

Documenting Annual Differences in Vegetation Cover, Height and Diversity near Barrow, Alaska



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Committee members: Drs. James Dunn and Gary Greer

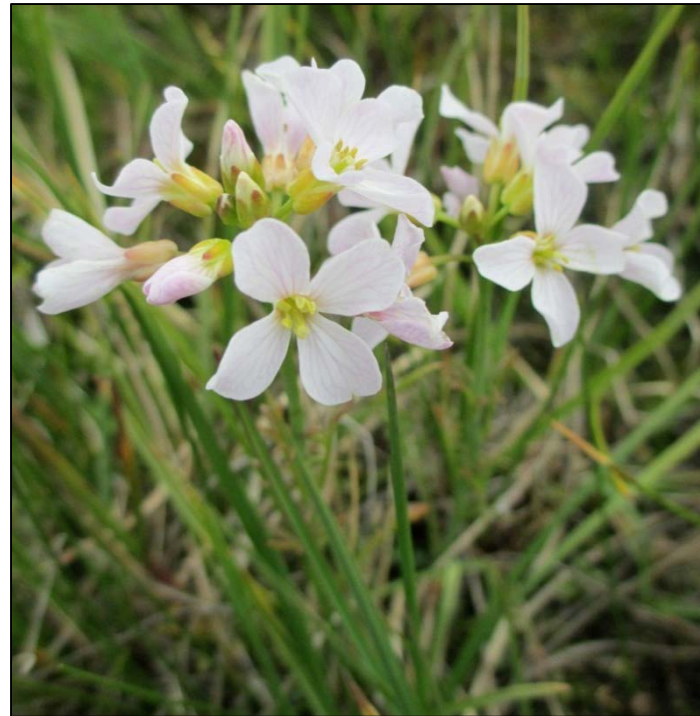
Masters Thesis Defense - April 2015

Background Information

- Importance of plants
- Focus vegetation changes in arctic regions

Individual Plant Species Importance

- Base of food web
- Other trophic levels
- Habitat suitability via habitat structure



Functional Group Importance

- Incorporates multiple individual species
- Saves time when sampling
- Simplistic modeling and mapping
- Used in climate warming studies
- Predictive power
- Growth forms



Cover and Height Importance

- Competition
- Albedo
- Habitat selection



Diversity Importance

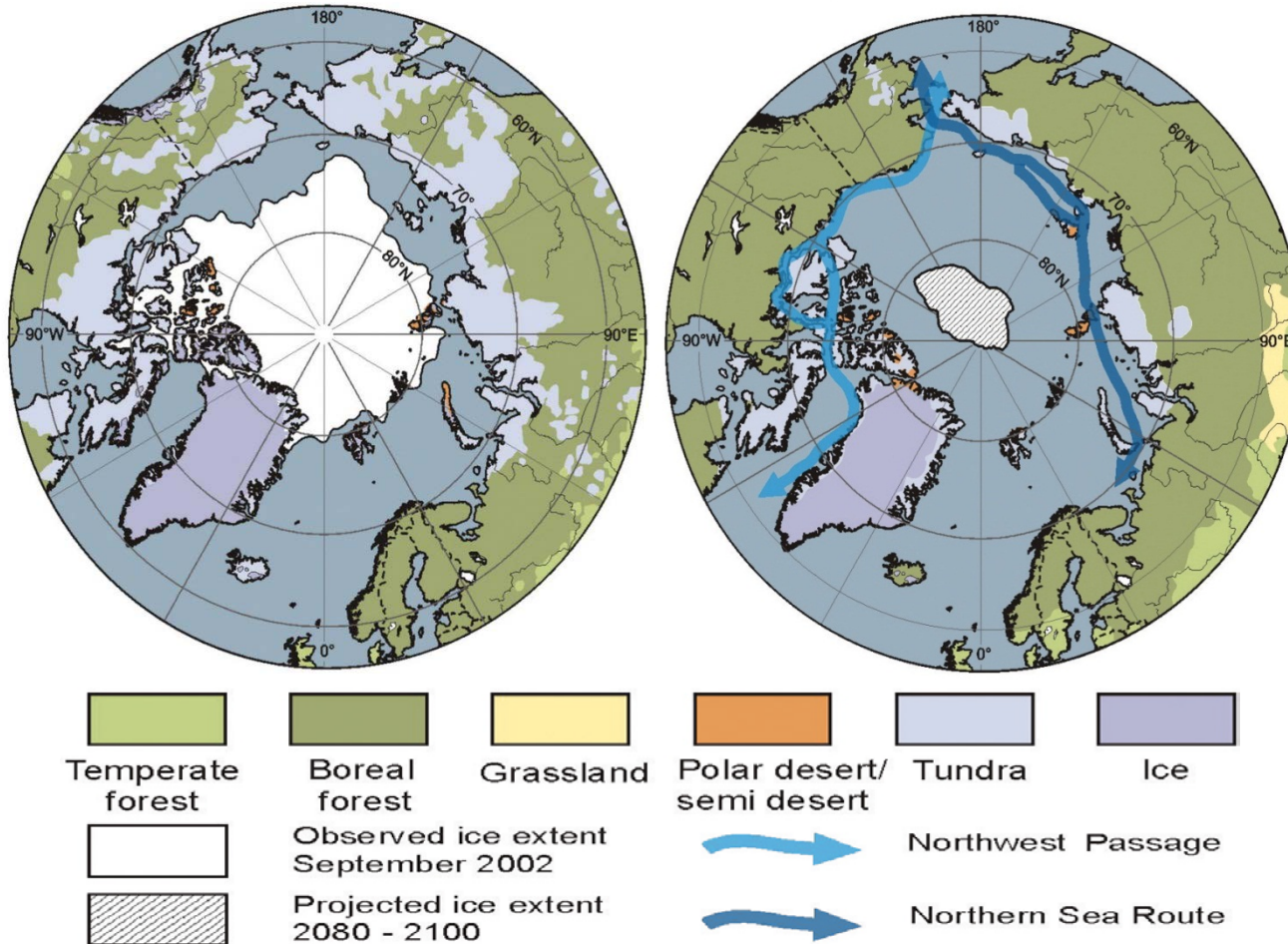
- Productivity
- Stability
- Function
- Predictive power



Focus on Arctic Regions

Current Arctic Conditions

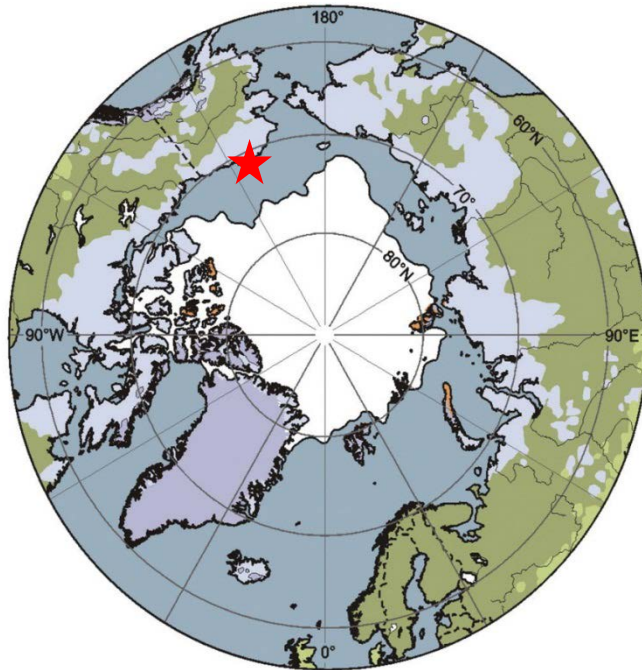
Projected Arctic Conditions



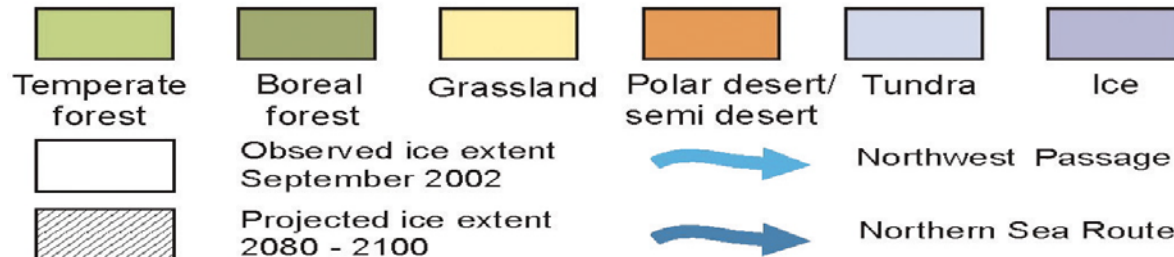
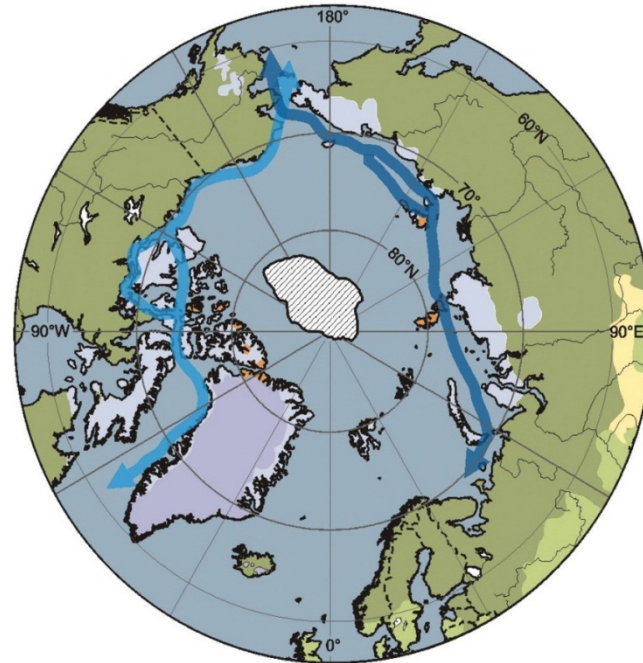
From IPCC 2007. Observed sea ice extent in 2002 and projected extent from 2080-2100 accompanied by shifts in distribution of vegetation and new shipping routes.

Focus on Arctic Regions

Current Arctic Conditions



Projected Arctic Conditions



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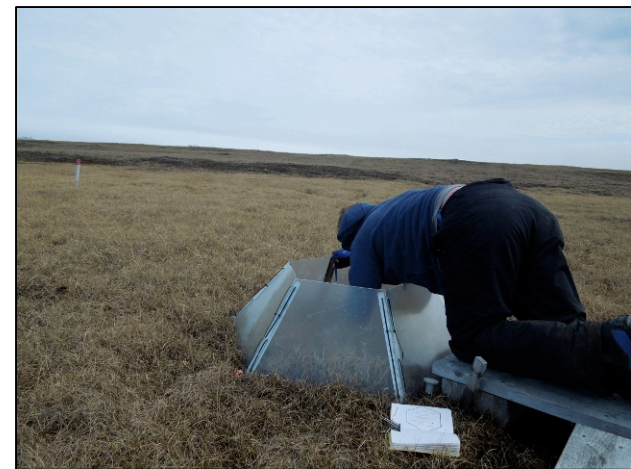
Documenting Change - ARCSS

- Funding Initiative
 - Established early 1990s
 - Interdisciplinary research
 - Grids a part of initiative
- Importance
 - Baseline information
 - Landscape level
 - Long-term
- Scope
 - Numerous sites



Documenting Change – AON and ITEX

- Arctic Observing Network
 - Developed 2006
 - 50+ projects
 - Current change
 - Future change
 - Adapting to change
- ITEX
 - Established 1990
 - 11+ countries, 40+ sites
 - Established protocols
 - Warming treatments
 - Climate warming syntheses over space and time
- Funding for this project and U.S. ITEX sites through AON





Knowledge Gaps

- **Understand changes in plant cover, height and diversity**



Knowledge Gaps

- Understand changes in plant cover, height and diversity
- **Consider multiple community types**

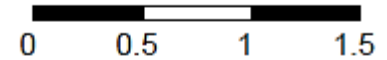
Research Questions

1. How has the vegetation metrics of cover, height and diversity changed over time?
2. What abiotic factors may explain the observed changes?
3. Are observed changes over time consistent across community types?

Study Location and Site



Kilometers

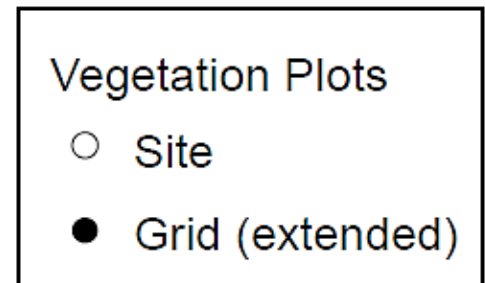
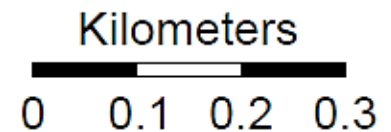
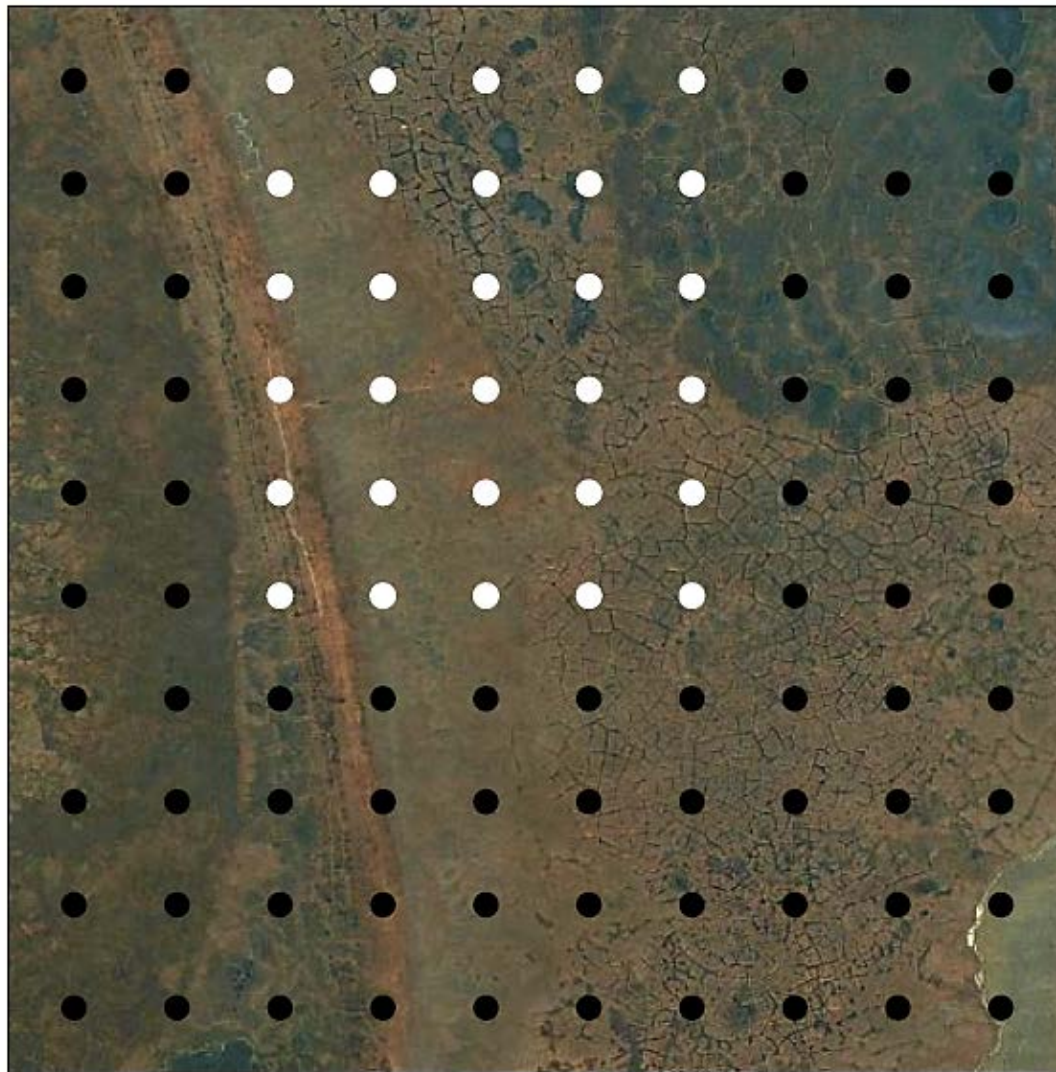


