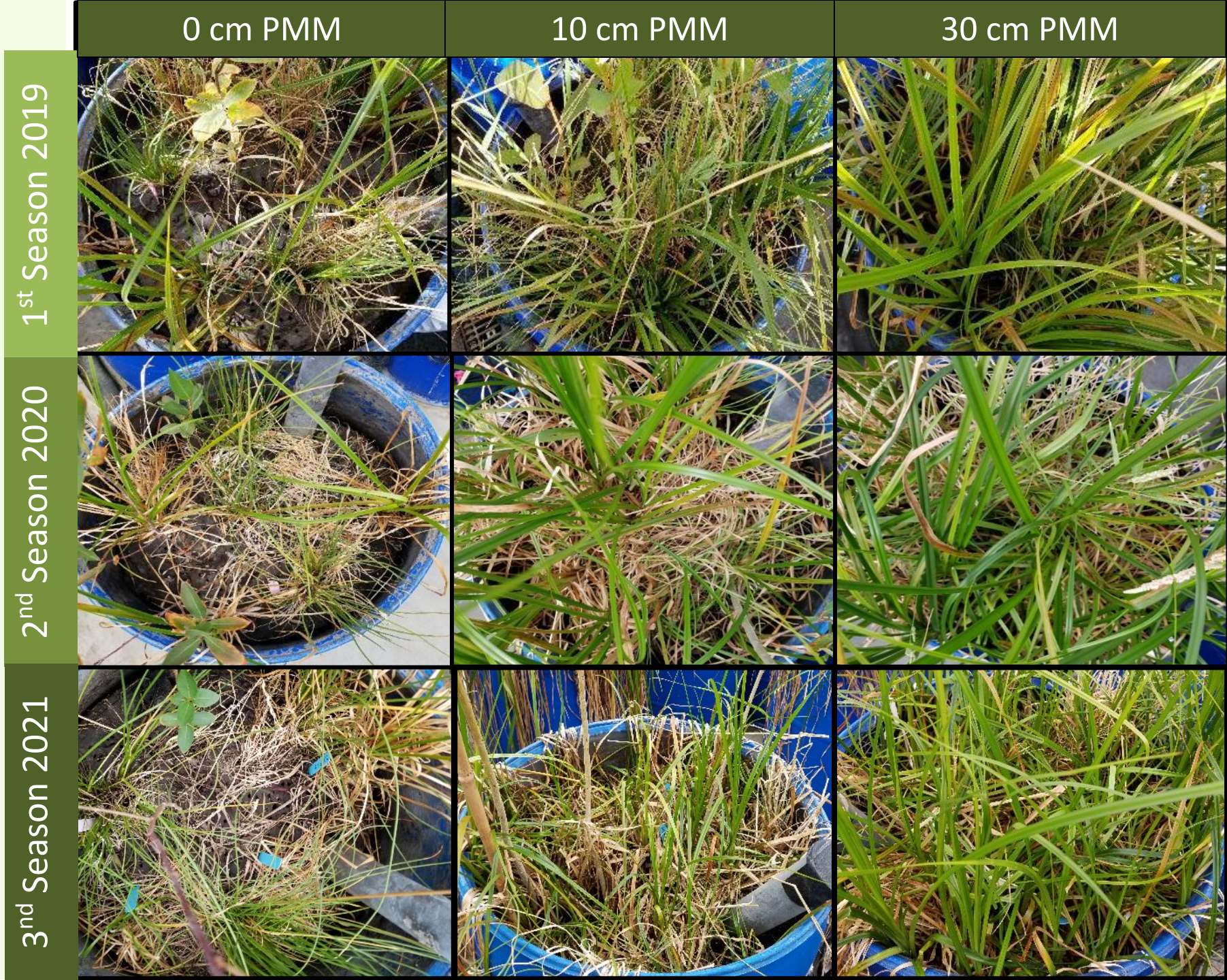
Centrifuge Tailings: Graminoid Fen

Salix bebbiana ✓

*Beckmannia
syzigachne* X

Triglochin maritima X

Scirpus microcarpus



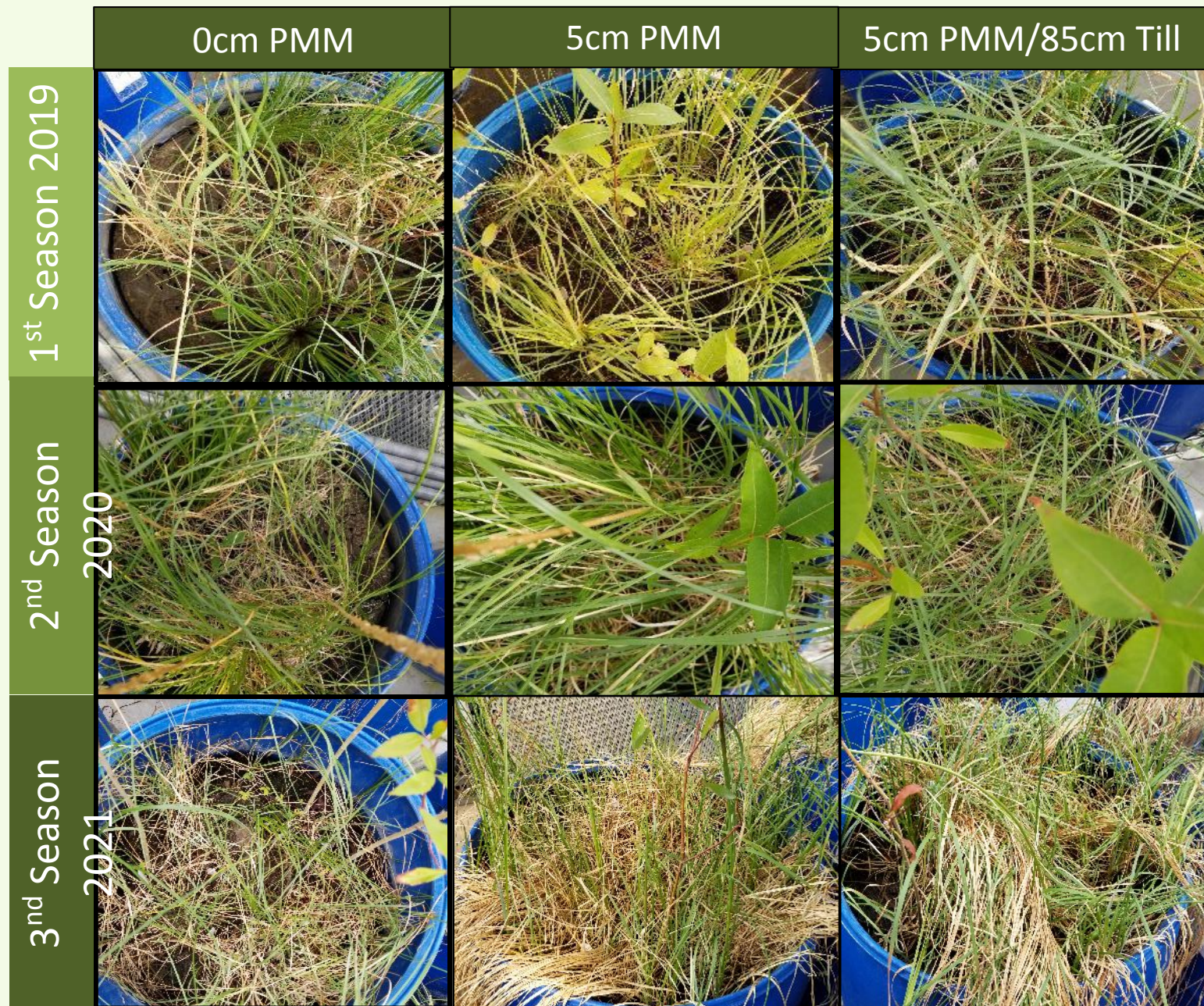
Co-Mix Tailings: Graminoid Fen

Salix bebbiana ✓

Beckmannia syzigachne ✓

Triglochin maritima X

Carex aquatilis ✓



Thickened Tailings: Wetland

Salix bebbiana ✓

Carex aquatilis ✓

Triglochin maritima X

Scirpus microcarpus
✓

Rumex salicifolius ✓

	0 cm PMM	10 cm PMM	30 cm PMM
1 st Season 2019			
2 nd Season 2020			
3 rd Season 2021			

