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PTAC Soil and Groundwater Forum - 2009

Development of Assessment and Remediation Approaches for Saline Water Releases to Canadian Boreal Peatland Environments:

2008 Progress Report
(Phase II Research Activities)

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- This project is intended to develop contaminated sites assessment and remediation approaches for saline water releases to western Canadian wetland environments.

- Formal approaches have been established for the remediation of salt ion releases to terrestrial soils or fish bearing waters; however, wetland ecosystems - and especially peatland ecosystems – are sufficiently different in their geochemical and ecological characteristics/functioning that established regimes are of doubtful applicability.

PROJECT OBJECTIVES (continued)

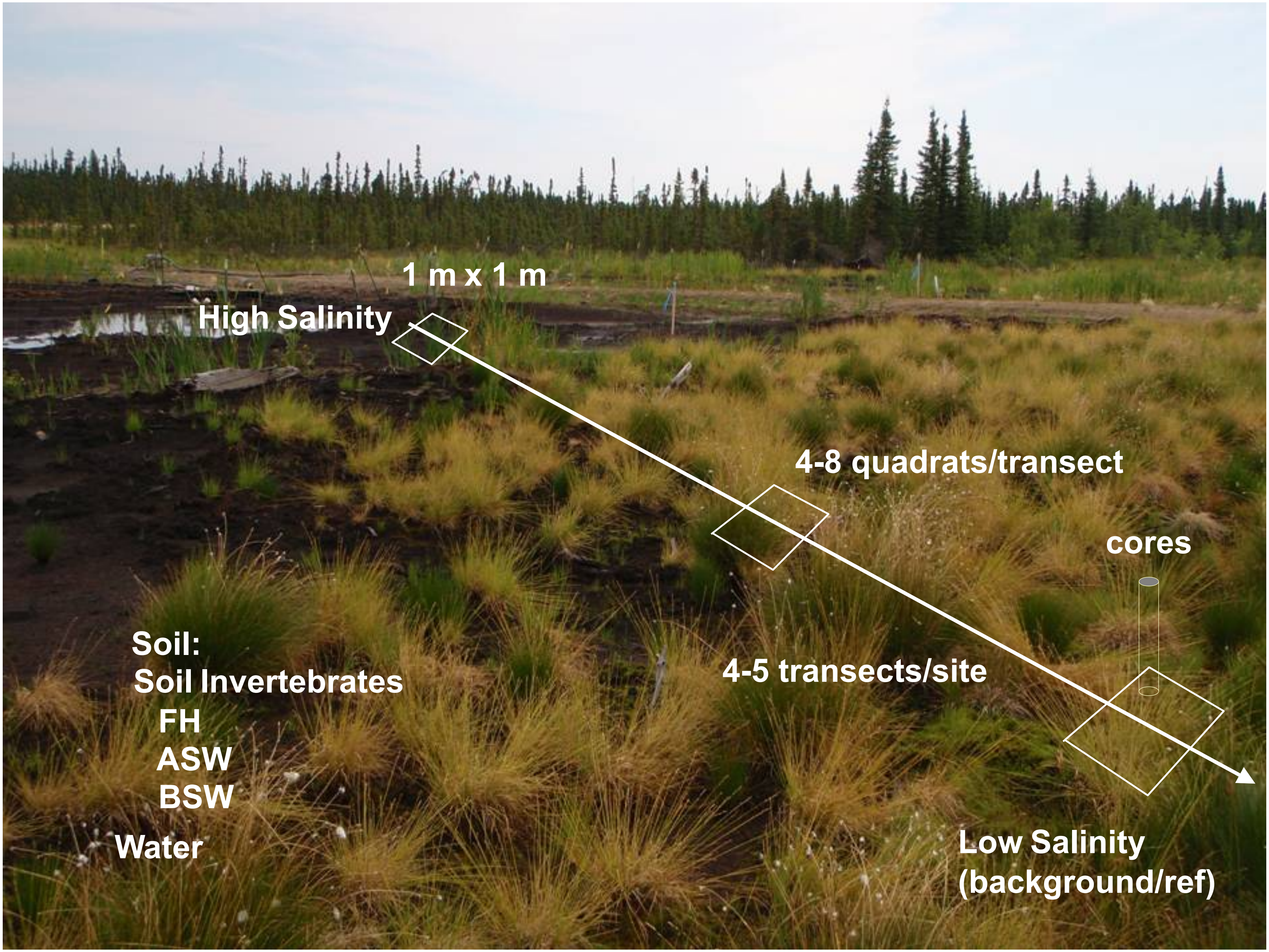
- Phase I: Literature Review: *"Risk Based Salinity Guidelines for Peatlands. Phase 1: Literature Review and Gap Analysis"* (May 2008)
  (http://www.ptac.org/env/dl/envp0808r.pdf)
- Phase II: Evaluation of ecological risks at produced water release field sites
  - Site screening/selection (Summer 2008)
  - Field sampling (August 2008)
  - Second round? (Summer of 2009)
- Phase III: Develop guidance document that presents risk-based thresholds for the protection of important peatland biota and habitats (2010)