Topography

• Vegetation plot

— Contour (1m)

23
0
Elevation (m)



- Sampling
 - 'Site' = 30 plots in 2012 and 2014
 - 'Grid' = 98 plots in 2010 and 2013

Data Collection

- Vegetation sampling
 - Permanently marked and resampled
 - 75cm² grid (100 intersections, spaced 7.5 cm apart)
 - All contacts recorded (including height and live or dead status)
 - Vascular plants to spp.
 - Non-vascular to growth form

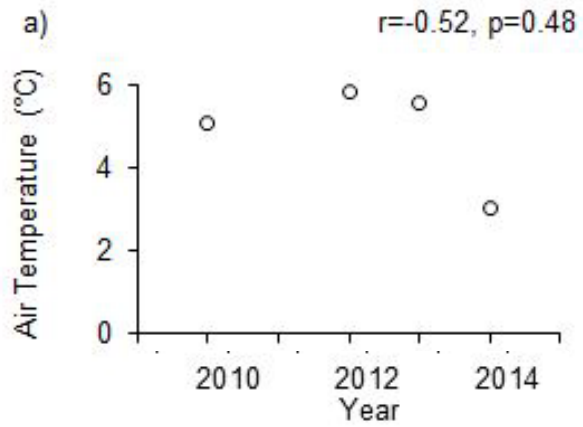


Data Collection

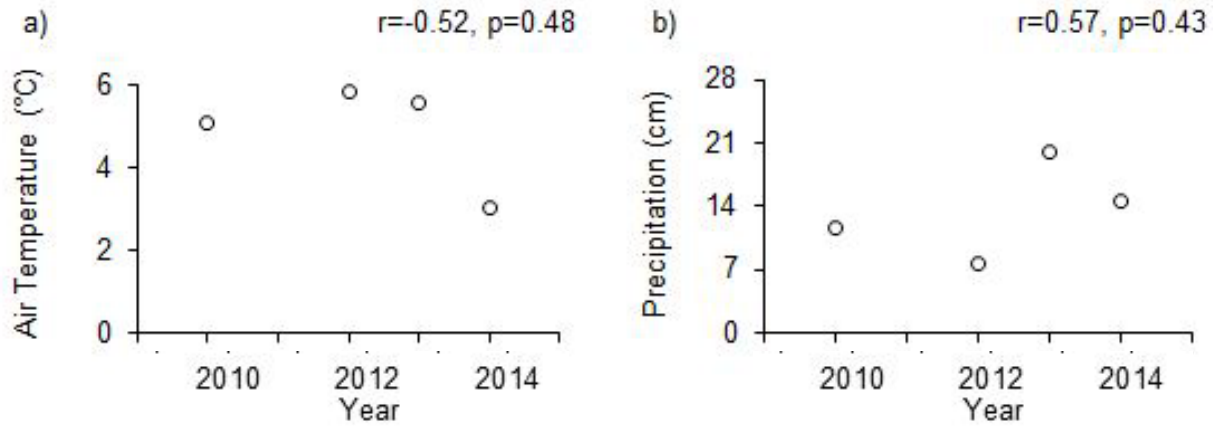
- Abiotic variables (summer)
- Site (1 value)
 - Air temperature (°C)
 - Precipitation (cm)
 - Thawing degree days (TDD)
sum of daily temperatures
- Plot (30 values - average)
 - Thaw depth (cm)
 - Soil temperature (°C)
 - Soil moisture (VWC %)



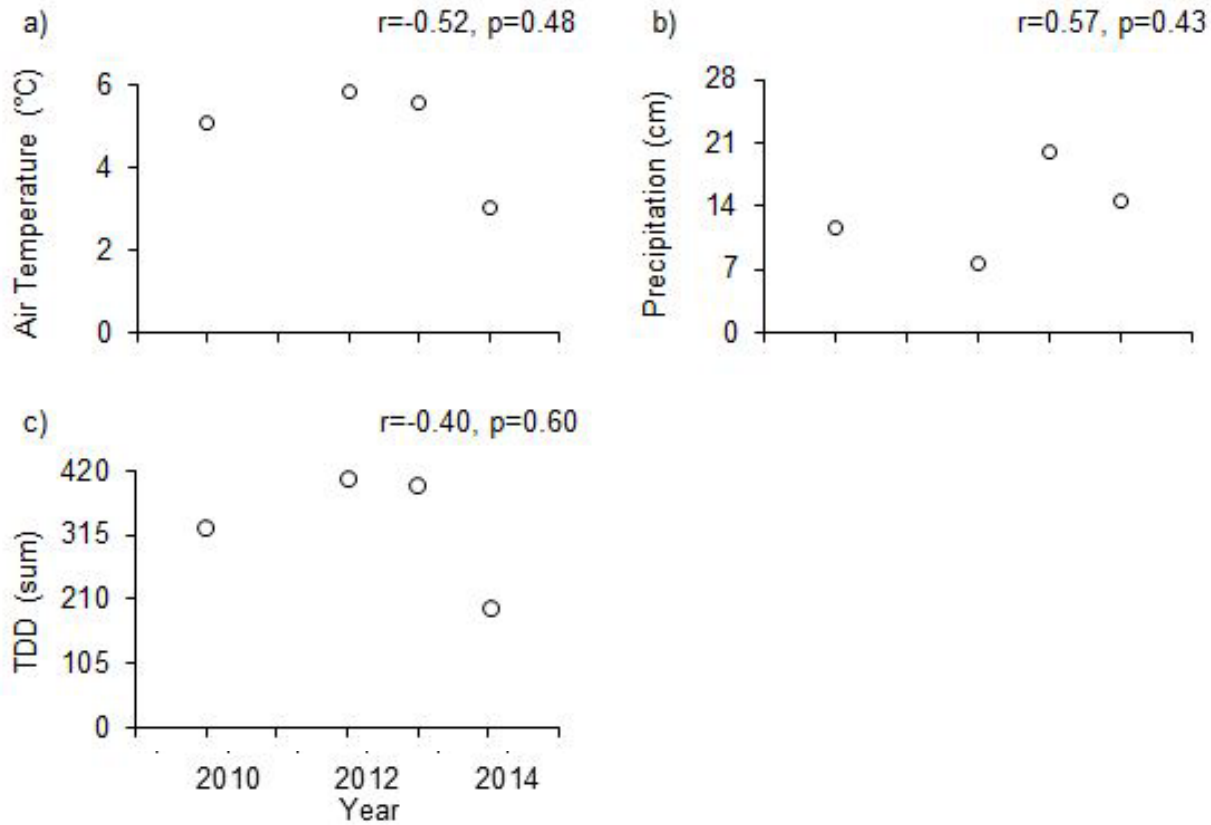
Abiotic Variables



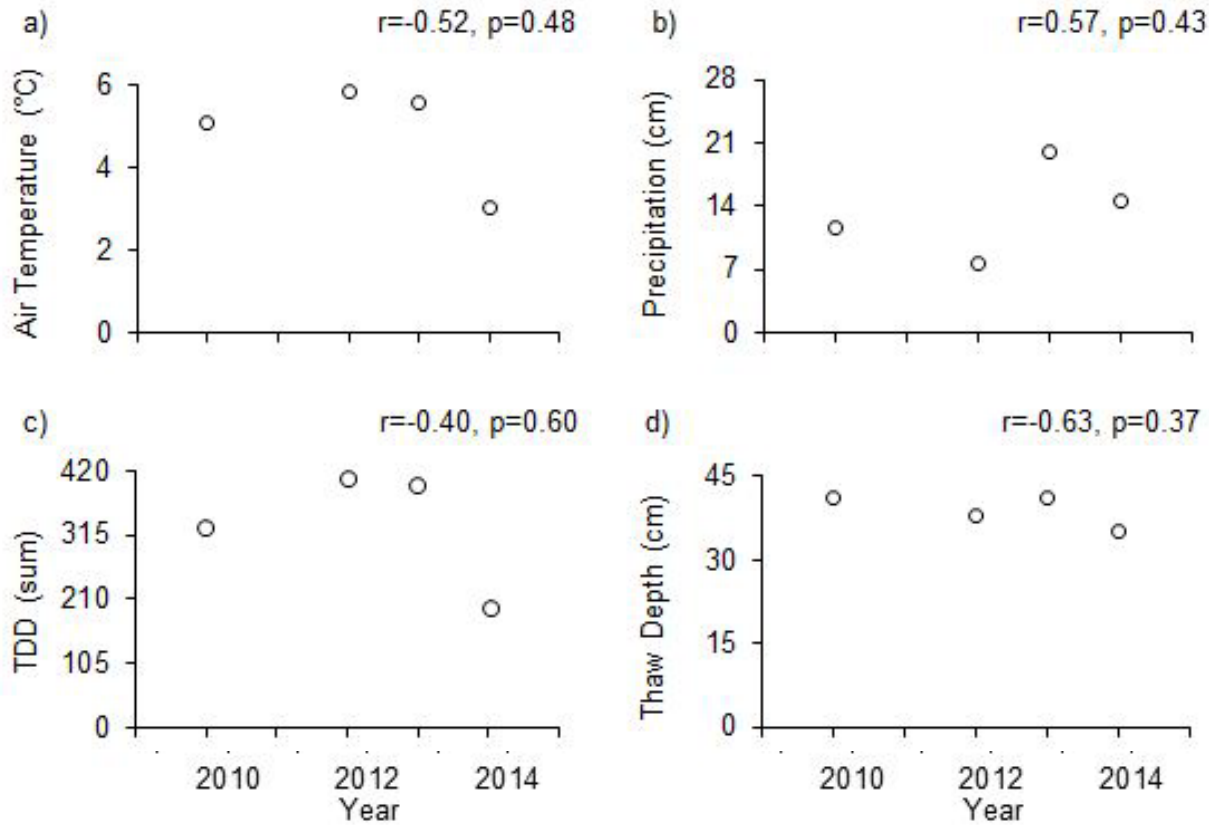
Abiotic Variables



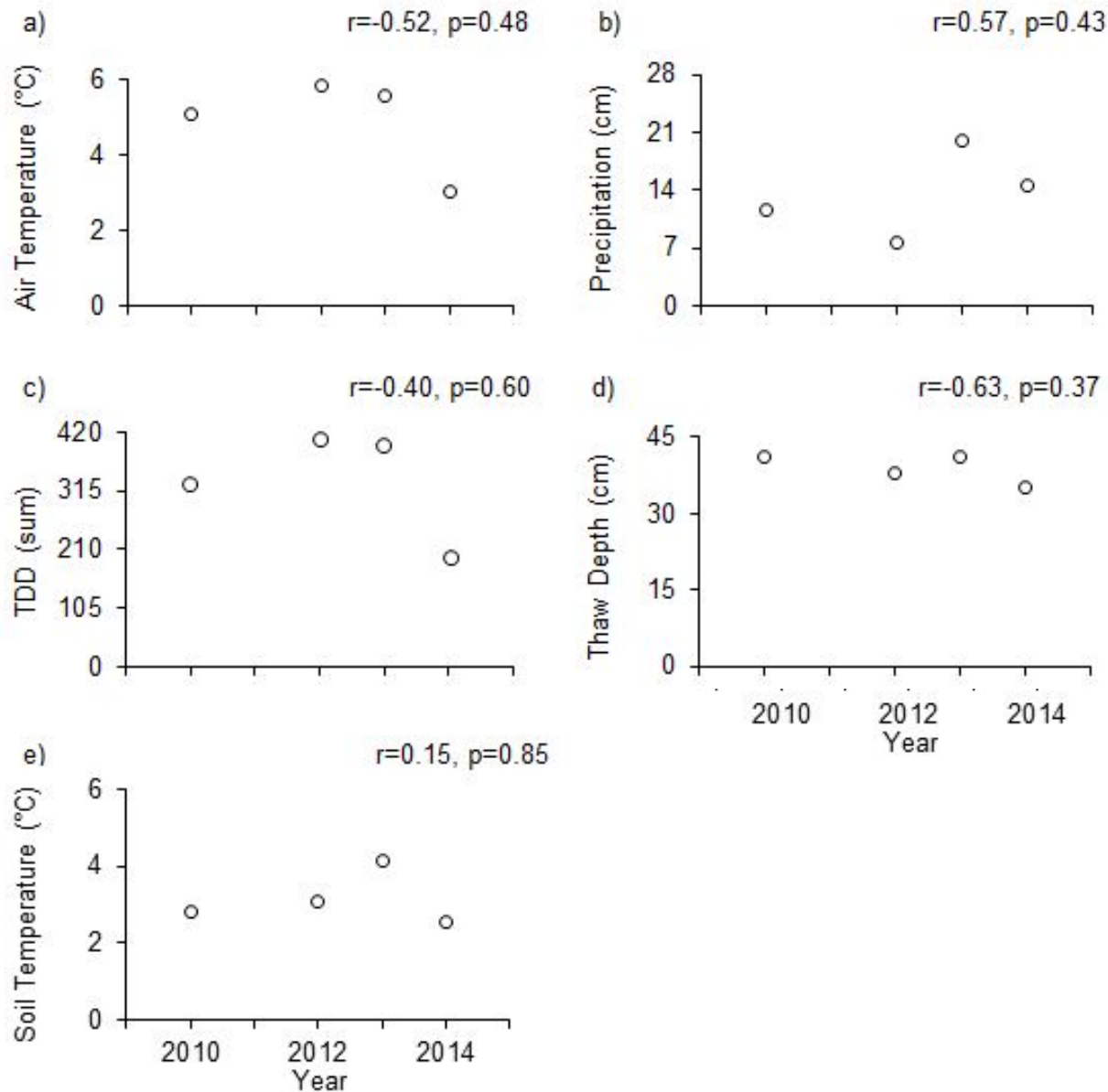
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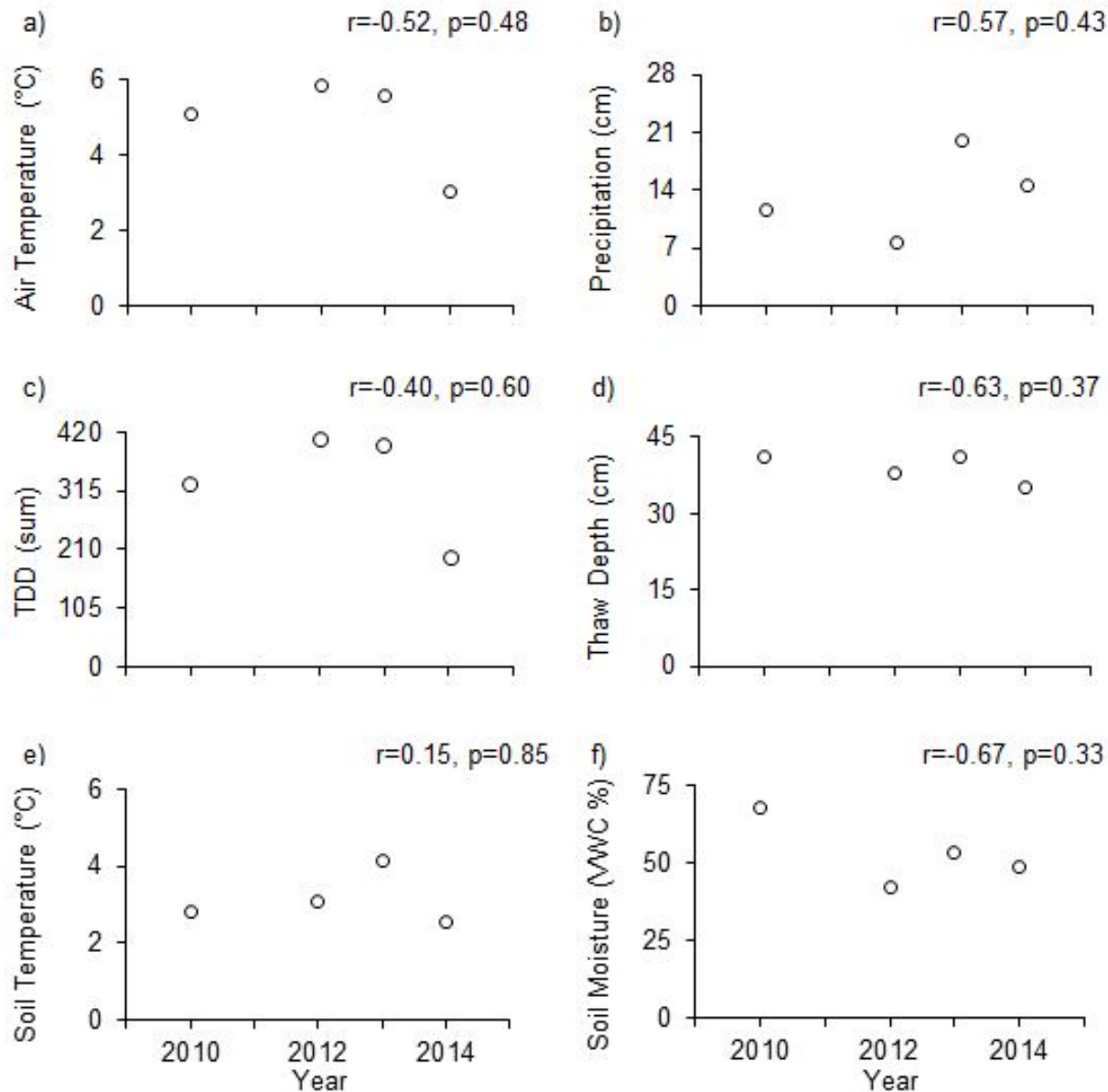
Abiotic Variables



