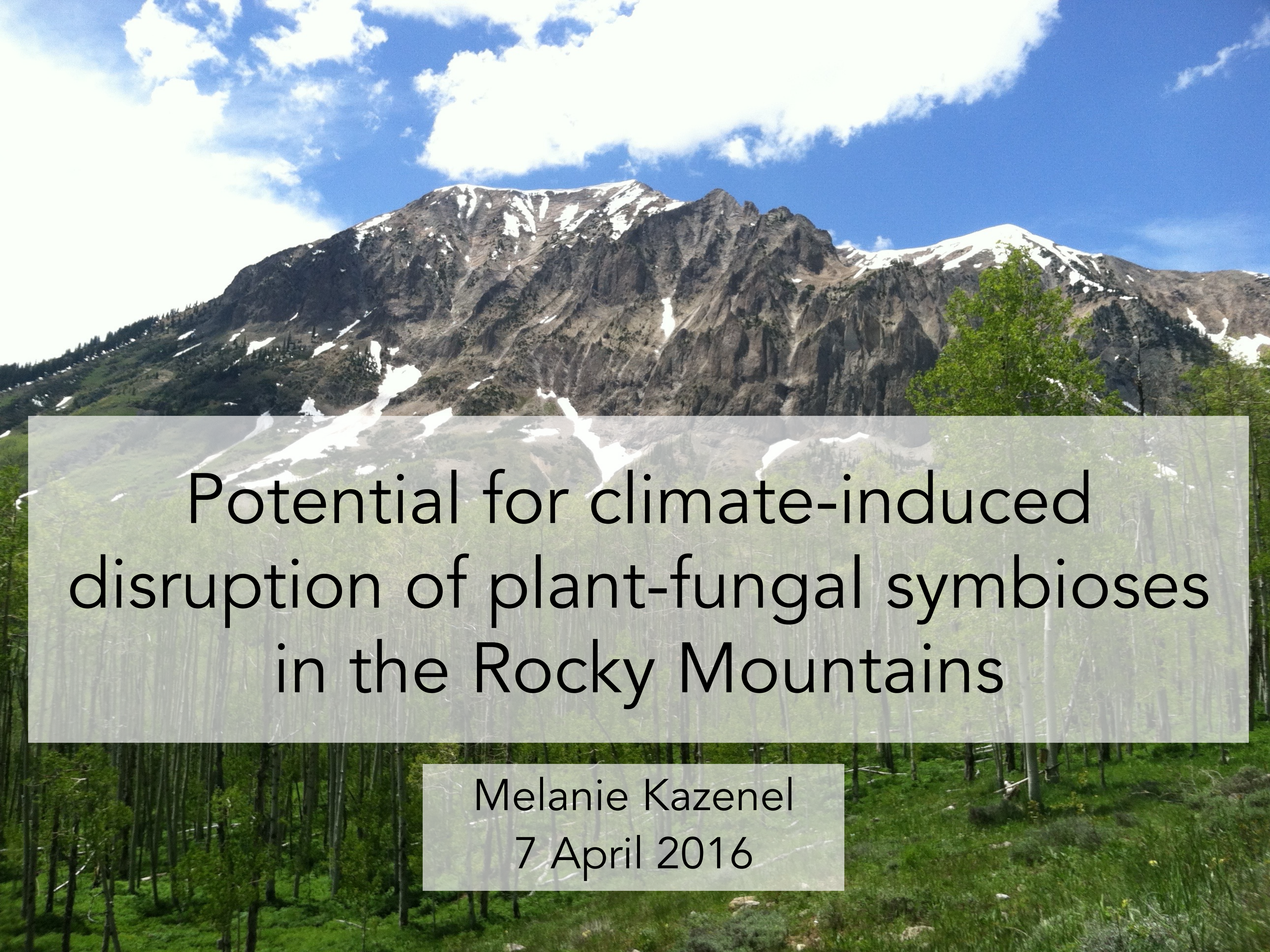
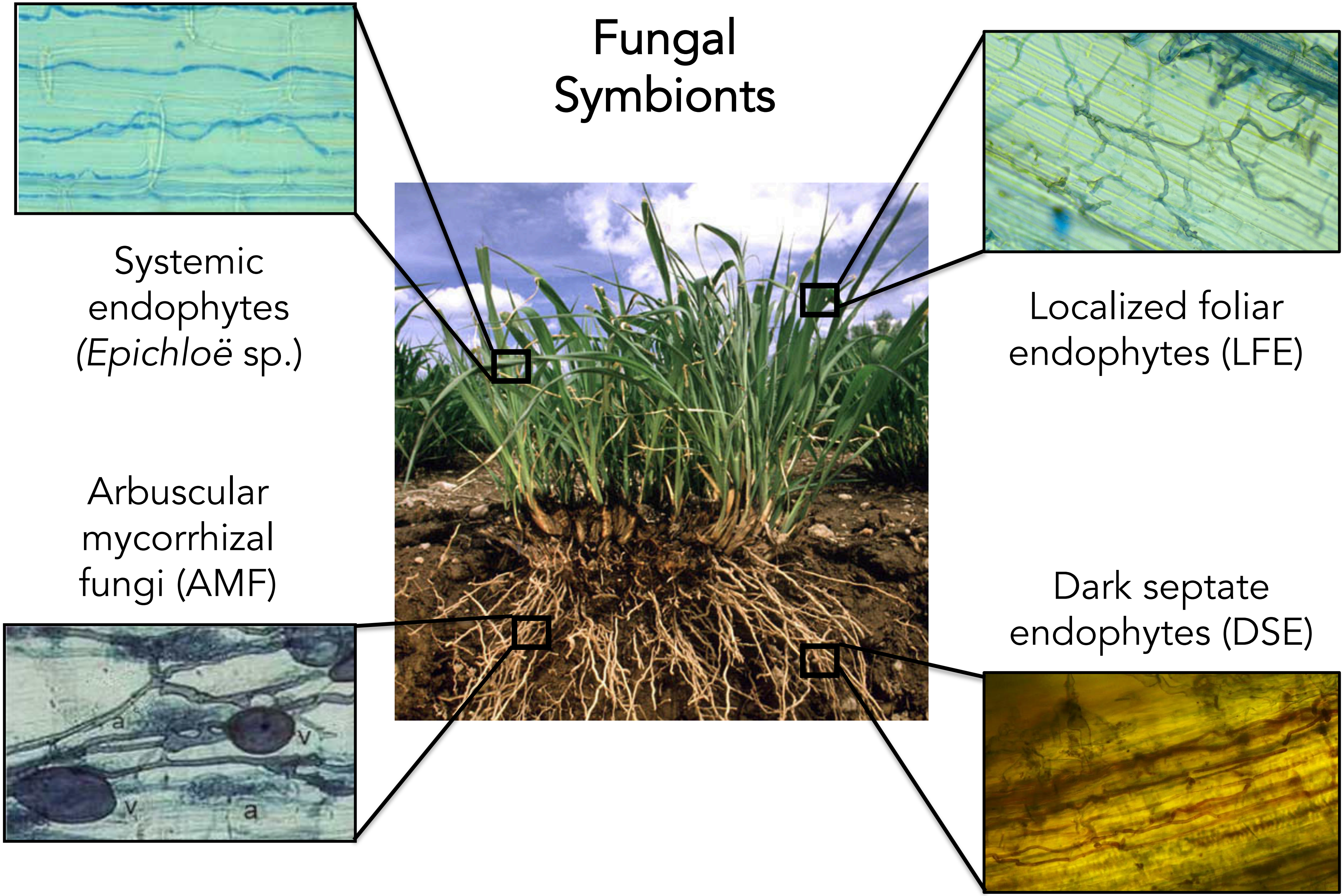


Potential for climate-induced disruption of plant-fungal symbioses in the Rocky Mountains

Melanie Kazenel
7 April 2016

How will climate change alter plant-symbiont interactions?