Site Selection

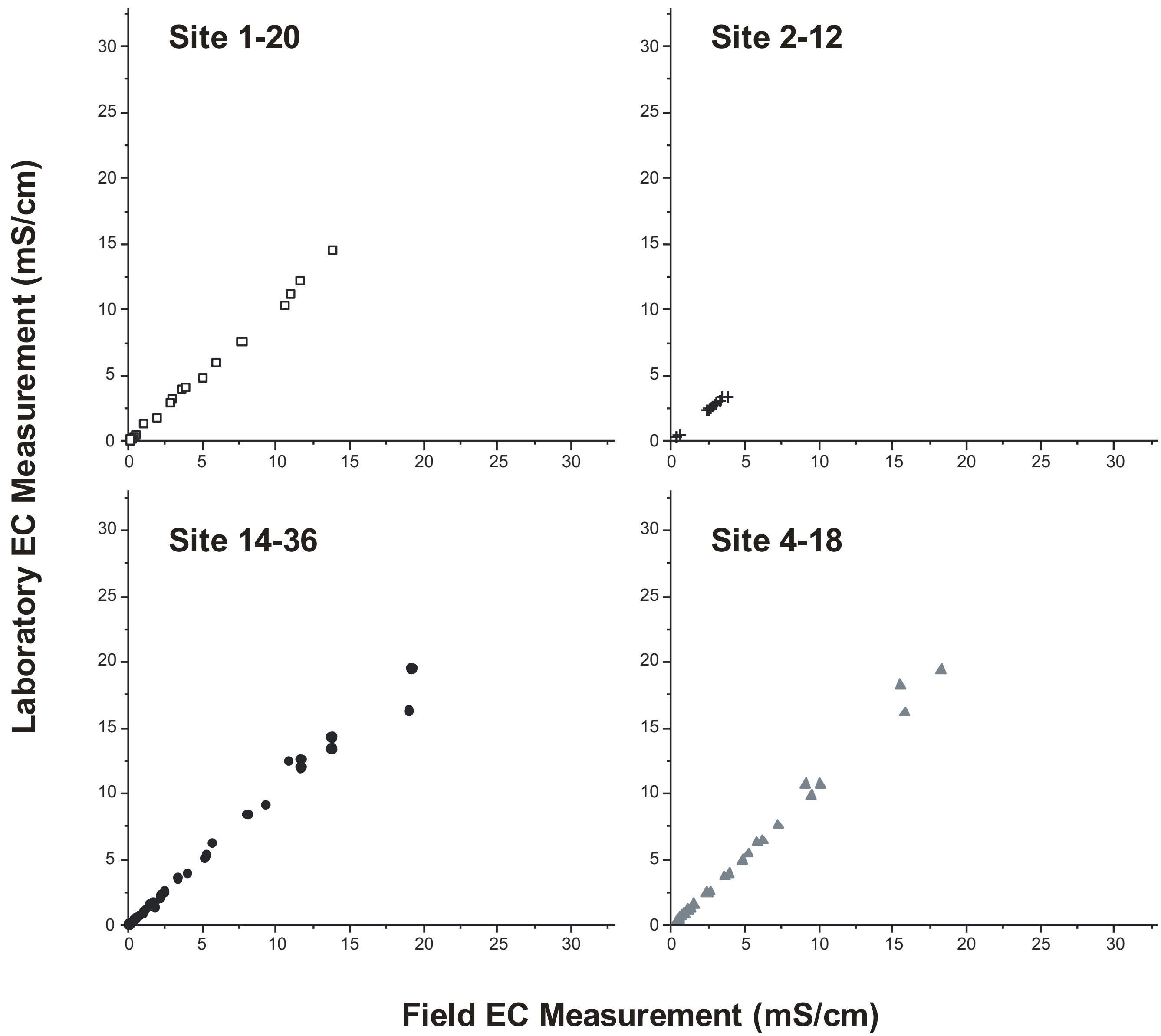
Site Name	Abbreviated Name	Saline Water Release Type	Locale
Kidney 01-20-091-05 W5M	1-20	Pipeline Release (July 2004)	~70 km NE of Red Earth, AB
05-05-93-05 W5M	5-05	Pipeline Release, identified Mar. 14, 2007	~60 km N. of Red Earth, AB
4-18-72-04 W5M	4-18	Emulsion line rupture in winter. Salt water run off on ice / snow toward lake and melted - surface impacts. Reed grass/ lake margin marsh environment.	Near Mitsue Lake
14-36-70-04 W5M	14-36	Emulsion pipeline rupture. Forest fire back in 1998 and 2001	Mitsue
7-19-80-08-W5M	7-19	Line break occurring on or prior to 21 April 2003.	Nipisi
12-14-79-08-W5M	12-14	Corrosion in the T connecting the well. 250 m3 produced water spill, in Feb. 2002	Nipisi
13-14-79-08-W5M, Well 285H	13-14	On 20 June 07, 100 m3 oil emulsion spill occurred on the flow line from Well 285H to Satellite 16.	Nipisi
02-12-80-08-W5M, Nipisi Well 344	2-12	oil emulsion spill of an estimated 315 m3 (August 7th, 2005).	Nipisi

- Sampling objective at each site was to obtain co-located samples for the evaluation of soil and water chemistry, bryophyte and vascular plant presence and abundance, and soil microarthropod community composition.

- desire to evaluate these variables across the available range of salt concentrations in surficial soils (within the biologically active zone), so that salt concentration – biotic response relationships could be formally assessed.


1 m x 1 m
High Salinity
4-8 quadrats/transect
cores
4-5 transects/site
Soil:
Soil Invertebrates
FH
ASW
BSW
Water
Low Salinity
(background/ref)

Range of Electrical Conductivities Encountered in Peatland Site Water



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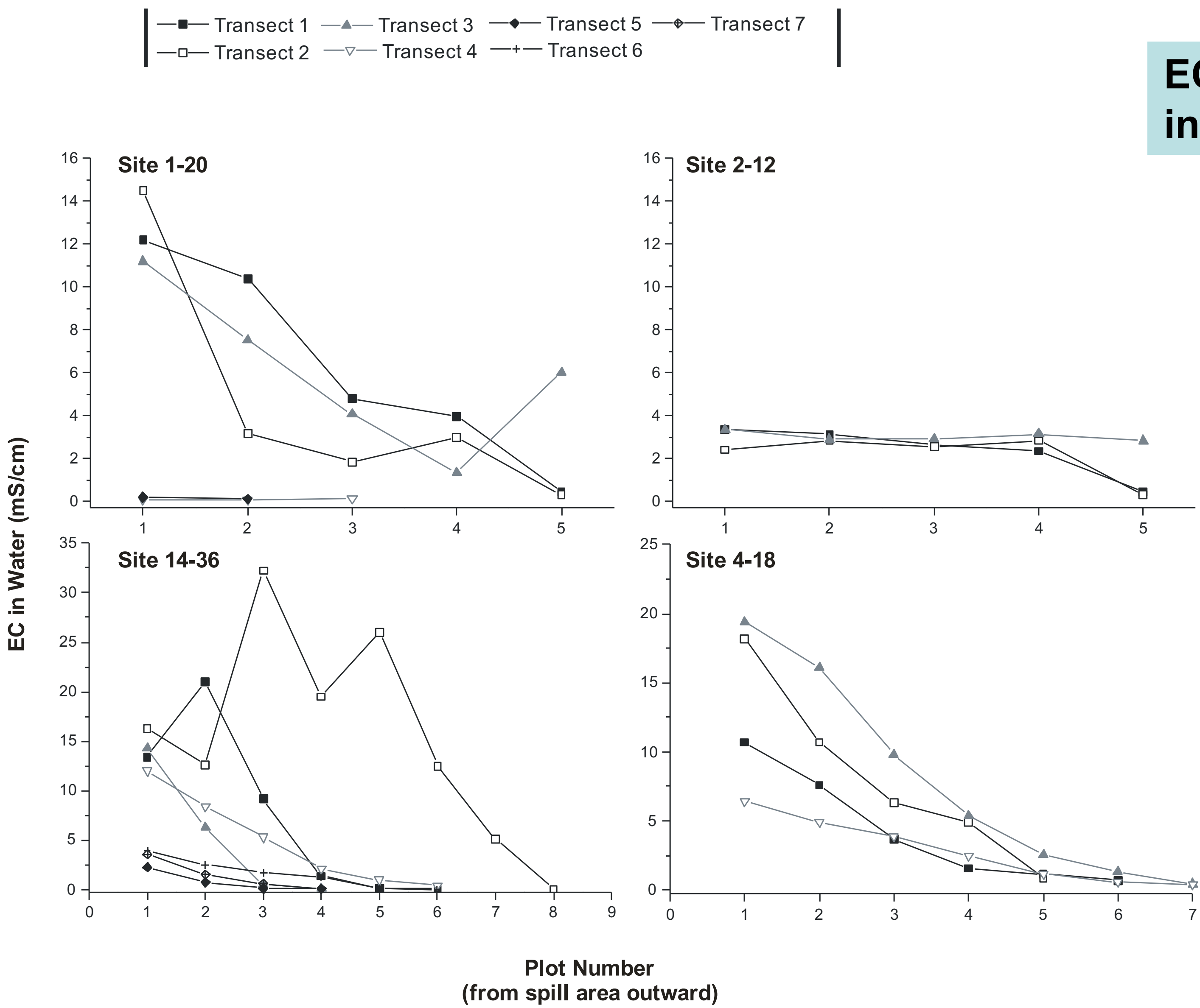
EC Gradients in Field Plots