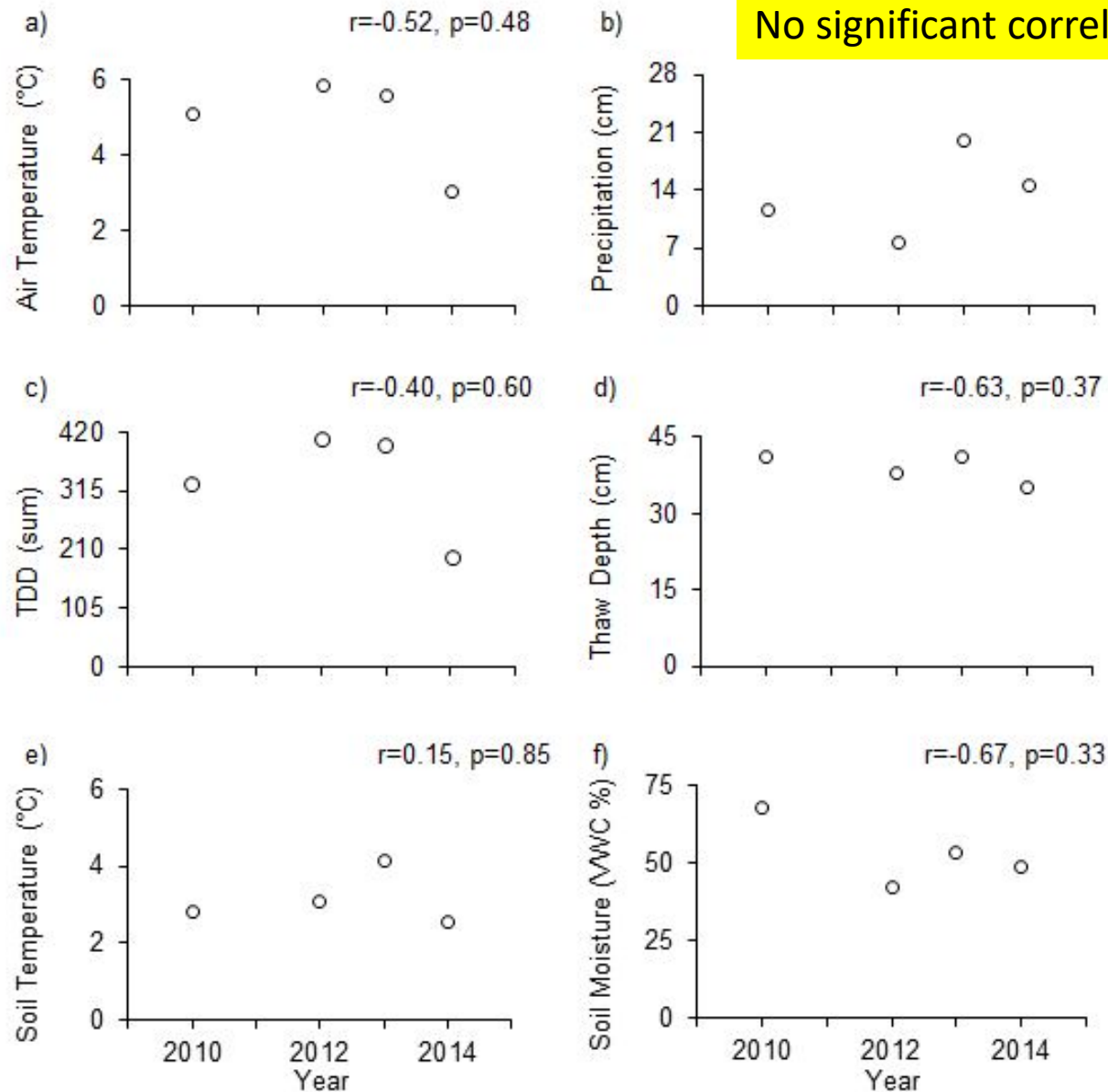
Abiotic Variables



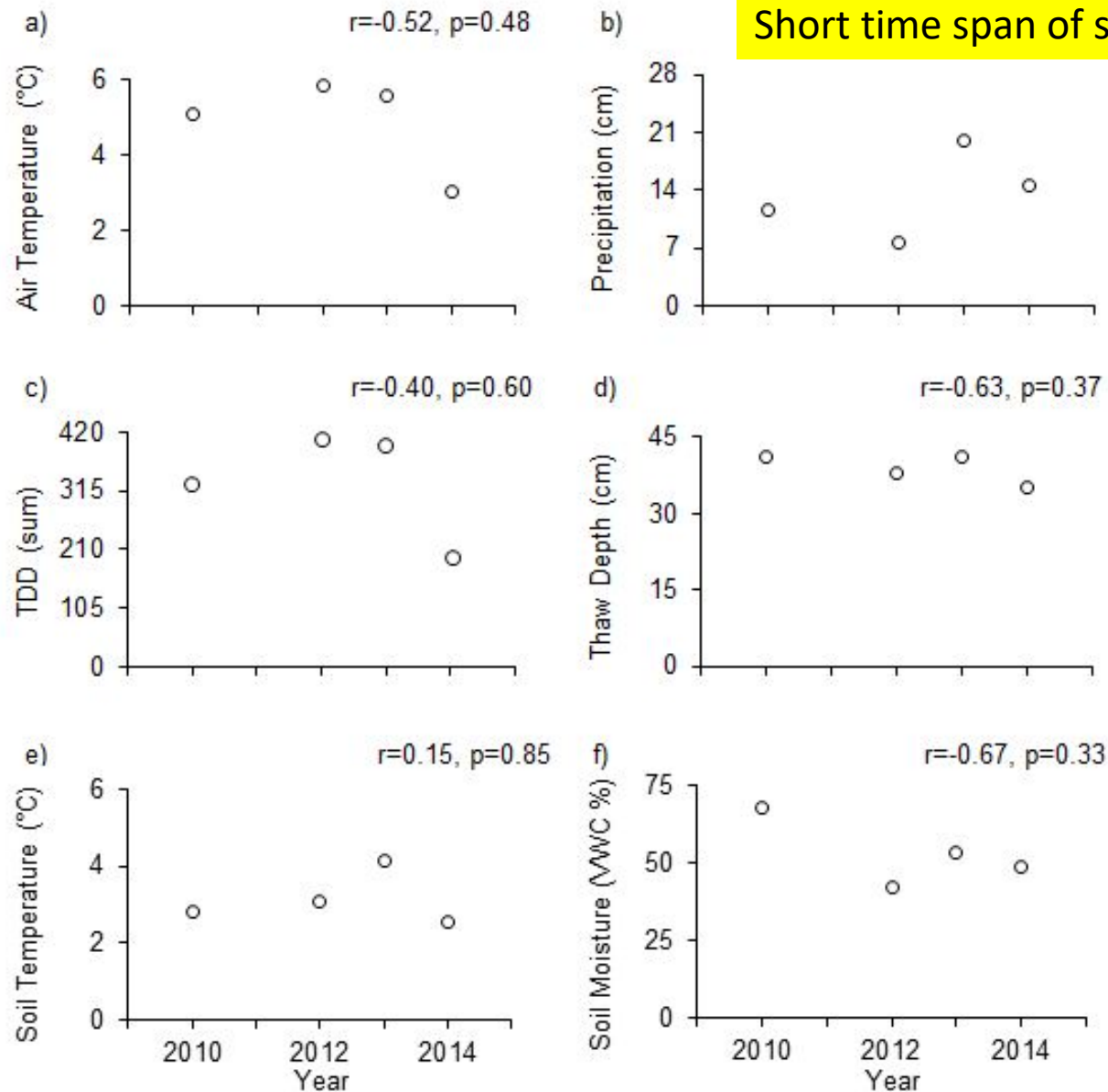
Abiotic Variables



Abiotic Variables



Abiotic Variables



Abiotic Variables

	Precipitation	TDD (sum)	Thaw depth	Soil temperature	Soil moisture
Air temperature	-0.25	0.99	0.72	0.60	0.01
Precipitation		-0.18	0.18	0.61	0.10
TDD (sum)			0.67	0.67	-0.10
Thaw depth				0.63	0.63
Soil temperature					-0.06

Abiotic Variables

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Only the sum of thawing degrees was correlated significantly with air temperature

Abiotic Variables

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TDD (sum) calculated directly from air temperature values

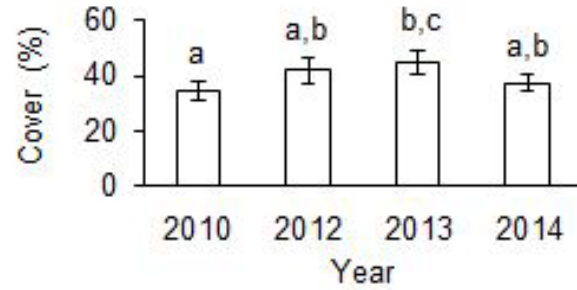
Research Questions

- 1. How has the vegetation metrics of cover, height and diversity changed over time?
(site only)**

Functional Groups

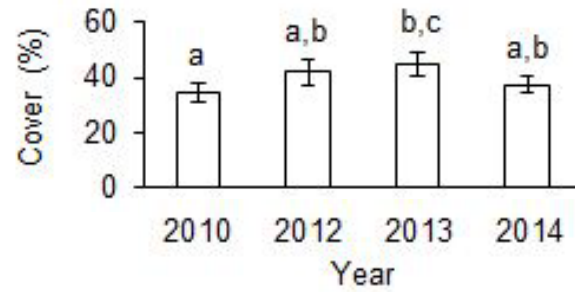


a) bryophytes

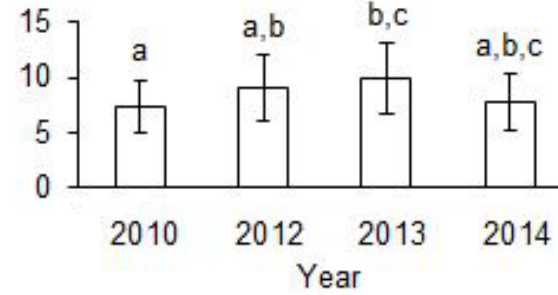


Functional Groups

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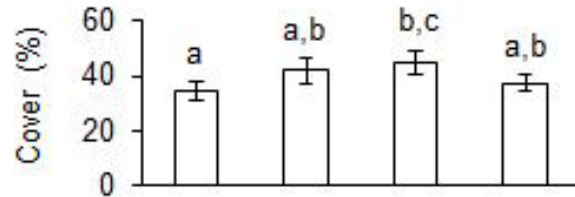


b) deciduous shrubs*

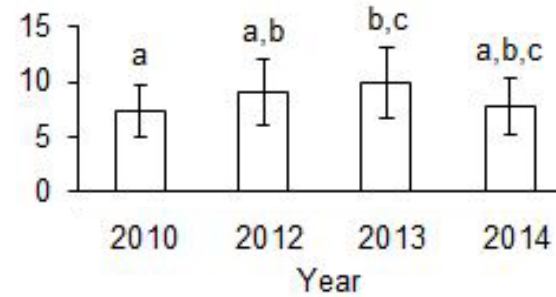


Functional Groups

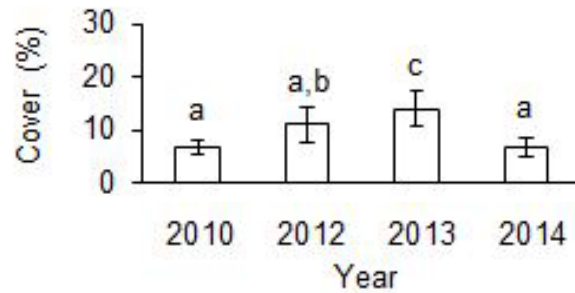
a) bryophytes



b) deciduous shrubs*

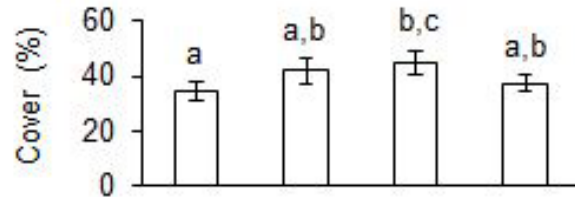


c) forbs*

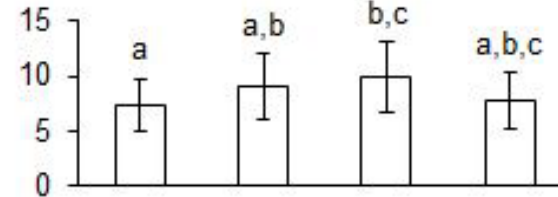


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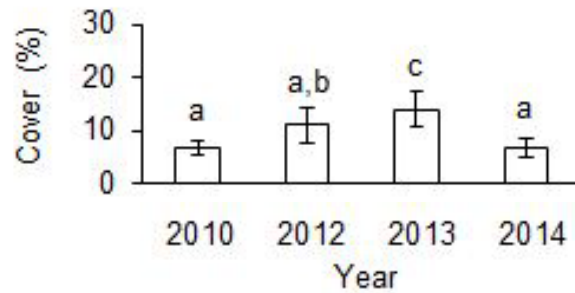
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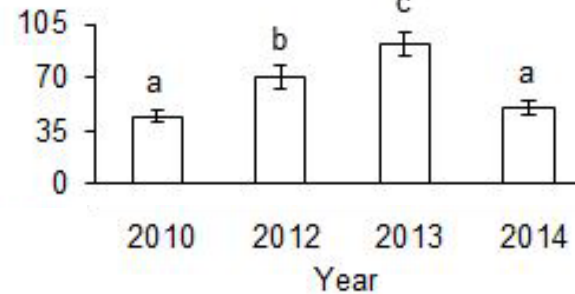
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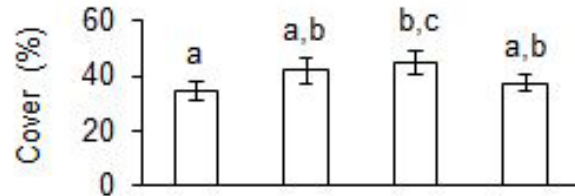


