Arctic LTER Project

Arctic Tundra in a Changing Climate

The Terrestrial Research Group
Laura Gough, Coordinator
University of Texas Arlington

Arctic LTER Mid-Term Review
18 June 2013

Arctic LTER Terrestrial PIs

- Natalie Boelman, Columbia
- Donie Bret-Harte, UAF
- Eugenie Euskirchen, UAF
- Ned Fetcher, Wilkes
- Kevin Griffin, Columbia
- Erik Hobbie, New Hampshire
- Feng Sheng Hu, Illinois Urbana-Champaign
- Michelle Mack, Florida
- Jim McGraw, West Virginia
- John Moore, Colorado State
- Ed Rastetter, MBL
- Adrian Rocha, Notre Dame
- Josh Schimel, UCSB
- Gus Shaver, MBL
- Heidi Steltzer, Ft. Lewis College
- Paddy Sullivan, Alaska Anchorage
- Matt Wallenstein, Colorado State
- Mike Weintraub, Toledo
- John Wingfield, UC Davis

Senior RA: Jim Laundre, MBL

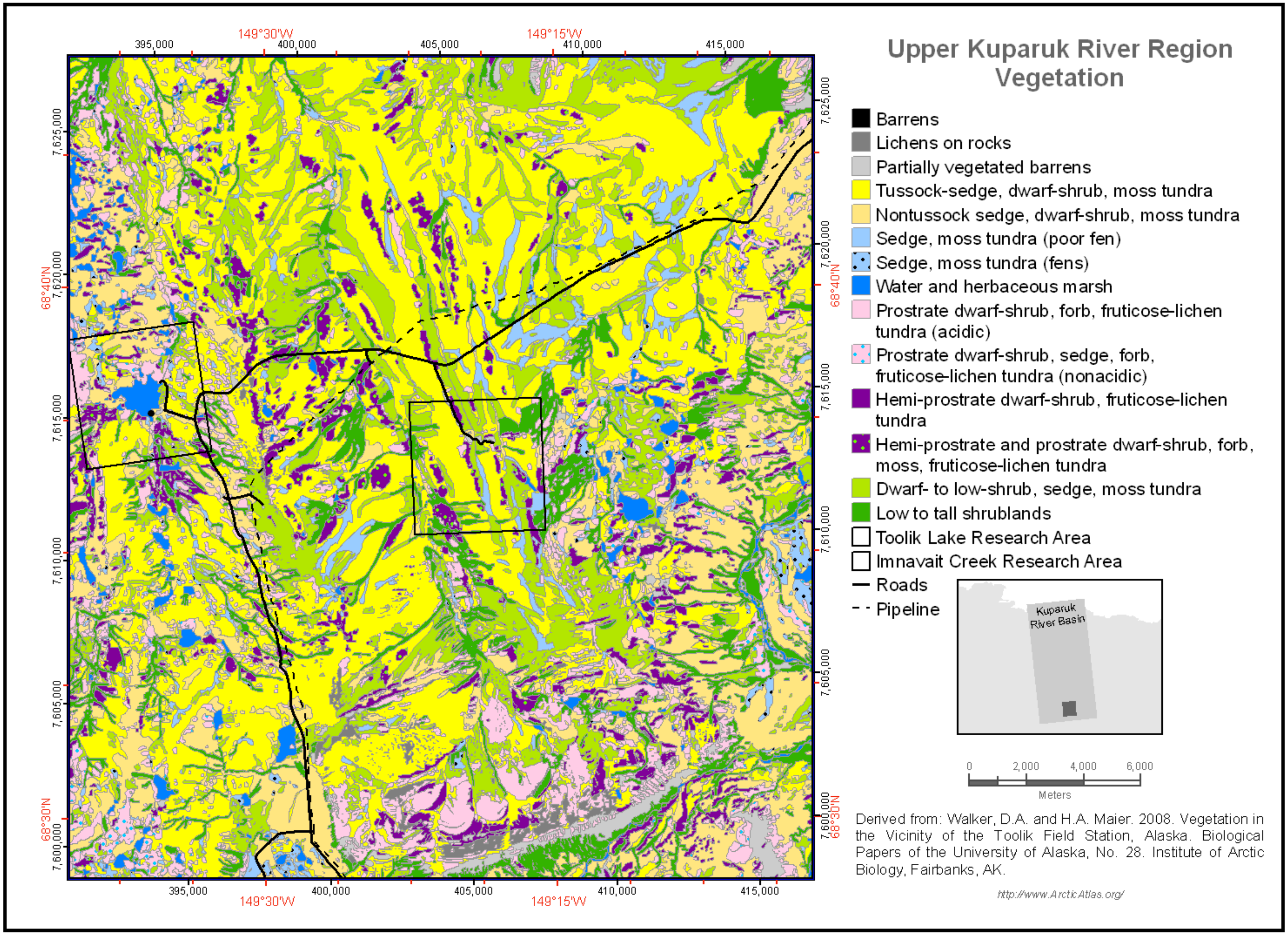
Mapping ArcLTER Objectives to Terrestrial Research

ArcLTER Shared Objectives

1. How does climate control ecosystem states, processes, and linkages?
2. How do disturbances change ecosystem states, processes, and linkages?
3. How do climate and disturbance <u>interact</u> to control biogeochemical cycles and biodiversity at catchment and landscape scales?

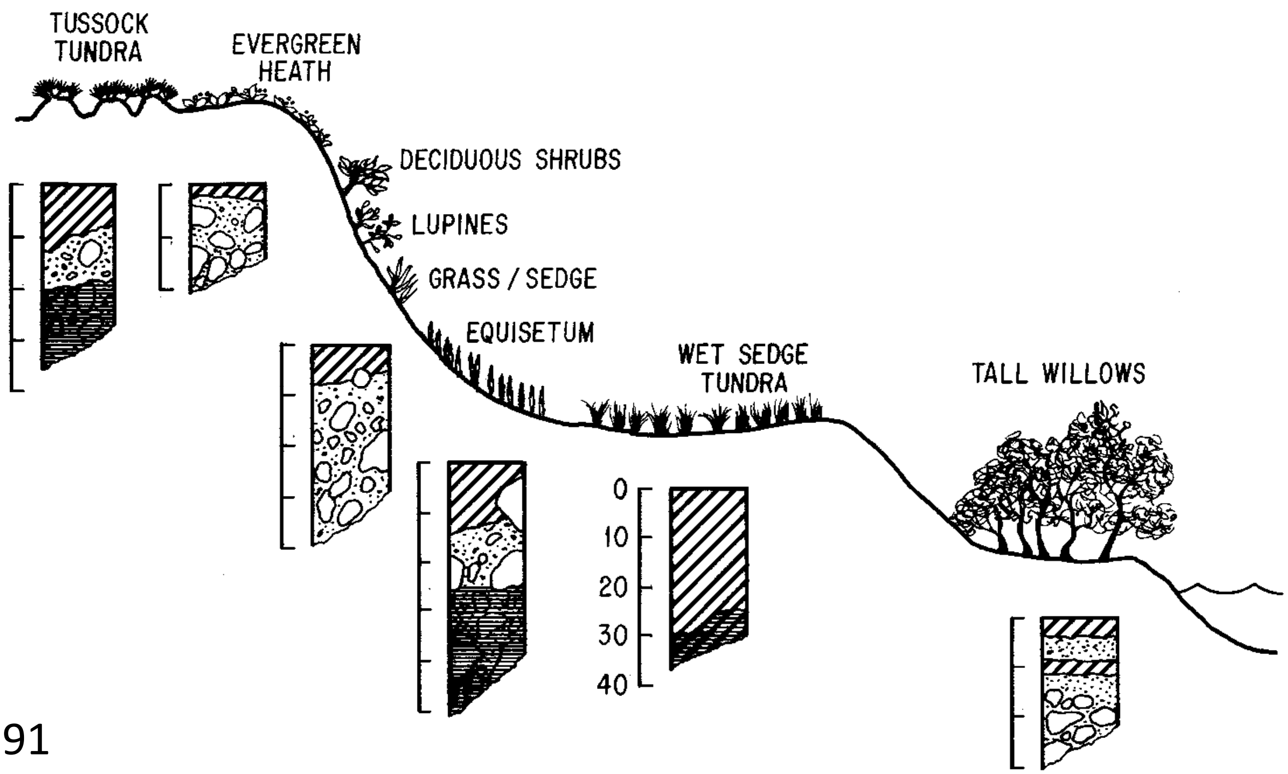
Terrestrial Research (This talk)

- "Shrubbification"
  - Landscape-level response to warming
  - Long-term fertilization experiments
  - Long-term warming experiments
  - Identifying the pathways of change
- Disturbance
  - Vegetation resilience to fire
  - Successional response to thermal erosion
- Consumers
  - Mammalian herbivores alter response to increased nutrients
  - Arthropod consumers in shrub and open tundra