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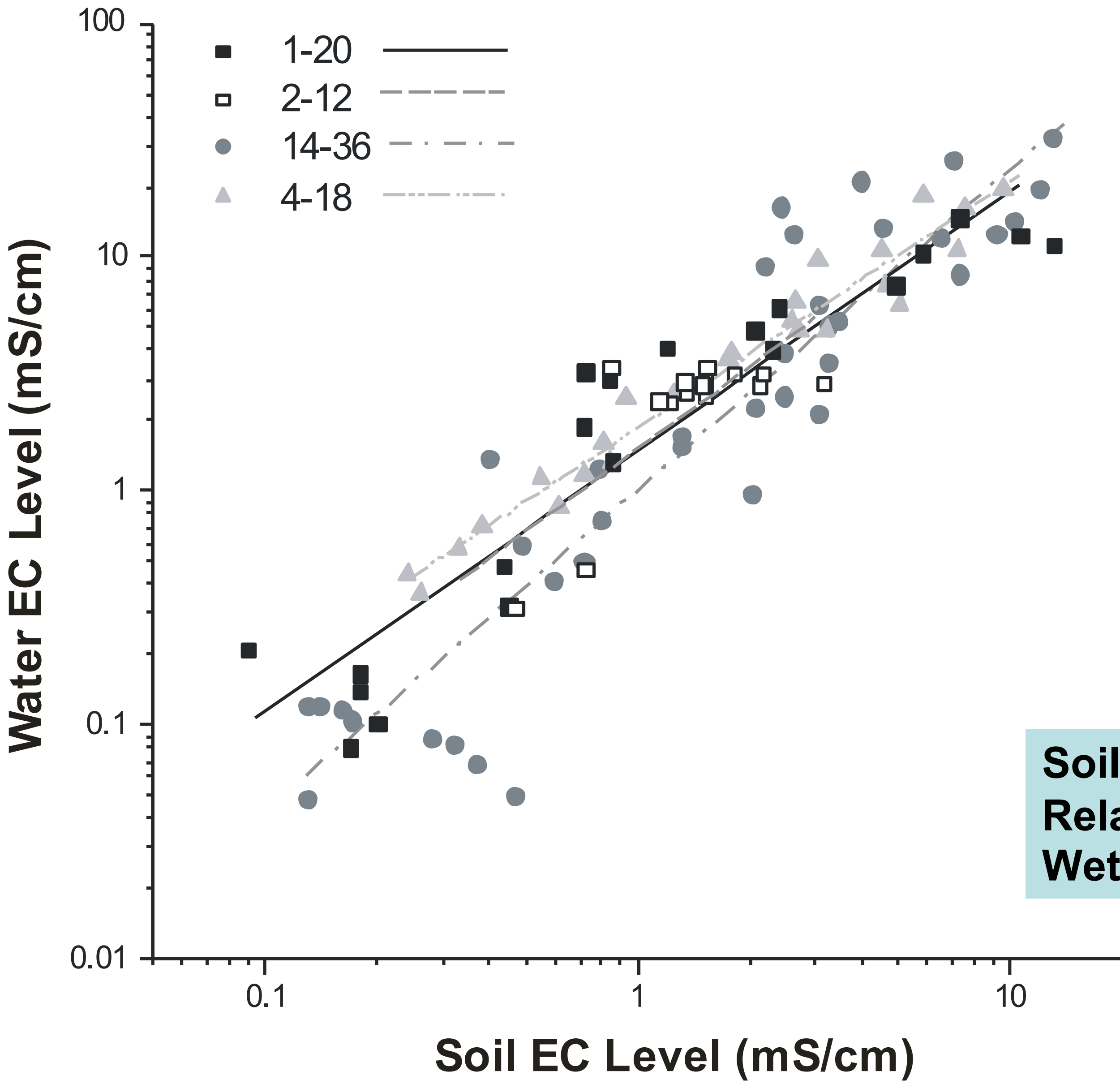
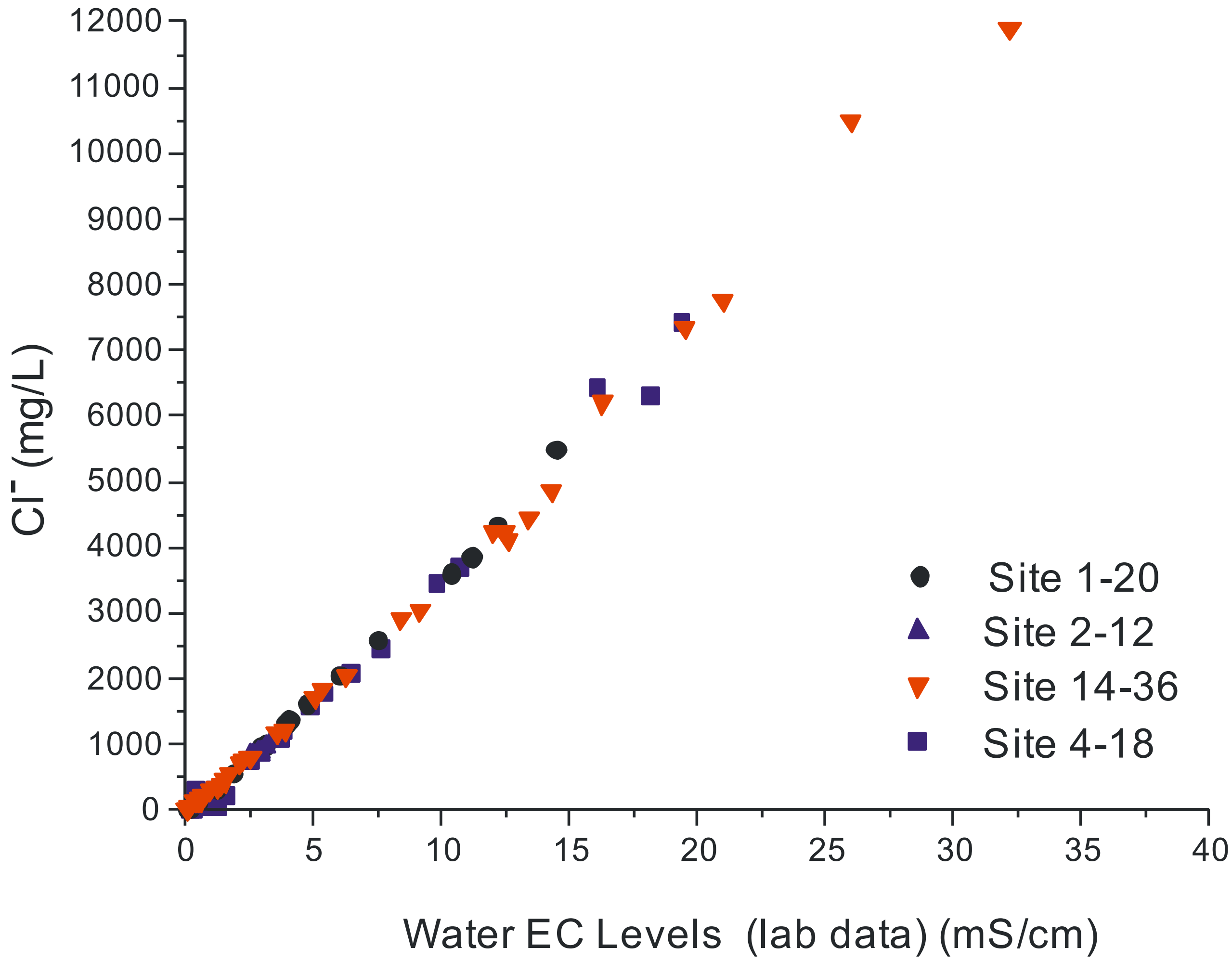