Thickened Tailings: Upland

Populus tremuloides



Cornus stolonifera



Pinus banksiana



Elymus trachycaulus



0 cm PMM

10 cm PMM

30 cm PMM

1st Season 2019



2nd Season 2020

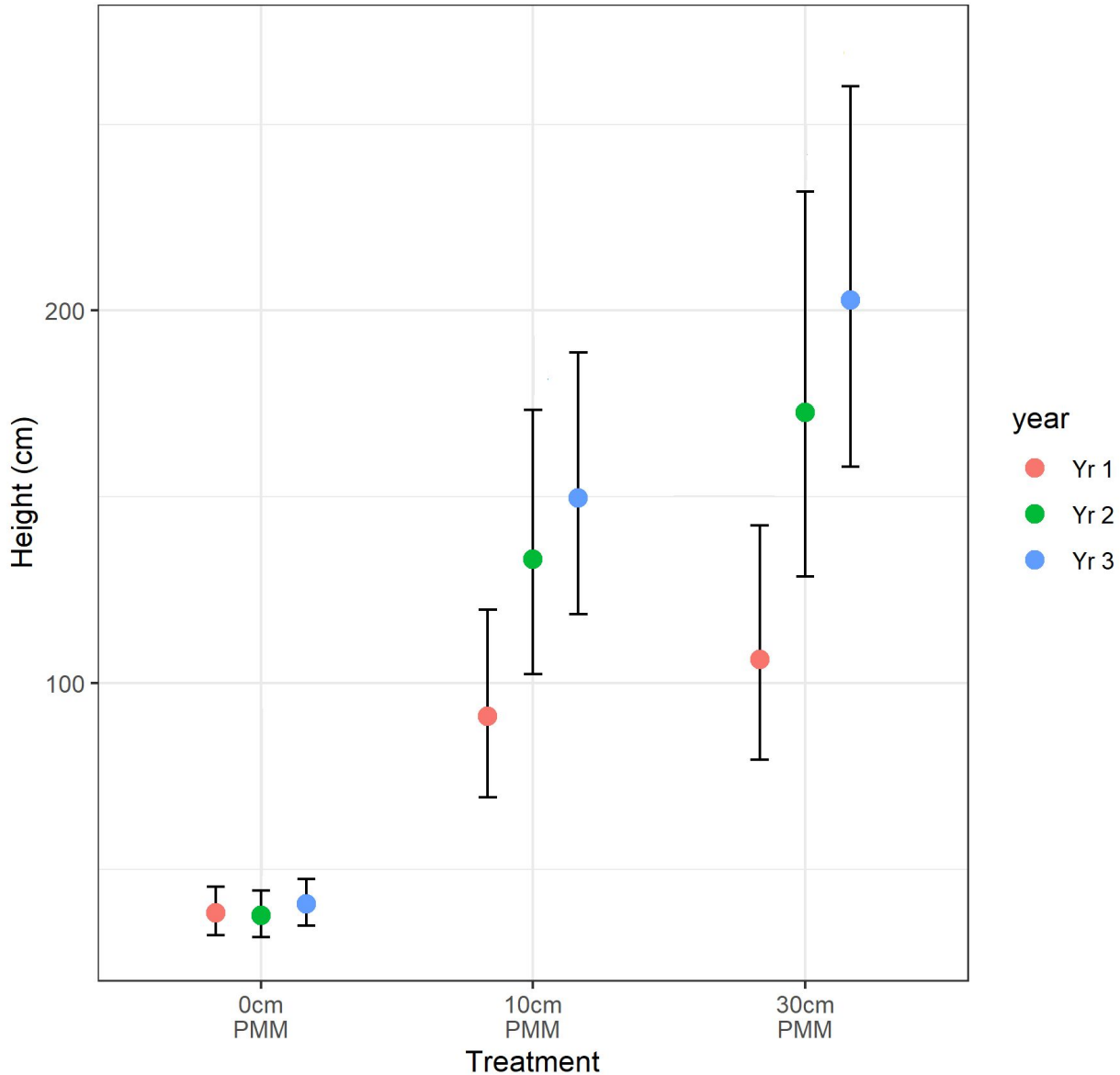


3rd Season 2021

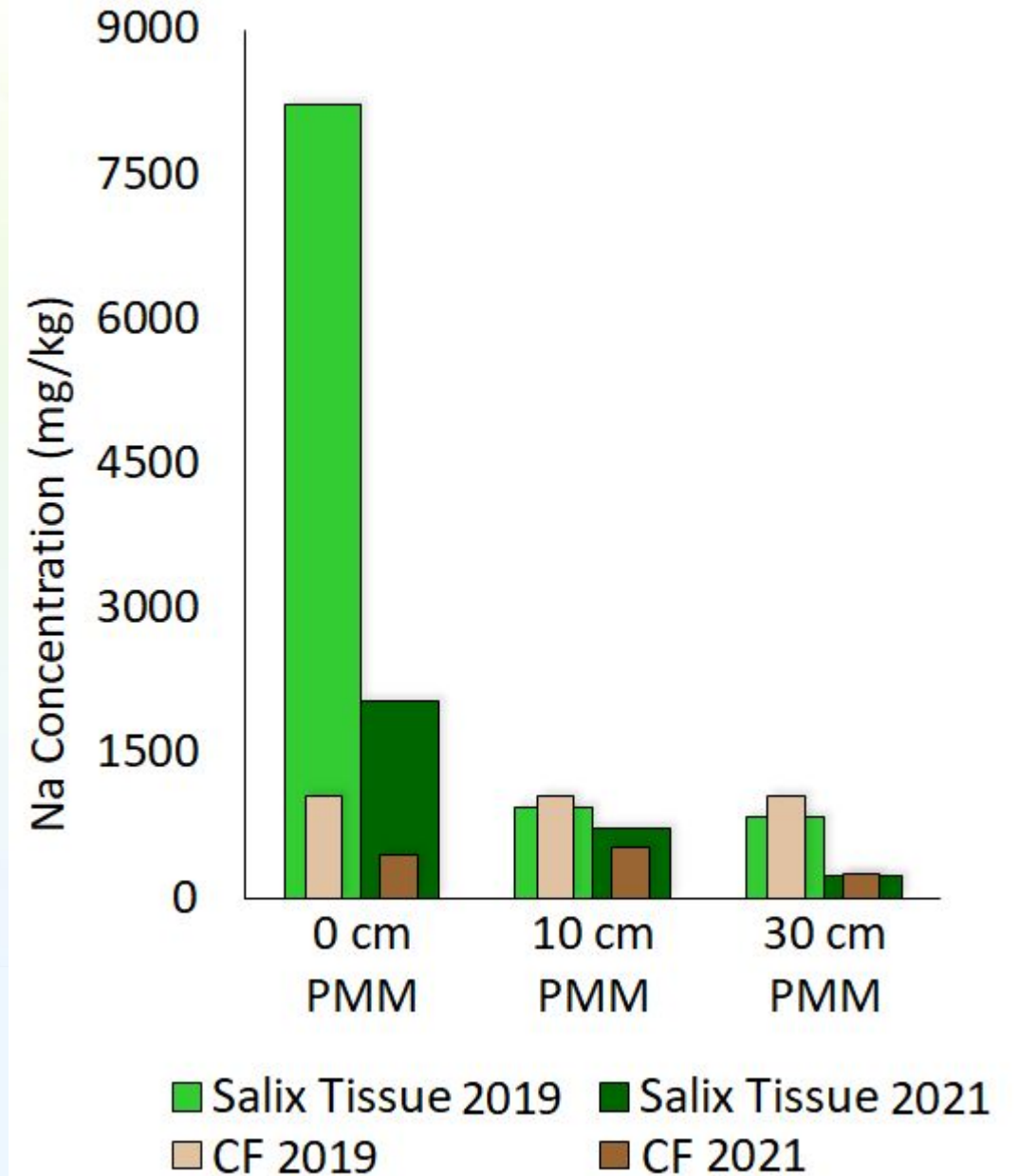


Plant Tissue - Sodium

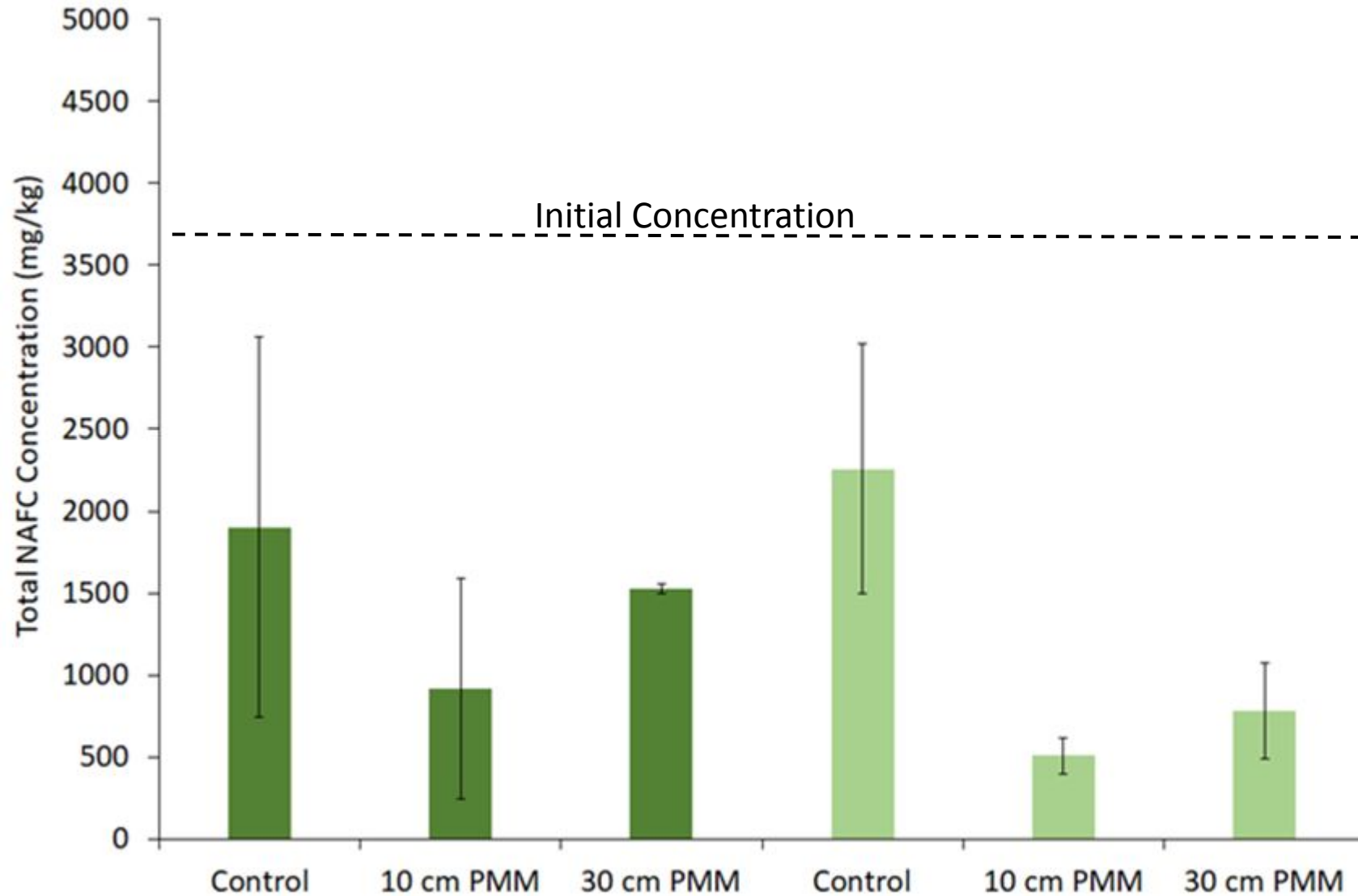