Plants and Fungal Symbionts



Symbionts can mediate plant responses to climate change

American Journal of Botany
American Journal of Botany 100(7): 1445–1457. 2013.

SPECIAL INVITED PAPER—GLOBAL BIOLOGICAL CHANGE

FUNGAL SYMBIONTS ALTER PLANT RESPONSES TO GLOBAL CHANGE[1]

STEPHANIE N. KIVLIN[2,5], SARAH M. EMERY[3], AND JENNIFER A. RUDGERS[4]

Symbionts altered plant responses to drought, N deposition, and warming

Climate change may disrupt symbioses as organisms experience range shifts

SCIENCE VOL 336 20 APRIL 2012

Recent Plant Diversity Changes on Europe's Mountain Summits

Harald Pauli,[1*] Michael Gottfried,[2†] Stefan Dullinger,[2,3*] Otari Abdaladze,[4] Maia Akhalkatsi,[4] José Luis Benito Alonso,[5] Gheorghe Coldea,[6] Jan Dick,[7] Brigitta Erschbamer,[8] Rosa Fernández Calzado,[9] Dany Ghosn,[10] Jarle I. Holten,[11] Robert Kanka,[12] George Kazakis,[10] Jozef Kollár,[12] Per Larsson,[13] Pavel Moiseev,[14] Dmitry Moiseev,[14] Ulf Molau,[13] Joaquín Molero Mesa,[9] Laszlo Nagy,[15,16] Giovanni Pelino,[17] Mihai Puşcaş,[18] Graziano Rossi,[19] Angela Stanisci,[17] Anne O. Syverhuset,[11] Jean-Paul Theurillat,[20,21] Marcello Tomaselli,[22] Peter Unterluggauer,[8] Luis Villar,[5] Pascal Vittoz,[23] Georg Grabherr[1]

nature climate change

LETTERS

PUBLISHED ONLINE: 10 JANUARY 2012 | DOI:10.1038/NCLIMATE1329

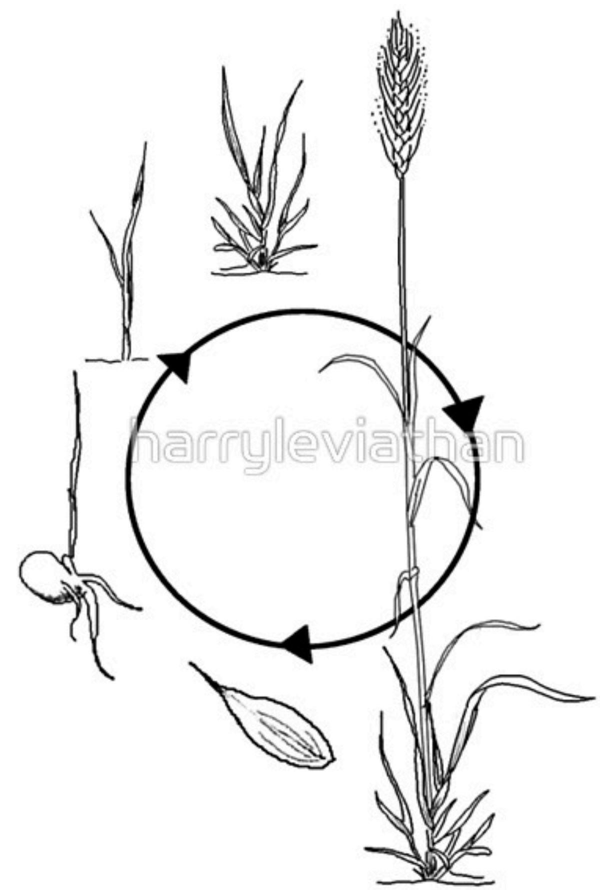
Continent-wide response of mountain vegetation to climate change

Michael Gottfried[1], Harald Pauli[2*], Andreas Futschik[3], Maia Akhalkatsi[4], Peter Barančok[5], José Luis Benito Alonso[6], Gheorghe Coldea[7], Jan Dick[8], Brigitta Erschbamer[9], María Rosa Fernández Calzado[10], George Kazakis[11], Ján Krajči[5], Per Larsson[12], Martin Mallaun[13], Ottar Michelsen[14], Dmitry Moiseev[15], Pavel Moiseev[15], Ulf Molau[16], Abderrahmane Merzouki[10], Laszlo Nagy[17,18], George Nakhutsrishvili[19], Bård Pedersen[20], Giovanni Pelino[21], Mihai Puscas[22], Graziano Rossi[23], Angela Stanisci[21], Jean-Paul Theurillat[24,25], Marcello Tomaselli[26], Luis Villar[6], Pascal Vittoz[27], Ioannis Vogiatzakis[28] and Georg Grabherr[2]

Mechanisms for disruption of plant-symbiont interactions

Plants and symbionts may have different:

- Physiological tolerances
- Dispersal rates
- Phenological responses



Study System

Mountains

- ~25% of land area on Earth
- 50% of the human water supply
- 1/3 of terrestrial plant diversity

Grasses

- Cover 1/3 of land area (>10,000 species)
- Provide the majority of food for humans and domesticated animals
- All have mycorrhizal fungi in roots and fungi in leaves

Altitudinal Gradients

Experimental Warming

Photo: Mary Ellen Harte

Focal questions

How do symbionts change with altitude and warming?

a) *Altitude response?*

b) *Warming response?*

c) *Are they the same?*

Warming Experiment
Rocky Mountain Biological Laboratory

Established in 1991
Warms top 15 cm of soil by ~2°C
Dries soil by 10-20%
Extends growing season by ~12 days on each end