Upper Kuparuk River Region
Vegetation
Barrens
Lichens on rocks
Partially vegetated barrens
Tussock-sedge, dwarf-shrub, moss tundra
Nontussock sedge, dwarf-shrub, moss tundra
Sedge, moss tundra (poor fen)
Sedge, moss tundra (fens)
Water and herbaceous marsh
Prostrate dwarf-shrub, forb, fruticose-lichen tundra (acidic)
Prostrate dwarf-shrub, sedge, forb, fruticose-lichen tundra (nonacidic)
Hemi-prostrate dwarf-shrub, fruticose-lichen tundra
Hemi-prostrate and prostrate dwarf-shrub, forb, moss, fruticose-lichen tundra
Dwarf- to low-shrub, sedge, moss tundra
Low to tall shrublands
Toolik Lake Research Area
Imnavait Creek Research Area
Roads
Pipeline
Kuparuk River Basin
0
2,000
4,000
6,000
Meters
149°30'W
149°15'W
395,000
400,000
405,000
410,000
415,000
68°40'N
68°30'N
7,600,000
7,605,000
7,610,000
7,615,000
7,620,000
7,625,000
Derived from: Walker, D.A. and H.A. Maier. 2008. Vegetation in the Vicinity of the Toolik Field Station, Alaska. Biological Papers of the University of Alaska, No. 28. Institute of Arctic Biology, Fairbanks, AK.
http://www.ArcticAtlas.org/

Characteristics of Arctic Tundra

- soils frozen, snow-covered most of the year
- clonal, long-lived perennial plants dominate
- species diversity, NPP low



Giblin et al. 1991

ARC LTER Themes

- *How does climate control ecosystem states, processes, and linkages?*
- *How do disturbances change ecosystem states, processes, and linkages?*
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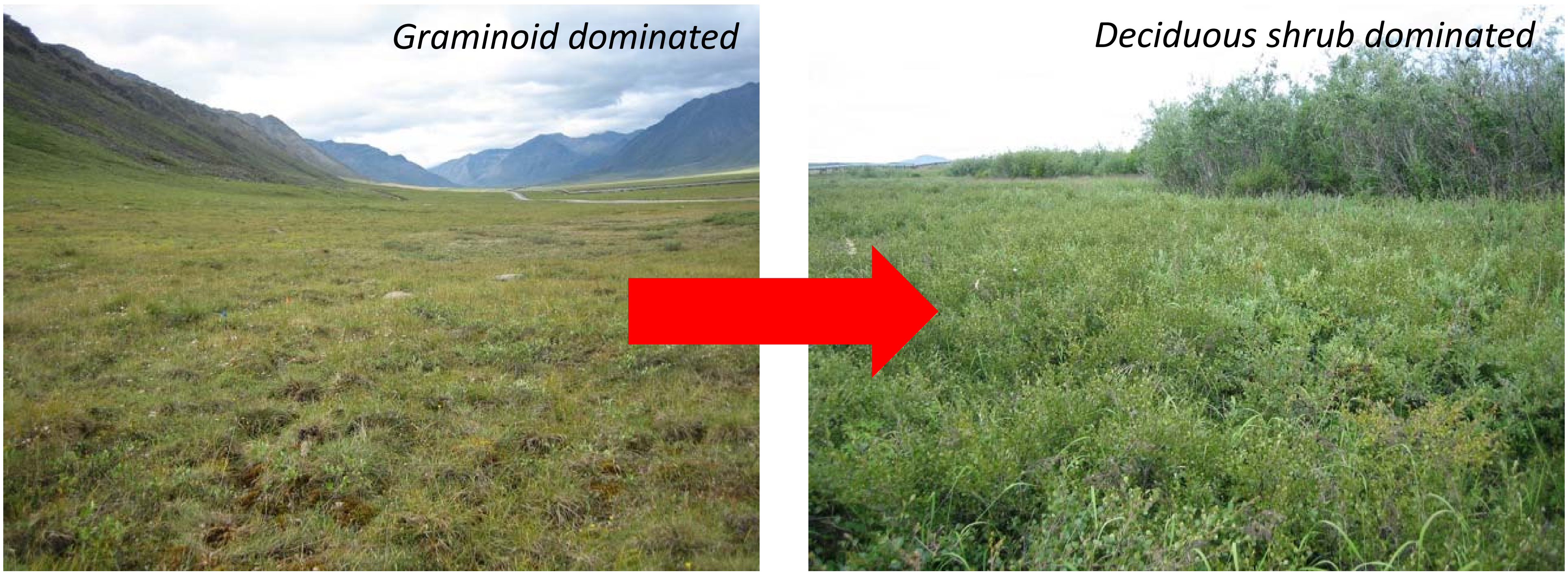
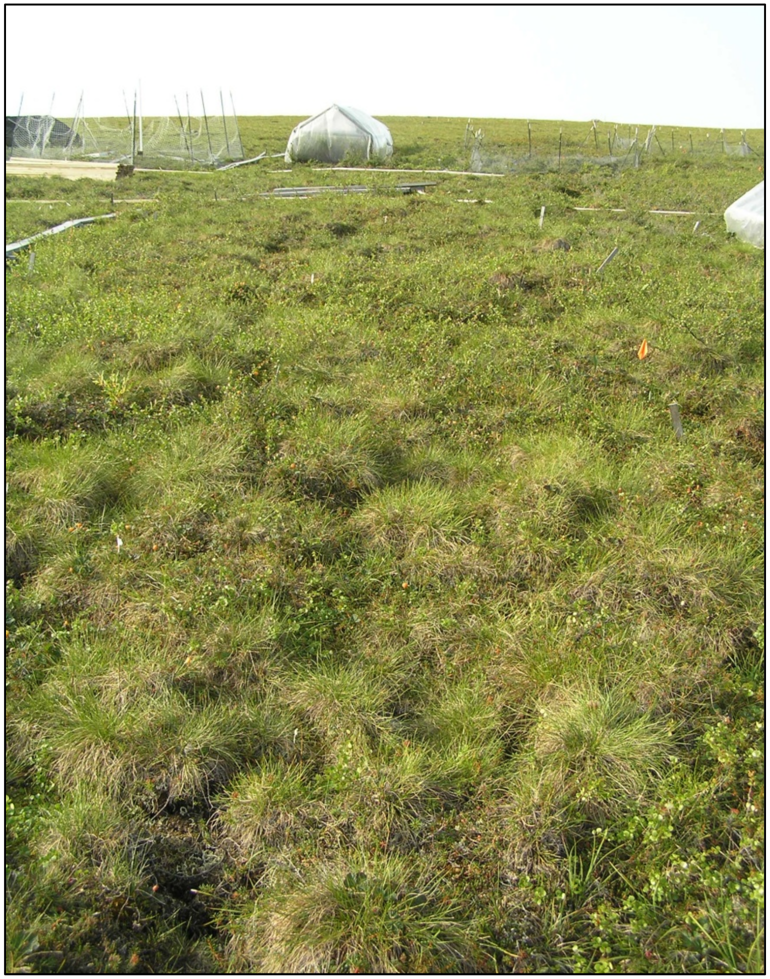
“Shrubbification”



1. repeat aerial photos
2. satellite imagery
3. plot-based measurements

Long-term Nutrient Addition

Moist Acidic Tussock Tundra (MAT)



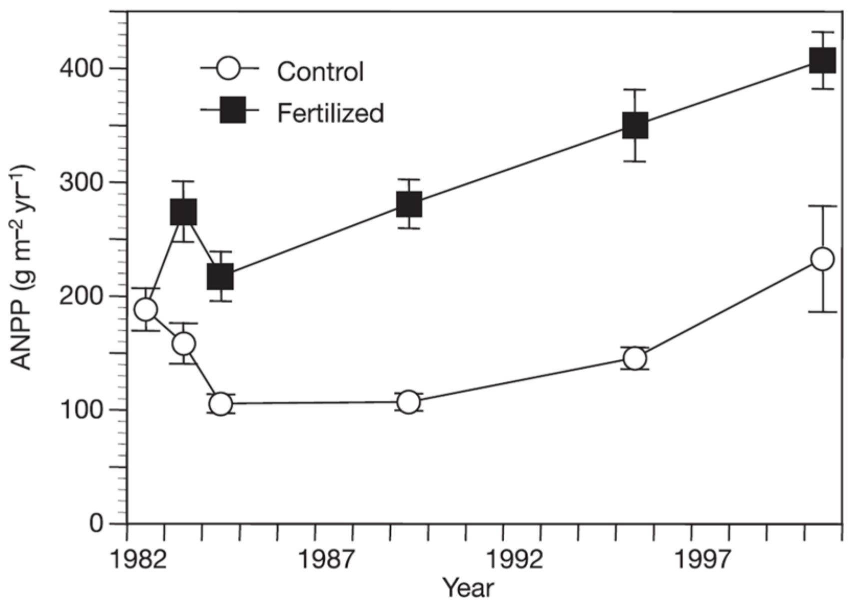
Control

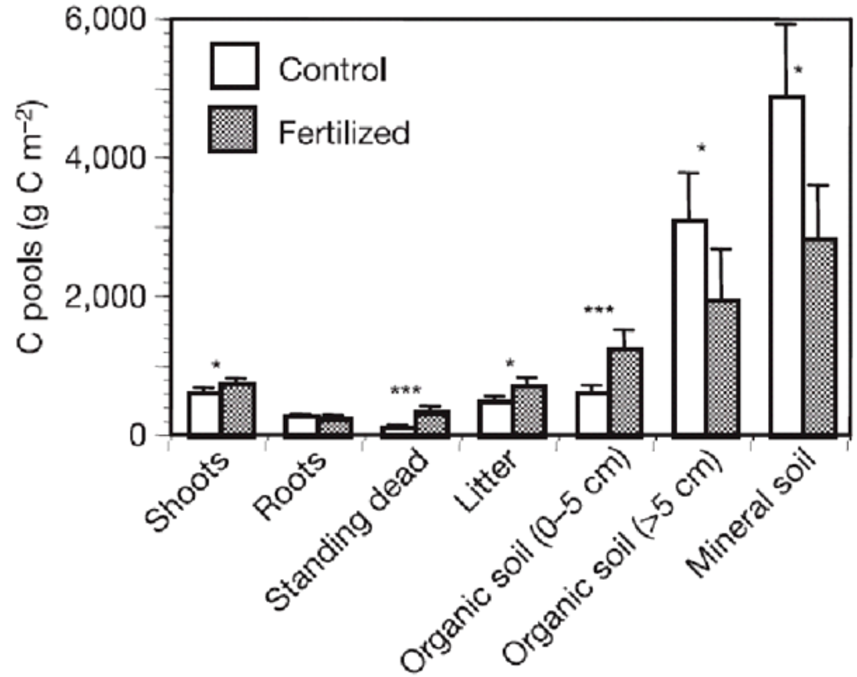
Annual N and P addition

Why does *Betula nana* (dwarf birch) respond positively to added nutrients?