Centrifuged Tailings



CF - Shrubby Fen - Salix - Na



Tailings - Naphthenic Acid



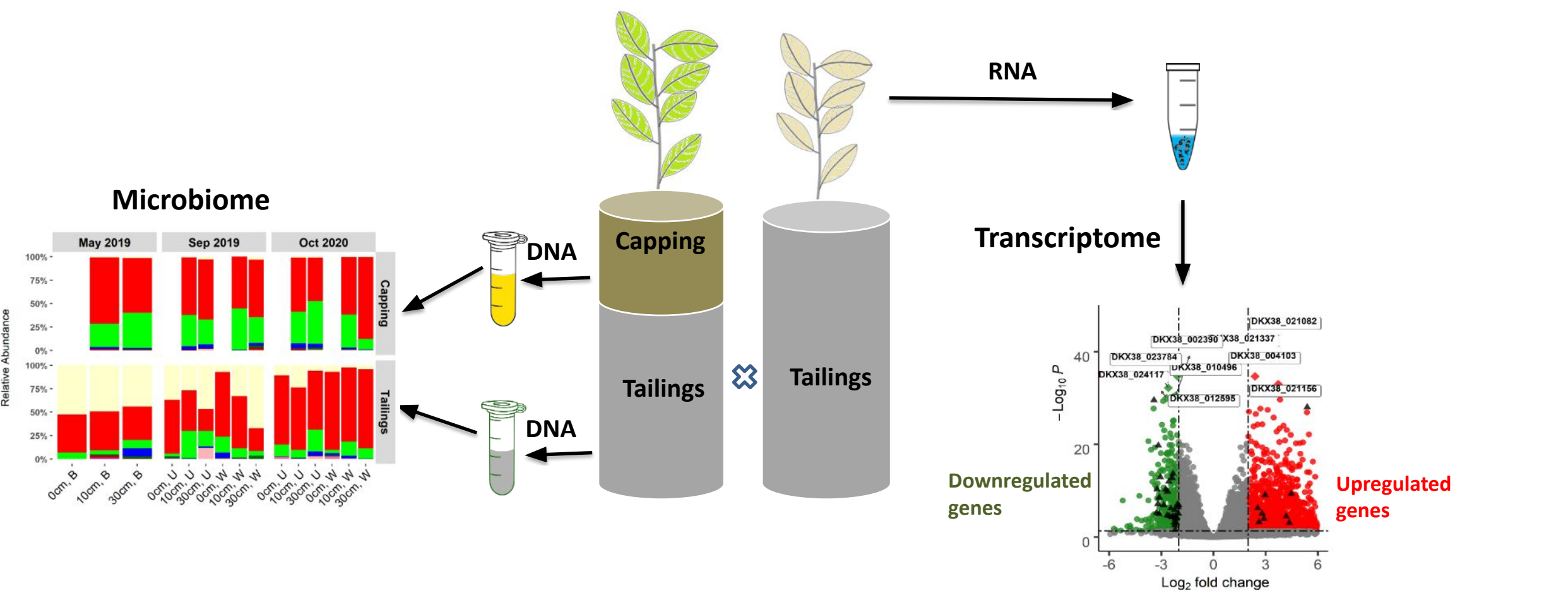
Centrifuge Tailings - 2021

Graminoid Fen: Control
 10 cm PMM