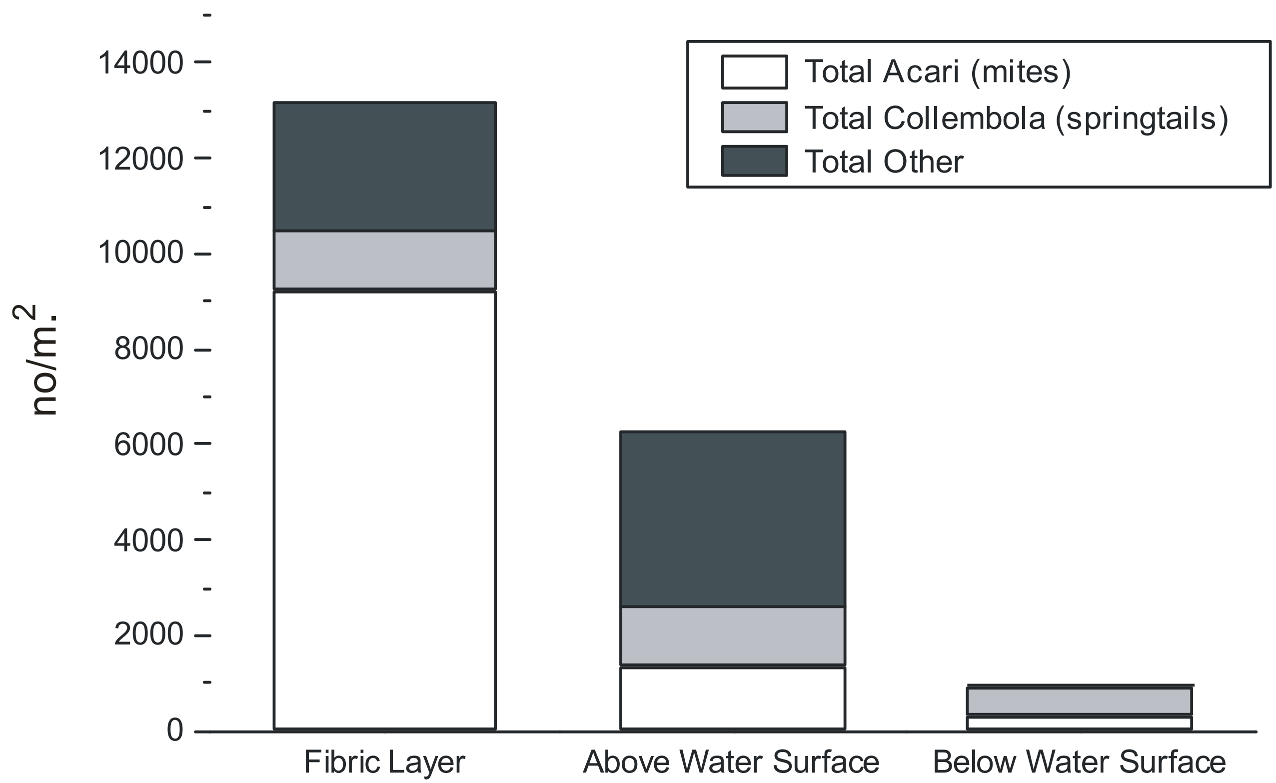
Soil-Water EC Relationships at Four Wetland Sites

Table A: Predictive Relationships for EC and Other Salt Ions in Field Plots

Site	Ion	Soils Data: Y = a[EC] + b			Water Data: Y = a[EC] + b		
		a	b	r^2	a	B	r^2
1-20	Ca^{2+}	278.8	141	0.920	57.8	1.17	0.985
1-20	Mg^{2+}	41.2	32.3	0.912	8.56	1.89	0.983
1-20	Na^{+}	754	223	0.918	137	-17.4	0.998
1-20	K^{+}	1.81	113	0.0026 (ns)	1.87	0.437	0.959
1-20	Cl^{-}	1808	346	0.919	1594	-2719	0.385
1-20	SO_4^{2-}	-1.24	42.6	0.115	0.0809	0.748	0.526
2-12	Ca^{2+}	632	-16.7	0.524	33.1	32.3	0.712
2-12	Mg^{2+}	108	30.9	0.441	4.71	10.2	0.609
2-12	Na^{+}	1928	-181	0.520	137	-40.5	0.993
2-12	K^{+}	16.9	151	0.0164 (ns)	2.30	-0.0859	0.544
2-12	Cl^{-}	4528	-427	0.543	332	-75.6	0.995
2-12	SO_4^{2-}	-16.0	194	0.0193 (ns)	-3.29	17.6	0.145
14-36	Ca^{2+}	448	-1.67	0.813	49.9	-15.4	0.989
14-36	Mg^{2+}	67.8	35.9	0.797	7.42	2.23	0.986
14-36	Na^{+}	1554	-142	0.784	167	-71.8	0.996
14-36	K^{+}	23.5	166	0.204	1.87	0.560	0.965
14-36	Cl^{-}	3562	-208	0.806	374	-117	0.995
14-36	SO_4^{2-}	19.6	13.9	0.575	3.35	-6.36	0.783
4-18	Ca^{2+}	329	109	0.868	65.0	21.9	0.996
4-18	Mg^{2+}	60.2	46.9	0.850	11.1	15.6	0.963
4-18	Na^{+}	766	-49.5	0.878	140	-76.8	0.992
4-18	K^{+}	9.62	38.5	0.215	1.60	-1.75	0.825
4-18	Cl^{-}	2019	-84.2	0.889	380	-236	0.992
4-18	SO_4^{2-}	5.51	26.3	0.128	0.887	-1.35	0.262