- developmental plasticity
  - Bret-Harte et al. 2001 *Ecology*
- mycorrhizae
  - Deslippe et al. 2011 *Global Change Biology*
- leaf-level physiology
  - Kornfeld et al. 2012 *New Phytologist*
  - Heskel et al. 2013 *Ecology and Evolution*

Long-Term Nutrient Addition

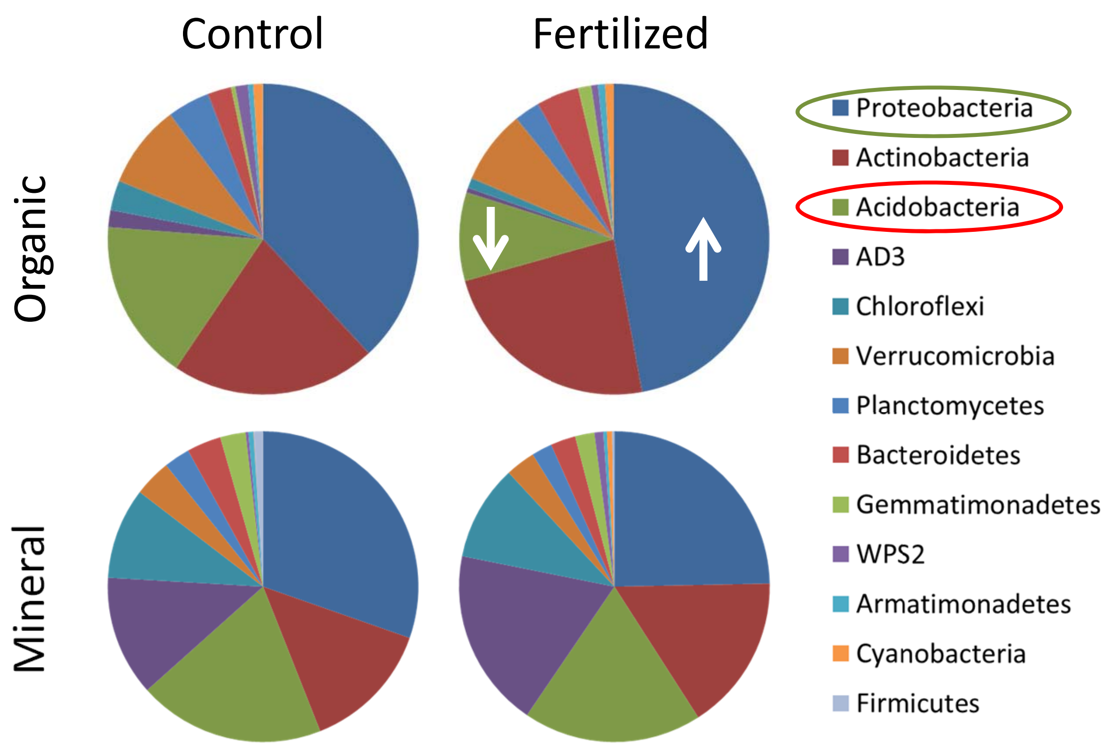


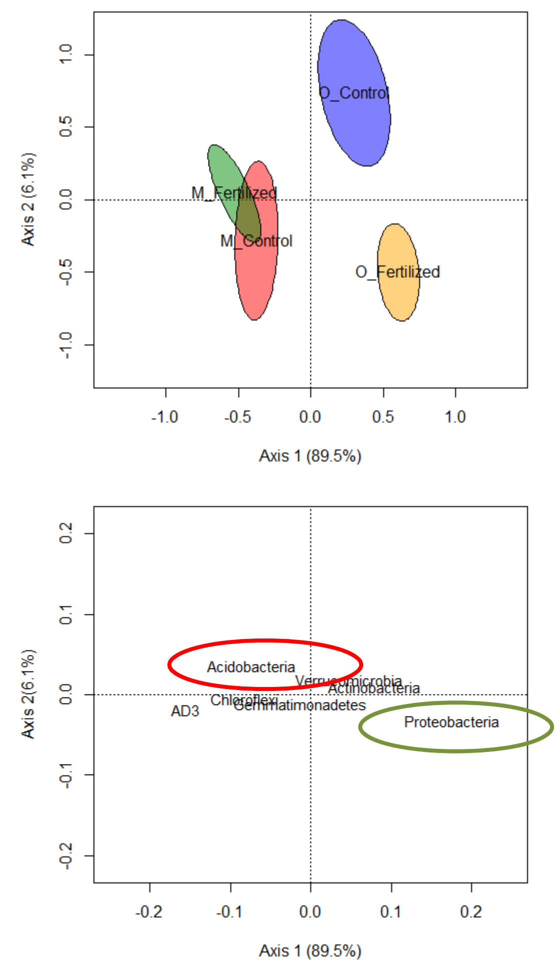


Net ecosystem loss of ~ 2,000 g C m^{-2} over 20 years

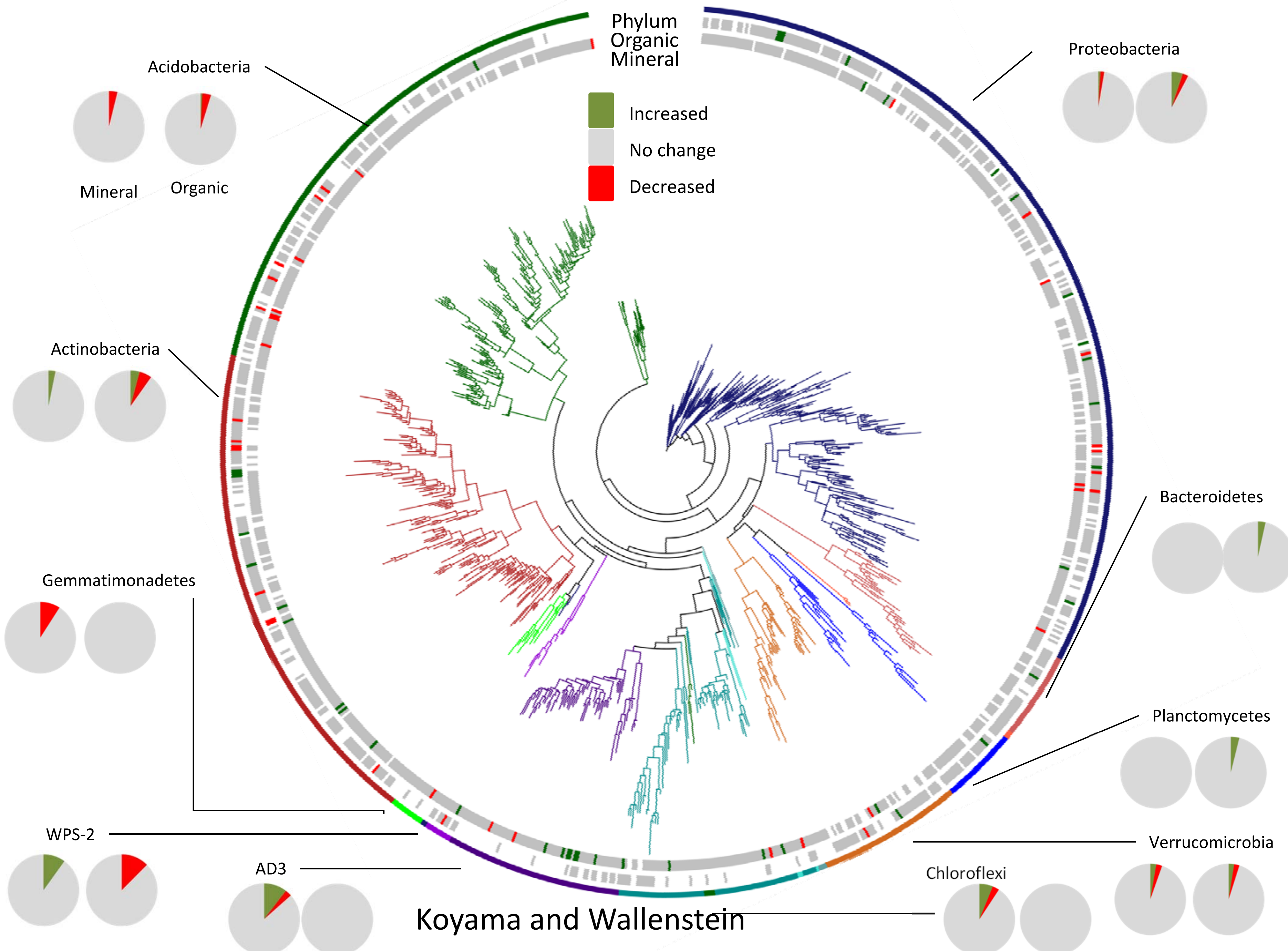
Mack et al. 2004 *Nature*

Long-Term Nutrient Addition





Koyama and Wallenstein


Phylum
Organic
Mineral
Increased
No change
Decreased
Acidobacteria
Mineral
Organic
Proteobacteria
Actinobacteria
Bacteroidetes
Gemmatimonadetes
Planctomycetes
WPS-2
AD3
Verrucomicrobia
Chloroflexi
Koyama and Wallenstein