d) graminoidst

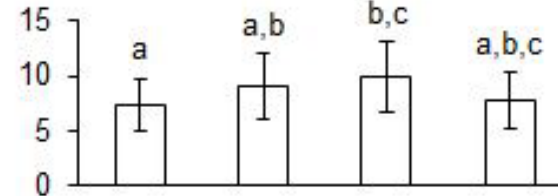


Functional Groups

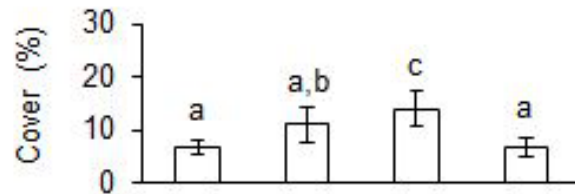
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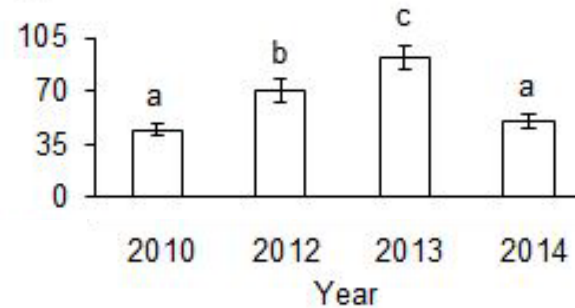
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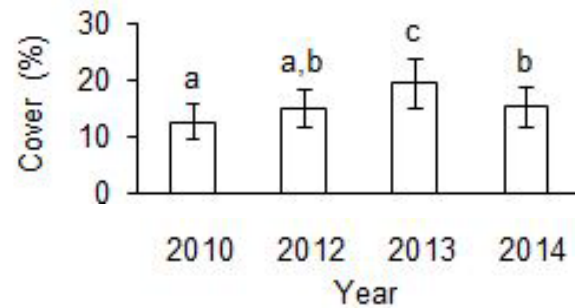
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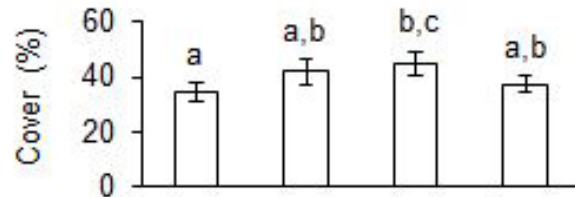


e) lichens*

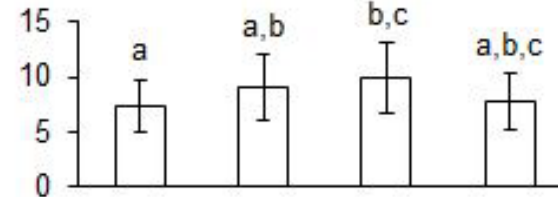


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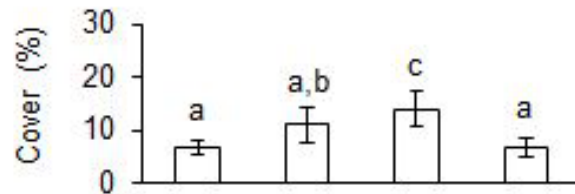
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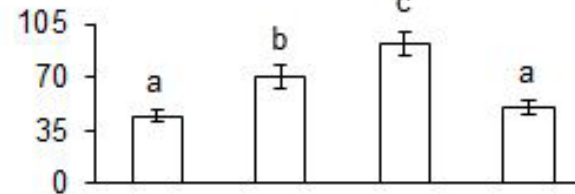
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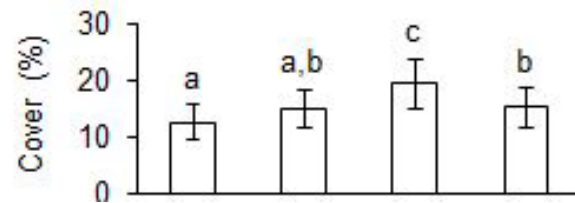
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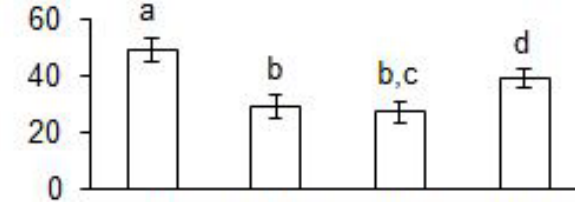
d) graminoids†



e) lichens*



f) litter‡

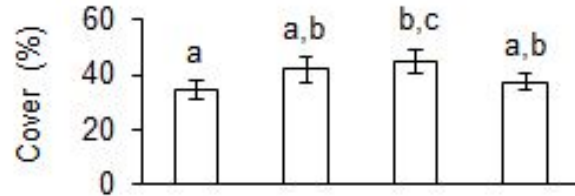


2010 2012 2013 2014
Year

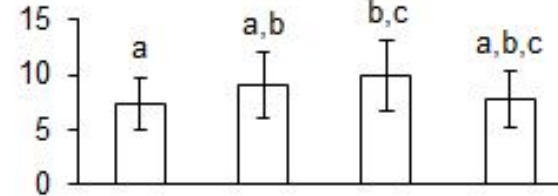
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Functional Groups

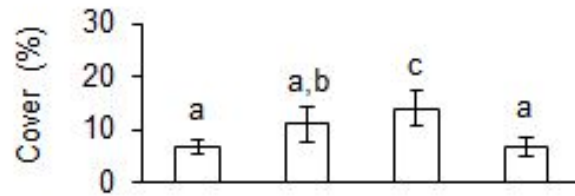
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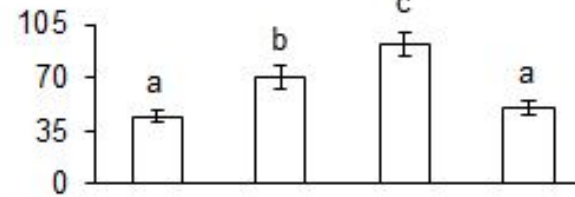
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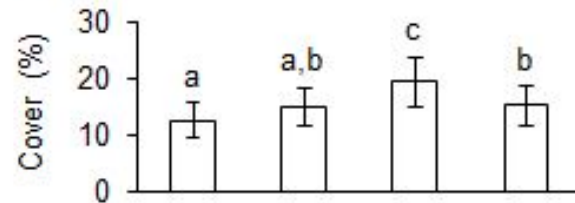
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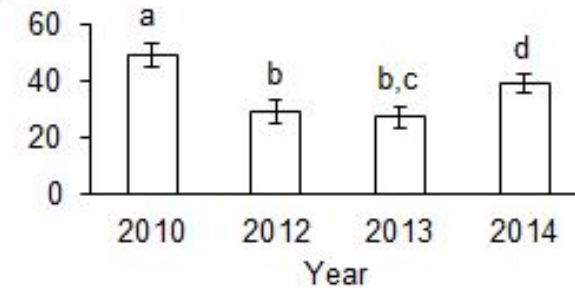
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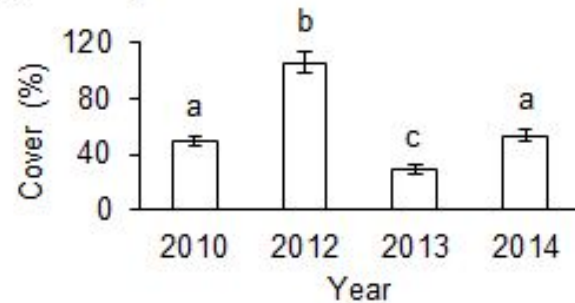
e) lichens*



f) litter‡

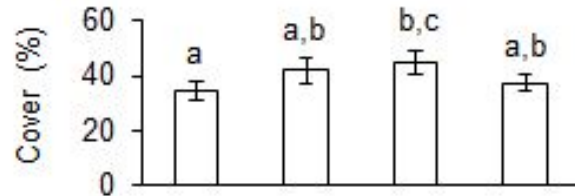


g) standing dead*

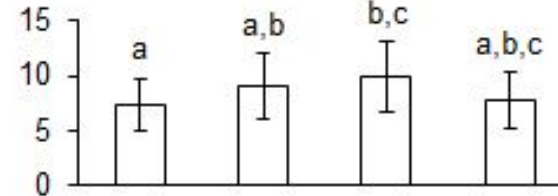


Functional Groups

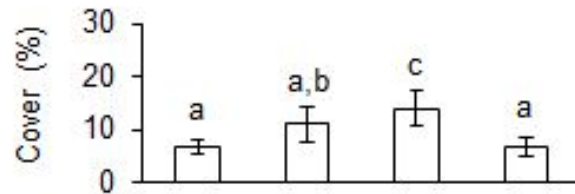
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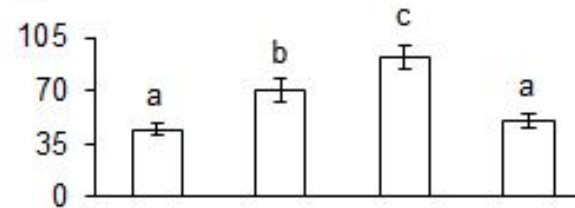
b) deciduous shrubs*



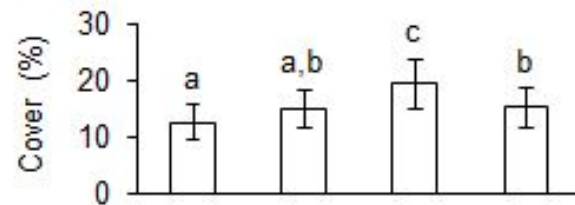
c) forbs*



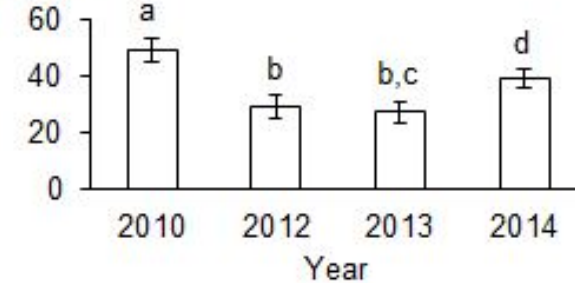
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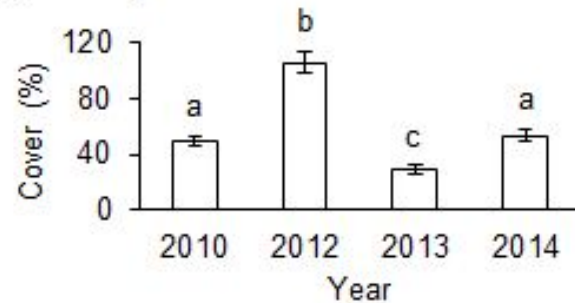
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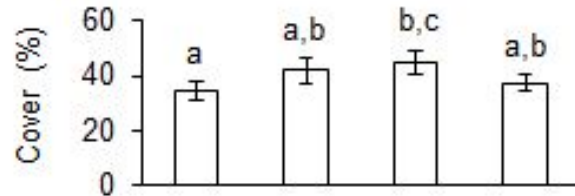
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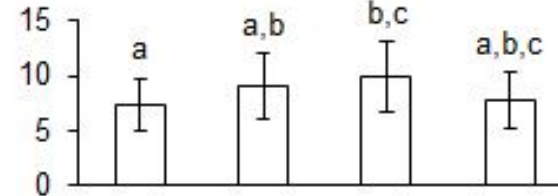
All functional groups changed significantly

Functional Groups

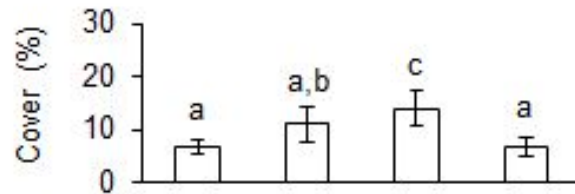
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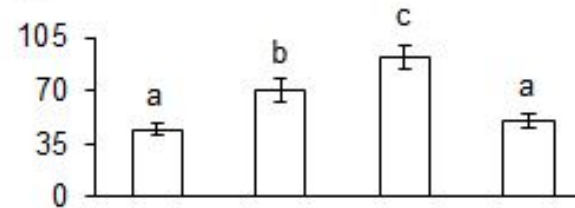
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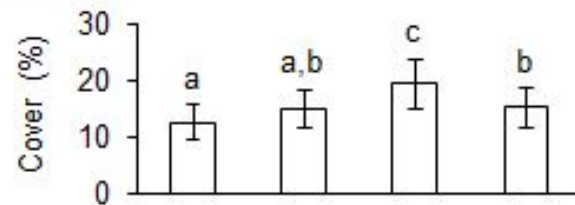
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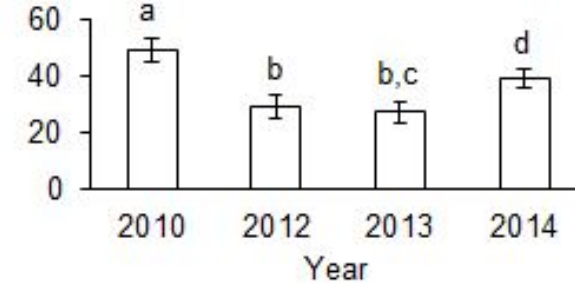
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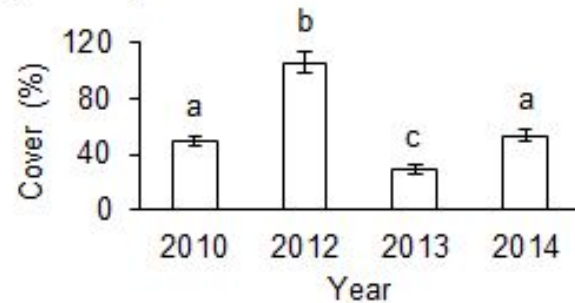
e) lichens*



f) litter‡



g) standing dead*



Changes were large from year to year

Shift focus to species within functional groups at the site

Metric

Vegetation cover

Bryophytes

Acrocarpous mosses[‡]

Pleurocarpous mosses[‡]

Deciduous shrubs*

*Salix rotundifolia**

Forbs*

*Petasites frigidus**

*Saxifraga cernua**

*Saxifraga foliolosa**

*Stellaria spp.**

Graminoids[†]

*Arctagrostis latifolia**

*Carex stans**

*Dupontia fisheri**

*Eriophorum triste**

*Eriophorum russeolum**

*Luzula arctica**

*Luzula confusa**

*Poa spp.**

Lichens*

Foliose*

Fruticose*

Litter[‡]