EC Levels in Soil or Water Were Highly Correlated with Other Measures of Salinity



Relative Abundance (No./m²) of Soil Invertebrates by Soil Strata

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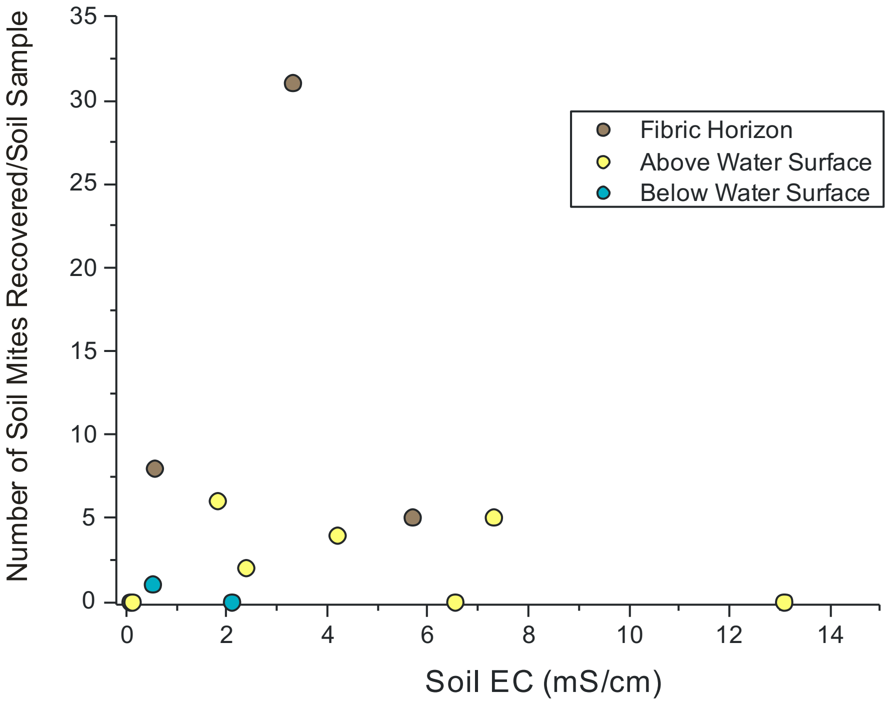
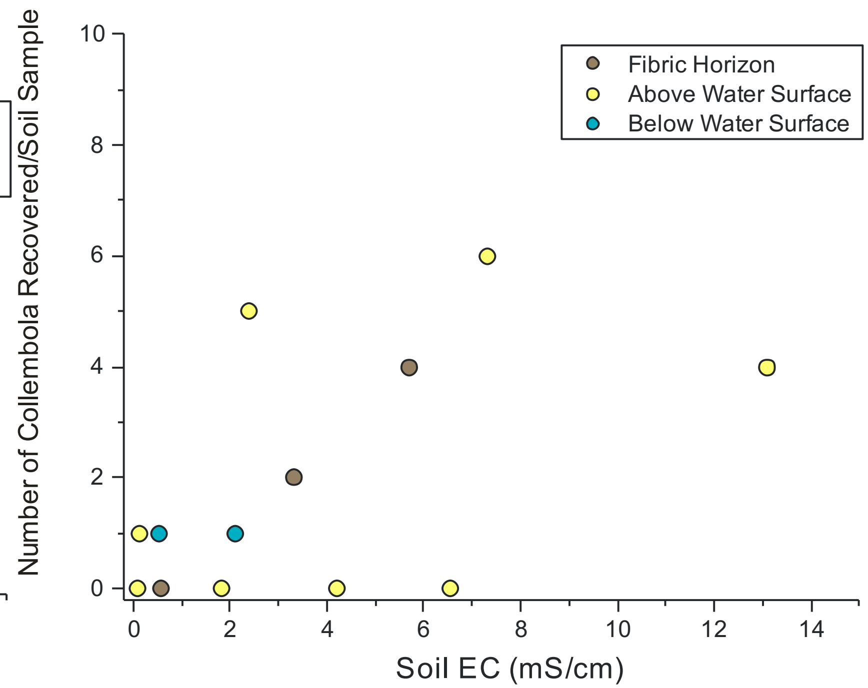
mites



collembola



Mite or Collembolan Abundance as a Function of Soil EC

Relationship Between Plant Species Diversity and Soil EC at Three Field Sites

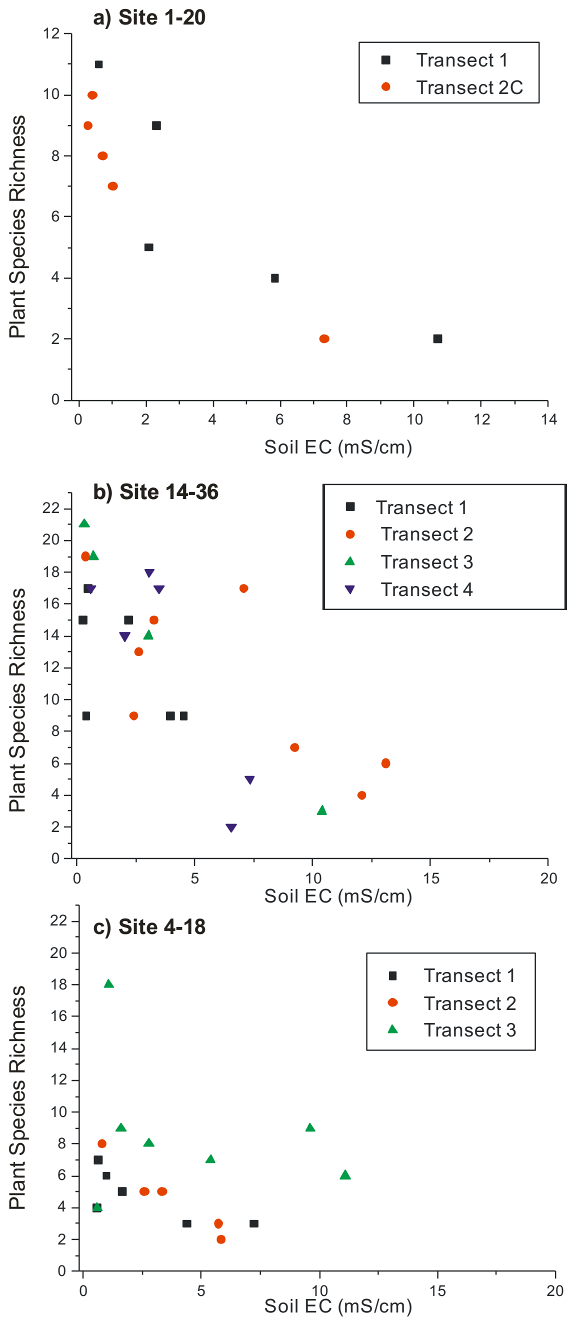


Table B: Summary of Individual Linear Concentration – Response Models for Plant Species Diversity

