STRUCTURAL COMPARISON OF ARCTIC PLANT COMMUNITIES ACROSS A SOIL MOISTURE GRADIENT IN RESPONSE TO WARMING IN NORTHERN ALASKA

September 18, 2013

Jessica Gregory
Grand Valley State University

Overview

- Introduction
- Project Objectives
- Experimental Design
- Preliminary Data
- Additional Goals

Introduction

- Atqasuk, Alaska (1996)

Image Credit: ine.uaf.edu

- Community Types
  - Wet meadow
    - Dominated by graminoids and bryophytes
    - Edge of thaw lake
  - Dry heath
    - Higher species diversity
    - Dry ridge

- Some changes in vegetation cover observed at sites
- Knowledge Gaps:
  - Structural modifications resulting from:
    - Number of individuals vs. Size of individuals
  - Broader landscape-level observations
    - Comparison of patterns across a range of abiotic conditions and community types

Polygonum bistorta

- Possible explanations for variation:
  - Competitive interactions
  - Increased colonization and recruitment
  - Species abundance
- Expected patterns in abundance:
  - Graminoids and erect shrubs will increase in abundance with warming
  - Forbs and prostrate shrubs will decrease in abundance

Shrubs from top – bottom: V. vitis-idaea, C. tetragona, D. lapponica

Project Objectives

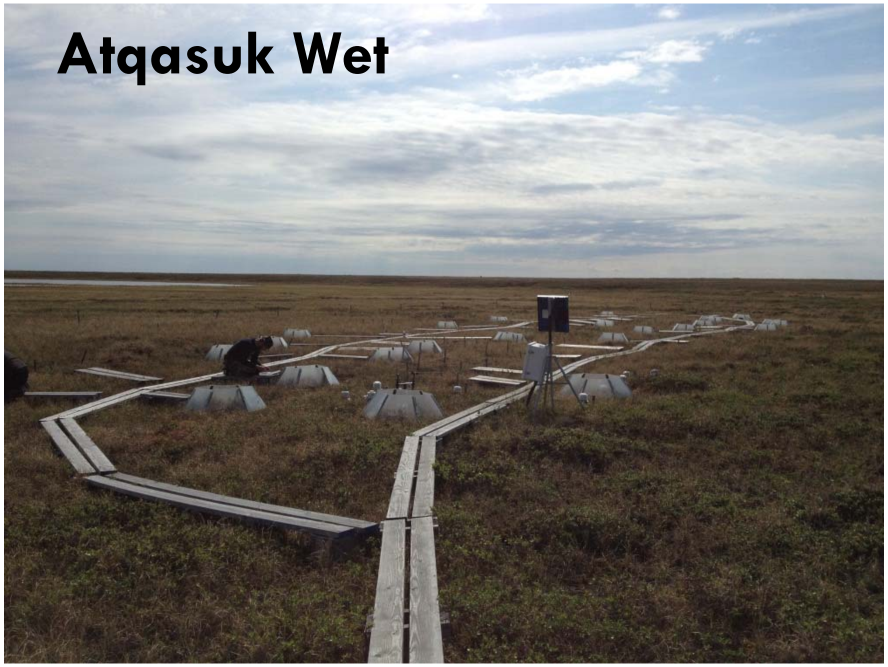
- Compare cover, abundance, and growth to provide detailed view of canopy change
  - Resulting from warming
  - Across a moisture gradient
- Applications for the tundra ecosystem
  - NDVI, albedo, and carbon cycling

Experimental Design

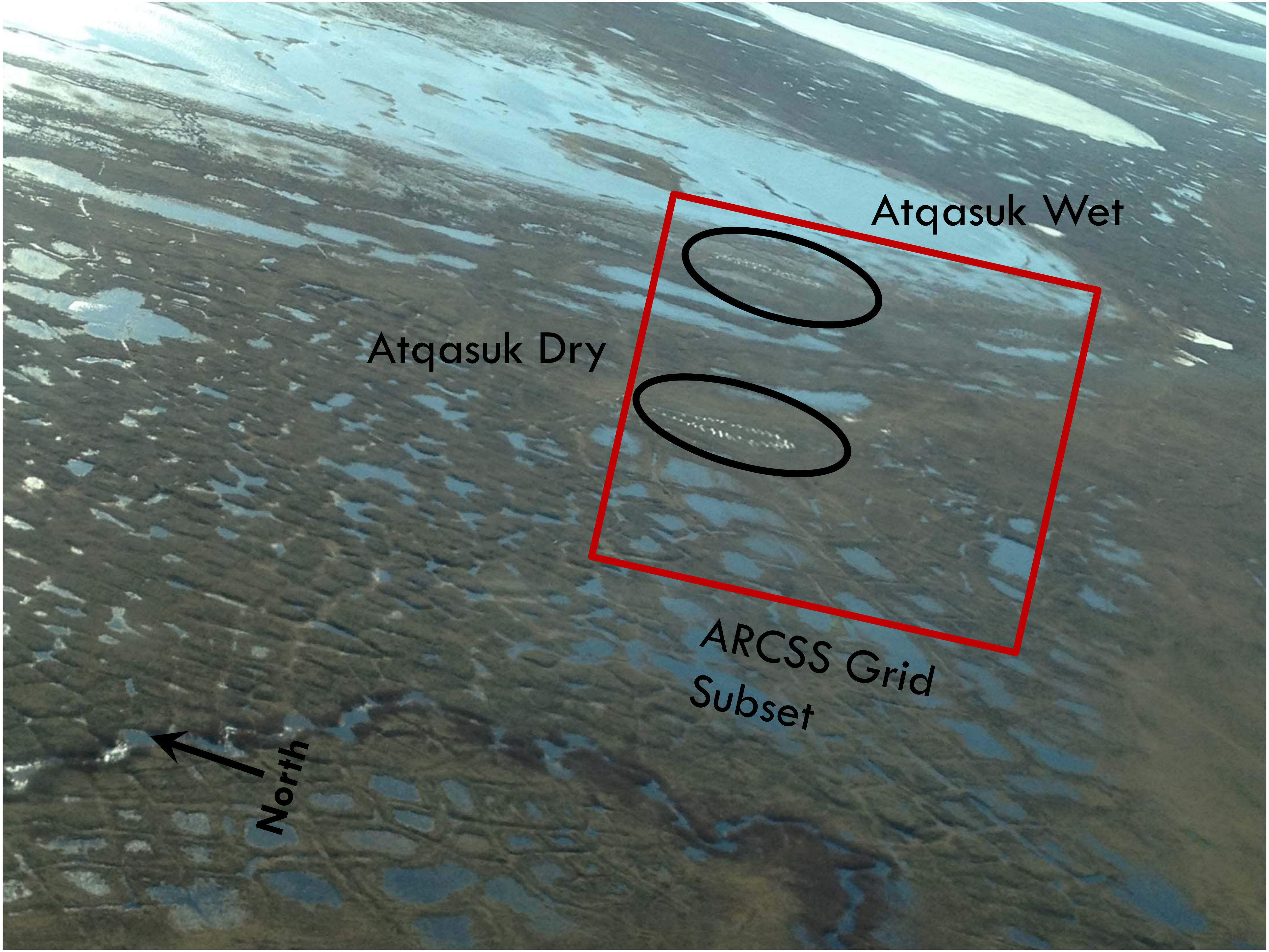
Question:

- How do vegetation cover and density vary across a soil moisture gradient?