Long-Term Greenhouse Warming

Long-Term Greenhouse Warming

Plant biomass (2002; g dry weight m^{-2})	**Control**	**Greenhouse**
Vascular aboveground	**369.5 ± 26.0**	**720.7 ± 85.9 *** **
Vascular belowground	**438.3 ± 88.7**	**712.4 ± 70.6 ***
Deciduous Shrub	**218.7 ± 51.8**	**551.2 ± 119.1 ***
Graminoid	227.0 ± 57.5	179.0 ± 92.9
Litter and standing dead	**569.3 ± 134**	**758.4 ± 171.4***
Moss	**75.5 ± 10.8**	**16.3 ± 4.4 ****
Lichen	**29.9 ± 6.4**	**11.8 ± 6.7 ***
all values reported as means ± one se		

Sistla et al. 2013 Nature

Long-Term Greenhouse Warming

	Surface organic		Deep organic		Mineral	
Soil characteristic	**Control**	**Greenhouse**	**Control**	**Greenhouse**	**Control**	**Greenhouse**
Carbon (g m^{-2})	1026.9 ± 101.2	929.1 ± 101.8	4547.2 ± 1064.4	3906.6 ± 638.0	**6381.7 ± 1411.1**	**8342.3 ± 786.5**
Nitrogen (g m^{-2})	26.5 ± 4.1	27.5 ± 3.1	163.5 ± 47.2	145.5 ± 18.1	318.0 ± 75.5	376.9 ± 29.3
C:N	**42.2 ± 1.7**	**35.8 ± 2.6**	31.5 ± 1.4	28.4 ± 1.3	**20. 4 ± 0.4**	**22.4 ± 0.6**
Bulk density (g soil cm^{-3})	0.05 ± 0.006	0.06 ± 0.02	0.14 ± 0.04	0.2 ± 0.04	1.0 ± 0.11	0.8 ± 0.1
Sampling depth (cm)	5 ± 0	5 ± 0	10.1 ± 1.5	11.2 ± 1.2	17.0 ± 1.6	15.7 ± 0.8
Percent water	443.5 ± 40.5	531.6 ± 65.2	391.8 ± 27.4	446.1 ± 82.3	75.5 ± 14.9	107.9 ± 24.1

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Sistla et al. 2013 Nature

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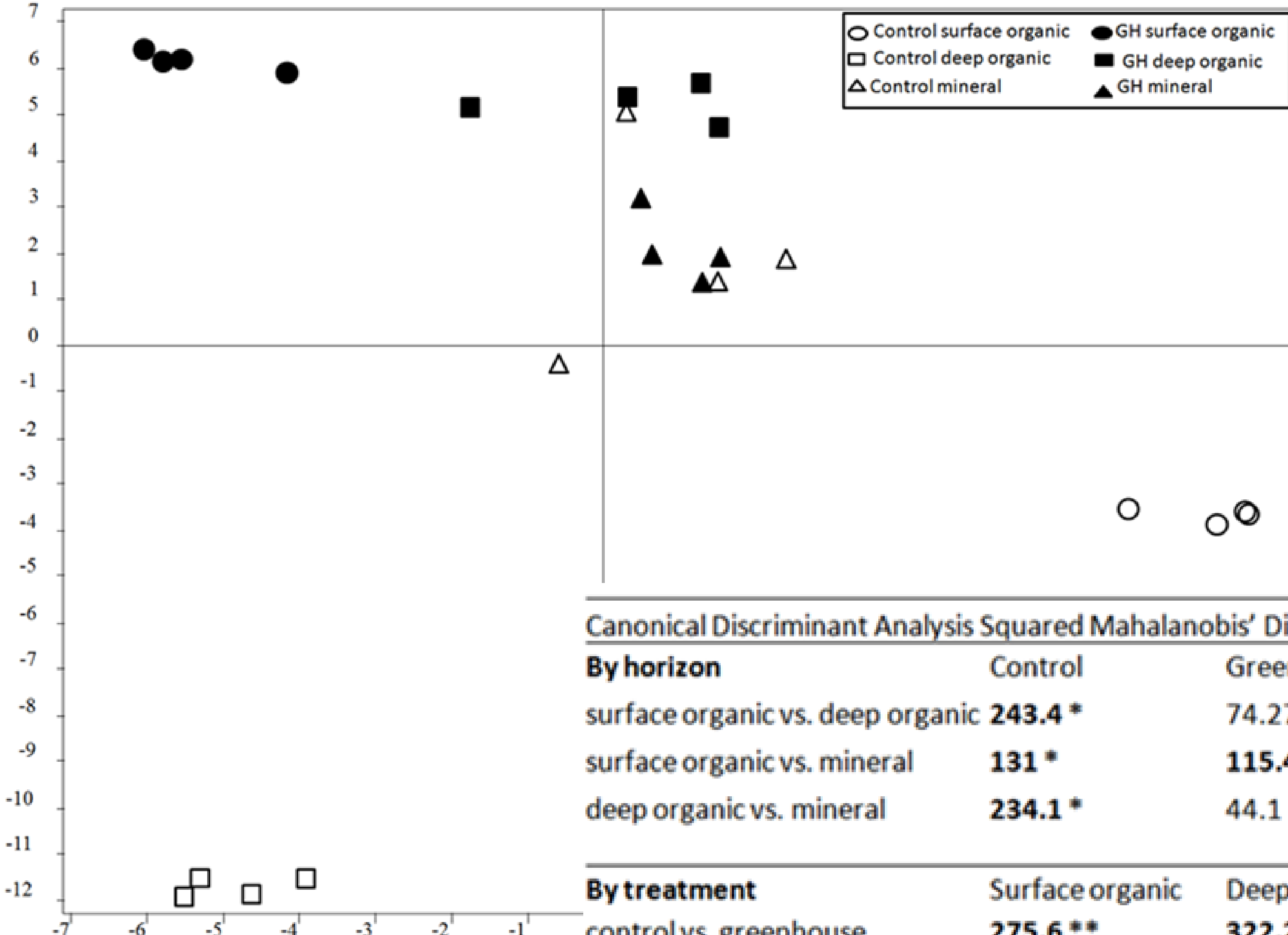
	Surface organic		Deep organic		Mineral	
Soil characteristic	**Control**	**Greenhouse**	**Control**	**Greenhouse**	**Control**	**Greenhouse**
Microbial biomass N (µg N soil g-1)	605 ± 106	563 ± 127	285 ± 63	307 ± 90	**5.78 ± 1.55**	**13.0 ± 3.86**
Fungal:bacterial biomass	181 ± 53	220 ± 53	**858 ± 305**	**163 ± 69**	115 ± 37	76 ± 70
SIR microbial biomass (µg C-CO2 soil g^{-1} day^{-1})	**6011 ± 733**	**4584 ± 664**	1604 ± 434	1848 ± 351	**59.9 ± 7.26**	**83.0 ± 4.28**
C-mineralization (µg C-CO_2 soil g^{-1} day^{-1})	31.83 ± 1.6	27.15 ± 11.6	12.37 ± 2.2	15.46 ± 3.4	**0.43 ± 0.05**	**0.64 ± 0.04**
Extractable organic C (mg C m^{-2})	111.07 ± 18.3	138.11 ± 37.1	610.94 ± 192.3	917.60 ± 57.2	**1343.14 ± 160.2**	**1092.11 ± 97.1**