Transect	Model	n	P	r	Max. spp. rich	Soil EC (mS/cm) predicted to result in a 25, 50 or 75% speciesl reduction		
						EC_{25}	EC_{50}	EC_{75}
1-20, T1	Richness = -7.06 log10[EC] + 9.34	5	0.032	-0.91	11	1.43	3.50	8.58
1-20, T2	Richness = -5.46 log10[EC] + 6.94	5	0.0055	-0.97	10	0.79	2.27	6.50
14-36, T1	*Not significant*	6	0.32	-0.49	17			
14-36, T2	Richness = -7.84 log10[EC] + 16.1	8	0.040	-0.73	17	2.67	9.32	32.47
14-36, T3	Richness = -11.6 log10[EC] + 16.7	4	0.038	-0.96	21	1.21	3.42	9.71
14-36, T4	Richness = -0.862 [EC] + 21.0	6	0.027	-0.86	*21**	6.09	12.18	18.27
4-18, T1	*Not significant*	6	0.086	-0.75	7			
4-18, T2	Richness = -1.04 [EC] + 8.40	5	0.0050	-0.97	*8.4**	2.02	4.04	6.06
4-18, T3	Richness = -7.15 log10[EC] + 10.9	7	0.0062	-0.90	18	0.43	1.84	7.85
				Geometric Mean Value	*13.5*	*1.53*	*4.20*	*10.6*

* Y-intercept of least-squares linear fit

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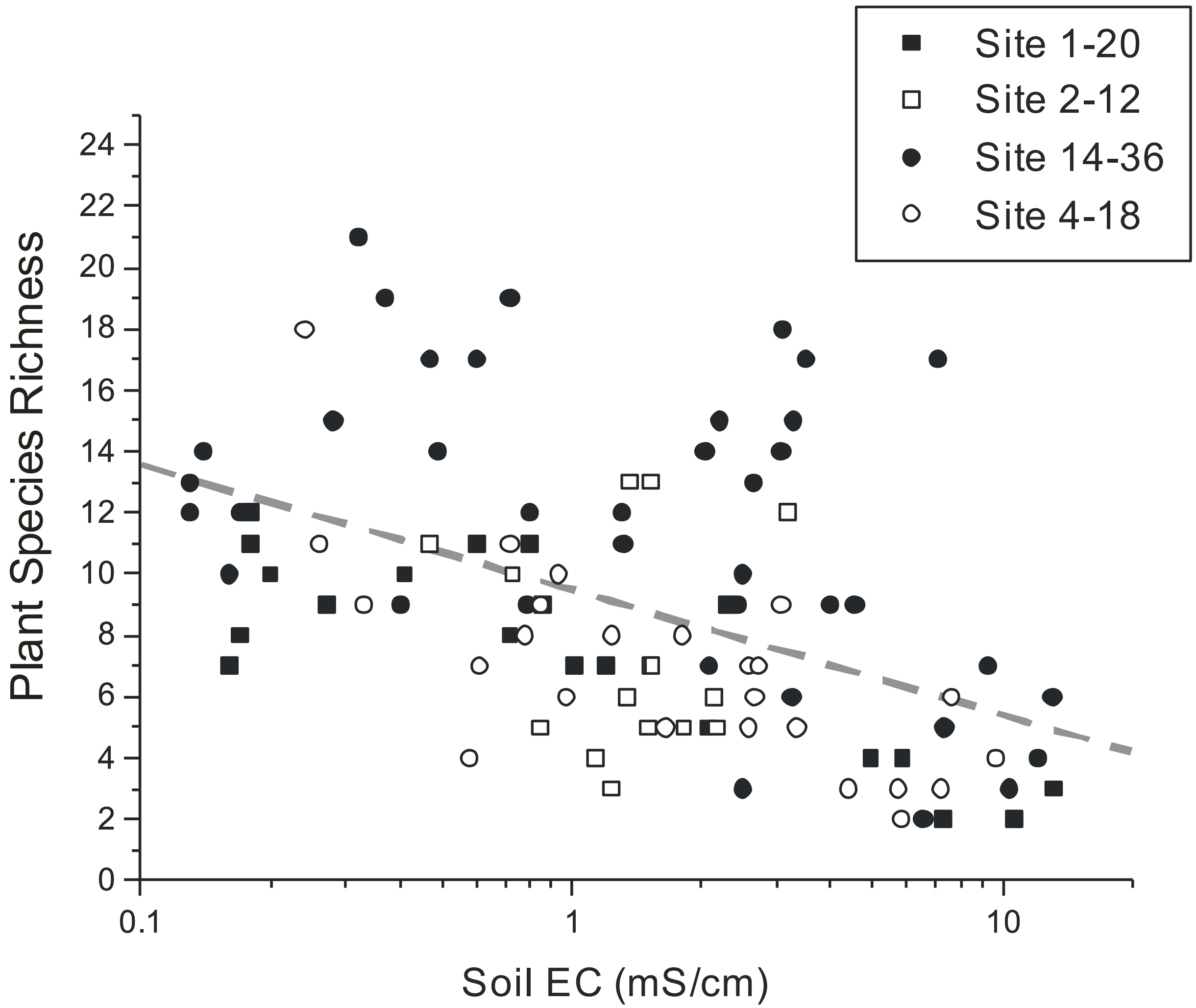
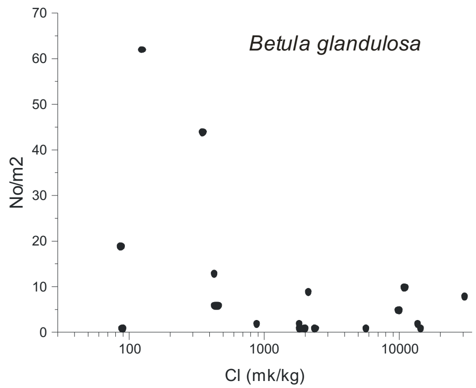
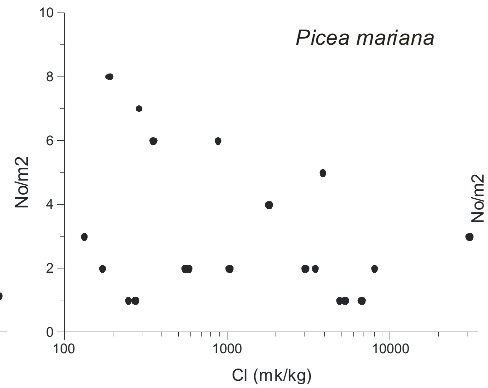


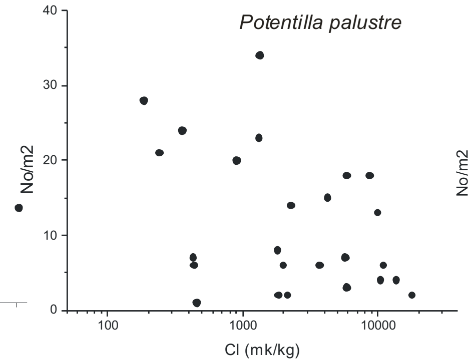
Least Squares Regression Model for Reduction in Plant Species Richness in Relation to Soil EC