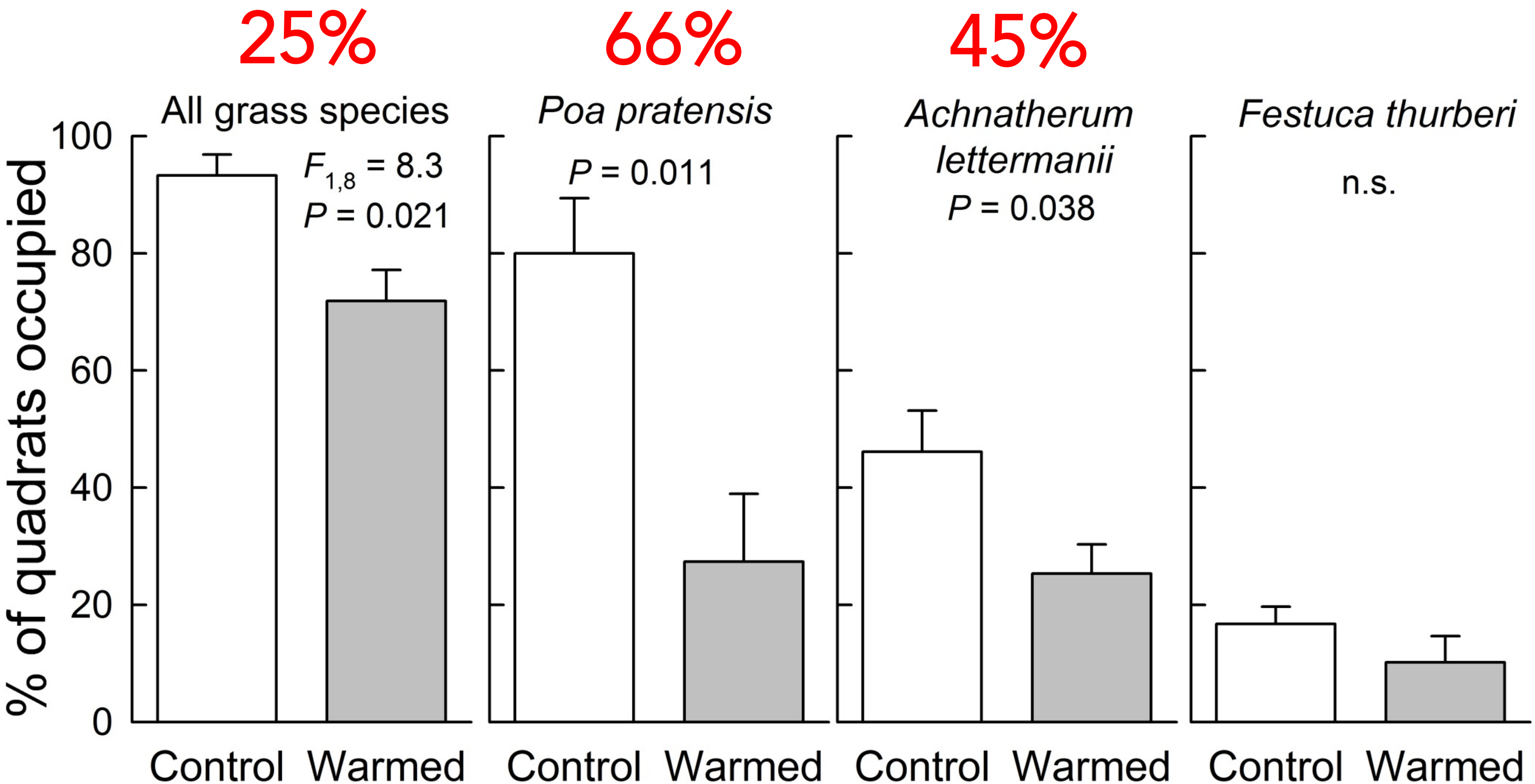
Study Species

Achnatherum lettermanii
(ACLE)

Festuca thurberi
(FETH)

Poa pratensis
(POPR)

Experimental warming reduced grasses (1991 – 2011)



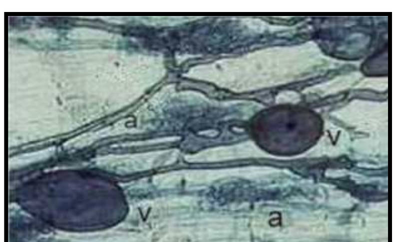
Mean % ± s.e. of 49 (0.2m×0.2m) quadrats surveyed per plot
n = 5 plots per warming treatment

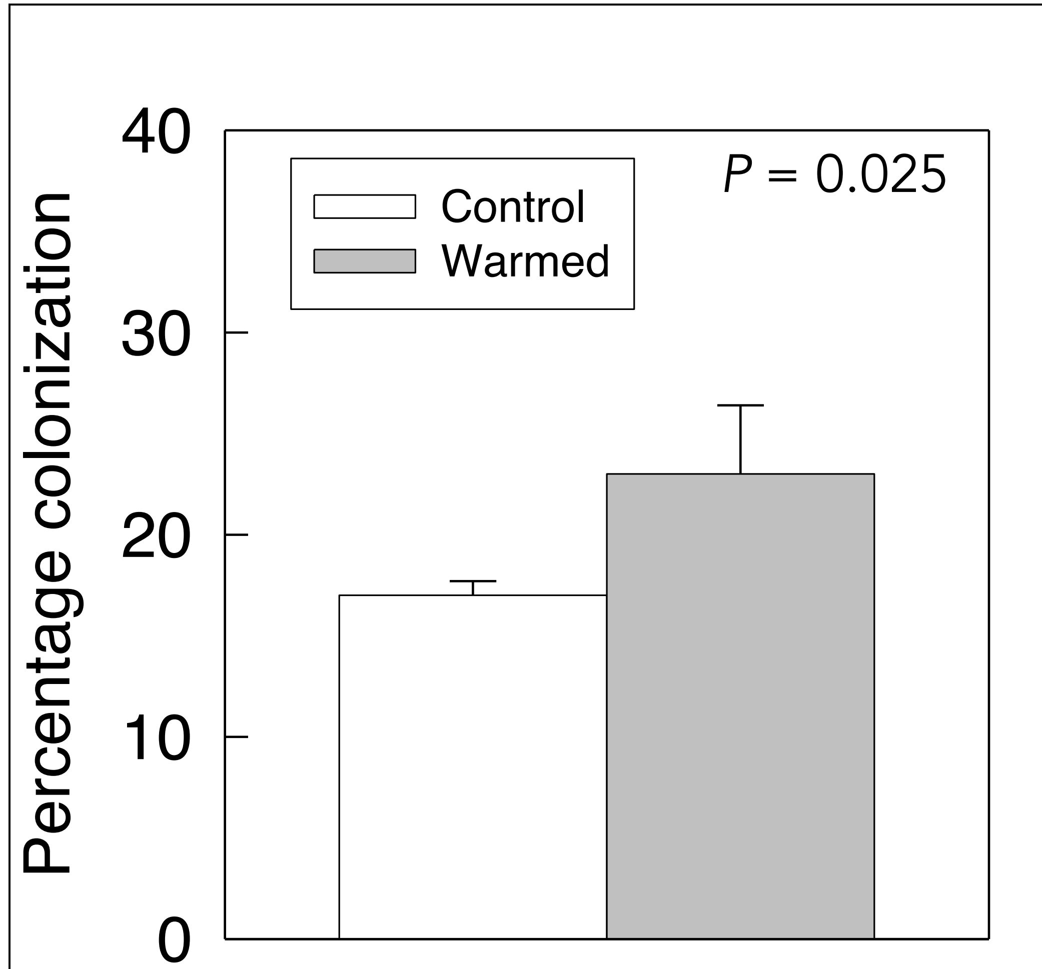
Rudgers et al. *Ecology* (2014)

Experimental warming increased mycorrhizal colonization of roots

A. lettermanii

Arbuscular mycorrhizal fungi





Rudgers et al. *Ecology* (2014)