Standing dead*

Metric	Change Over Time			
	2010	2012	2013	2014
Vegetation cover				
Bryophytes	34.5 (3.2)	41.9 (4.8)	44.8 (4.1)	37.4 (3.3)
Acrocarpous mosses [‡]	17.6 (2.9)	14.1 (2.7)	19.1 (2.5)	13.6 (2.2)
Pleurocarpous mosses [‡]	16.4 (3.8)	27.4 (5.2)	24.8 (4.3)	23.5 (3.9)
Deciduous shrubs*	7.4 (2.4)	9.0 (3.1)	9.9 (3.2)	7.8 (2.6)
<i>Salix rotundifolia</i> *	5.8 (2.0)	6.4 (2.1)	7.9 (2.5)	6.6 (2.3)
Forbs*	6.7 (1.4)	11.0 (3.4)	14.0 (3.2)	6.7 (1.7)
<i>Petasites frigidus</i> *	1.8 (0.7)	5.8 (3.1)	4.3 (2.1)	2.3 (1.2)
<i>Saxifraga cernua</i> *	1.4 (0.5)	1.0 (0.4)	2.2 (0.6)	0.8 (0.2)
<i>Saxifraga foliolosa</i> *	0.3 (0.2)	0.5 (0.3)	0.9 (0.3)	0.5 (0.3)
<i>Stellaria spp.</i> *	1.9 (0.6)	1.6 (0.6)	2.7 (1.0)	1.5 (0.5)
Graminoids [†]	44.4 (4.0)	69.6 (7.6)	92.1 (7.5)	50.1 (4.6)
<i>Arctagrostis latifolia</i> *	2.0 (0.8)	2.6 (0.9)	3.2 (1.1)	1.8 (0.8)
<i>Carex stans</i> *	17.7 (2.9)	27.6 (4.5)	40.0 (6.1)	17.2 (2.7)
<i>Dupontia fisheri</i> *	6.8 (1.7)	9.9 (2.5)	10.2 (2.8)	6.2 (1.7)
<i>Eriophorum triste</i> *	2.7 (0.9)	9.0 (3.0)	8.1 (2.8)	6.7 (2.3)
<i>Eriophorum russeolum</i> *	5.2 (1.0)	8.0 (2.7)	11.0 (2.9)	7.9 (2.1)
<i>Luzula arctica</i> *	2.0 (0.9)	3.2 (1.2)	4.3 (1.9)	1.8 (1.0)
<i>Luzula confusa</i> *	1.7 (0.5)	1.6 (0.5)	2.4 (0.8)	1.0 (0.4)
<i>Poa spp.</i> *	4.8 (1.4)	6.4 (2.9)	11.2 (3.8)	6.1 (2.0)
Lichens*	12.8 (3.1)	15.2 (3.3)	19.6 (4.3)	15.3 (3.3)
Foliose*	3.3 (0.9)	5.2 (1.4)	6.6 (1.7)	4.6 (1.3)
Fruticose*	9.4 (2.5)	9.8 (2.5)	12.5 (3.1)	10.3 (2.4)
Litter [‡]	49.1 (3.9)	29.2 (3.9)	27.6 (3.7)	39.2 (3.2)
Standing dead*	49.6 (4.1)	105.8 (7.7)	29.5 (3.6)	53.3 (4.3)

Metric	Change Over Time				ANOVA
	2010	2012	2013	2014	p
Vegetation cover					
Bryophytes	34.5 (3.2)	41.9 (4.8)	44.8 (4.1)	37.4 (3.3)	0.05
Acrocarpous mosses [‡]	17.6 (2.9)	14.1 (2.7)	19.1 (2.5)	13.6 (2.2)	0.88
Pleurocarpous mosses [‡]	16.4 (3.8)	27.4 (5.2)	24.8 (4.3)	23.5 (3.9)	<0.01
Deciduous shrubs*	7.4 (2.4)	9.0 (3.1)	9.9 (3.2)	7.8 (2.6)	<0.01
<i>Salix rotundifolia</i> *	5.8 (2.0)	6.4 (2.1)	7.9 (2.5)	6.6 (2.3)	0.01
Forbs*	6.7 (1.4)	11.0 (3.4)	14.0 (3.2)	6.7 (1.7)	<0.01
<i>Petasites frigidus</i> *	1.8 (0.7)	5.8 (3.1)	4.3 (2.1)	2.3 (1.2)	0.19
<i>Saxifraga cernua</i> *	1.4 (0.5)	1.0 (0.4)	2.2 (0.6)	0.8 (0.2)	0.01
<i>Saxifraga foliolosa</i> *	0.3 (0.2)	0.5 (0.3)	0.9 (0.3)	0.5 (0.3)	0.13
<i>Stellaria spp.</i> *	1.9 (0.6)	1.6 (0.6)	2.7 (1.0)	1.5 (0.5)	0.20
Graminoids [†]	44.4 (4.0)	69.6 (7.6)	92.1 (7.5)	50.1 (4.6)	<0.01
<i>Arctagrostis latifolia</i> *	2.0 (0.8)	2.6 (0.9)	3.2 (1.1)	1.8 (0.8)	0.01
<i>Carex stans</i> *	17.7 (2.9)	27.6 (4.5)	40.0 (6.1)	17.2 (2.7)	<0.01
<i>Dupontia fisheri</i> *	6.8 (1.7)	9.9 (2.5)	10.2 (2.8)	6.2 (1.7)	<0.01
<i>Eriophorum triste</i> *	2.7 (0.9)	9.0 (3.0)	8.1 (2.8)	6.7 (2.3)	<0.01
<i>Eriophorum russeolum</i> *	5.2 (1.0)	8.0 (2.7)	11.0 (2.9)	7.9 (2.1)	0.02
<i>Luzula arctica</i> *	2.0 (0.9)	3.2 (1.2)	4.3 (1.9)	1.8 (1.0)	<0.01
<i>Luzula confusa</i> *	1.7 (0.5)	1.6 (0.5)	2.4 (0.8)	1.0 (0.4)	0.03
<i>Poa spp.</i> *	4.8 (1.4)	6.4 (2.9)	11.2 (3.8)	6.1 (2.0)	<0.01
Lichens*	12.8 (3.1)	15.2 (3.3)	19.6 (4.3)	15.3 (3.3)	<0.01
Foliose*	3.3 (0.9)	5.2 (1.4)	6.6 (1.7)	4.6 (1.3)	0.01
Fruticose*	9.4 (2.5)	9.8 (2.5)	12.5 (3.1)	10.3 (2.4)	<0.01
Litter [‡]	49.1 (3.9)	29.2 (3.9)	27.6 (3.7)	39.2 (3.2)	<0.01
Standing dead*	49.6 (4.1)	105.8 (7.7)	29.5 (3.6)	53.3 (4.3)	<0.01

The cover of many species within functional groups significantly changed over time

Metric	Change Over Time				ANOVA
	2010	2012	2013	2014	p
Vegetation cover					
Bryophytes	34.5 (3.2)	41.9 (4.8)	44.8 (4.1)	37.4 (3.3)	0.05
Acrocarpous mosses [‡]	17.6 (2.9)	14.1 (2.7)	19.1 (2.5)	13.6 (2.2)	0.88
Pleurocarpous mosses [‡]	16.4 (3.8)	27.4 (5.2)	24.8 (4.3)	23.5 (3.9)	<0.01
Deciduous shrubs*	7.4 (2.4)	9.0 (3.1)	9.9 (3.2)	7.8 (2.6)	<0.01
<i>Salix rotundifolia</i> *	5.8 (2.0)	6.4 (2.1)	7.9 (2.5)	6.6 (2.3)	0.01
Forbs*	6.7 (1.4)	11.0 (3.4)	14.0 (3.2)	6.7 (1.7)	<0.01
<i>Petasites frigidus</i> *	1.8 (0.7)	5.8 (3.1)	4.3 (2.1)	2.3 (1.2)	0.19
<i>Saxifraga cernua</i> *	1.4 (0.5)	1.0 (0.4)	2.2 (0.6)	0.8 (0.2)	0.01
<i>Saxifraga foliolosa</i> *	0.3 (0.2)	0.5 (0.3)	0.9 (0.3)	0.5 (0.3)	0.13
<i>Stellaria spp.</i> *	1.9 (0.6)	1.6 (0.6)	2.7 (1.0)	1.5 (0.5)	0.20
Graminoids [†]	44.4 (4.0)	69.6 (7.6)	92.1 (7.5)	50.1 (4.6)	<0.01
<i>Arctagrostis latifolia</i> *	2.0 (0.8)	2.6 (0.9)	3.2 (1.1)	1.8 (0.8)	0.01
<i>Carex stans</i> *	17.7 (2.9)	27.6 (4.5)	40.0 (6.1)	17.2 (2.7)	<0.01
<i>Dupontia fisheri</i> *	6.8 (1.7)	9.9 (2.5)	10.2 (2.8)	6.2 (1.7)	<0.01
<i>Eriophorum triste</i> *	2.7 (0.9)	9.0 (3.0)	8.1 (2.8)	6.7 (2.3)	<0.01
<i>Eriophorum russeolum</i> *	5.2 (1.0)	8.0 (2.7)	11.0 (2.9)	7.9 (2.1)	0.02
<i>Luzula arctica</i> *	2.0 (0.9)	3.2 (1.2)	4.3 (1.9)	1.8 (1.0)	<0.01
<i>Luzula confusa</i> *	1.7 (0.5)	1.6 (0.5)	2.4 (0.8)	1.0 (0.4)	0.03
<i>Poa spp.</i> *	4.8 (1.4)	6.4 (2.9)	11.2 (3.8)	6.1 (2.0)	<0.01
Lichens*	12.8 (3.1)	15.2 (3.3)	19.6 (4.3)	15.3 (3.3)	<0.01
Foliose*	3.3 (0.9)	5.2 (1.4)	6.6 (1.7)	4.6 (1.3)	0.01
Fruticose*	9.4 (2.5)	9.8 (2.5)	12.5 (3.1)	10.3 (2.4)	<0.01
Litter [‡]	49.1 (3.9)	29.2 (3.9)	27.6 (3.7)	39.2 (3.2)	<0.01
Standing dead*	49.6 (4.1)	105.8 (7.7)	29.5 (3.6)	53.3 (4.3)	<0.01

Metric	Change Over Time				ANOVA	Correlation	
	2010	2012	2013	2014	p	C	p
Vegetation cover							
Bryophytes	34.5 (3.2)	41.9 (4.8)	44.8 (4.1)	37.4 (3.3)	0.05	0.09	0.34
Acrocarpous mosses [‡]	17.6 (2.9)	14.1 (2.7)	19.1 (2.5)	13.6 (2.2)	0.88	-0.01	0.92
Pleurocarpous mosses [‡]	16.4 (3.8)	27.4 (5.2)	24.8 (4.3)	23.5 (3.9)	<0.01	0.16	0.07
Deciduous shrubs*	7.4 (2.4)	9.0 (3.1)	9.9 (3.2)	7.8 (2.6)	<0.01	0.05	0.58
<i>Salix rotundifolia</i> *	5.8 (2.0)	6.4 (2.1)	7.9 (2.5)	6.6 (2.3)	0.01	0.03	0.74
Forbs*	6.7 (1.4)	11.0 (3.4)	14.0 (3.2)	6.7 (1.7)	<0.01	<0.01	0.97
<i>Petasites frigidus</i> *	1.8 (0.7)	5.8 (3.1)	4.3 (2.1)	2.3 (1.2)	0.19	0.01	0.87
<i>Saxifraga cernua</i> *	1.4 (0.5)	1.0 (0.4)	2.2 (0.6)	0.8 (0.2)	0.01	0.01	0.89
<i>Saxifraga foliolosa</i> *	0.3 (0.2)	0.5 (0.3)	0.9 (0.3)	0.5 (0.3)	0.13	0.09	0.31
<i>Stellaria spp.</i> *	1.9 (0.6)	1.6 (0.6)	2.7 (1.0)	1.5 (0.5)	0.20	0.01	0.89
Graminoids [†]	44.4 (4.0)	69.6 (7.6)	92.1 (7.5)	50.1 (4.6)	<0.01	0.18	0.05
<i>Arctagrostis latifolia</i> *	2.0 (0.8)	2.6 (0.9)	3.2 (1.1)	1.8 (0.8)	0.01	0.01	0.96
<i>Carex stans</i> *	17.7 (2.9)	27.6 (4.5)	40.0 (6.1)	17.2 (2.7)	<0.01	0.04	0.68
<i>Dupontia fisheri</i> *	6.8 (1.7)	9.9 (2.5)	10.2 (2.8)	6.2 (1.7)	<0.01	-0.04	0.69
<i>Eriophorum triste</i> *	2.7 (0.9)	9.0 (3.0)	8.1 (2.8)	6.7 (2.3)	<0.01	0.12	0.18
<i>Eriophorum russeolum</i> *	5.2 (1.0)	8.0 (2.7)	11.0 (2.9)	7.9 (2.1)	0.02	0.05	0.62
<i>Luzula arctica</i> *	2.0 (0.9)	3.2 (1.2)	4.3 (1.9)	1.8 (1.0)	<0.01	<0.01	0.78
<i>Luzula confusa</i> *	1.7 (0.5)	1.6 (0.5)	2.4 (0.8)	1.0 (0.4)	0.03	-0.12	0.21
<i>Poa spp.</i> *	4.8 (1.4)	6.4 (2.9)	11.2 (3.8)	6.1 (2.0)	<0.01	0.07	0.45
Lichens*	12.8 (3.1)	15.2 (3.3)	19.6 (4.3)	15.3 (3.3)	<0.01	0.03	0.73
Foliose*	3.3 (0.9)	5.2 (1.4)	6.6 (1.7)	4.6 (1.3)	0.01	0.04	0.65
Fruticose*	9.4 (2.5)	9.8 (2.5)	12.5 (3.1)	10.3 (2.4)	<0.01	0.04	0.63
Litter [‡]	49.1 (3.9)	29.2 (3.9)	27.6 (3.7)	39.2 (3.2)	<0.01	-0.20	0.03
Standing dead*	49.6 (4.1)	105.8 (7.7)	29.5 (3.6)	53.3 (4.3)	<0.01	-0.19	0.03

The cover of 3 functional groups was significantly correlated with year

Metric	Change Over Time				ANOVA	Correlation	
	2010	2012	2013	2014	p	C	p
Vegetation cover							
Bryophytes	34.5 (3.2)	41.9 (4.8)	44.8 (4.1)	37.4 (3.3)	0.05	0.09	0.34
Acrocarpous mosses [‡]	17.6 (2.9)	14.1 (2.7)	19.1 (2.5)	13.6 (2.2)	0.88	-0.01	0.92
Pleurocarpous mosses [‡]	16.4 (3.8)	27.4 (5.2)	24.8 (4.3)	23.5 (3.9)	<0.01	0.16	0.07
Deciduous shrubs*	7.4 (2.4)	9.0 (3.1)	9.9 (3.2)	7.8 (2.6)	<0.01	0.05	0.58
<i>Salix rotundifolia</i> *	5.8 (2.0)	6.4 (2.1)	7.9 (2.5)	6.6 (2.3)	0.01	0.03	0.74
Forbs*	6.7 (1.4)	11.0 (3.4)	14.0 (3.2)	6.7 (1.7)	<0.01	<0.01	0.97
<i>Petasites frigidus</i> *	1.8 (0.7)	5.8 (3.1)	4.3 (2.1)	2.3 (1.2)	0.19	0.01	0.87
<i>Saxifraga cernua</i> *	1.4 (0.5)	1.0 (0.4)	2.2 (0.6)	0.8 (0.2)	0.01	0.01	0.89
<i>Saxifraga foliolosa</i> *	0.3 (0.2)	0.5 (0.3)	0.9 (0.3)	0.5 (0.3)	0.13	0.09	0.31
<i>Stellaria spp.</i> *	1.9 (0.6)	1.6 (0.6)	2.7 (1.0)	1.5 (0.5)	0.20	0.01	0.89
Graminoids [†]	44.4 (4.0)	69.6 (7.6)	92.1 (7.5)	50.1 (4.6)	<0.01	0.18	0.05
<i>Arctagrostis latifolia</i> *	2.0 (0.8)	2.6 (0.9)	3.2 (1.1)	1.8 (0.8)	0.01	0.01	0.96
<i>Carex stans</i> *	17.7 (2.9)	27.6 (4.5)	40.0 (6.1)	17.2 (2.7)	<0.01	0.04	0.68
<i>Dupontia fisheri</i> *	6.8 (1.7)	9.9 (2.5)	10.2 (2.8)	6.2 (1.7)	<0.01	-0.04	0.69
<i>Eriophorum triste</i> *	2.7 (0.9)	9.0 (3.0)	8.1 (2.8)	6.7 (2.3)	<0.01	0.12	0.18
<i>Eriophorum russeolum</i> *	5.2 (1.0)	8.0 (2.7)	11.0 (2.9)	7.9 (2.1)	0.02	0.05	0.62
<i>Luzula arctica</i> *	2.0 (0.9)	3.2 (1.2)	4.3 (1.9)	1.8 (1.0)	<0.01	<0.01	0.78
<i>Luzula confusa</i> *	1.7 (0.5)	1.6 (0.5)	2.4 (0.8)	1.0 (0.4)	0.03	-0.12	0.21
<i>Poa spp.</i> *	4.8 (1.4)	6.4 (2.9)	11.2 (3.8)	6.1 (2.0)	<0.01	0.07	0.45
Lichens*	12.8 (3.1)	15.2 (3.3)	19.6 (4.3)	15.3 (3.3)	<0.01	0.03	0.73
Foliose*	3.3 (0.9)	5.2 (1.4)	6.6 (1.7)	4.6 (1.3)	0.01	0.04	0.65
Fruticose*	9.4 (2.5)	9.8 (2.5)	12.5 (3.1)	10.3 (2.4)	<0.01	0.04	0.63
Litter [‡]	49.1 (3.9)	29.2 (3.9)	27.6 (3.7)	39.2 (3.2)	<0.01	-0.20	0.03
Standing dead*	49.6 (4.1)	105.8 (7.7)	29.5 (3.6)	53.3 (4.3)	<0.01	-0.19	0.03