all values reported as means ± one se

Sistla et al. 2013 Nature

Long-Term Greenhouse Warming



Canonical Discriminant Analysis Squared Mahalanobis' Distances

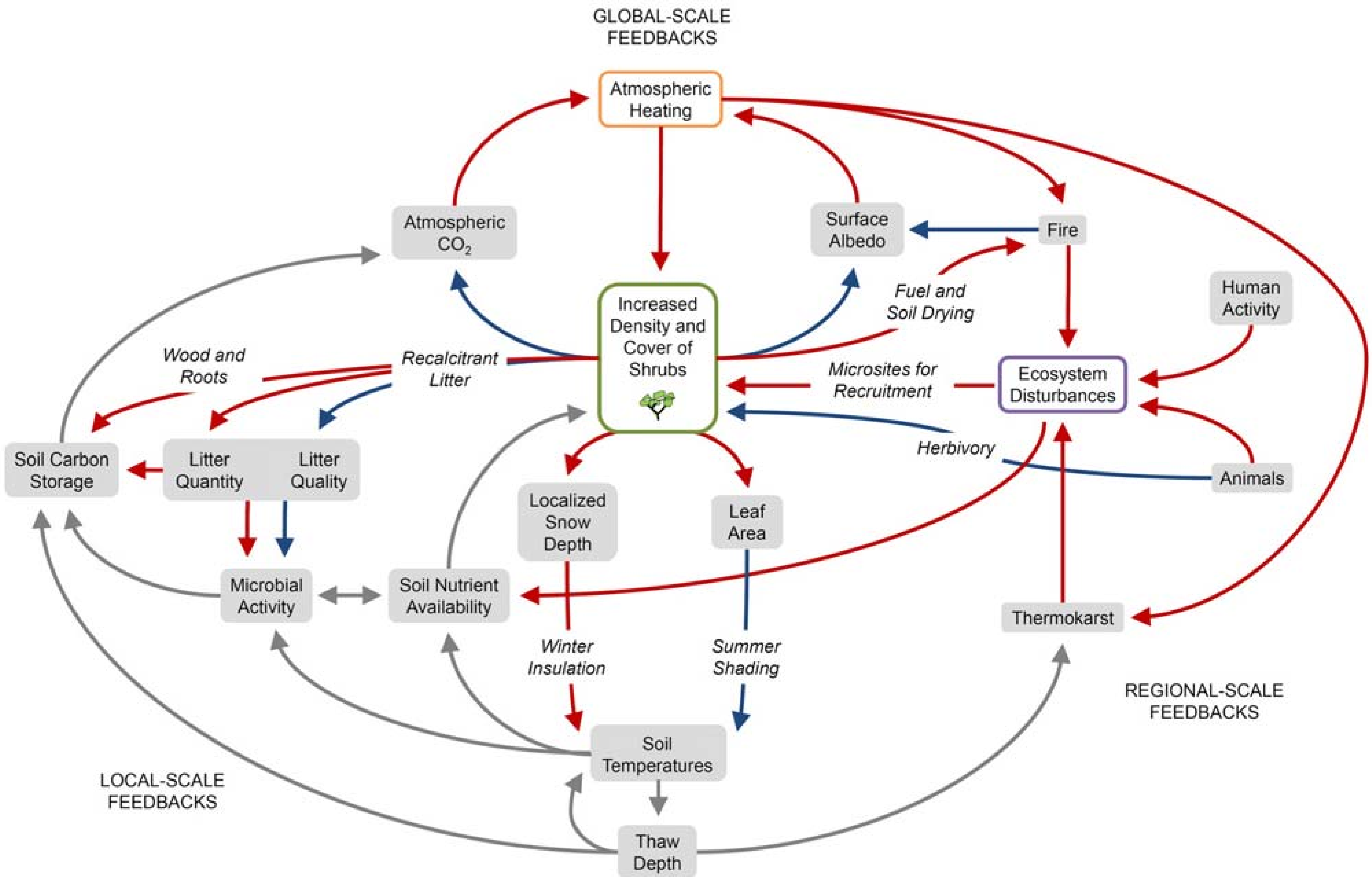
By horizon	Control	Greenhouse	
surface organic vs. deep organic	**243.4** *	74.27	
surface organic vs. mineral	**131** *	**115.4** *	
deep organic vs. mineral	**234.1** *	44.1	
By treatment	Surface organic	Deep organic	Mineral
control vs. greenhouse	**275.6** **	**322.2** **	0.1

Sistla et al. 2013 Nature

Long-Term Greenhouse Warming

- no difference in soil C or N stocks despite differences in temperatures, thaw depth, soil communities, and plant community
- greatest biogeochemical differences at depth

- over two decades, MAT soil C and N resistant to warming



Myers-Smith et al. 2011

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Anaktuvuk River Fire 2007

Fire

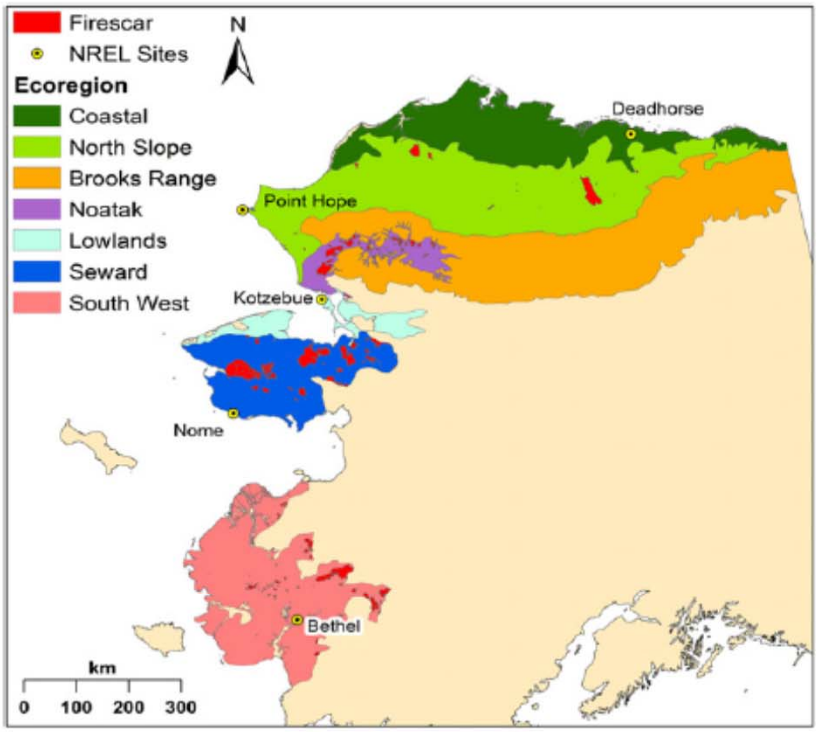


Figure 1. Map of tundra ecoregions, NREL sites and tundra fire scar distributions in Alaska.

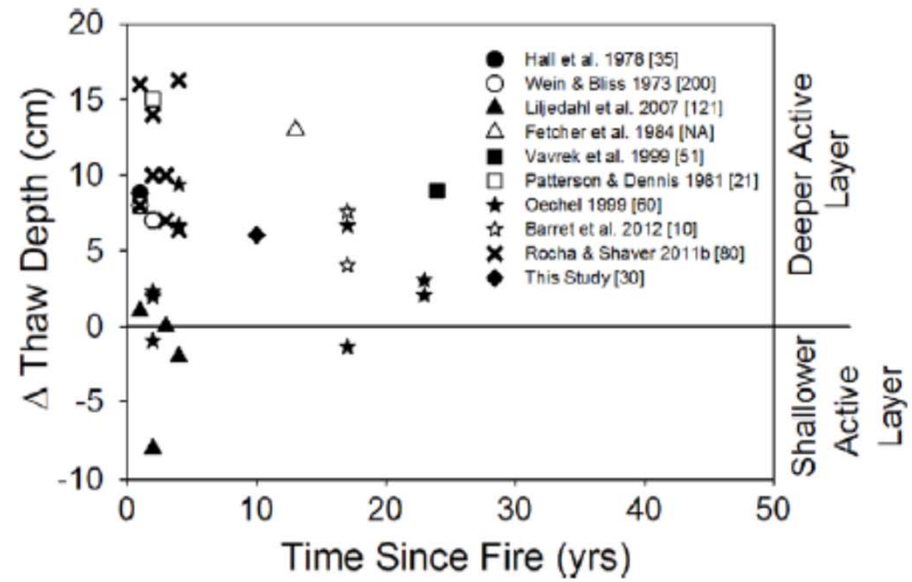
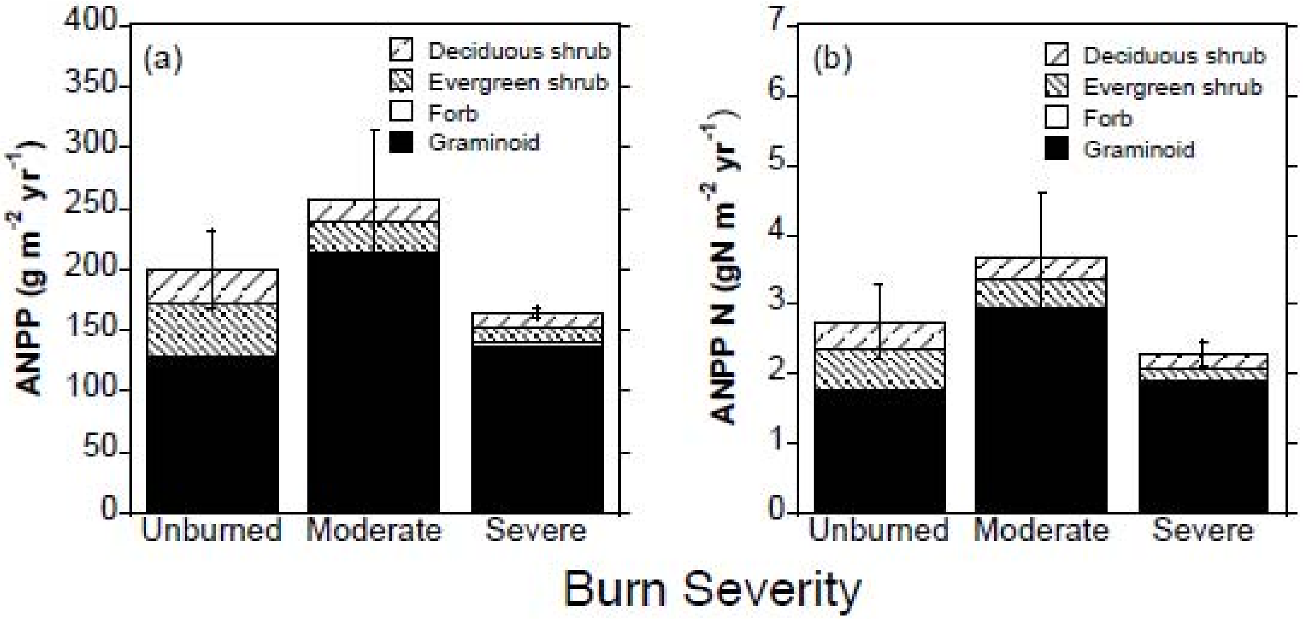