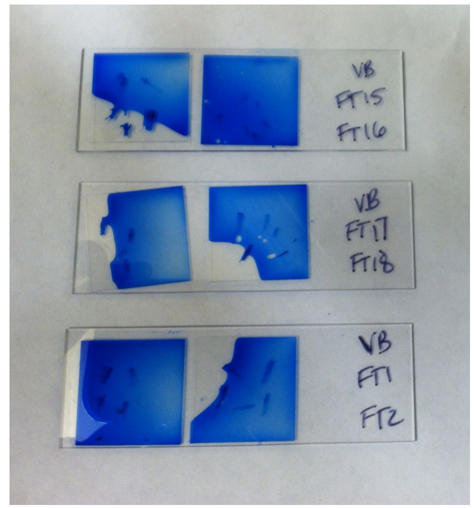
Field collection methods

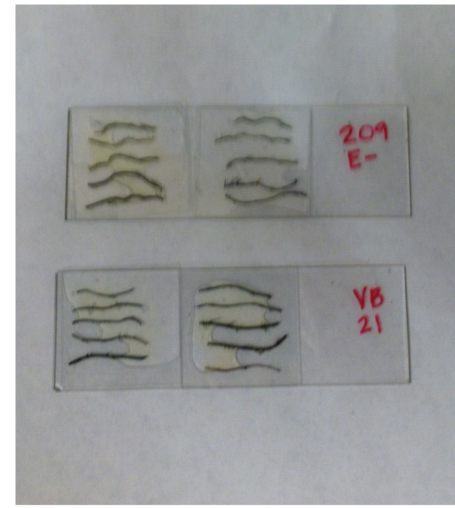
- 3 focal grass species:
  - *Achnatherum lettermanii*
  - *Poa pratensis*
  - *Festuca thurberi*
- 6 individual plants collected per species per plot
- Roots and leaves (2014)
- Phenology: June and September


Photo: Noah Whiteman

Laboratory methods

- Staining and microscopy → colonization



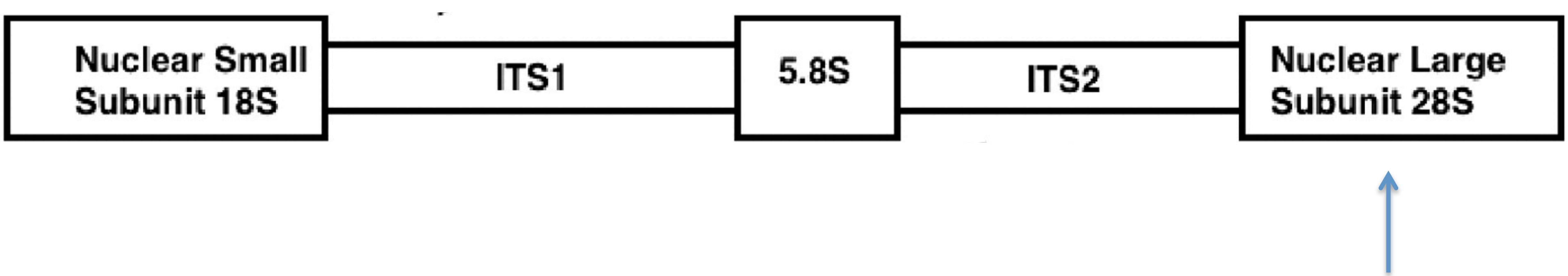


- Illumina MiSeq DNA sequencing → composition

Illumina Sequencing

Paired-end sequencing of fungal nuclear ribosomal DNA using primers targeting:

- ITS2 region (for VTE, LFE, and DSE)
- ~300bp in the 28S region (for AMF) (FLR3-FLR4 primers)



Bioinformatics

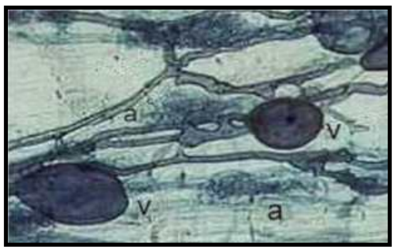
- Quality filtering in QIIME
- Sumaclust to place similar sequences into operational taxonomic units (OTUs) at ~97% identity
- NCBI BLAST to assign taxonomy
  - Discarded all OTUs with <97% identity to entry in database
- Normalized data using DESeq2
- Discarded singletons