Likely due to increased graminoid abundance, lemming herbivory and leaf retention time

Metric	Change Over Time				ANOVA	Correlation	
	2010	2012	2013	2014	p	C	p
Vegetation cover							
Bryophytes	34.5 (3.2)	41.9 (4.8)	44.8 (4.1)	37.4 (3.3)	0.05	0.09	0.34
Acrocarpous mosses [‡]	17.6 (2.9)	14.1 (2.7)	19.1 (2.5)	13.6 (2.2)	0.88	-0.01	0.92
Pleurocarpous mosses [‡]	16.4 (3.8)	27.4 (5.2)	24.8 (4.3)	23.5 (3.9)	<0.01	0.16	0.07
Deciduous shrubs*	7.4 (2.4)	9.0 (3.1)	9.9 (3.2)	7.8 (2.6)	<0.01	0.05	0.58
<i>Salix rotundifolia</i> *	5.8 (2.0)	6.4 (2.1)	7.9 (2.5)	6.6 (2.3)	0.01	0.03	0.74
Forbs*	6.7 (1.4)	11.0 (3.4)	14.0 (3.2)	6.7 (1.7)	<0.01	<0.01	0.97
<i>Petasites frigidus</i> *	1.8 (0.7)	5.8 (3.1)	4.3 (2.1)	2.3 (1.2)	0.19	0.01	0.87
<i>Saxifraga cernua</i> *	1.4 (0.5)	1.0 (0.4)	2.2 (0.6)	0.8 (0.2)	0.01	0.01	0.89
<i>Saxifraga foliolosa</i> *	0.3 (0.2)	0.5 (0.3)	0.9 (0.3)	0.5 (0.3)	0.13	0.09	0.31
<i>Stellaria spp.</i> *	1.9 (0.6)	1.6 (0.6)	2.7 (1.0)	1.5 (0.5)	0.20	0.01	0.89
Graminoids [†]	44.4 (4.0)	69.6 (7.6)	92.1 (7.5)	50.1 (4.6)	<0.01	0.18	0.05
<i>Arctagrostis latifolia</i> *	2.0 (0.8)	2.6 (0.9)	3.2 (1.1)	1.8 (0.8)	0.01	0.01	0.96
<i>Carex stans</i> *	17.7 (2.9)	27.6 (4.5)	40.0 (6.1)	17.2 (2.7)	<0.01	0.04	0.68
<i>Dupontia fisheri</i> *	6.8 (1.7)	9.9 (2.5)	10.2 (2.8)	6.2 (1.7)	<0.01	-0.04	0.69
<i>Eriophorum triste</i> *	2.7 (0.9)	9.0 (3.0)	8.1 (2.8)	6.7 (2.3)	<0.01	0.12	0.18
<i>Eriophorum russeolum</i> *	5.2 (1.0)	8.0 (2.7)	11.0 (2.9)	7.9 (2.1)	0.02	0.05	0.62
<i>Luzula arctica</i> *	2.0 (0.9)	3.2 (1.2)	4.3 (1.9)	1.8 (1.0)	<0.01	<0.01	0.78
<i>Luzula confusa</i> *	1.7 (0.5)	1.6 (0.5)	2.4 (0.8)	1.0 (0.4)	0.03	-0.12	0.21
<i>Poa spp.</i> *	4.8 (1.4)	6.4 (2.9)	11.2 (3.8)	6.1 (2.0)	<0.01	0.07	0.45
Lichens*	12.8 (3.1)	15.2 (3.3)	19.6 (4.3)	15.3 (3.3)	<0.01	0.03	0.73
Foliose*	3.3 (0.9)	5.2 (1.4)	6.6 (1.7)	4.6 (1.3)	0.01	0.04	0.65
Fruticose*	9.4 (2.5)	9.8 (2.5)	12.5 (3.1)	10.3 (2.4)	<0.01	0.04	0.63
Litter [‡]	49.1 (3.9)	29.2 (3.9)	27.6 (3.7)	39.2 (3.2)	<0.01	-0.20	0.03
Standing dead*	49.6 (4.1)	105.8 (7.7)	29.5 (3.6)	53.3 (4.3)	<0.01	-0.19	0.03



Metric

Diversity

Alpha

Beta

Evenness[‡]

Height

Deciduous shrubs

Forbs[‡]

Graminoids[‡]

Abundant taxa cover

Acrocarpous mosses[‡]

Pleurocarpous mosses[‡]

Carex stans[‡]

Dupontia fisheri[†]

Eriophorum russeolum[†]



Metric	n
Diversity	
Alpha	30
Beta	30
Evenness [‡]	30
Height	
Deciduous shrubs	9
Forbs [‡]	22
Graminoids [‡]	30
Abundant taxa cover	
Acrocarpous mosses [‡]	23
Pleurocarpous mosses [‡]	22
<i>Carex stans</i> [‡]	22
<i>Dupontia fisheri</i> [†]	17
<i>Eriophorum russeolum</i> [†]	16



Metric	n	Change Over Time			
		2010	2012	2013	2014
Diversity					
Alpha	30	7.1 (0.4)	6.7 (0.4)	8.1 (0.5)	7.3 (0.5)
Beta	30	0.26 (0.01)	0.26 (0.01)	0.27 (0.01)	0.26 (0.01)
Evenness [‡]	30	0.43 (0.02)	0.40 (0.02)	0.41 (0.02)	0.41 (0.02)
Height					
Deciduous shrubs	9	1.9 (0.4)	3.0 (0.6)	2.2 (0.4)	2.3 (0.4)
Forbs [‡]	22	5.1 (0.8)	6.2 (1.1)	4.7 (0.7)	3.7 (0.6)
Graminoids [‡]	30	11.1 (0.7)	14.3 (0.9)	13.0 (0.9)	13.2 (1.0)
Abundant taxa cover					
Acrocarpous mosses [‡]	23	21.9 (3.1)	16.1 (3.1)	21.4 (2.8)	16.1 (2.5)
Pleurocarpous mosses [‡]	22	22.3 (4.6)	35.2 (6.2)	32.2 (5.0)	30.4 (4.3)
<i>Carex stans</i> [‡]	22	24.1 (3.0)	37.2 (4.7)	54.0 (6.0)	23.1 (2.7)
<i>Dupontia fisheri</i> [†]	17	11.4 (2.5)	16.9 (3.7)	17.4 (4.2)	10.7 (2.8)
<i>Eriophorum russeolum</i> [†]	16	8.0 (1.3)	14.9 (4.5)	18.4 (4.4)	13.9 (3.3)



Metric	n	Change Over Time				ANOVA
		2010	2012	2013	2014	p
Diversity						
Alpha	30	7.1 (0.4)	6.7 (0.4)	8.1 (0.5)	7.3 (0.5)	<0.01
Beta	30	0.26 (0.01)	0.26 (0.01)	0.27 (0.01)	0.26 (0.01)	0.56
Evenness [‡]	30	0.43 (0.02)	0.40 (0.02)	0.41 (0.02)	0.41 (0.02)	0.80
Height						
Deciduous shrubs	9	1.9 (0.4)	3.0 (0.6)	2.2 (0.4)	2.3 (0.4)	0.31
Forbs [‡]	22	5.1 (0.8)	6.2 (1.1)	4.7 (0.7)	3.7 (0.6)	0.14
Graminoids [‡]	30	11.1 (0.7)	14.3 (0.9)	13.0 (0.9)	13.2 (1.0)	0.01
Abundant taxa cover						
Acrocarpous mosses [‡]	23	21.9 (3.1)	16.1 (3.1)	21.4 (2.8)	16.1 (2.5)	0.13
Pleurocarpous mosses [‡]	22	22.3 (4.6)	35.2 (6.2)	32.2 (5.0)	30.4 (4.3)	<0.01
<i>Carex stans</i> [‡]	22	24.1 (3.0)	37.2 (4.7)	54.0 (6.0)	23.1 (2.7)	<0.01
<i>Dupontia fisheri</i> [†]	17	11.4 (2.5)	16.9 (3.7)	17.4 (4.2)	10.7 (2.8)	0.98
<i>Eriophorum russeolum</i> [†]	16	8.0 (1.3)	14.9 (4.5)	18.4 (4.4)	13.9 (3.3)	0.12

Other vegetation metrics also changed significantly over time

Metric	n	Change Over Time				ANOVA
		2010	2012	2013	2014	p
Diversity						
Alpha	30	7.1 (0.4)	6.7 (0.4)	8.1 (0.5)	7.3 (0.5)	<0.01
Beta	30	0.26 (0.01)	0.26 (0.01)	0.27 (0.01)	0.26 (0.01)	0.56
Evenness [‡]	30	0.43 (0.02)	0.40 (0.02)	0.41 (0.02)	0.41 (0.02)	0.80
Height						
Deciduous shrubs	9	1.9 (0.4)	3.0 (0.6)	2.2 (0.4)	2.3 (0.4)	0.31
Forbs [‡]	22	5.1 (0.8)	6.2 (1.1)	4.7 (0.7)	3.7 (0.6)	0.14
Graminoids [‡]	30	11.1 (0.7)	14.3 (0.9)	13.0 (0.9)	13.2 (1.0)	0.01
Abundant taxa cover						
Acrocarpous mosses [‡]	23	21.9 (3.1)	16.1 (3.1)	21.4 (2.8)	16.1 (2.5)	0.13
Pleurocarpous mosses [‡]	22	22.3 (4.6)	35.2 (6.2)	32.2 (5.0)	30.4 (4.3)	<0.01
<i>Carex stans</i> [‡]	22	24.1 (3.0)	37.2 (4.7)	54.0 (6.0)	23.1 (2.7)	<0.01
<i>Dupontia fisheri</i> [†]	17	11.4 (2.5)	16.9 (3.7)	17.4 (4.2)	10.7 (2.8)	0.98
<i>Eriophorum russeolum</i> [†]	16	8.0 (1.3)	14.9 (4.5)	18.4 (4.4)	13.9 (3.3)	0.12

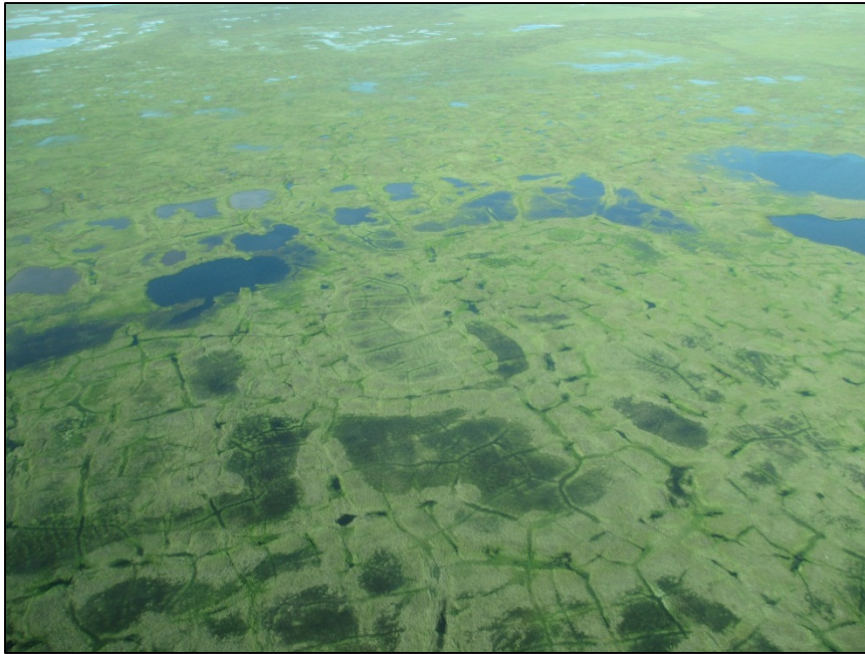


Metric	n	Change Over Time				ANOVA	Correlation	
		2010	2012	2013	2014	p	r	p
Diversity								
Alpha	30	7.1 (0.4)	6.7 (0.4)	8.1 (0.5)	7.3 (0.5)	<0.01	0.07	0.47
Beta	30	0.26 (0.01)	0.26 (0.01)	0.27 (0.01)	0.26 (0.01)	0.56	0.03	0.73
Evenness [‡]	30	0.43 (0.02)	0.40 (0.02)	0.41 (0.02)	0.41 (0.02)	0.80	-0.05	0.61
Height								
Deciduous shrubs	9	1.9 (0.4)	3.0 (0.6)	2.2 (0.4)	2.3 (0.4)	0.31	0.08	0.65
Forbs [‡]	22	5.1 (0.8)	6.2 (1.1)	4.7 (0.7)	3.7 (0.6)	0.14	-0.14	0.20
Graminoids [‡]	30	11.1 (0.7)	14.3 (0.9)	13.0 (0.9)	13.2 (1.0)	0.01	0.15	0.10
Abundant taxa cover								
Acrocarpous mosses [‡]	23	21.9 (3.1)	16.1 (3.1)	21.4 (2.8)	16.1 (2.5)	0.13	-0.10	0.33
Pleurocarpous mosses [‡]	22	22.3 (4.6)	35.2 (6.2)	32.2 (5.0)	30.4 (4.3)	<0.01	0.17	0.11
<i>Carex stans</i> [‡]	22	24.1 (3.0)	37.2 (4.7)	54.0 (6.0)	23.1 (2.7)	<0.01	0.13	0.22
<i>Dupontia fisheri</i> [†]	17	11.4 (2.5)	16.9 (3.7)	17.4 (4.2)	10.7 (2.8)	0.98	0.04	0.74
<i>Eriophorum russeolum</i> [†]	16	8.0 (1.3)	14.9 (4.5)	18.4 (4.4)	13.9 (3.3)	0.12	0.13	0.31

Therefore caution against non-consecutive time series sampling

Metric	n	Change Over Time				ANOVA	Correlation	
		2010	2012	2013	2014	p	r	p
Diversity								
Alpha	30	7.1 (0.4)	6.7 (0.4)	8.1 (0.5)	7.3 (0.5)	<0.01	0.07	0.47
Beta	30	0.26 (0.01)	0.26 (0.01)	0.27 (0.01)	0.26 (0.01)	0.56	0.03	0.73
Evenness [‡]	30	0.43 (0.02)	0.40 (0.02)	0.41 (0.02)	0.41 (0.02)	0.80	-0.05	0.61
Height								
Deciduous shrubs	9	1.9 (0.4)	3.0 (0.6)	2.2 (0.4)	2.3 (0.4)	0.31	0.08	0.65
Forbs [‡]	22	5.1 (0.8)	6.2 (1.1)	4.7 (0.7)	3.7 (0.6)	0.14	-0.14	0.20
Graminoids [‡]	30	11.1 (0.7)	14.3 (0.9)	13.0 (0.9)	13.2 (1.0)	0.01	0.15	0.10
Abundant taxa cover								
Acrocarpous mosses [‡]	23	21.9 (3.1)	16.1 (3.1)	21.4 (2.8)	16.1 (2.5)	0.13	-0.10	0.33
Pleurocarpous mosses [‡]	22	22.3 (4.6)	35.2 (6.2)	32.2 (5.0)	30.4 (4.3)	<0.01	0.17	0.11
<i>Carex stans</i> [‡]	22	24.1 (3.0)	37.2 (4.7)	54.0 (6.0)	23.1 (2.7)	<0.01	0.13	0.22
<i>Dupontia fisheri</i> [†]	17	11.4 (2.5)	16.9 (3.7)	17.4 (4.2)	10.7 (2.8)	0.98	0.04	0.74
<i>Eriophorum russeolum</i> [†]	16	8.0 (1.3)	14.9 (4.5)	18.4 (4.4)	13.9 (3.3)	0.12	0.13	0.31