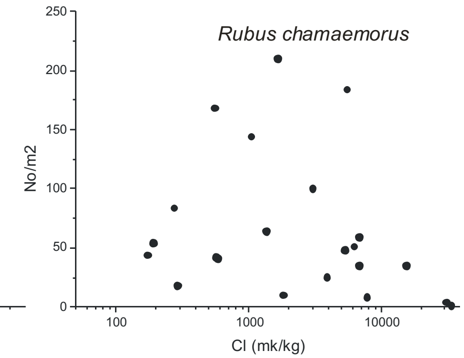
EC_{25}: 0.46 mS/cm
EC_{50}: 3.5 mS/cm
EC_{75}: 27 mS/cm

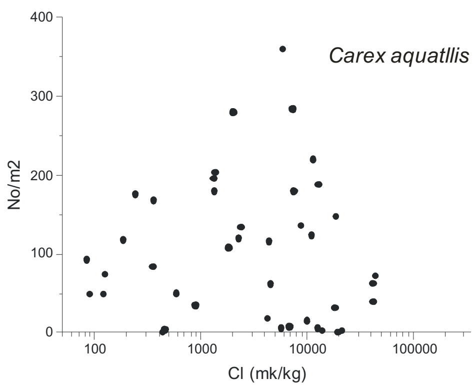
Species Richness = -4.08 log10[ECsoil] +9.49; *n = 98; P<0.001; r = -0.48*