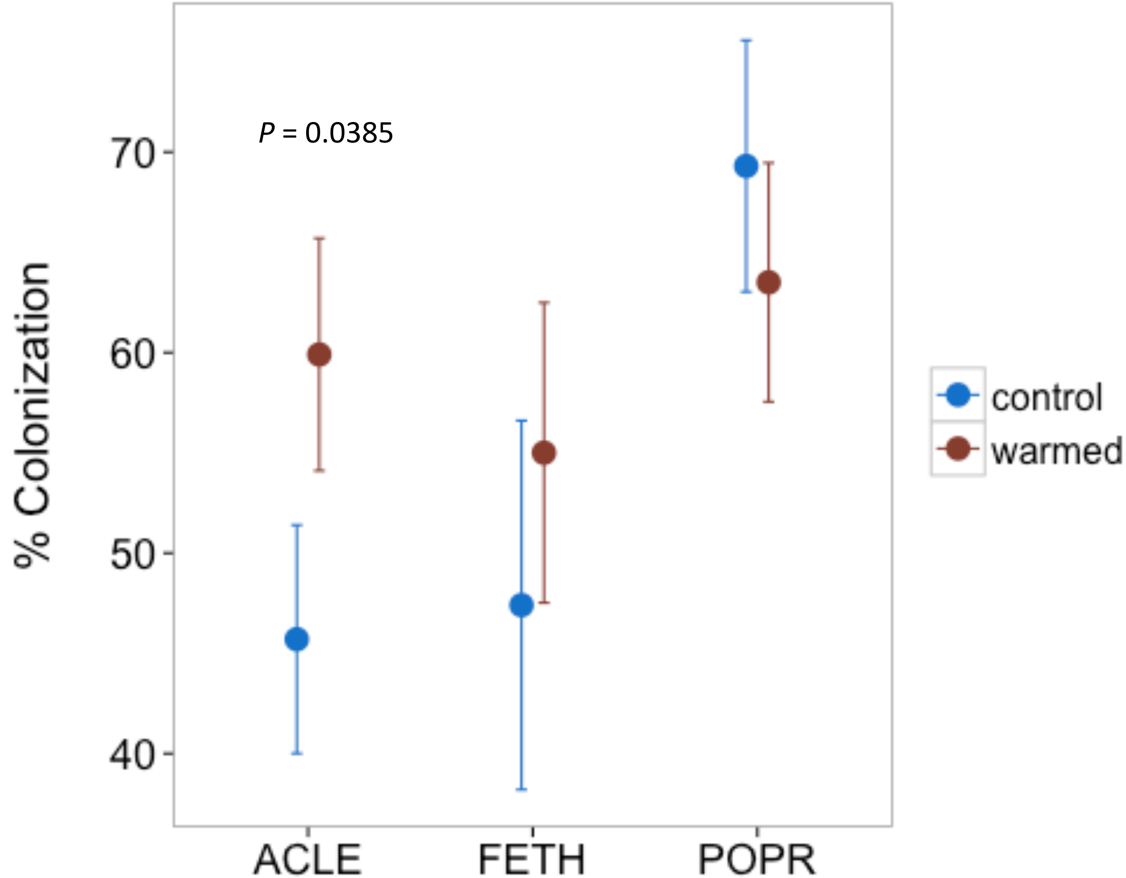
→ Conducted analyses on 802 OTUs

Analyses

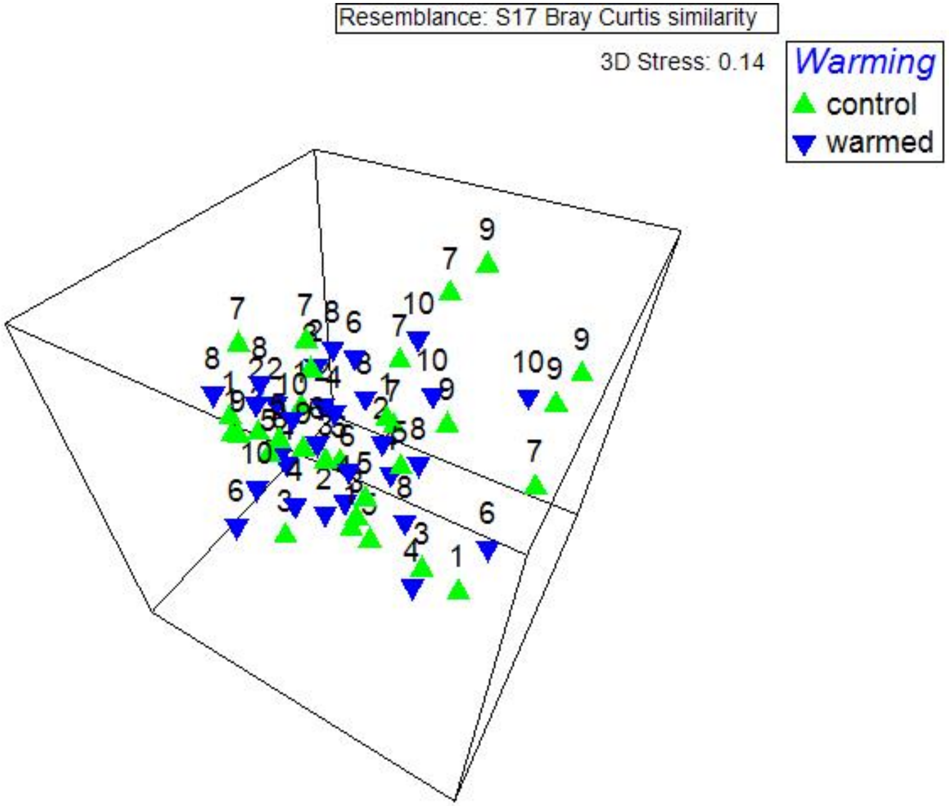
- NMDS: to visualize OTU composition
- perMANOVA: to test how variables of interest affect OTU composition
  - Fixed effects: warming treatment, host species, sampling date
  - Random effect: block (pair of plots)
- PERMDISP: to test for dispersion within groups
- Indicator species analysis (SIMPER): to identify OTUs that contributed strongly to differences among groups

Arbuscular mycorrhizal fungi

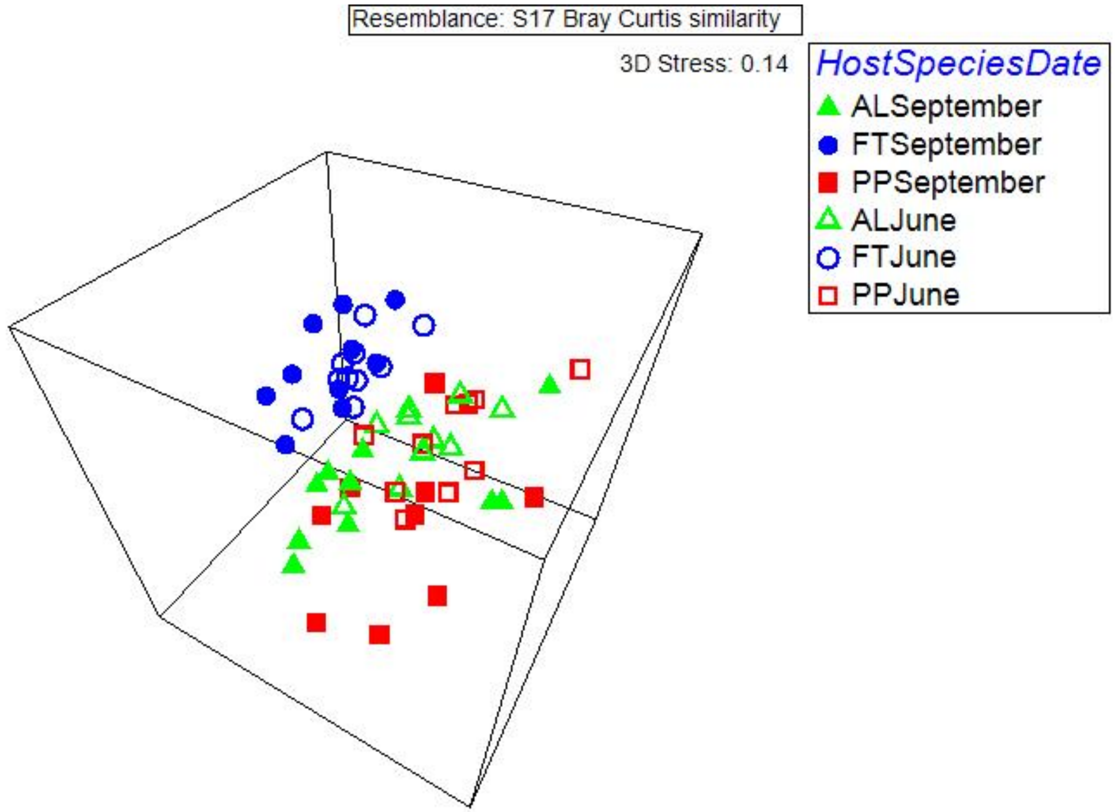




Results: All Species



- OTU composition did not differ between warming treatments (df = 1, pseudo-F = 1.361, P = 0.1391)
- High stress value
- Spatial heterogeneity (significant effect of block)