Aerial Evidence of Vegetation Changes



Mid August 2013



Mid August 2014

Research Questions

1. How has the vegetation metrics of cover, height and diversity changed over time?
2. **What abiotic factors may explain the observed changes? (site only)**



Vegetation cover

- Bryophytes
- Deciduous shrubs*
- Forbs*
- Graminoids†
- Lichens*
- Litter‡
- Standing dead*

Diversity

- Alpha
- Beta
- Evenness

Height

- Deciduous shrubs
- Forbs
- Graminoids

Abundant taxa cover

- Acrocarpous mosses
 - Pleurocarpous mosses
 - Carex stans*
 - Dupontia fisheri*
 - Eriophorum russeolum*
-



	Air temperature
Vegetation cover	
Bryophytes	0.09
Deciduous shrubs*	0.02
Forbs*	0.12
Graminoids†	0.24
Lichens*	0.03
Litter‡	-0.21
Standing dead*	0.27
Diversity	
Alpha	0.01
Beta	0.37
Evenness	-0.01
Height	
Deciduous shrubs	0.09
Forbs	0.12
Graminoids	0.03
Abundant taxa cover	
Acrocarpous mosses	0.06
Pleurocarpous mosses	-0.01
<i>Carex stans</i>	0.35
<i>Dupontia fisheri</i>	0.15
<i>Eriophorum russeolum</i>	0.06

	Air temperature	Precipitation
Vegetation cover		
Bryophytes	0.09	0.08
Deciduous shrubs*	0.02	0.04
Forbs*	0.12	0.09
Graminoids†	0.24	0.24
Lichens*	0.03	0.03
Litter‡	-0.21	-0.09
Standing dead*	0.27	-0.67
Diversity		
Alpha	0.01	0.19
Beta	0.37	0.27
Evenness	-0.01	0.03
Height		
Deciduous shrubs	0.09	0.09
Forbs	0.12	0.12
Graminoids	0.03	0.03
Abundant taxa cover		
Acrocarpous mosses	0.06	0.10
Pleurocarpous mosses	-0.01	0.06
<i>Carex stans</i>	0.35	0.27
<i>Dupontia fisheri</i>	0.15	0.03
<i>Eriophorum russeolum</i>	0.06	0.12

	Air temperature	Precipitation	TDD (sum)
Vegetation cover			
Bryophytes	0.09	0.08	0.11
Deciduous shrubs*	0.02	0.04	0.02
Forbs*	0.12	0.09	0.12
Graminoids†	0.24	0.24	0.29
Lichens*	0.03	0.03	0.03
Litter‡	-0.21	-0.09	-0.26
Standing dead*	0.27	-0.67	0.27
Diversity			
Alpha	0.01	0.19	0.02
Beta	0.37	0.27	0.82
Evenness	-0.01	0.03	-0.01
Height			
Deciduous shrubs	0.09	0.09	0.10
Forbs	0.12	0.12	0.19
Graminoids	0.03	0.03	0.06
Abundant taxa cover			
Acrocarpous mosses	0.06	0.10	0.05
Pleurocarpous mosses	-0.01	0.06	0.02
<i>Carex stans</i>	0.35	0.27	0.40
<i>Dupontia fisheri</i>	0.15	0.03	0.17
<i>Eriophorum russeolum</i>	0.06	0.12	0.08

	Air temperature	Precipitation	TDD (sum)	Thaw depth
Vegetation cover				
Bryophytes	0.09	0.08	0.11	0.03
Deciduous shrubs*	0.02	0.04	0.02	0.01
Forbs*	0.12	0.09	0.12	0.15
Graminoids†	0.24	0.24	0.29	0.16
Lichens*	0.03	0.03	0.03	0.02
Litter‡	-0.21	-0.09	-0.26	-0.01
Standing dead*	0.27	-0.67	0.27	-0.45
Diversity				
Alpha	0.01	0.19	0.02	0.09
Beta	0.37	0.27	0.82	0.35
Evenness	-0.01	0.03	-0.01	0.03
Height				
Deciduous shrubs	0.09	0.09	0.10	-0.12
Forbs	0.12	0.12	0.19	0.10
Graminoids	0.03	0.03	0.06	-0.12
Abundant taxa cover				
Acrocarpous mosses	0.06	0.10	0.05	0.09
Pleurocarpous mosses	-0.01	0.06	0.02	-0.10
<i>Carex stans</i>	0.35	0.27	0.40	0.27
<i>Dupontia fisheri</i>	0.15	0.03	0.17	0.06
<i>Eriophorum russeolum</i>	0.06	0.12	0.08	0.02

	Air temperature	Precipitation	TDD (sum)	Thaw depth	Soil temperature
Vegetation cover					
Bryophytes	0.09	0.08	0.11	0.03	0.15
Deciduous shrubs*	0.02	0.04	0.02	0.01	0.05
Forbs*	0.12	0.09	0.12	0.15	0.18
Graminoids†	0.24	0.24	0.29	0.16	0.43
Lichens*	0.03	0.03	0.03	0.02	0.05
Litter‡	-0.21	-0.09	-0.26	-0.01	-0.29
Standing dead*	0.27	-0.67	0.27	-0.45	-0.18
Diversity					
Alpha	0.01	0.19	0.02	0.09	0.15
Beta	0.37	0.27	0.82	0.35	0.92
Evenness	-0.01	0.03	-0.01	0.03	0.01
Height					
Deciduous shrubs	0.09	0.09	0.10	-0.12	<0.01
Forbs	0.12	0.12	0.19	0.10	0.04
Graminoids	0.03	0.03	0.06	-0.12	0.05
Abundant taxa cover					
Acrocarpous mosses	0.06	0.10	0.05	0.09	0.11
Pleurocarpous mosses	-0.01	0.06	0.02	-0.10	0.07
<i>Carex stans</i>	0.35	0.27	0.40	0.27	0.53
<i>Dupontia fisheri</i>	0.15	0.03	0.17	0.06	0.16
<i>Eriophorum russeolum</i>	0.06	0.12	0.08	0.02	0.16

	Air temperature	Precipitation	TDD (sum)	Thaw depth	Soil temperature	Soil moisture
Vegetation cover						
Bryophytes	0.09	0.08	0.11	0.03	0.15	-0.11
Deciduous shrubs*	0.02	0.04	0.02	0.01	0.05	-0.03
Forbs*	0.12	0.09	0.12	0.15	0.18	0.01
Graminoids†	0.24	0.24	0.29	0.16	0.43	-0.19
Lichens*	0.03	0.03	0.03	0.02	0.05	-0.02
Litter‡	-0.21	-0.09	-0.26	-0.01	-0.29	0.32
Standing dead*	0.27	-0.67	0.27	-0.45	-0.18	-0.50
Diversity						
Alpha	0.01	0.19	0.02	0.09	0.15	0.05
Beta	0.37	0.27	0.82	0.35	0.92	-0.19
Evenness	-0.01	0.03	-0.01	0.03	0.01	0.05
Height						
Deciduous shrubs	0.09	0.09	0.10	-0.12	<0.01	-0.25
Forbs	0.12	0.12	0.19	0.10	0.04	-0.02
Graminoids	0.03	0.03	0.06	-0.12	0.05	-0.24
Abundant taxa cover						
Acrocarpous mosses	0.06	0.10	0.05	0.09	0.11	0.19
Pleurocarpous mosses	-0.01	0.06	0.02	-0.10	0.07	-0.19
<i>Carex stans</i>	0.35	0.27	0.40	0.27	0.53	-0.16
<i>Dupontia fisheri</i>	0.15	0.03	0.17	0.06	0.16	-0.12
<i>Eriophorum russeolum</i>	0.06	0.12	0.08	0.02	0.16	-0.11

Metrics are correlated significantly with various abiotic factors

	Air temperature	Precipitation	TDD (sum)	Thaw depth	Soil temperature	Soil moisture
Vegetation cover						
Bryophytes	0.09	0.08	0.11	0.03	0.15	-0.11
Deciduous shrubs*	0.02	0.04	0.02	0.01	0.05	-0.03
Forbs*	0.12	0.09	0.12	0.15	0.18	0.01
Graminoids†	0.24	0.24	0.29	0.16	0.43	-0.19
Lichens*	0.03	0.03	0.03	0.02	0.05	-0.02
Litter‡	-0.21	-0.09	-0.26	-0.01	-0.29	0.32
Standing dead*	0.27	-0.67	0.27	-0.45	-0.18	-0.50
Diversity						
Alpha	0.01	0.19	0.02	0.09	0.15	0.05
Beta	0.37	0.27	0.82	0.35	0.92	-0.19
Evenness	-0.01	0.03	-0.01	0.03	0.01	0.05
Height						
Deciduous shrubs	0.09	0.09	0.10	-0.12	<0.01	-0.25
Forbs	0.12	0.12	0.19	0.10	0.04	-0.02
Graminoids	0.03	0.03	0.06	-0.12	0.05	-0.24
Abundant taxa cover						
Acrocarpous mosses	0.06	0.10	0.05	0.09	0.11	0.19
Pleurocarpous mosses	-0.01	0.06	0.02	-0.10	0.07	-0.19
<i>Carex stans</i>	0.35	0.27	0.40	0.27	0.53	-0.16
<i>Dupontia fisheri</i>	0.15	0.03	0.17	0.06	0.16	-0.12
<i>Eriophorum russeolum</i>	0.06	0.12	0.08	0.02	0.16	-0.11

	Air temperature	Precipitation	TDD (sum)	Thaw depth	Soil temperature	Soil moisture
Vegetation cover						
Bryophytes	0.09	0.08	0.11	0.03	0.15	-0.11
Deciduous shrubs*	0.02	0.04	0.02	0.01	0.05	-0.03
Forbs*	0.12	0.09	0.12	0.15	0.18	0.01
Graminoids†	0.24	0.24	0.29	0.16	0.43	-0.19
Lichens*	0.03	0.03	0.03	0.02	0.05	-0.02
Litter‡	-0.21	-0.09	-0.26	-0.01	-0.29	0.32
Standing dead*	0.27	-0.67	0.27	-0.45	-0.18	-0.50
Diversity						
Alpha	0.01	0.19	0.02	0.09	0.15	0.05
Beta	0.37	0.27	0.82	0.35	0.92	-0.19
Evenness	-0.01	0.03	-0.01	0.03	0.01	0.05
Height						
Deciduous shrubs	0.09	0.09	0.10	-0.12	<0.01	-0.25
Forbs	0.12	0.12	0.19	0.10	0.04	-0.02
Graminoids	0.03	0.03	0.06	-0.12	0.05	-0.24
Abundant taxa cover						
Acrocarpous mosses	0.06	0.10	0.05	0.09	0.11	0.19
Pleurocarpous mosses	-0.01	0.06	0.02	-0.10	0.07	-0.19
<i>Carex stans</i>	0.35	0.27	0.40	0.27	0.53	-0.16
<i>Dupontia fisheri</i>	0.15	0.03	0.17	0.06	0.16	-0.12
<i>Eriophorum russeolum</i>	0.06	0.12	0.08	0.02	0.16	-0.11

Metrics are the most strongly correlated with different abiotic factors

	Air temperature	Precipitation	TDD (sum)	Thaw depth	Soil temperature	Soil moisture
Vegetation cover						
Bryophytes	0.09	0.08	0.11	0.03	0.15	-0.11
Deciduous shrubs*	0.02	0.04	0.02	0.01	0.05	-0.03
Forbs*	0.12	0.09	0.12	0.15	0.18	0.01
Graminoids†	0.24	0.24	0.29	0.16	0.43	-0.19
Lichens*	0.03	0.03	0.03	0.02	0.05	-0.02
Litter‡	-0.21	-0.09	-0.26	-0.01	-0.29	0.32
Standing dead*	0.27	-0.67	0.27	-0.45	-0.18	-0.50
Diversity						
Alpha	0.01	0.19	0.02	0.09	0.15	0.05
Beta	0.37	0.27	0.82	0.35	0.92	-0.19
Evenness	-0.01	0.03	-0.01	0.03	0.01	0.05
Height						
Deciduous shrubs	0.09	0.09	0.10	-0.12	<0.01	-0.25
Forbs	0.12	0.12	0.19	0.10	0.04	-0.02
Graminoids	0.03	0.03	0.06	-0.12	0.05	-0.24
Abundant taxa cover						
Acrocarpous mosses	0.06	0.10	0.05	0.09	0.11	0.19
Pleurocarpous mosses	-0.01	0.06	0.02	-0.10	0.07	-0.19
<i>Carex stans</i>	0.35	0.27	0.40	0.27	0.53	-0.16
<i>Dupontia fisheri</i>	0.15	0.03	0.17	0.06	0.16	-0.12
<i>Eriophorum russeolum</i>	0.06	0.12	0.08	0.02	0.16	-0.11

Research Questions

1. How has the vegetation metrics of cover, height and diversity changed over time?
2. What abiotic factors may explain the observed changes?
3. **Are observed changes over time consistent across community types? (grid only)**

Identifying Community Types

- **Based on land cover classification map developed by other researchers**

Identifying Community Types

- Based on land cover classification map developed by other researchers
- **Modified using field observations**

Identifying Community Types

- Based on land cover classification map developed by other researchers
- Modified using field observations
- **Four vegetation community types identified**

Community Types and Dominant Species

Dry dwarf shrub graminoid tundra (Dry)

-*Carex stans*

-*Eriophorum triste*

-*Poa arctica*

-*Petasites frigidus*

-*Salix rotundifolia*

Community Types and Dominant Species

Dry dwarf shrub graminoid tundra (Dry)

- Carex stans*
- Eriophorum triste*
- Poa arctica*
- Petasites frigidus*
- Salix rotundifolia*

Dry-moist dwarf shrub graminoid tundra (Dry-moist)

- Carex stans*
- Dupontia fisheri*
- Eriophorum russeolum*
- Eriophorum triste*
- Salix rotundifolia*

Community Types and Dominant Species

Dry dwarf shrub graminoid tundra (Dry)

- Carex stans*
- Eriophorum triste*
- Poa arctica*
- Petasites frigidus*
- Salix rotundifolia*

Dry-moist dwarf shrub graminoid tundra (Dry-moist)

- Carex stans*
- Dupontia fisheri*
- Eriophorum russeolum*
- Eriophorum triste*
- Salix rotundifolia*

Moist graminoid tundra (Moist)

- Carex stans*
- Dupontia fisheri*
- Eriophorum russeolum*
- Eriophorum triste*
- Gymnocolea inflata*

Community Types and Dominant Species

Dry dwarf shrub graminoid tundra (Dry)

- Carex stans*
- Eriophorum triste*
- Poa arctica*
- Petasites frigidus*
- Salix rotundifolia*

Dry-moist dwarf shrub graminoid tundra (Dry-moist)

- Carex stans*
- Dupontia fisheri*
- Eriophorum russeolum*
- Eriophorum triste*
- Salix rotundifolia*

Moist graminoid tundra (Moist)

- Carex stans*
- Dupontia fisheri*
- Eriophorum russeolum*
- Eriophorum triste*
- Gymnocolea inflata*

Wet graminoid tundra (Wet)

- Carex stans*
- Dupontia fisheri*
- Eriophorum russeolum*
- Eriophorum triste*
- Bryum capillare*

Community Types and Dominant Species

Dry dwarf shrub graminoid tundra (Dry)

- Carex stans*
- Eriophorum triste*
- Poa arctica*
- Petasites frigidus*
- Salix rotundifolia*