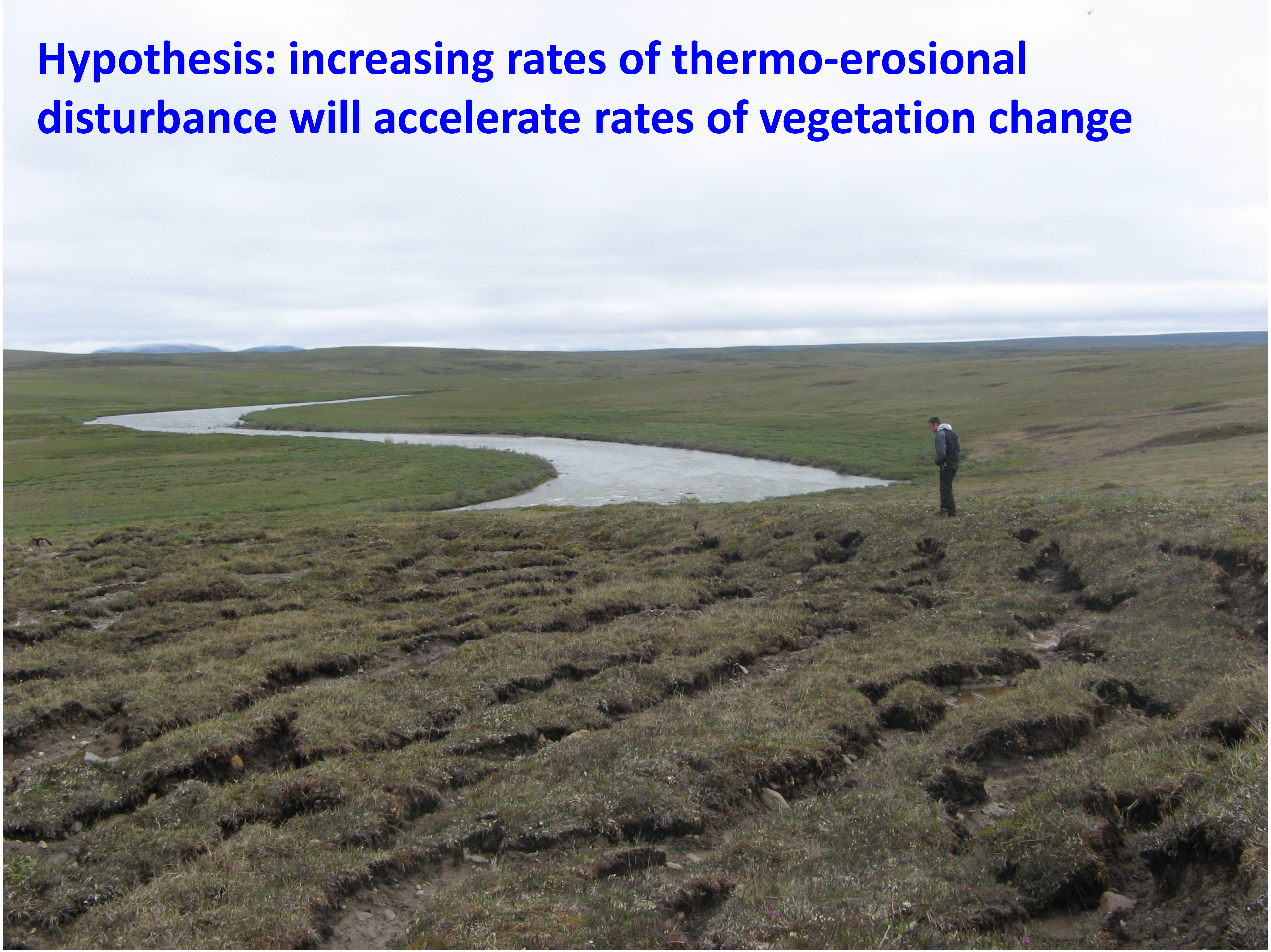
Figure 5. Post-fire changes in thaw depth obtained from the literature. Reported sample size for each burned/unburned pair reported in brackets following the citation. Positive values indicate greater thaw depth and a deeper active layer, while negative values indicate shallower thaw depth and active layer in fire scars of a given age.

Rocha et al. 2012 *Environmental Research Letters*

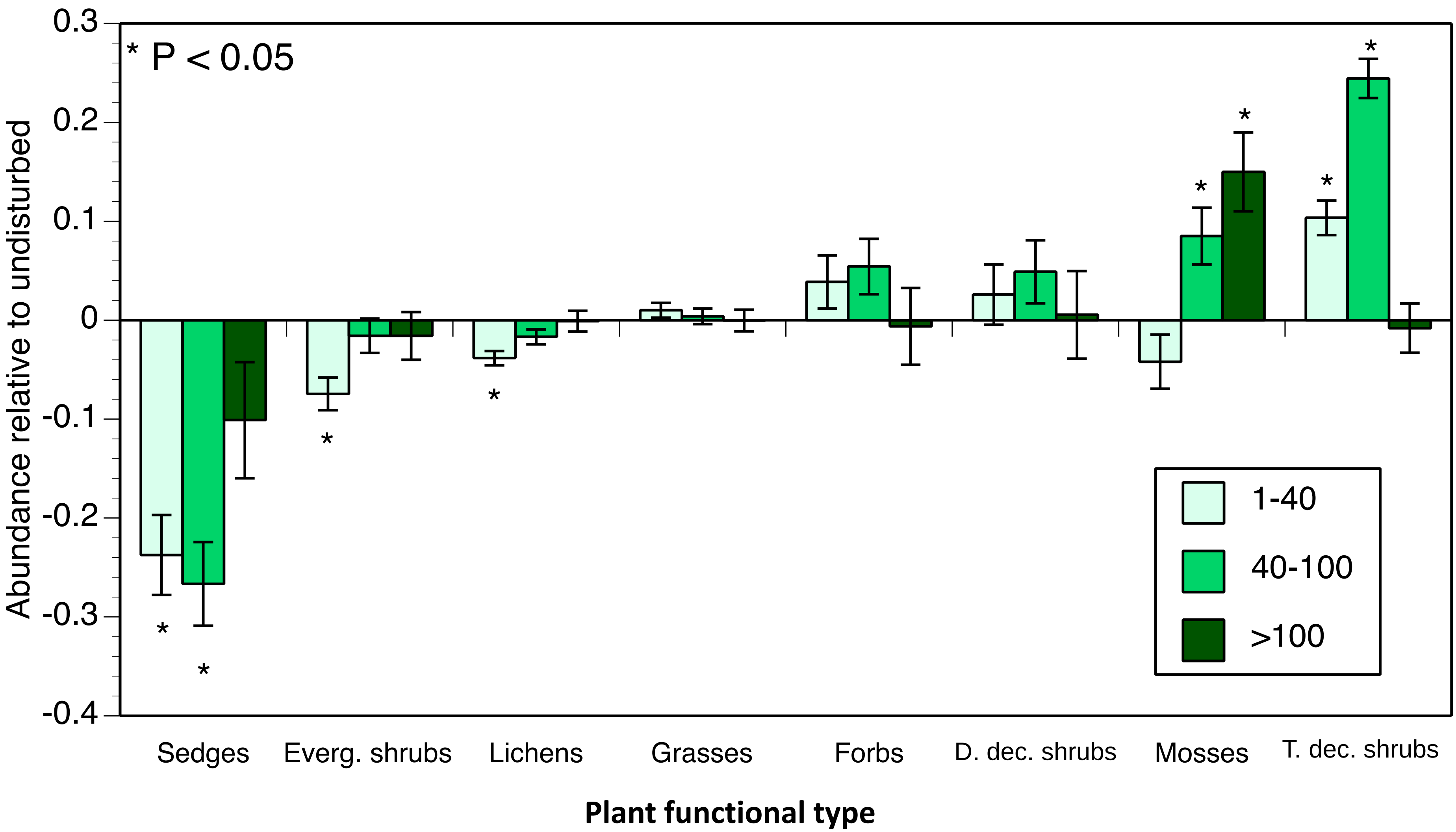


Bret-Harte et al. in press Proc. Royal Academy London B

Hypothesis: increasing rates of thermo-erosional disturbance will accelerate rates of vegetation change