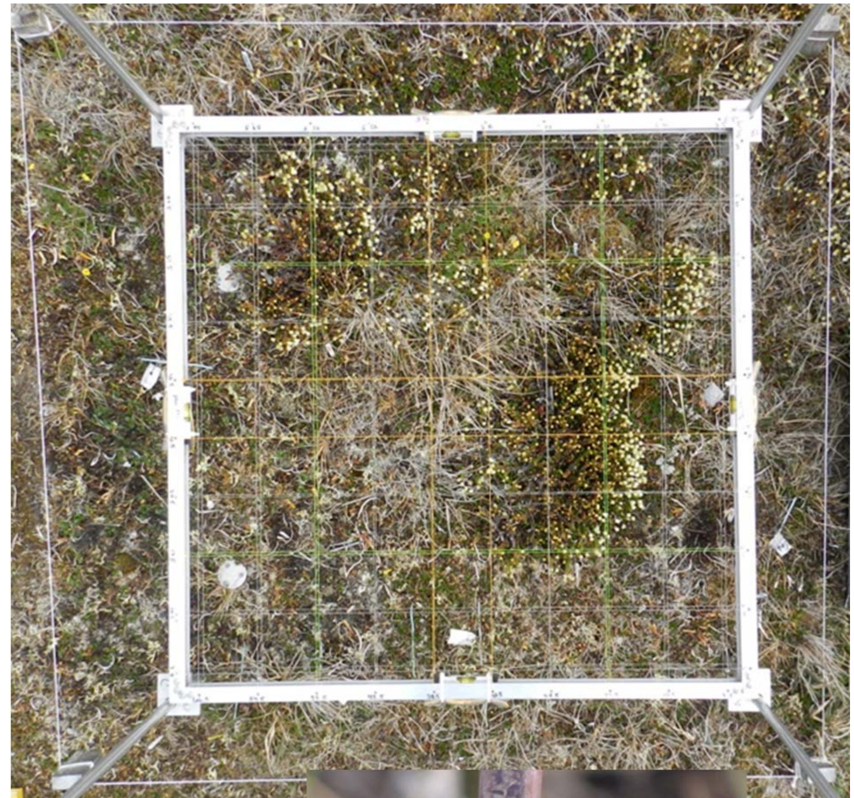
- ITEX plots (1996)
  - Long-term warming experiment
  - 48 plots at each site (24 control, 24 warmed)
  - Provides additional replication at dry and wet extremes of moisture gradient



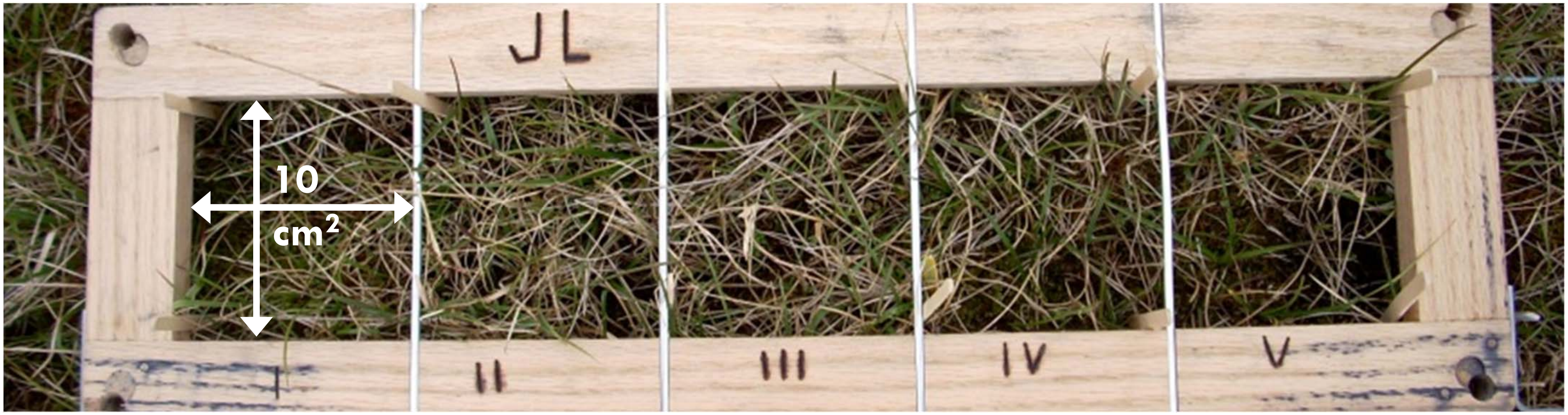
- ARCSS grid (2010)
  - Provides data across a broader landscape area
  - Approximately 100 permanent plots spread across a 1-km^2 grid
  - Subset of 30 plots measured regularly


Atqasuk Wet
Atqasuk Dry
ARCSS Grid
Subset
North

- Cover data
  - Point frame method
  - Measures each contact below each point on the grid
  - Measured on ARCSS grid subset (2013) and ITEX plots (2012)
  - Used all live vascular plant hits to calculate cover by growth form



- Density data
  - Measured in ARCSS grid subset and ITEX plots using a 10 x 50 cm frame
  - Frame position permanently marked; corresponds with point frame placement
  - Individuals counted and given a status
  - Provides the density of all vascular plants