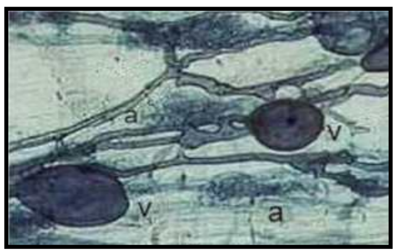


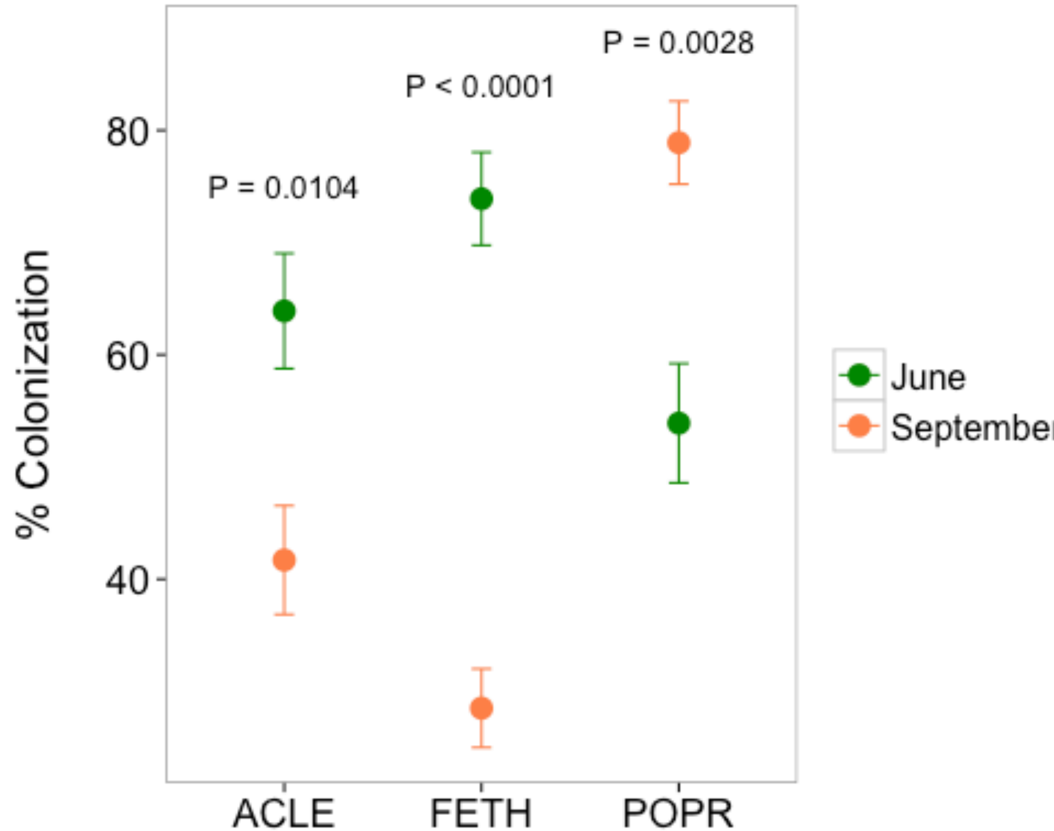
OTU composition differed between **sampling dates** (df = 1, pseudo-F = 2.9483, P = 0.0009) and among **host species** (df = 2, pseudo-F = 5.4469, P = 0.0001)

- FT differed from AL and PP
- Communities of AL and PP were significantly more dispersed relative to communities of FT (PERMDISP)

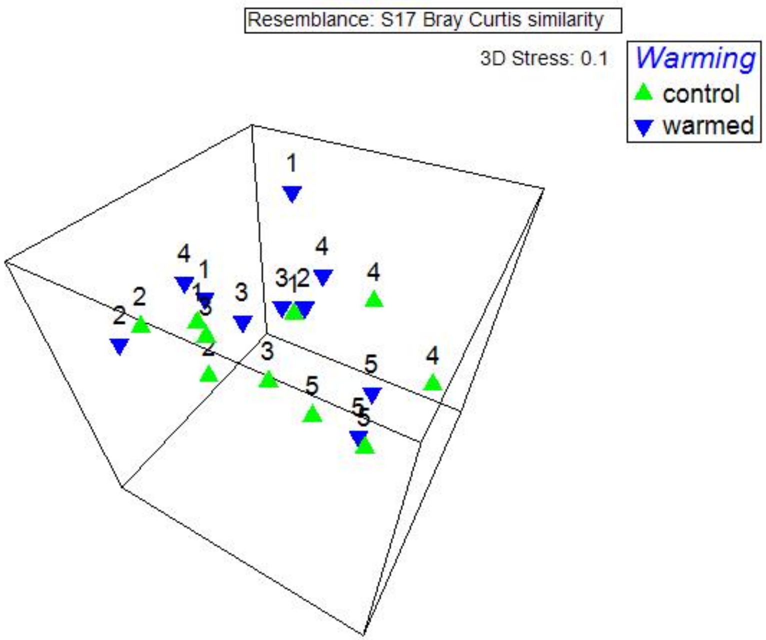
Changes in AMF colonization between June and September for all three grasses