 30 cm PMM

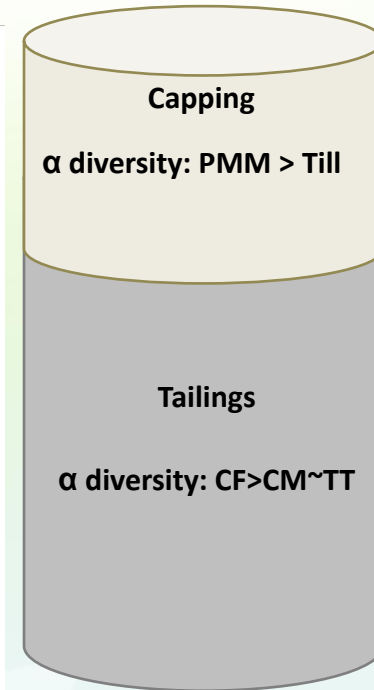
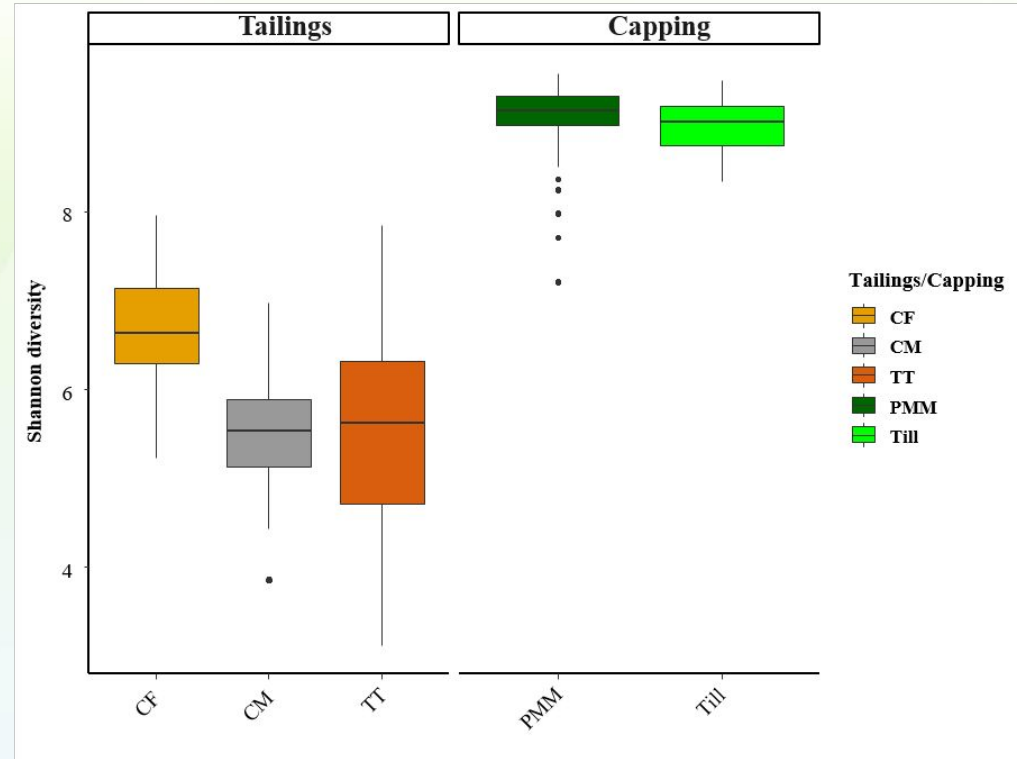
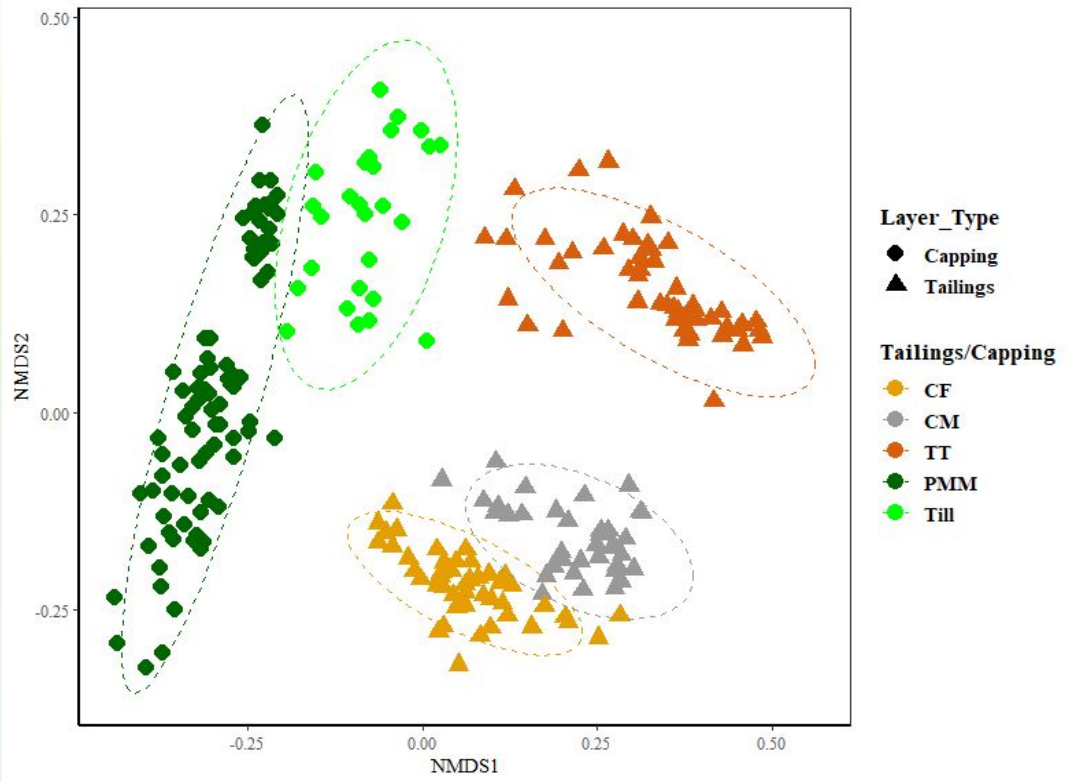
Shrubby Fen: Control
 10 cm PMM
 30 cm PMM