Shows Moisture Gradient

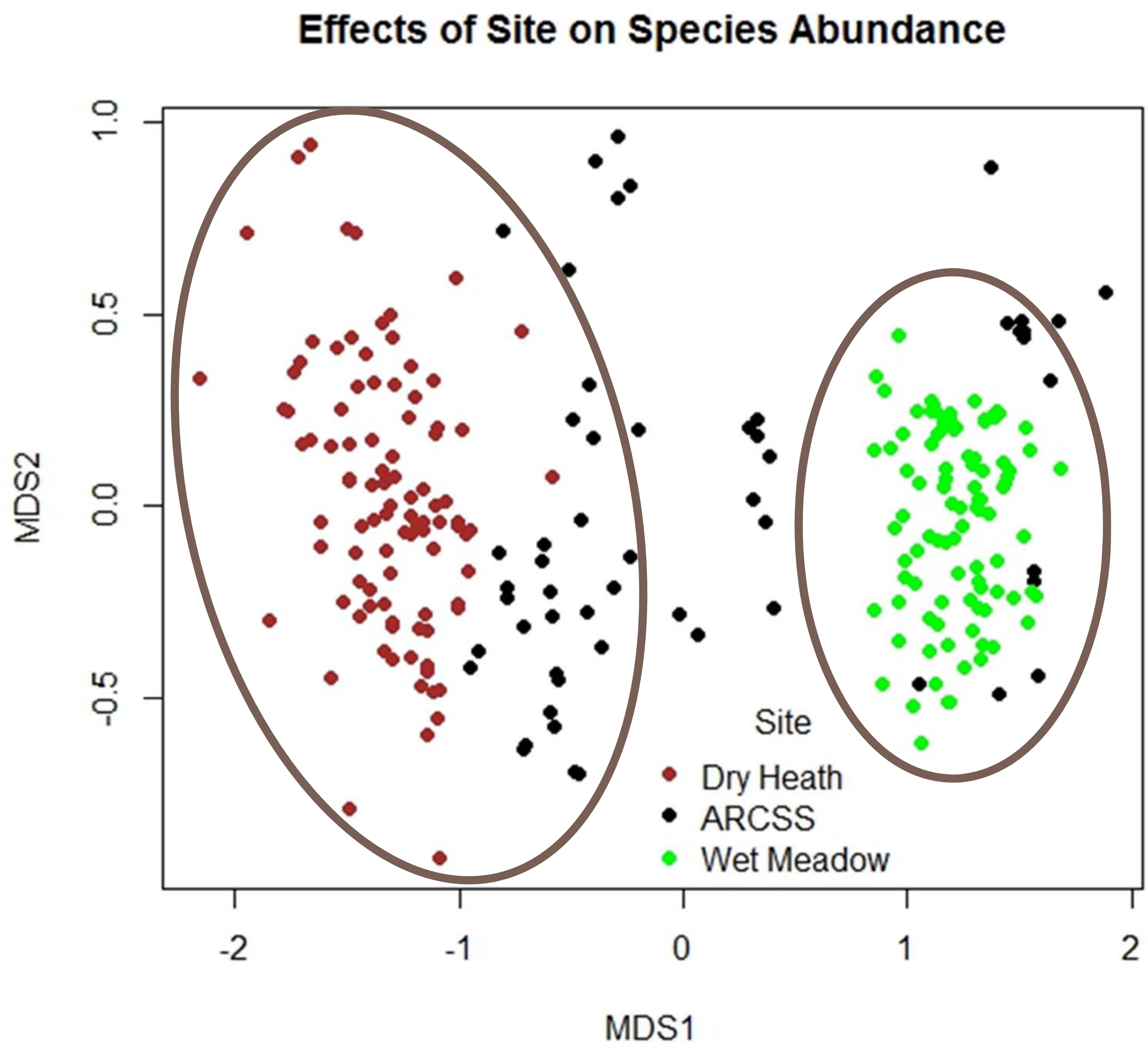
Stress = 0.0949

Global R: 0.7606

ANOSIM p-value: **0.001**

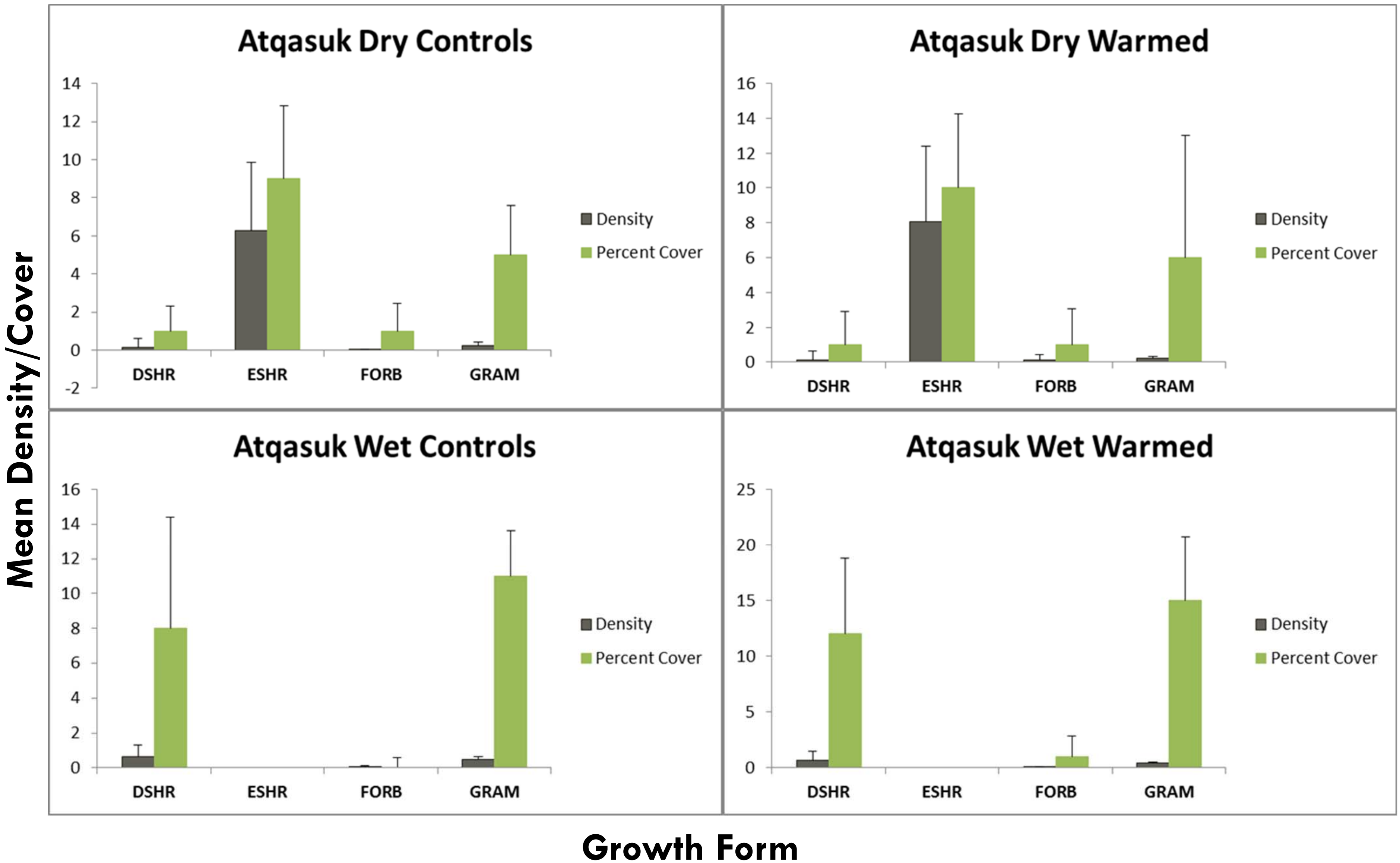
MRPP delta: **0.001**