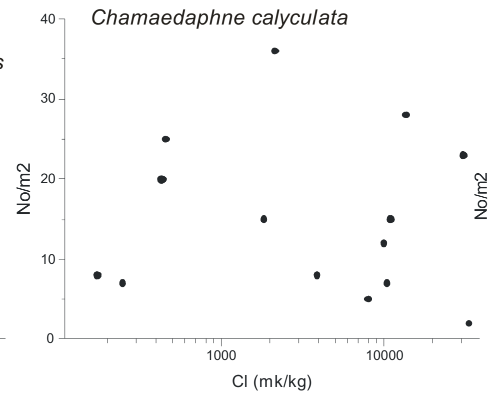


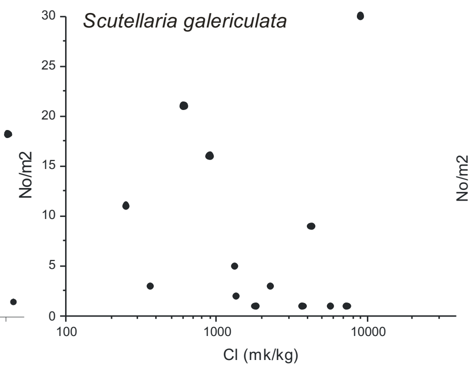


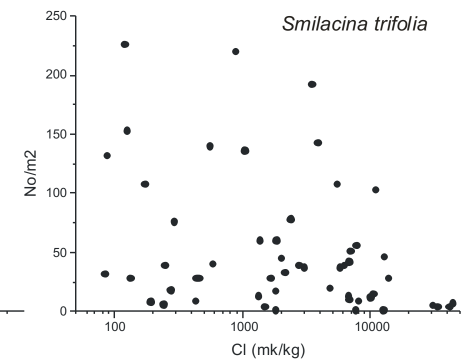


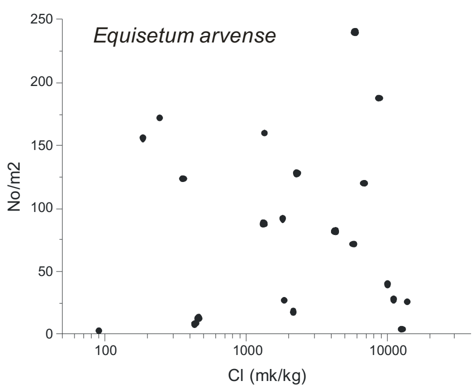


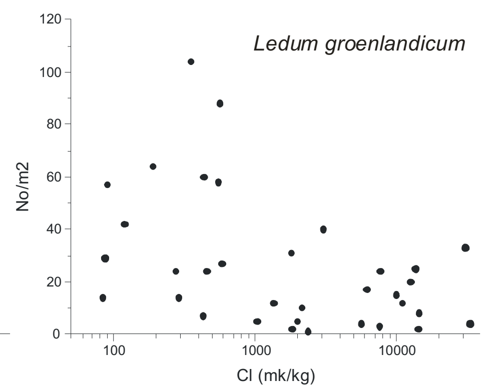












Relationship Between Plant Abundance and Soil Chloride Levels

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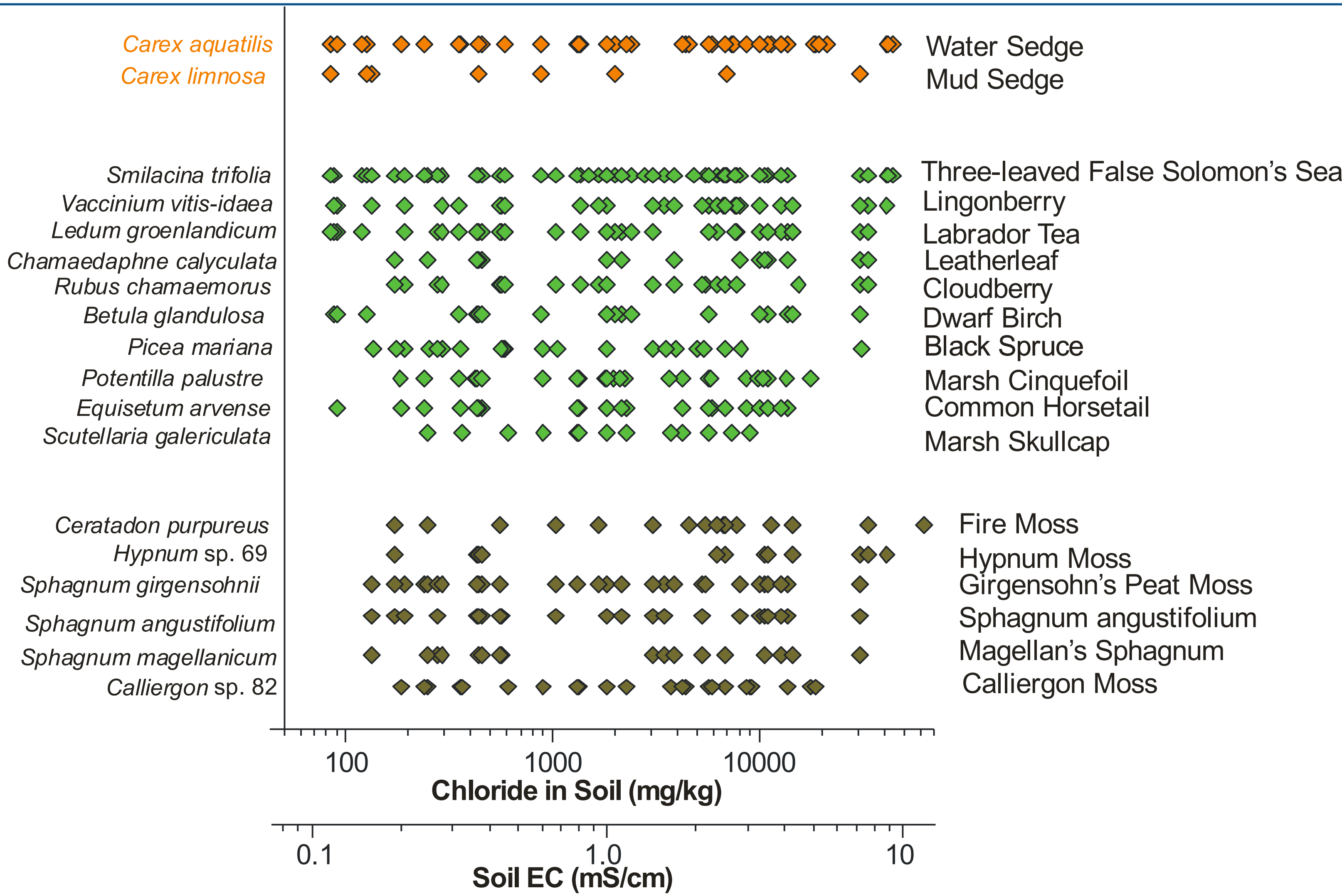
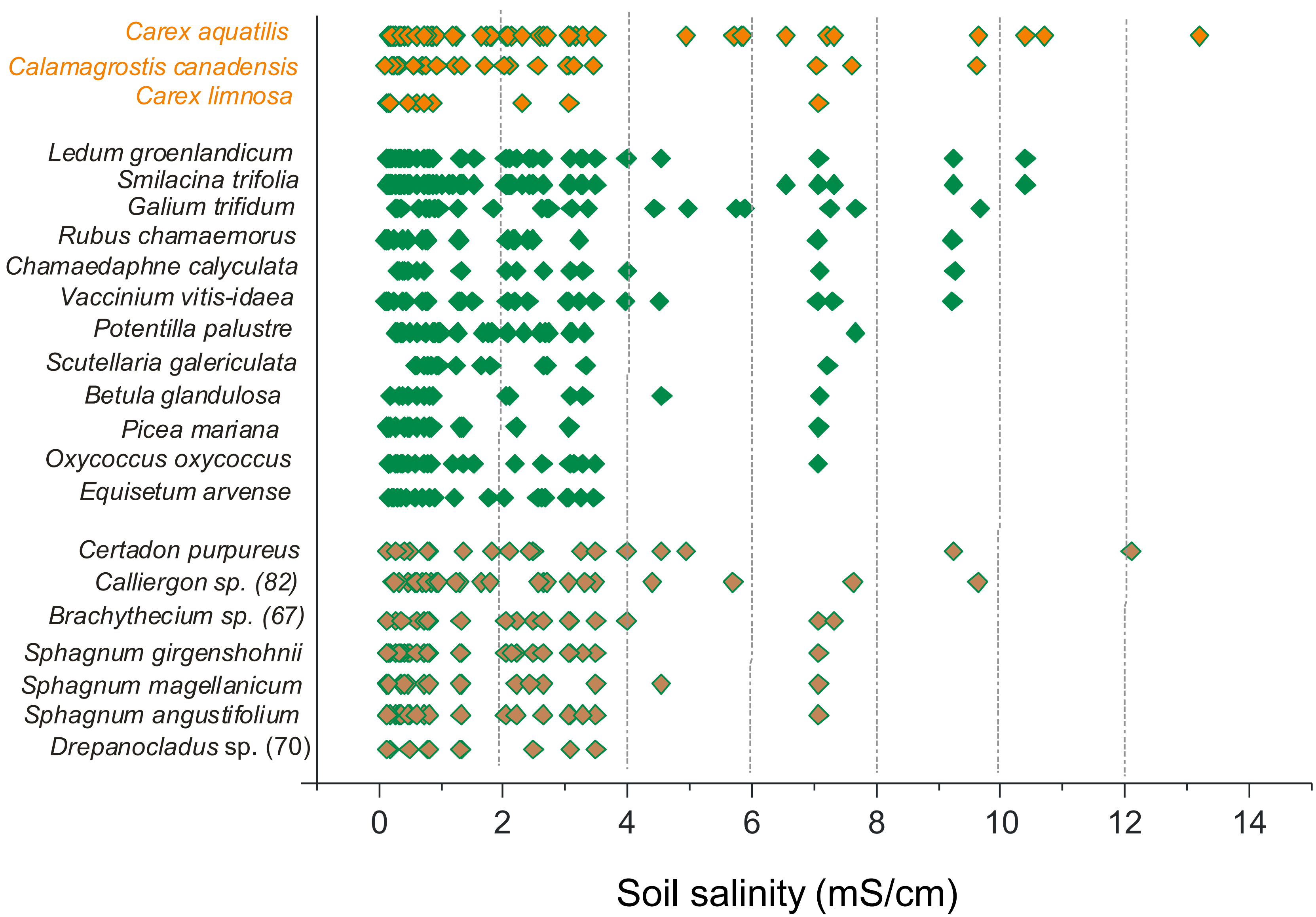


Occurrence of Plants and Bryophytes Based on Measured Salt Concentrations in Soil



Carex aquatilis
Calamagrostis canadensis
Carex limnosa
Ledum groenlandicum
Smilacina trifolia
Galium trifidum
Rubus chamaemorus
Chamaedaphne calyculata
Vaccinium vitis-idaea
Potentilla palustre
Scutellaria galericulata
Betula glandulosa
Picea mariana
Oxycoccus oxycoccus
Equisetum arvense
Certadon purpureus
Calliergon sp. (82)
Brachythecium sp. (67)
Sphagnum girgenshohnii
Sphagnum magellanicum
Sphagnum angustifolium
Drepanocladus sp. (70)
0
2
4
6
8
10
12
14
Soil salinity (mS/cm)

Preliminary Conclusions/Observations

- Soil invertebrate data to come.
- 3 of 4 sites suitable for evaluating peatland salinity – biotic relationships.
- Plant (and bryophyte) species richness tended to decrease linearly with the $\log_{10}$ of the soil or water salt concentration. No threshold of effects was evident.
- Accuracy of EC_X estimates better within the mid-range of data observations (i.e., at mid-range salinities and species richness). EC_X estimates more sensitive to data leverage at high and low values (e.g. EC_{10} to EC_{25}, EC_{90}).

Cont'd

- some species reduction would be expected at very low soil EC concentrations, in the range that might be encountered at uncontaminated reference peatlands under a minimal influence of natural salts.
- More work to be done to define EC_X and LC_X estimates for individual plant and bryophyte species based on data for abundance/m^2 or percent cover.