Genomics Analysis: Microbial DNA, Plant RNA



Microbial Diversity



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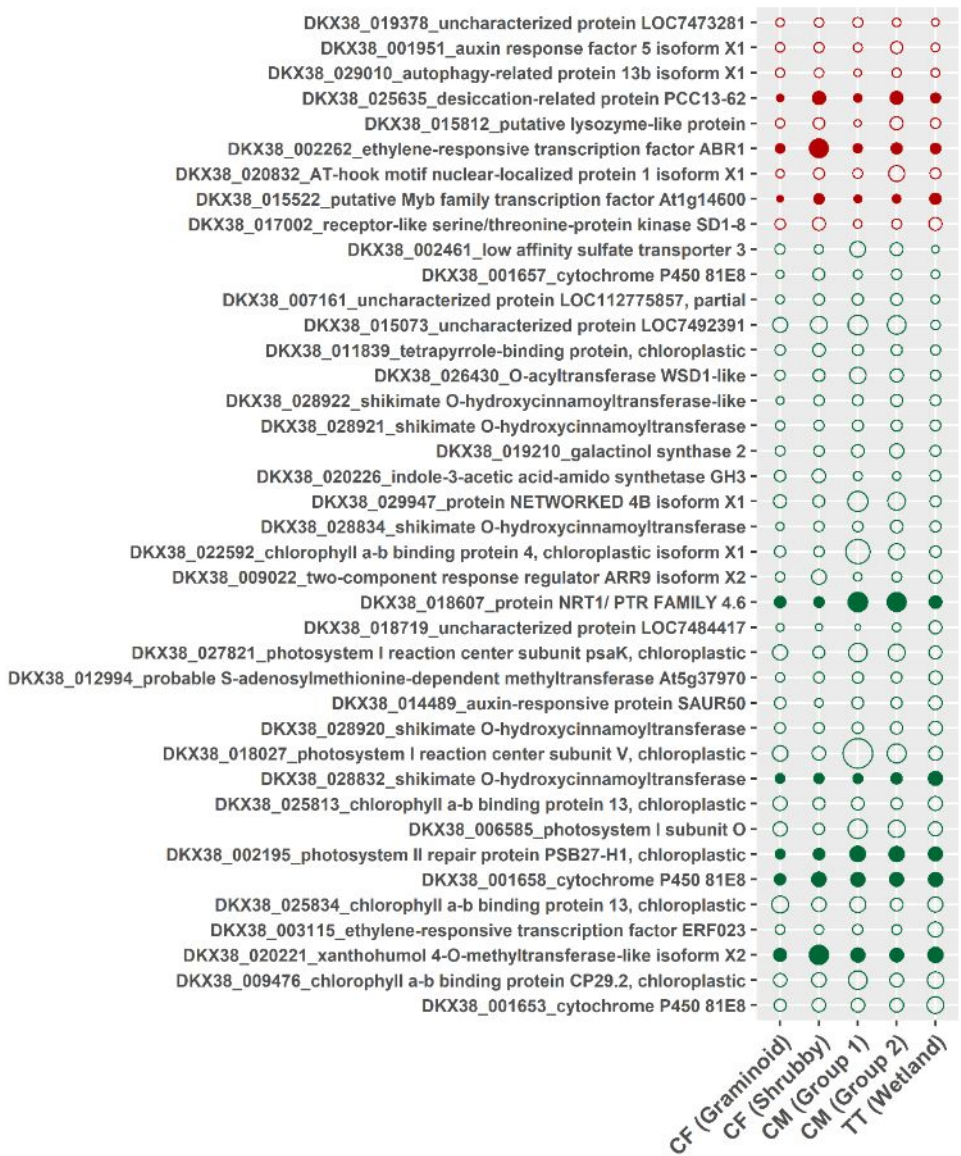