ADONIS p-value: **0.001**



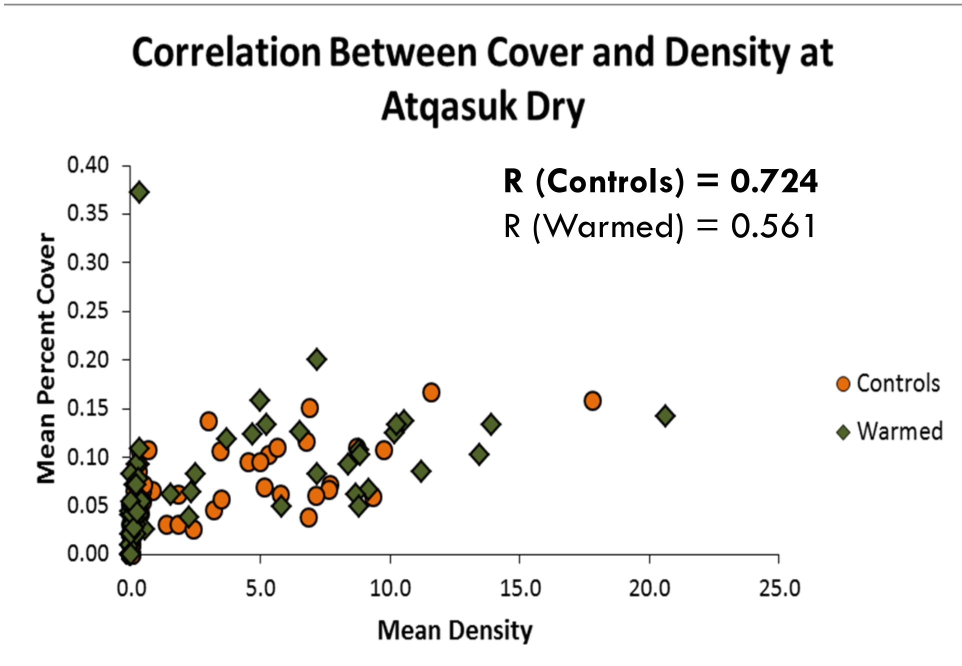
- Mean density and cover

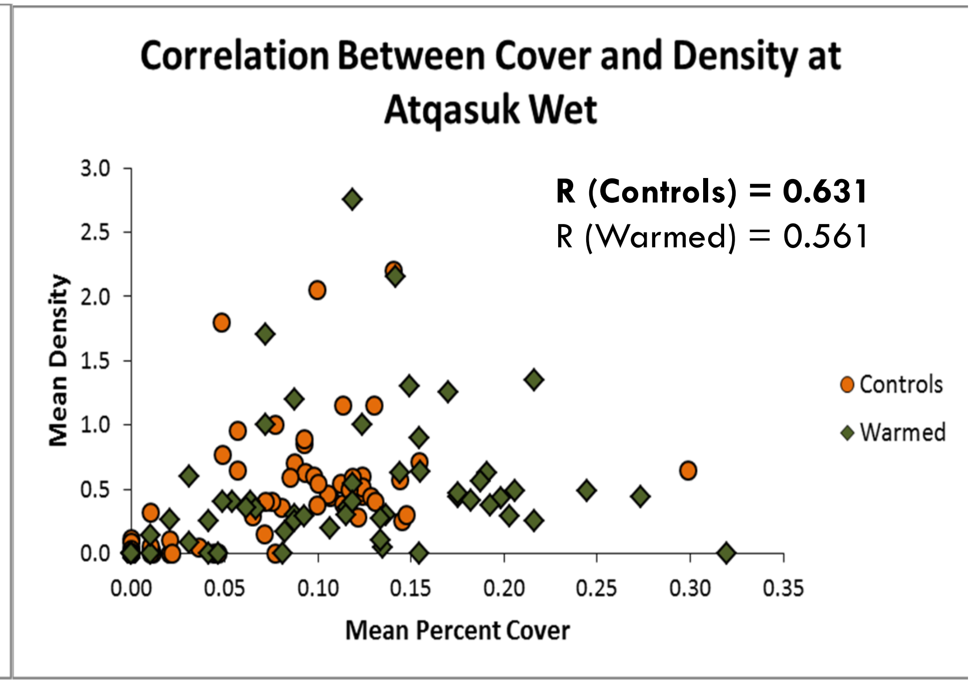
*Cover data from 2012; Density data from 2013