Response of plant functional group abundance to thermokarst disturbance



Michelle Mack, unpublished

Disturbance

- tracking soil and vegetation change following pulse disturbances
- tundra may be resilient, but may also undergo several alternate successional pathways
  - implications for ecosystem function

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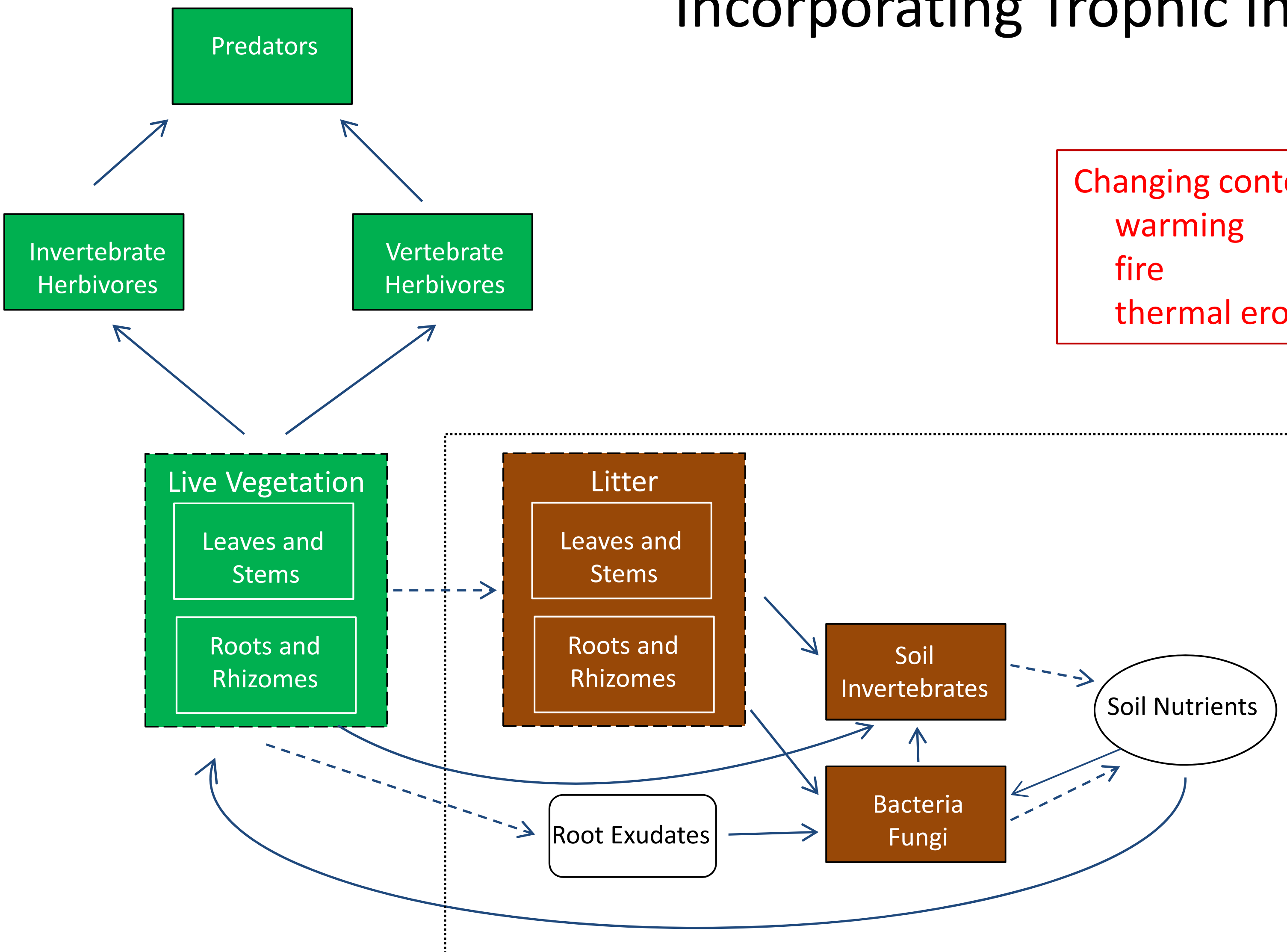
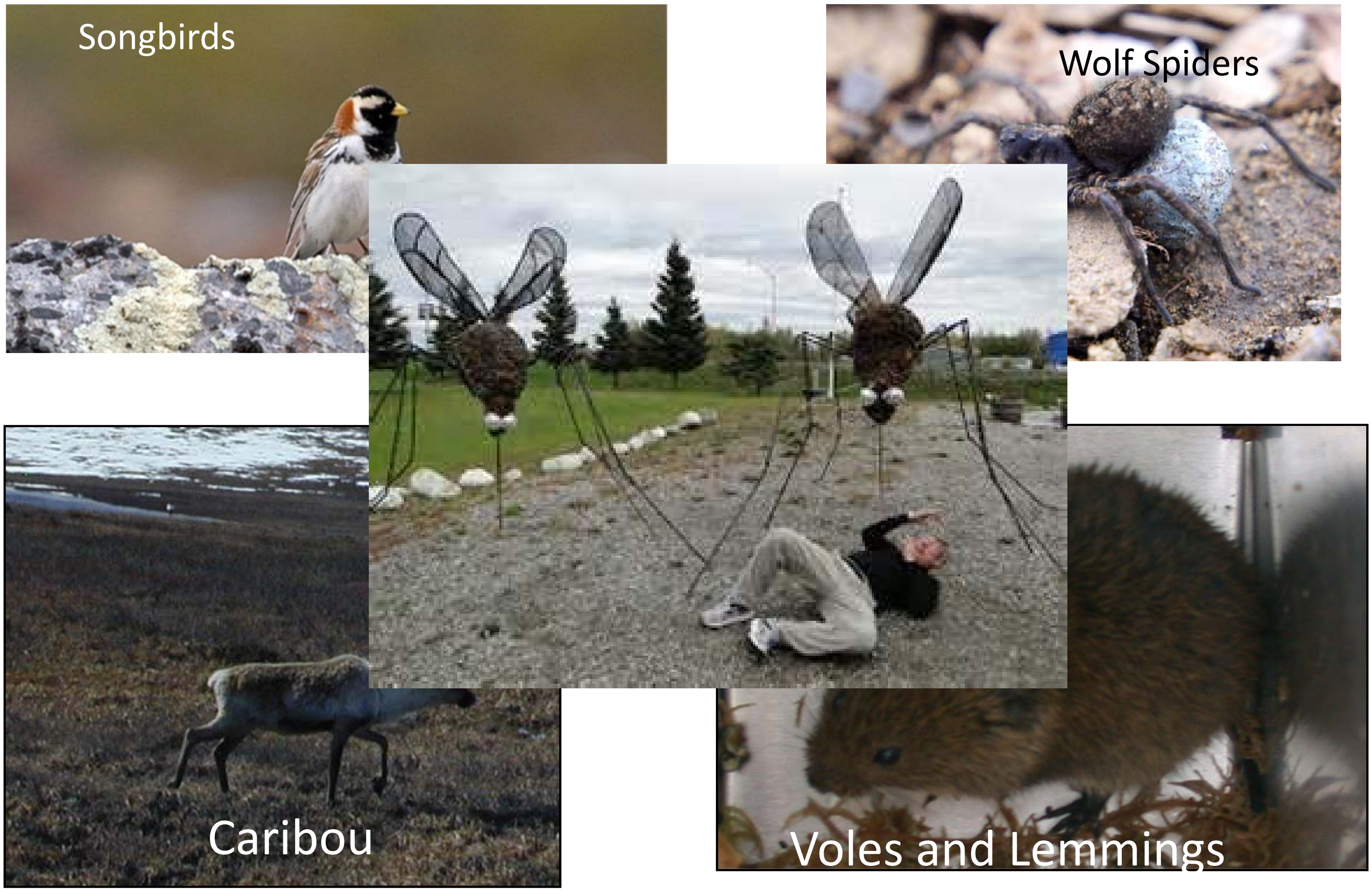
Incorporating Trophic Interactions