Arbuscular mycorrhizal fungi

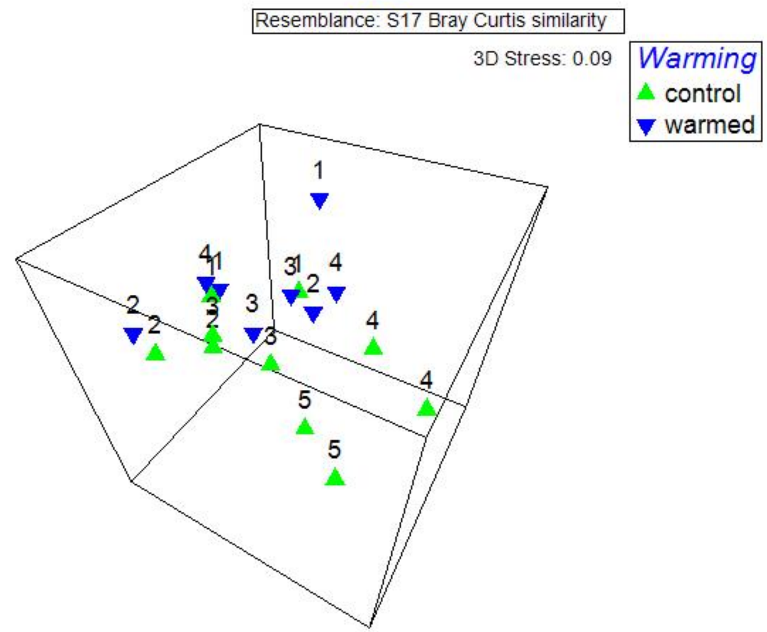




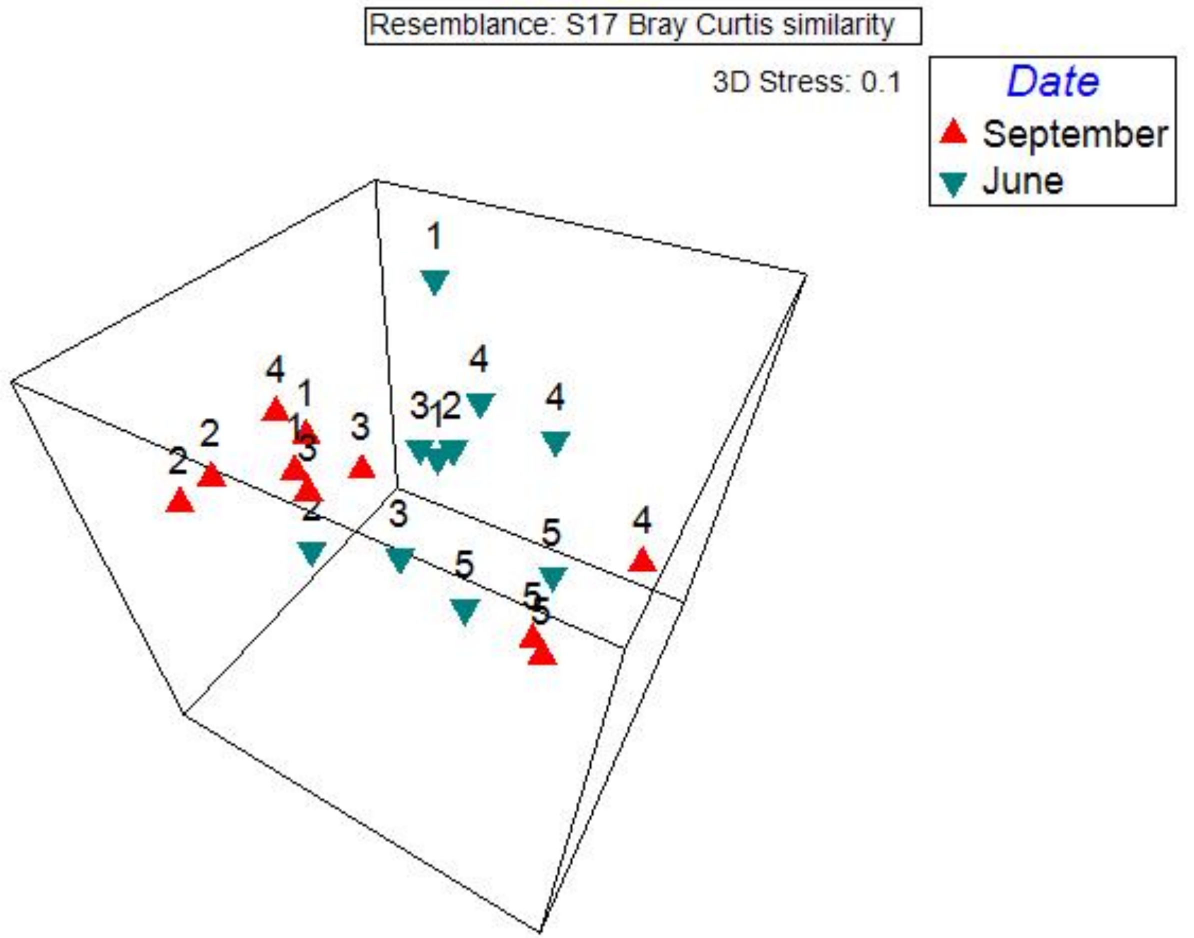
Results: *A. lettermanii*



All data

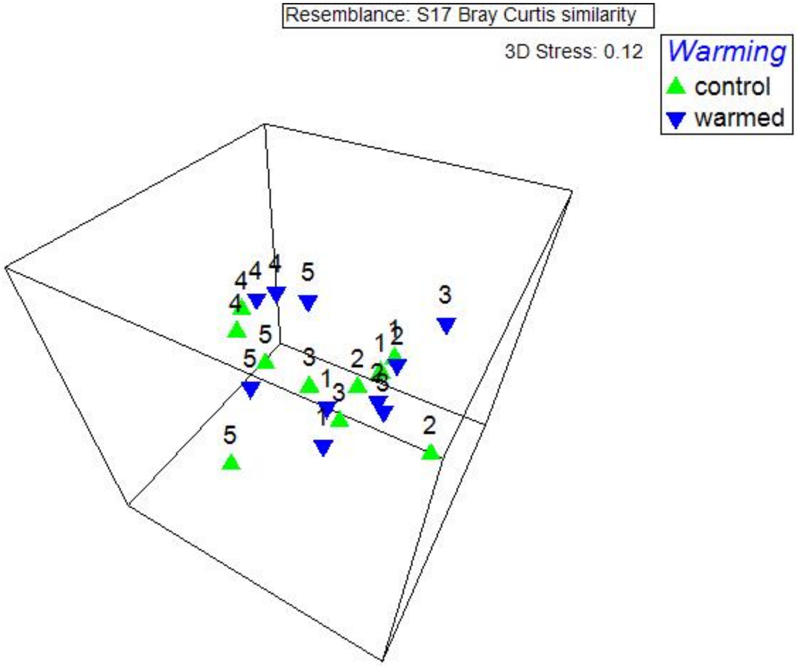


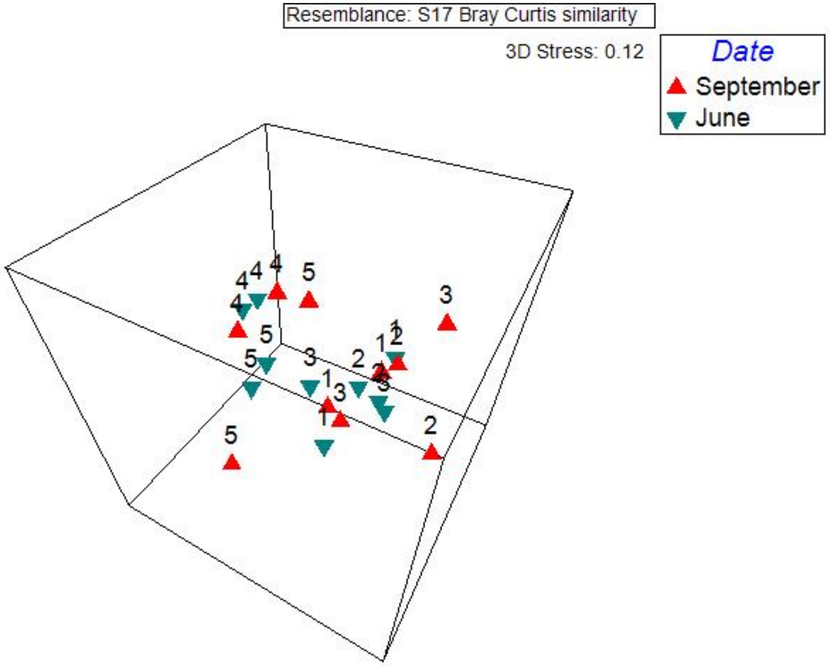
Plot 10 data removed



- Sampling date affected OTU composition (df = 1, psuedo-F = 3.1274, P = 0.0024
- No difference in dispersion between two dates
- Grouping by plot