- Relationship between density and cover

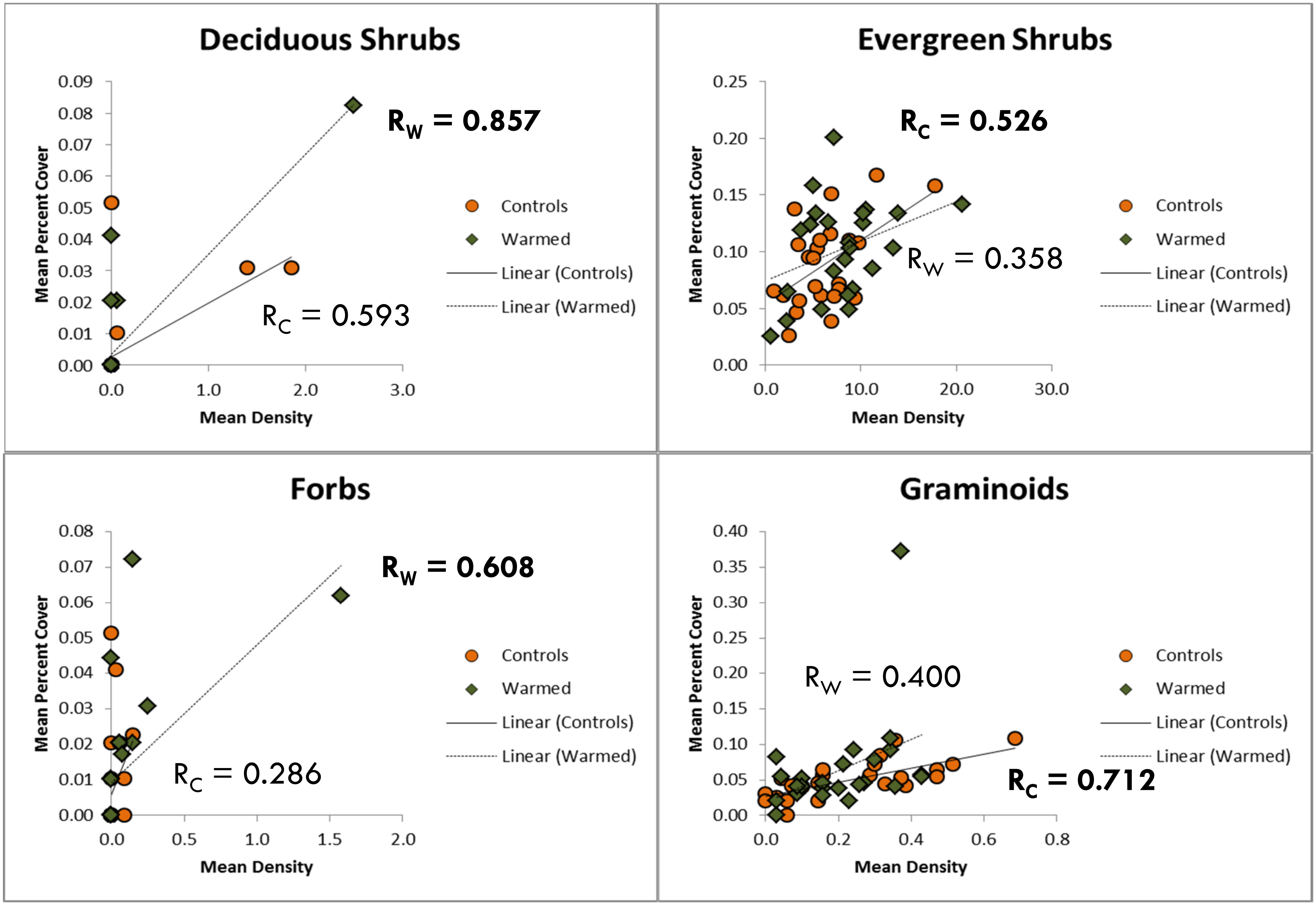
1. By Treatment
   - Correlations—stronger in controls
   - Compare regression slopes—not yet tested



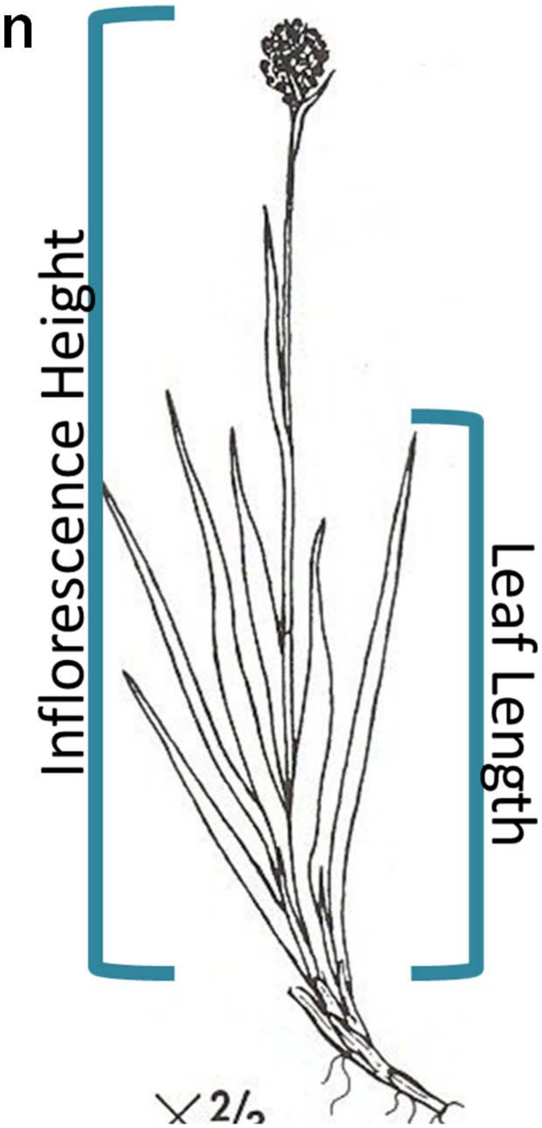


2. By Growth Form

Correlation Between Density and Cover at Atqasuk Dry



- Density is not the only factor
- Use individual growth measurements to help explain differences between density and cover
  - Leaf length
  - Number of green leaves



Summary: Additional Goals

- Barrow and Atqasuk
- Incorporate individual growth data
- Describe how correlations change with a soil moisture gradient

Acknowledgements

- National Science Foundation
- International Tundra Experiment
- Grand Valley State University
- Dr. Robert Hollister, Academic Advisor, GVSU Faculty
- Dr. James Dunn, Graduate Committee Member, GVSU Faculty
- Dr. Heather Rueth, Graduate Committee Member, GVSU Faculty
- Dr. Melvin Northup, GVSU Natural Resources Management Faculty
- Current and Previous Lab Members:
  - Jeremy May
  - Rob Slider-Barrett
  - Jennifer Liebig
  - Kelseyann Kremers
  - Timothy Botting
  - Andrew Smith
  - Michaela Clingaman