Changing context:
- warming
- fire
- thermal erosion

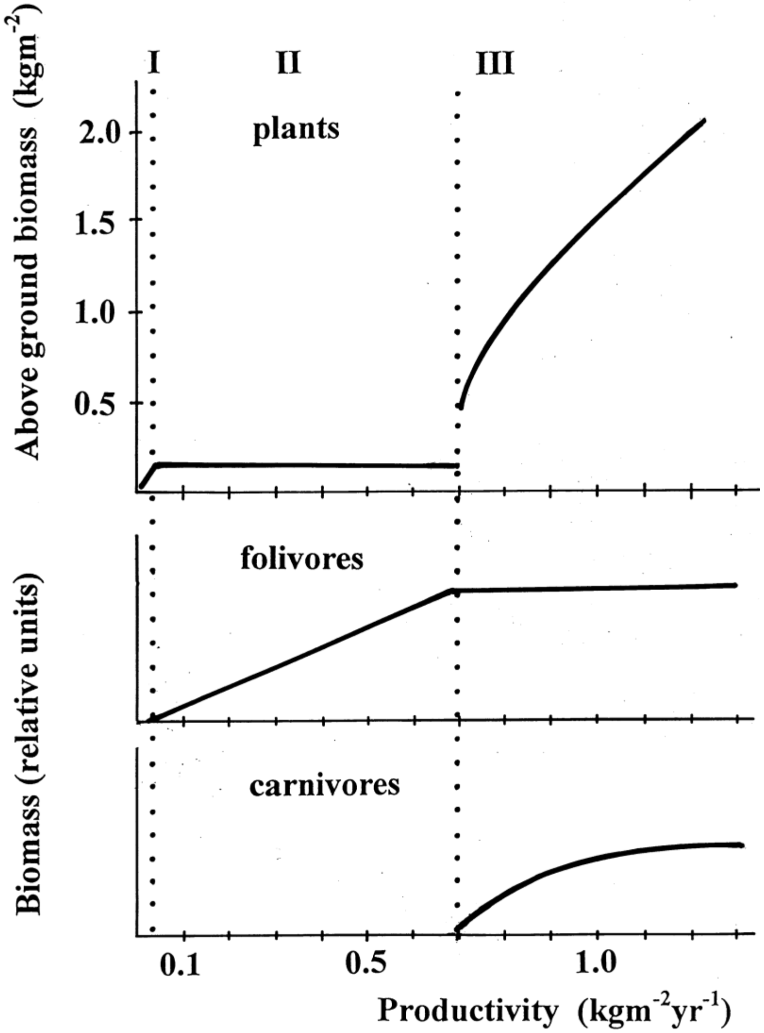


Terrestrial Consumers

Terrestrial Consumers

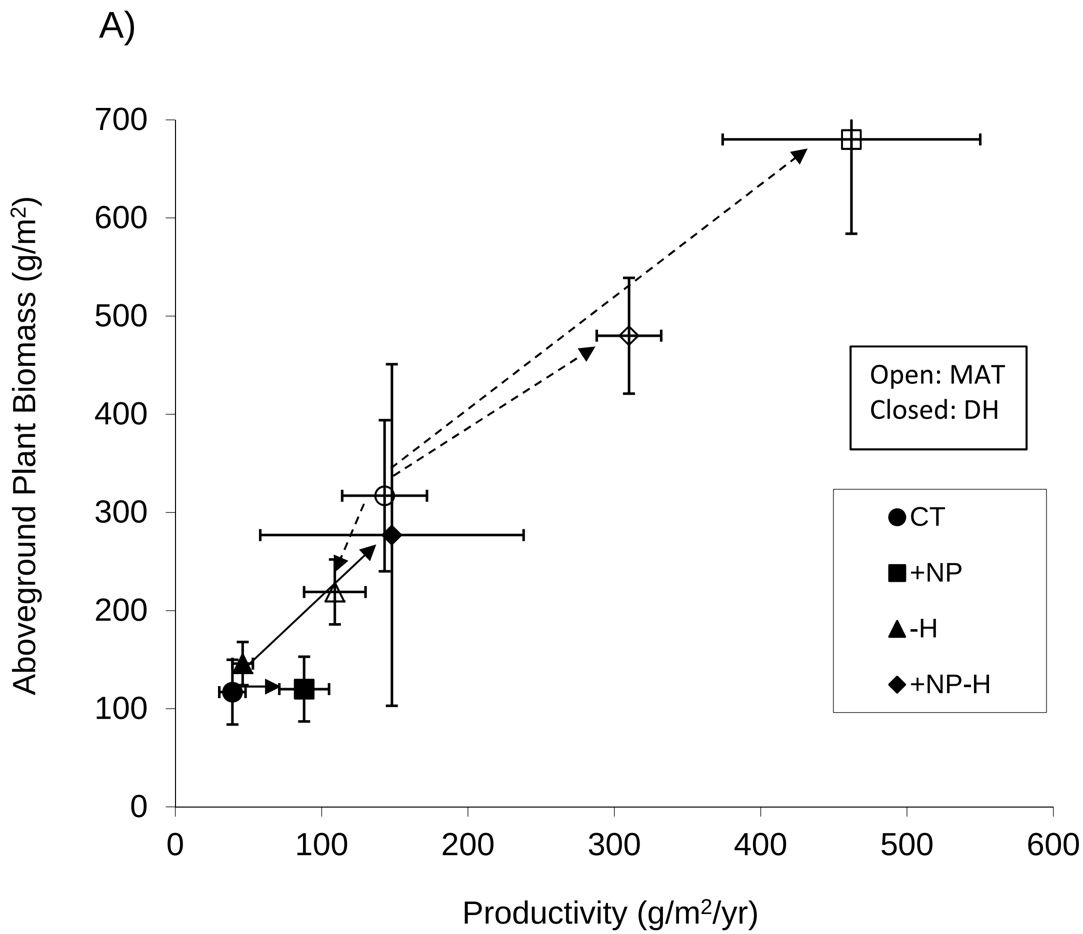


Testing the Exploitation Ecosystem Hypothesis (EEH) Above- and Belowground



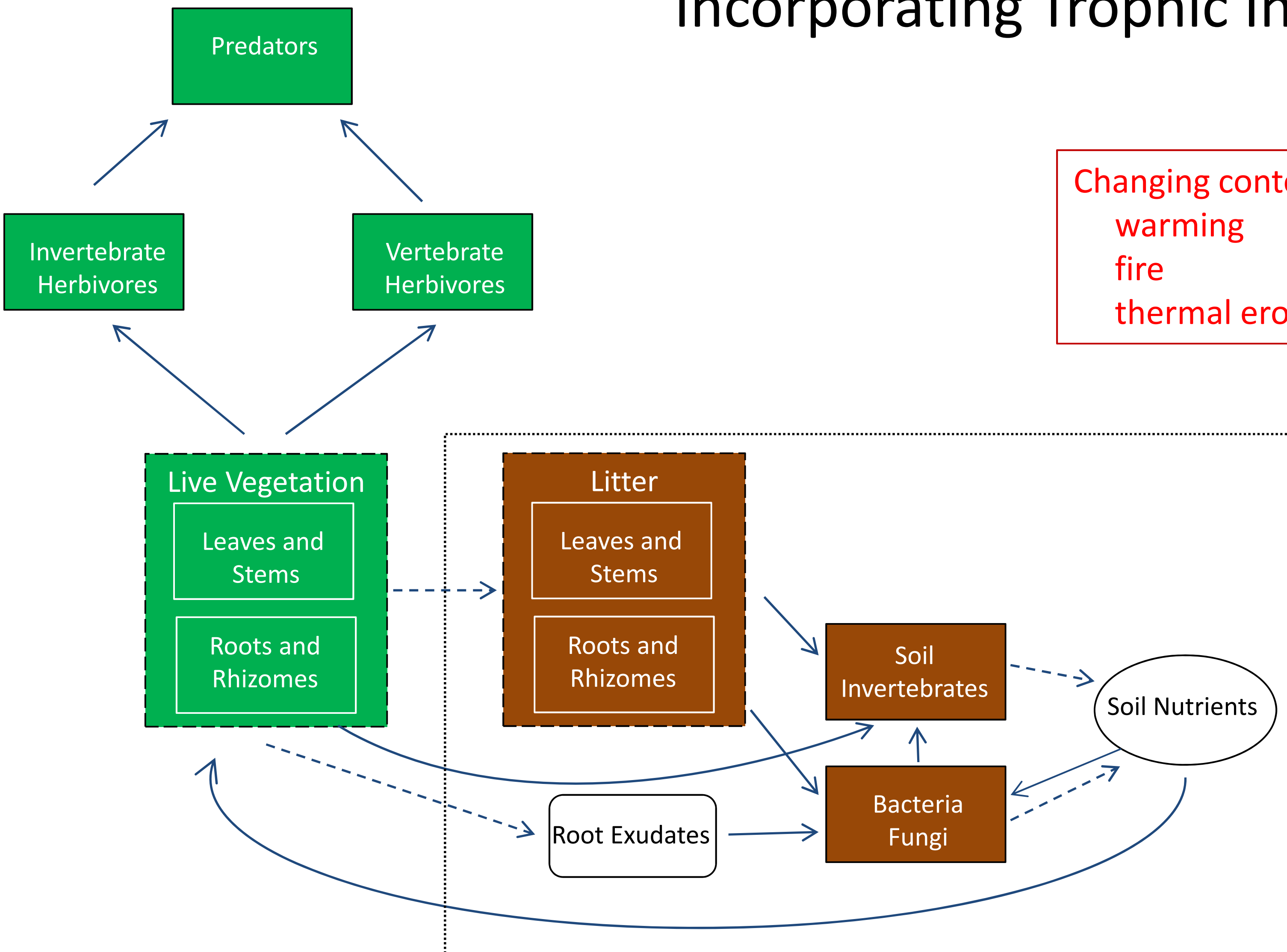
Oksanen and Oksanen 2000

Testing the Exploitation Ecosystem Hypothesis (EEH) Aboveground



Gough et al. 2012 *Ecology*

Incorporating Trophic Interactions



Changing context:
- warming
- fire
- thermal erosion

The Next Three Years

- monitoring, simulating, and modeling responses to climate change
- investigating disturbance effects
  - changes in consumers
  - fire
  - thermal erosion
- role of individual species and community structure in ecosystem processes

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Questions?