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Plant Transcriptomics: Genes Identified



Plant hormones and stress-responsive transcription factors

Shared genes

- Upregulated
- Downregulated

$-\log_{10}(p_value)$

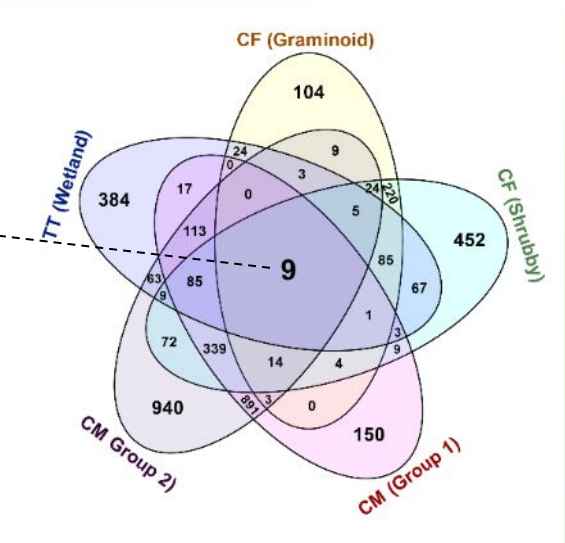
- 25
- 50
- 75

qPCR_validation

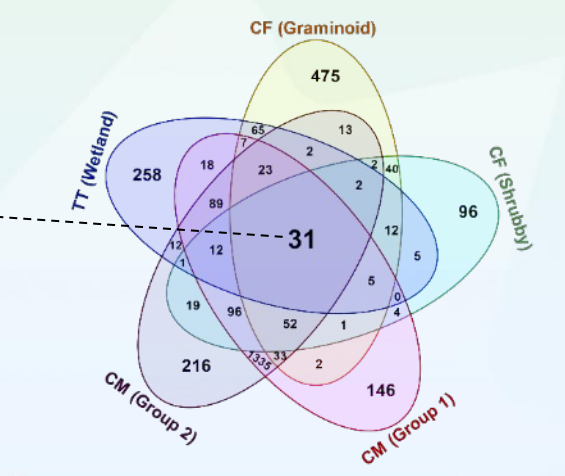
- No
- Yes

Photosynthetic activity and chloroplast structure and function

Upregulated Genes



Downregulated Genes



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Summary

- The cap enhanced plant growth and establishment in the first 3 years by reducing the exposure and uptake of the harmful compounds
- Clay-dominated tailings have reduced plant available water, higher root resistance compared to sand-dominated tailings
- *The best performing woody species: Salix bebbiana, Pinus banksiana, Populus tremuloides, Cornus stolonifera*
- *Best performing Graminoid species: Carex aquatilis and Scirpus microcarpus*



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How can soft tailings material be used in reclamation to create sustainable boreal landscapes?

Tailings, a mixture of water and fine to sandy materials, are a by-product of oil sands extraction. Several treatment technologies are being used to remove water and enhance the consolidation of tailings materials into a more solid, trafficable substrate. Both terrestrial and wetland reclamation scenarios are being considered as final closure landforms. This study will help to understand the impacts of various capping treatments on treated tailings and plant communities.

In this greenhouse experiment we tested different types of tailings, depths and combinations of capping materials to learn which native plant species grow best under which conditions. We tested both upland and wetland plant communities.



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After three growing seasons, we have observed that **plant survival and growth improved with increasing depth of peat mineral mix and till.** Our final results improve our understanding of species responses over time to different types of tailings and capping materials as reclamation cover soils.



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