References

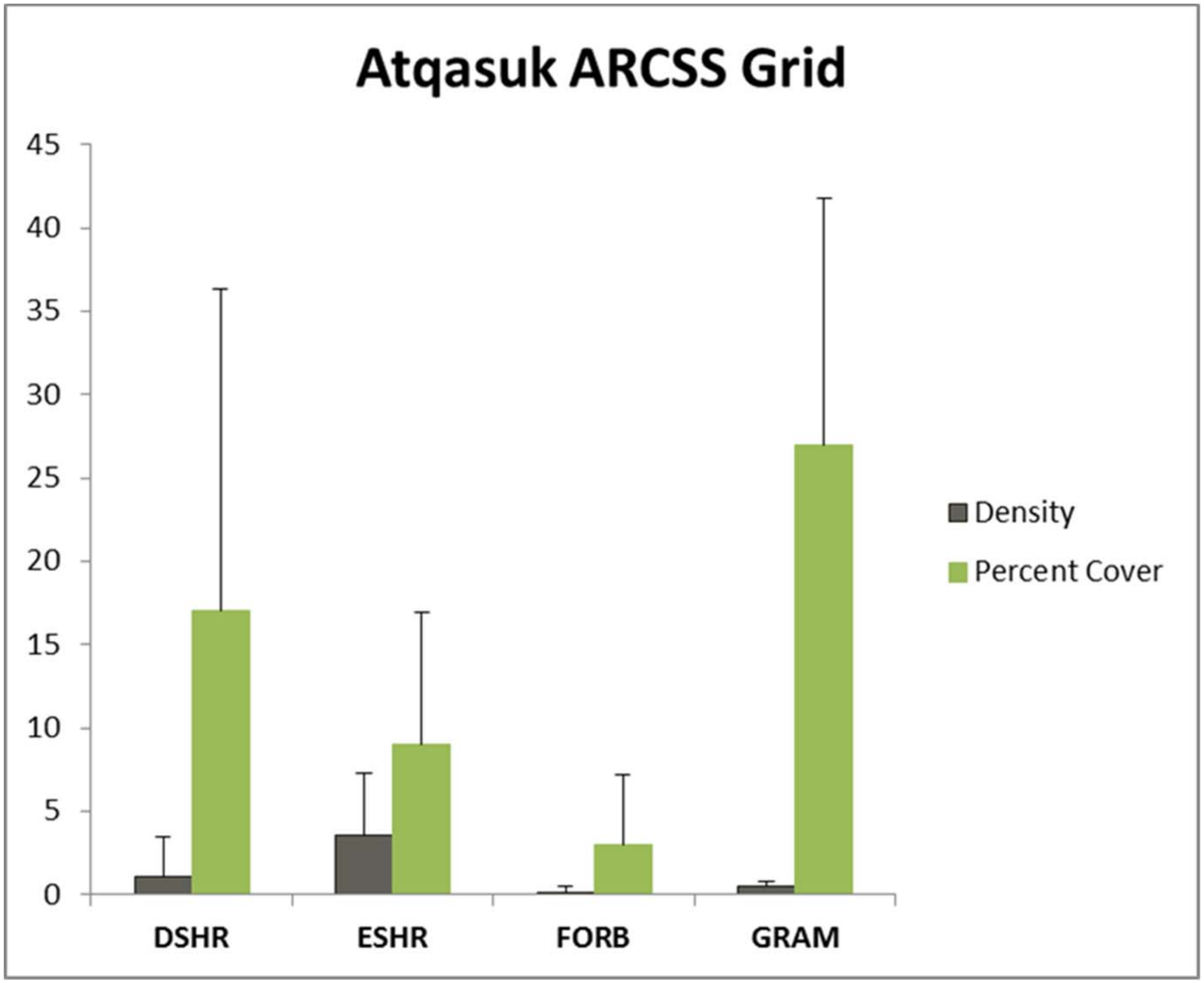
1. http://www.arcus.org/ARCSS/index.html
2. ACIA, 2004, *Impacts of a Warming Arctic*. Cambridge University Press, Cambridge.
3. ACIA, 2005, *Scientific Report, Chapter 7: Arctic tundra and polar ecosystems*. Cambridge University Press, Cambridge.
4. Arft, A. M., Walker, M. D., Gurevitch, J., Alatalo, J. M., Bret-Harte, M. S., & Dale, M. et al., (1999). Responses of tundra plants to experimental warming: Meta-analysis of the International Tundra Experiment. *Ecological Monographs, 69*, 491-511.
5. Barrett, K., Rocha, A. V., Van de Weg, M. J., & Shaver, G. (2012). Vegetation shifts observed in Arctic tundra 17 years after fire. *Remote Sensing Letters, 3*, 729-736.
6. Bilskie, J. (2001). Soil water status: content and potential. Campbell Scientific, Inc.
7. Cottam, G., and Curtis, J. T. (1956). The use of distance measures in phytosociological sampling. *Ecology, 37*, 451-460.
8. Curtis, J., Wendler, G., Stone, R., & Dutton, E. (1998) Precipitation decrease in the western Arctic, with special emphasis on Barrow and Barter Island, Alaska. *International Journal of Climatology, 18*, 1687–1707.
9. Elmendorf, S. C., Henry, G. H. R., Hollister, R. D., Bjork, R. G., Bjorkman, A. D., & Callaghan, T. V. (2012). Global assessment of experimental climate warming on tundra vegetation: Heterogeneity over space and time. *Ecology Letters, 15*, 164-175.
10. Haugen, R. K., and Brown, J. (1980). Coastal-inland distributions of summer air temperature and precipitation in Northern Alaska. *Arctic and Alpine Research, 12*, 403-412.
11. Henry, G. H. R., and Molau, U. (1997). Tundra plants and climate change: the International Tundra Experiment (ITEX). *Global Change Biology, 3*, 1-9.
12. Hill, G. B., and Henry, G. H. R. (2011). Responses of High Arctic wet sedge tundra to climate warming since 1980. *Global Change Biology, 17*, 276-287.
13. Hinkel, K. M., Paetzold, F., Nelson, F. E., & Bocheim, J. G. (2001). Patterns of soil temperature and moisture in the active layer and upper permafrost at Barrow, Alaska: 1993-1999. *Global and Planetary Change, 29*, 293-309.
14. Hinzman, L. D., Bettez, N. D., Bolton, W. R., Chapin, F. S., Dyurgerov, M. B., & Fastie, C. L. (2005). Evidence and implications of recent climate change in northern Alaska and other arctic regions. *Climate Change, 72*, 251-298.
15. Hollister, R. D. (1998). Response of wet meadow tundra to interannual and manipulated temperature variation: Implications for climate change research. Master's Thesis, Michigan State University, East Lansing, Michigan, USA.
16. Hollister, R. D., and Webber, P. J. (2000). Biotic validation of small open-top chambers in a tundra ecosystem. *Global Change Biology, 6*, 835-842.