Dry-moist dwarf shrub graminoid tundra (Dry-moist)

- Carex stans*
- Dupontia fisheri*
- Eriophorum russeolum*
- Eriophorum triste*
- Salix rotundifolia*

Moist graminoid tundra (Moist)

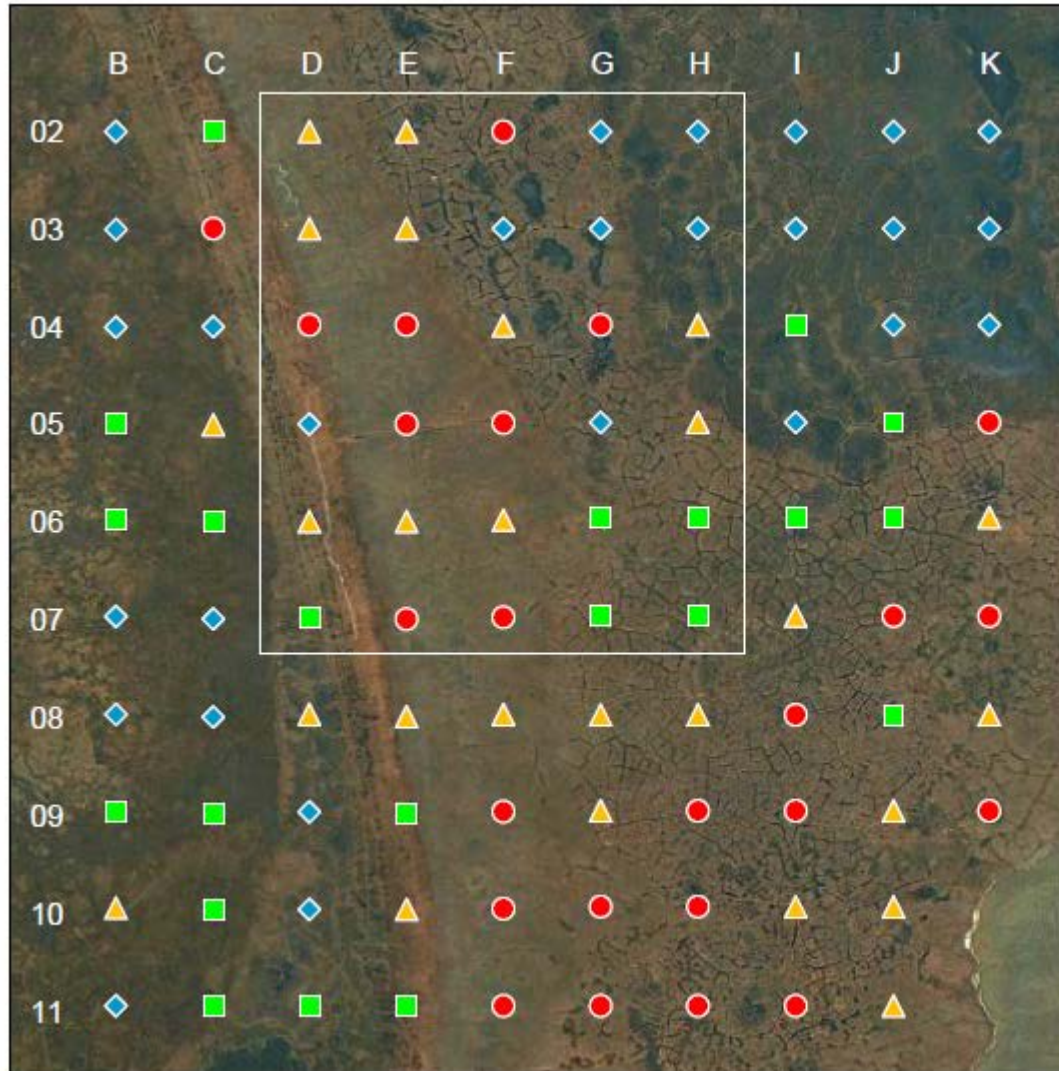
- Carex stans*
- Dupontia fisheri*
- Eriophorum russeolum*
- Eriophorum triste*
- Gymnocolea inflata*

Wet graminoid tundra (Wet)

- Carex stans*
- Dupontia fisheri*
- Eriophorum russeolum*
- Eriophorum triste*
- Bryum capillare*

Considerable amount of overlap of species within community types

Distribution of Communities



Kilometers

0 0.1 0.2 0.3

Community Type

- Dry
- ▲ Dry-moist
- Moist
- ◆ Wet



Metric

Vegetation cover

Bryophytes‡

Deciduous shrubs‡

Forbs‡

Graminoids‡

Lichens‡

Litter‡

Standing dead‡

Abundant taxa cover

Acrocarpous mosses‡

Pleurocarpous mosses‡

Carex stans‡

Dupontia fisheri‡

Eriophorum russeolum†



Metric	Dry
Vegetation cover	
Bryophytes‡	24
Deciduous shrubs‡	24
Forbs‡	24
Graminoids‡	24
Lichens‡	24
Litter‡	24
Standing dead‡	24
Abundant taxa cover	
Acrocarpous mosses‡	24
Pleurocarpous mosses‡	18
<i>Carex stans</i> ‡	17
<i>Dupontia fisheri</i> ‡	12
<i>Eriophorum russeolum</i> †	17



Metric	n	
	Dry	Dry-moist
Vegetation cover		
Bryophytes‡	24	26
Deciduous shrubs‡	24	26
Forbs‡	24	26
Graminoids‡	24	26
Lichens‡	24	26
Litter‡	24	26
Standing dead‡	24	26
Abundant taxa cover		
Acrocarpous mosses‡	24	25
Pleurocarpous mosses‡	18	16
<i>Carex stans</i> ‡	17	19
<i>Dupontia fisheri</i> ‡	12	15
<i>Eriophorum russeolum</i> †	17	17



Metric	n		
	Dry	Dry-moist	Moist
Vegetation cover			
Bryophytes‡	24	26	21
Deciduous shrubs‡	24	26	21
Forbs‡	24	26	21
Graminoids‡	24	26	21
Lichens‡	24	26	21
Litter‡	24	26	21
Standing dead‡	24	26	21
Abundant taxa cover			
Acrocarpous mosses‡	24	25	17
Pleurocarpous mosses‡	18	16	20
<i>Carex stans</i> ‡	17	19	15
<i>Dupontia fisheri</i> ‡	12	15	21
<i>Eriophorum russeolum</i> †	17	17	19



Metric	n			
	Dry	Dry-moist	Moist	Wet
Vegetation cover				
Bryophytes‡	24	26	21	27
Deciduous shrubs‡	24	26	21	27
Forbs‡	24	26	21	27
Graminoids‡	24	26	21	27
Lichens‡	24	26	21	27
Litter‡	24	26	21	27
Standing dead‡	24	26	21	27
Abundant taxa cover				
Acrocarpous mosses‡	24	25	17	19
Pleurocarpous mosses‡	18	16	20	25
<i>Carex stans</i> ‡	17	19	15	20
<i>Dupontia fisheri</i> ‡	12	15	21	24
<i>Eriophorum russeolum</i> †	17	17	19	23



Metric	n				Year
	Dry	Dry-moist	Moist	Wet	
Vegetation cover					
Bryophytes‡	24	26	21	27	<0.01
Deciduous shrubs‡	24	26	21	27	0.54
Forbs‡	24	26	21	27	<0.01
Graminoids‡	24	26	21	27	<0.01
Lichens‡	24	26	21	27	0.11
Litter‡	24	26	21	27	<0.01
Standing dead‡	24	26	21	27	<0.01
Abundant taxa cover					
Acrocarpous mosses‡	24	25	17	19	0.01
Pleurocarpous mosses‡	18	16	20	25	<0.01
<i>Carex stans</i> ‡	17	19	15	20	<0.01
<i>Dupontia fisheri</i> ‡	12	15	21	24	0.06
<i>Eriophorum russeolum</i> †	17	17	19	23	<0.01

The cover of most functional groups and abundant taxa significantly changed over time

Metric	n				Year
	Dry	Dry-moist	Moist	Wet	
Vegetation cover					
Bryophytes [‡]	24	26	21	27	<0.01
Deciduous shrubs [‡]	24	26	21	27	0.54
Forbs [‡]	24	26	21	27	<0.01
Graminoids [‡]	24	26	21	27	<0.01
Lichens [‡]	24	26	21	27	0.11
Litter [‡]	24	26	21	27	<0.01
Standing dead [‡]	24	26	21	27	<0.01
Abundant taxa cover					
Acrocarpous mosses [‡]	24	25	17	19	0.01
Pleurocarpous mosses [‡]	18	16	20	25	<0.01
<i>Carex stans</i> [‡]	17	19	15	20	<0.01
<i>Dupontia fisheri</i> [‡]	12	15	21	24	0.06
<i>Eriophorum russeolum</i> [†]	17	17	19	23	<0.01



Metric	n				ANOVA (p Val)	
	Dry	Dry-moist	Moist	Wet	Year	Community
Vegetation cover						
Bryophytes [‡]	24	26	21	27	<0.01	<0.01
Deciduous shrubs [‡]	24	26	21	27	0.54	<0.01
Forbs [‡]	24	26	21	27	<0.01	0.01
Graminoids [‡]	24	26	21	27	<0.01	<0.01
Lichens [‡]	24	26	21	27	0.11	<0.01
Litter [‡]	24	26	21	27	<0.01	<0.01
Standing dead [‡]	24	26	21	27	<0.01	0.08
Abundant taxa cover						
Acrocarpous mosses [‡]	24	25	17	19	0.01	0.09
Pleurocarpous mosses [‡]	18	16	20	25	<0.01	<0.01
<i>Carex stans</i> [‡]	17	19	15	20	<0.01	<0.01
<i>Dupontia fisheri</i> [‡]	12	15	21	24	0.06	0.03
<i>Eriophorum russeolum</i> [†]	17	17	19	23	<0.01	<0.01



The cover of most functional groups and abundant taxa significantly differed within communities

Metric	n				ANOVA (p Val)	
	Dry	Dry-moist	Moist	Wet	Year	Community
Vegetation cover						
Bryophytes [‡]	24	26	21	27	<0.01	<0.01
Deciduous shrubs [‡]	24	26	21	27	0.54	<0.01
Forbs [‡]	24	26	21	27	<0.01	0.01
Graminoids [‡]	24	26	21	27	<0.01	<0.01
Lichens [‡]	24	26	21	27	0.11	<0.01
Litter [‡]	24	26	21	27	<0.01	<0.01
Standing dead [‡]	24	26	21	27	<0.01	0.08
Abundant taxa cover						
Acrocarpous mosses [‡]	24	25	17	19	0.01	0.09
Pleurocarpous mosses [‡]	18	16	20	25	<0.01	<0.01
<i>Carex stans</i> [‡]	17	19	15	20	<0.01	<0.01
<i>Dupontia fisheri</i> [‡]	12	15	21	24	0.06	0.03
<i>Eriophorum russeolum</i> [†]	17	17	19	23	<0.01	<0.01



Metric	n				ANOVA (p Value)		
	Dry	Dry-moist	Moist	Wet	Year	Community	Interaction
Vegetation cover							
Bryophytes [‡]	24	26	21	27	<0.01	<0.01	0.37
Deciduous shrubs [‡]	24	26	21	27	0.54	<0.01	0.94
Forbs [‡]	24	26	21	27	<0.01	0.01	0.85
Graminoids [‡]	24	26	21	27	<0.01	<0.01	0.98
Lichens [‡]	24	26	21	27	0.11	<0.01	0.40
Litter [‡]	24	26	21	27	<0.01	<0.01	0.87
Standing dead [‡]	24	26	21	27	<0.01	0.08	0.21
Abundant taxa cover							
Acrocarpous mosses [‡]	24	25	17	19	0.01	0.09	0.51
Pleurocarpous mosses [‡]	18	16	20	25	<0.01	<0.01	0.91
<i>Carex stans</i> [‡]	17	19	15	20	<0.01	<0.01	0.84
<i>Dupontia fisheri</i> [‡]	12	15	21	24	0.06	0.03	0.84
<i>Eriophorum russeolum</i> [†]	17	17	19	23	<0.01	<0.01	0.91



There were no significant interactions between year and community type

Metric	n				ANOVA (p Value)		
	Dry	Dry-moist	Moist	Wet	Year	Community	Interaction
Vegetation cover							
Bryophytes [‡]	24	26	21	27	<0.01	<0.01	0.37
Deciduous shrubs [‡]	24	26	21	27	0.54	<0.01	0.94
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Abundant taxa cover							
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<i>Eriophorum russeolum</i> [†]	17	17	19	23	<0.01	<0.01	0.91

Communities responded similarly over time

Metric	n				ANOVA (p Value)		
	Dry	Dry-moist	Moist	Wet	Year	Community	Interaction
Vegetation cover							
Bryophytes [‡]	24	26	21	27	<0.01	<0.01	0.37
Deciduous shrubs [‡]	24	26	21	27	0.54	<0.01	0.94
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<i>Eriophorum russeolum</i> [†]	17	17	19	23	<0.01	<0.01	0.91



Use of two vegetation community types is representative of the landscape in Barrow

Metric	n				ANOVA (p Value)		
	Dry	Dry-moist	Moist	Wet	Year	Community	Interaction
Vegetation cover							
Bryophytes [‡]	24	26	21	27	<0.01	<0.01	0.37
Deciduous shrubs [‡]	24	26	21	27	0.54	<0.01	0.94
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Lichens [‡]	24	26	21	27	0.11	<0.01	0.40
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Abundant taxa cover							
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<i>Eriophorum russeolum</i> [†]	17	17	19	23	<0.01	<0.01	0.91

Research Questions

- 1. How has the vegetation metrics of cover, height and diversity changed over time?**



Conclusions

1. How has the vegetation metrics of cover, height and diversity changed over time?
 - **Changes were huge from year to year**



Conclusions

1. How has the vegetation metrics of cover, height and diversity changed over time?
 - Changes were huge from year to year
 - **Cover of all functional groups changed significantly over time**



Conclusions

1. How has the vegetation metrics of cover, height and diversity changed over time?
 - Changes were huge from year to year
 - Cover of all functional groups changed significantly over time
 - **Cover of 3 functional groups correlated significantly with year**



Conclusions

1. How has the vegetation metrics of cover, height and diversity changed over time?
 - Changes were huge from year to year
 - Cover of all functional groups changed significantly over time
 - Cover of 3 functional groups correlated significantly with year
 - **Therefore caution with monitoring over a non-consecutive time series**

Research Questions

- 2. What abiotic factors may explain the observed changes?**

Research Questions

2. What abiotic factors may explain the observed changes?

- **Functional groups correlated significantly and the most strongly with different abiotic variables**

Research Questions

2. What abiotic factors may explain the observed changes?
 - Functional groups correlated significantly and the most strongly with different abiotic variables
 - **Therefore need to consider many abiotic factors when documenting vegetation changes**

Research Questions

- 3. Are observed changes over time consistent across community types?**

Research Questions

3. Are observed changes over time consistent across community types?
 - **No interaction between community type and year for functional group or abundant taxa cover**

Research Questions

3. Are observed changes over time consistent across community types?
 - No interaction between community type and year for functional group or abundant taxa cover
 - **Considerable overlap of species across the grid**

Research Questions

3. Are observed changes over time consistent across community types?
 - No interaction between community type and year for functional group or abundant taxa cover
 - Considerable overlap of species across the grid
 - **One or two community type analyses representative of changes across the landscape**

Future Research

- **Consider other factors**



Future Research

- Consider other factors
 - **Herbivory**



Future Research

- Consider other factors
 - Herbivory
 - **Analyses incorporating a combination of factors together rather than individually**



Future Research

- Consider other factors
 - Herbivory
 - Analyses incorporating a combination of factors together rather than individually
 - **Growth vs. density**



Future Research

- Consider other factors
 - Herbivory
 - Analyses incorporating a combination of factors
 - Growth vs. density
- **Longer consecutive time series**



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Questions?