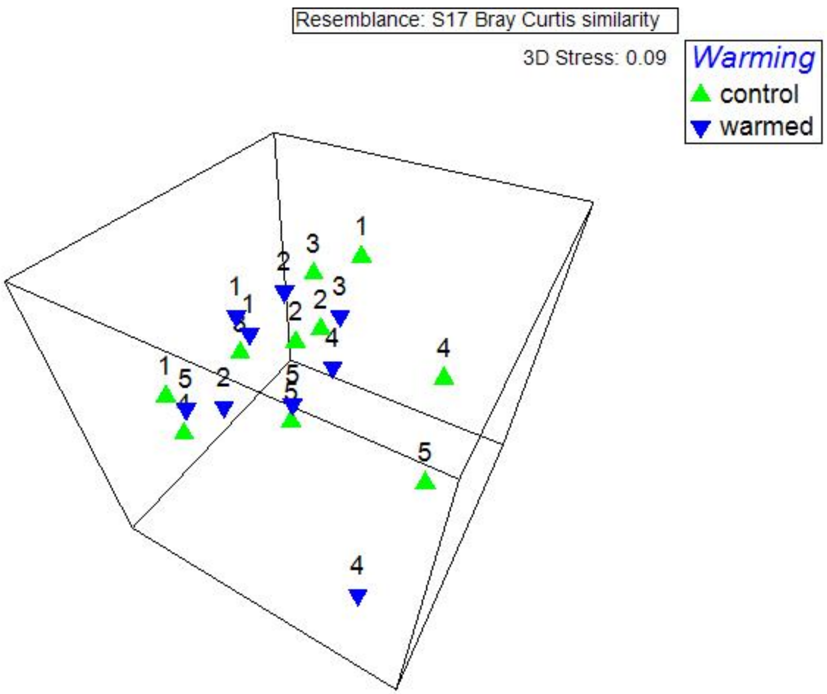
Results: *F. thurberi*

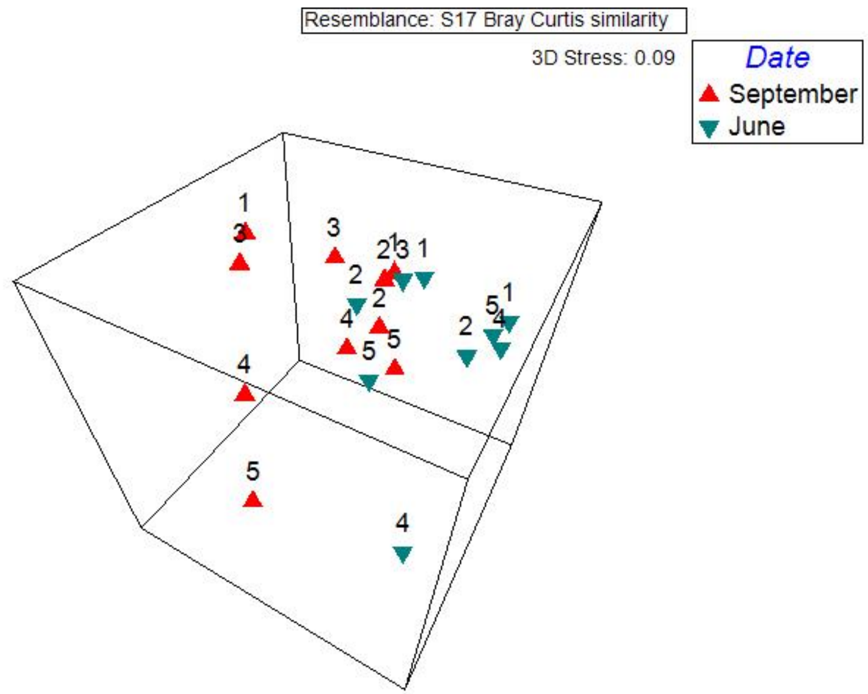




No effect of warming or sampling date

Results: *P. pratensis*





- No effect of warming
- Effect of sampling date (df = 1, pseudo-F = 2.6595, P = 0.0065

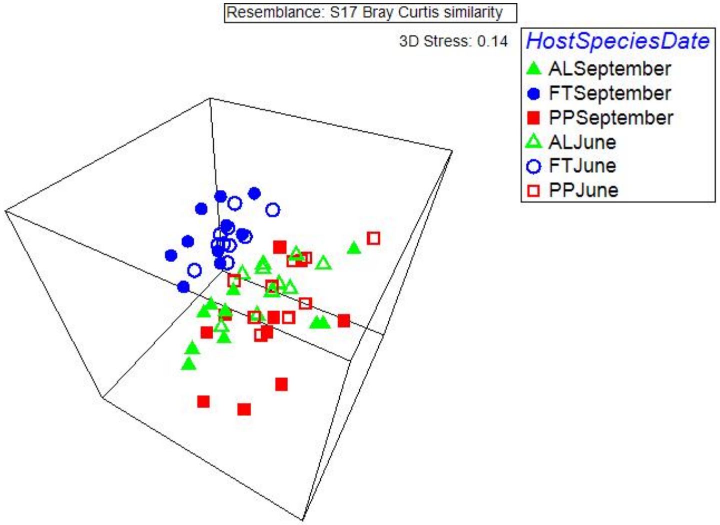
Indicator Species Analysis (SIMPER)

Control vs. warmed plots

OTU	Control Avg. Abundance	Warmed Avg. Abundance	Avg. Dissimilarity	Contribution %
OTU5	7.19	6.72	0.47	0.96
OTU4	7.52	7.14	0.42	0.86
OTU6	3.5	1.94	0.42	0.86
OTU15	3.99	4.02	0.42	0.85
OTU12	4.05	4.59	0.42	0.84

F. thurberi vs. *P. pratensis*

OTU	FETH Avg. Abundance	POPR Avg. Abundance	Avg. Dissimilarity	Contribution %
OTU15	7.17	2.36	0.53	1.02
OTU16	5.39	2.01	0.5	0.96
OTU11	4.39	8.72	0.49	0.95
OTU24	5.04	0.78	0.48	0.93
OTU12	5.96	2.72	0.47	0.91



F. thurberi vs. *A. lettermanii*

OTU	FETH Avg. Abundance	ACLE Avg. Abundance	Avg. Dissimilarity	Contribution %
OTU15	7.17	2.41	0.54	1.07
OTU5	4.81	8.68	0.53	1.05
OTU24	5.04	0.3	0.5	0.98
OTU16	5.39	1.46	0.47	0.92
OTU11	4.39	7.53	0.43	0.85

Taxonomy

OTU	Top BLAST Hit	Top BLAST Hit Details *Study Location*	*Study System*	*Citation*
OTU16	Uncultured Glomeromycota	California, USA	Giant sequoia (*Sequoiadendron giganteum*)	Fahey et al. 2012, *Mycologia*
OTU15	Uncultured Glomus	Michigan, USA	Northern hardwood forest dominated by sugar maple (*Acer saccharum*)	van Diepen et al. 2013, *Applied Soil Ecology*
OTU24	Uncultured Glomeromycota	Qinghai-Tibetan Plateau, China	Alpine meadow	Yang et al. 2013, *PLOS ONE*
OTU11	Uncultured Glomeromycota	Hungary	Agricultural system (corn, wheat, alfalfa, barley, peas)	Magurno et al. 2014, *Open Journal of Ecology*
OTU5	Uncultured Glomeromycota	Montana, USA	Native grassland vs. system dominated by *Centaurea maculosa* (spotted knapweed)	Mummey and Rillig 2006, *Plant and Soil*
OTU12	Uncultured Glomeraceae	Czech Republic	*Knautia arvensis* (Caprifoliaceae)	Doubková et al. 2013, *Mycorrhiza*
OTU4	Uncultured Glomeromycota	Tibetan Plateau, China	Herbaceous plants	Li et al., Unpublished
OTU6	Uncultured Glomeromycota	Canada	Crested wheatgrass (*Agropyron cristatum*)	Perez et al. 2008, *Agriculture and Agrifood Canada*
OTU10	Uncultured Glomeromycota	Canada	Switchgrass (*Panicum virgatum*)	Perez et al. 2008, *Agriculture and Agrifood Canada*

Questions or comments?