References

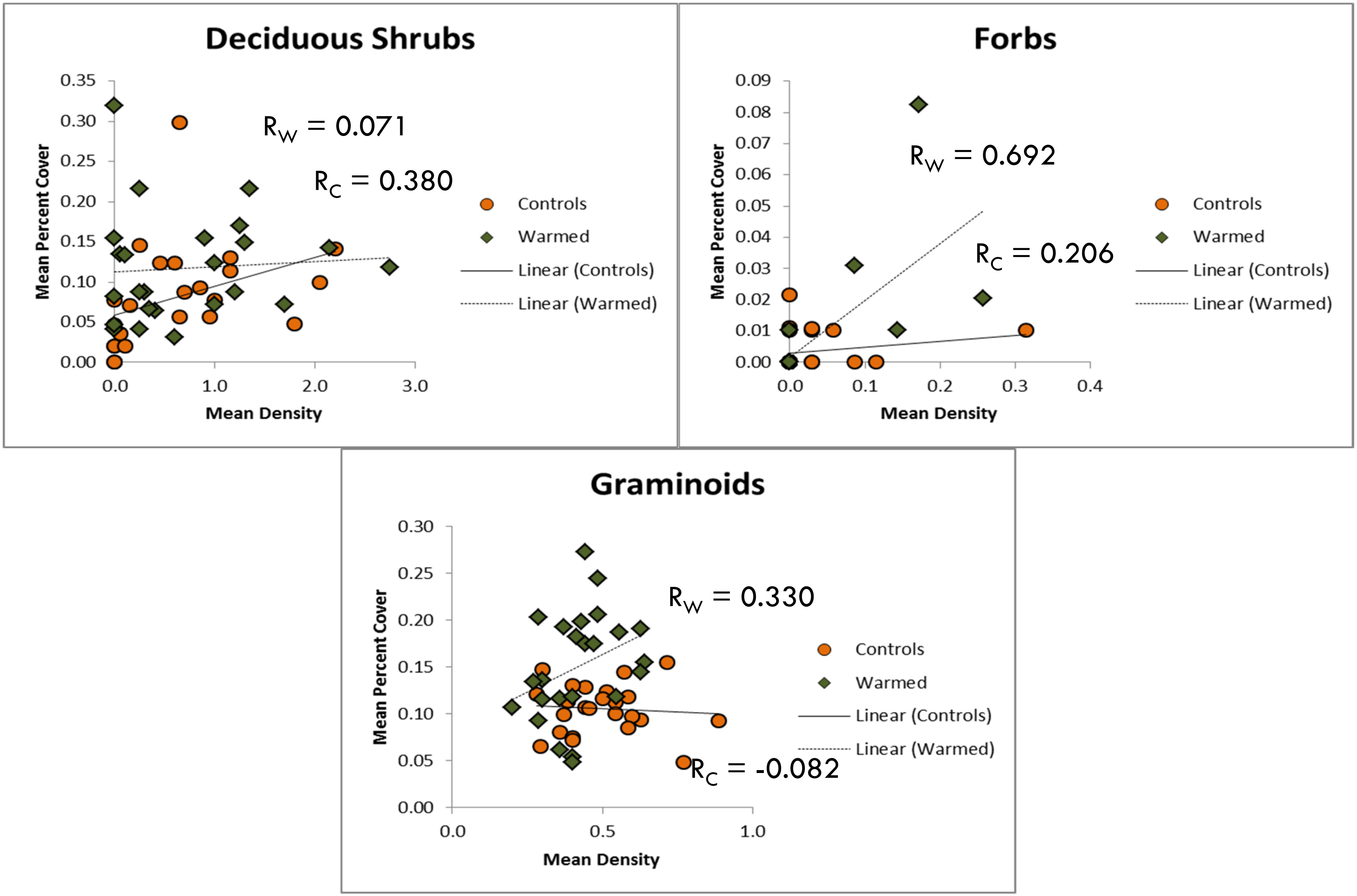
17. Hollister, R. D., (2003). Implications for forecasting vegetation change. PhD Dissertation, Michigan State University, East Lansing, Michigan, USA.
18. Hollister, R. D., Webber, P. J., & Bay, C. (2005a). Plant response to temperature in northern Alaska: Implications for predicting vegetation change. *Ecology*, *86*, 1562-1570.
19. Hollister, R. D., Webber, P. J., & Tweedie, C. E. (2005b). The response of Alaskan arctic tundra to experimental warming: Differences between short- and long-term responses. *Global Change Biology, 11*, *525-536.*
20. Hollister, R. D., and Flaherty, K. J. (2010). Above- and below-ground plant biomass response to experimental warming in northern Alaska. *Applied Vegetation Science, 13*, 378-387.
21. IPCC, 2007, *Impacts, Adaptation, and Vulnerability*, *Contribution of Working Group II to the Fourth Assessment Report*. Cambridge University Press, Cambridge.
22. Johnson, L. C., Shaver, G. R., Cades, D. H, Rastetter, E., Nadelhoffer, K., & Giblin, A., et. al. (2000). Plant carbon-nutrient interactions control CO2 exchange in Alaskan wet sedge tundra ecosystems. *Ecology, 81*, 453-469.
23. Klady, R. A., Henry, G. H. R., & Lemay, V. (2011). Changes in high arctic tundra plant reproduction in response to long-term experimental warming. *Global Change Biology, 17*, 1611-1624.
24. Komarkova, V., & Webber, P.J. (1980). Two Low Arctic Vegetation Maps near Atkasook, Alaska. *Arctic and alpine research*, *12*, *447-472.*
25. May, J. L., and Hollister, R.D. (2012). Validation of a simplified point frame method to detect change in tundra vegetation. *Polar Biology*, *35,* 1815-1823.
26. Miller, P. C., Stoner, W. A., & Tieszen, L. L. (1976). A model of stand photosynthesis for the wet meadow tundra at Barrow, Alaska. *Ecology, 57*, 411-430.
27. Murray, J. L., de March, B. G. E., & Hargrave, B. T. (1997). Chapter 4: Ecological characteristics of the Arctic. In *AMAP Assessment Report, Arctic pollution issues: a state of the Arctic environment report,* J. L. Murray, Ed., 117-139.
28. Simpson, J. J., Hufford, G. L., Fleming, M. D., Berg, J. S., & Ashton, J. B. (2002). Long-term climate patterns in Alaskan surface temperature and precipitation and their biological consequences. *Transactions on Geoscience and Remote Sensing, 40*, 1164-1184.
29. Walker, M. D., Wahren, C. H., Hollister, R. D., Henry, G. H. R., Ahlquist, L. E., & Alatalo, J. M. (2006). Plant community responses to experimental warming across the tundra biome. *Proceeding of the National Academy of Sciences, 103*, 1342-1346.
30. Welker, J. M., Fahnestock, J. T., Henry, G. H. R., O'Dea, K. W., and Chimner, R. A. (2004). CO_2 exchange in three Canadian High Arctic ecosystems: response to long-term experimental warming. *Global Change Biology, 10*, 1981–1995.

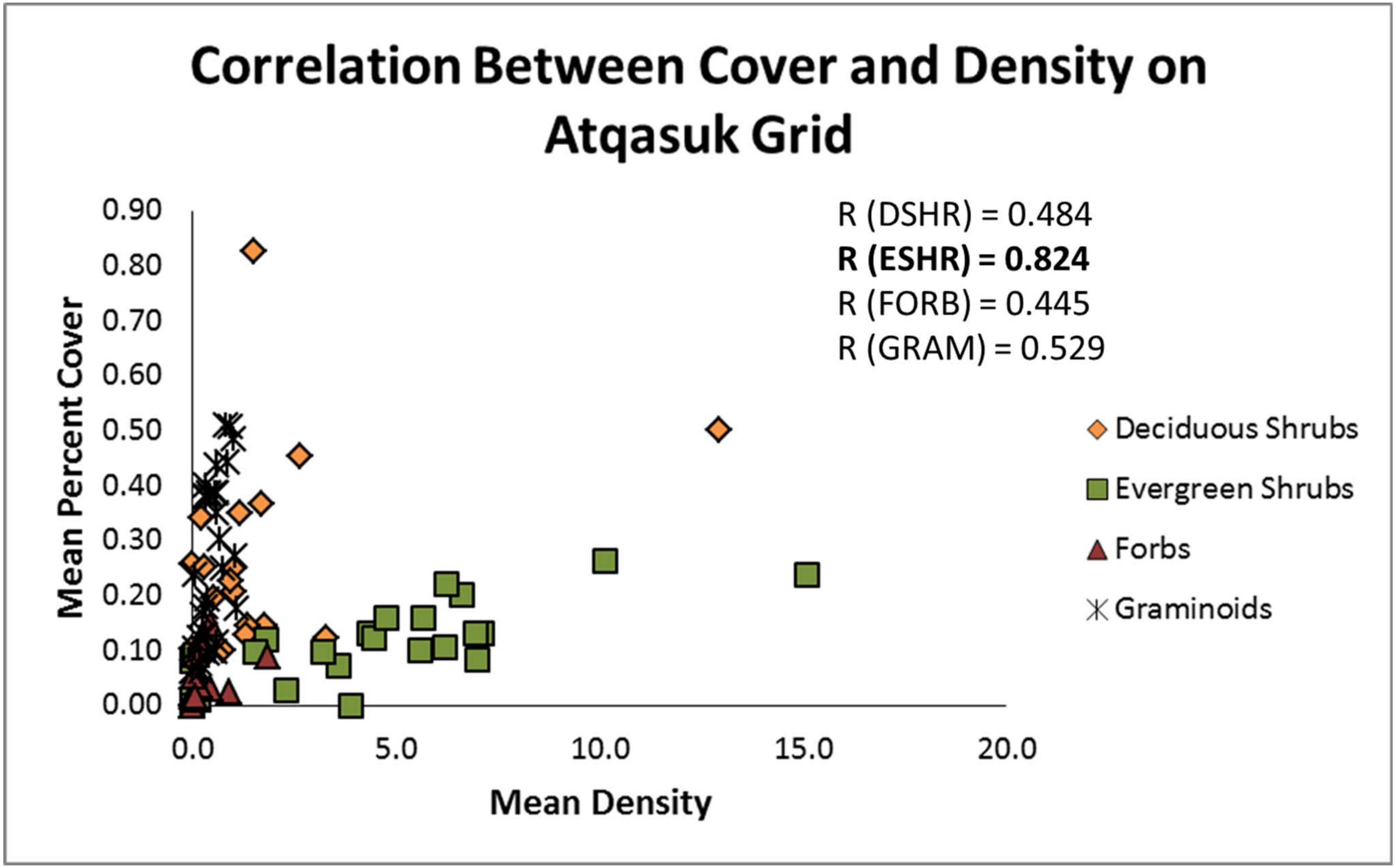
Table 1: List of species present at Atqasuk research sites, ITEX and ARCSS grid; families listed in bold. Superscript indicates site: d = Atqasuk Dry, w = Atqasuk Wet, g = ARCSS.

Deciduous Shrubs	Forbs	Forbs (Continued)	Graminoids (Continued)
Betulaceae	***Asteraeceae***	***Ranunculaceae***	*Eriophorum russeolum* [w,g]
Betula Nana [w,g]	*Artemisia borealis* [d]	*Ranunculus pallasii* [g]	*Eriophorum vaginatum* [g]
	Antennaria friesianna [d]		
Salicaceae		***Rosaceae***	***Juncaceae***
Salix phlebophylla [d,g]	***Caryophyllaceae***	*Rubus chamaemorus* [g]	*Luzula artica* [d,g]
Salix polaris [w,g]	*Minuartia obtusiloba* [d]		*Luzula confusa* [d,g]
Salix pulchra [w,g]		***Scrophulariaceae***	*Luzula wahlenbergii* [w,g]
	Empetraceae	*Pedicularis sudetica* [w,g]	
Evergreen Shrubs	*Empetrium nigrans* [g]	*Pedicularis lapponica* [d,g]	***Poaceae***
Diapensiaceae			*Dupontia fisheri* [w,g]
Diapensia lapponica [d,g]	***Polygonaceae***	Graminoids	*Hierechloe alpina* [d,g]
	Polygonum bistora [d,g]	***Cyperaceae***	*Trisetum spicatum* [d,g]
Ericaceae	*Polygonum viviparum* [w,g]	*Carex aquatilis* [w,g]	
Andromeda polifolia [g]		*Carex bigelowii* [d,g]	
Cassiope tetragona [d,g]	***Pyrolaceae***	*Carex rariflora* [w]	
Ledum palustre [d,g]	*Pyrola grandiflora* [g]	*Carex rotundata* [w,g]	
Vaccinium vitis-idaea [d,g]		*Eriophorum angustifolium* [w,g]	


Atqasuk ARCSS Grid
45
40
35
30
25
20
15
10
5
0
DSHR
ESHR
FORB
GRAM
Density
Percent Cover

Correlation Between Density and Cover at Atqasuk Wet




Correlation Between Cover and Density on Atqasuk Grid
R (DSHR) = 0.484
R (ESHR) = 0.824
R (FORB) = 0.445
R (GRAM) = 0.529
Mean Percent Cover
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.0
5.0
10.0
15.0
20.0
Mean Density
Deciduous Shrubs
Evergreen Shrubs
Forbs
Graminoids