

# Structure and resilience of fungal communities in Alaskan boreal forest soils

An aerial photograph showing a wide, winding river flowing through a vast boreal forest landscape. The river meanders through the forest, creating several large islands and peninsulas. The forest is a mix of green and brown, suggesting different types of trees and possibly some areas of disturbance or fire. The sky is clear and blue, and the overall scene is a typical representation of a boreal forest environment in Alaska.

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Photographer: Roger Ruess

# Summary of Three Fungal Community Structure Studies

- I. Two broad surveys, 1) UP and 2) TKN black spruce sites
  - a. Inter-annual variation
  - b. Successional dynamics
- II. 3) Intra-annual variation, single spruce site
- III. Conclusions

# Coupling Diversity with Function: Metagenomics of Boreal Forest Fungi

USDA-NSF Microbial Genome Sequencing Program, 2003-2007

## Goals

- Fill out **sequence space** for Alaskan fungi
  - Sporocarps
  - Soil DNA
- Determine how to adequately sample fungi in soil
- Characterize fungal community structure within the BNZ LTER site across time space and time





# BROAD INSTITUTE

*The Broad Institute is a research collaboration of MIT, Harvard and its affiliated Hospitals, and the Whitehead Institute, created to bring the power of genomics to medicine.*

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## Prestigious cancer award bestowed

Broad Cancer Program  
director Todd Golub  
honored with cancer  
research award



## New Broad Institute fellowship awarded

Harvard graduate student Ilan Wapinski  
receives Broad Institute's new Lawrence  
H. Summers Fellowship



## Innovators recognized with new award

Three Broad associate members earn NIH  
Fellowships

## SPOTLIGHT



## ALTERING THE FINGERPRINT OF CANCER

The arches, loops,  
and whorls in a  
fingerprint represent  
a unique pattern that  
can help distinguish  
one individual from  
another. While the  
value of fingerprint  
identification in  
forensics is  
renowned, a similar

# BNZ Upland “UP” Core Sites; Interior Alaska Black Spruce TKN Sites

## Upland

- 9 sites: UP1a, b, c - early successional  
UP2a, b, c - mid successional  
UP3a, b, c - late successional

## Black spruce

- 12 sites:
  - 3 dry, acidic
  - 3 wet, acidic
  - 3 dry, non-acidic
  - 3 wet, non-acidic
- Sampled same locations in 2004, 2005
- 50 cores per site/sampling date, 2100 cores total
- Cores divided into *organic* and *mineral* fractions; fractions pooled within sites



Co-conspirators:

Jack McFarland

Teresa Hollingsworth

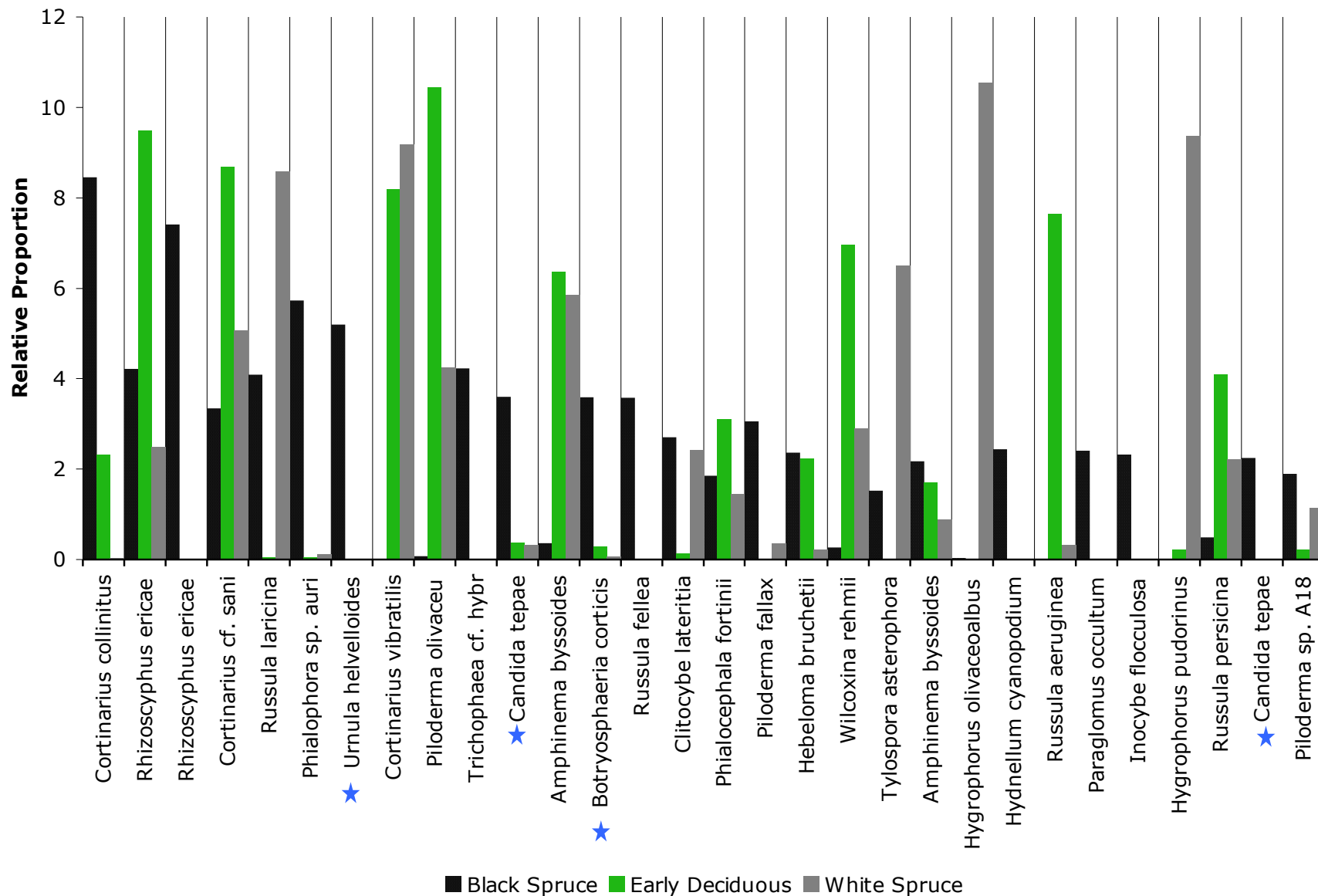
Roger Ruess

Niall Lennon

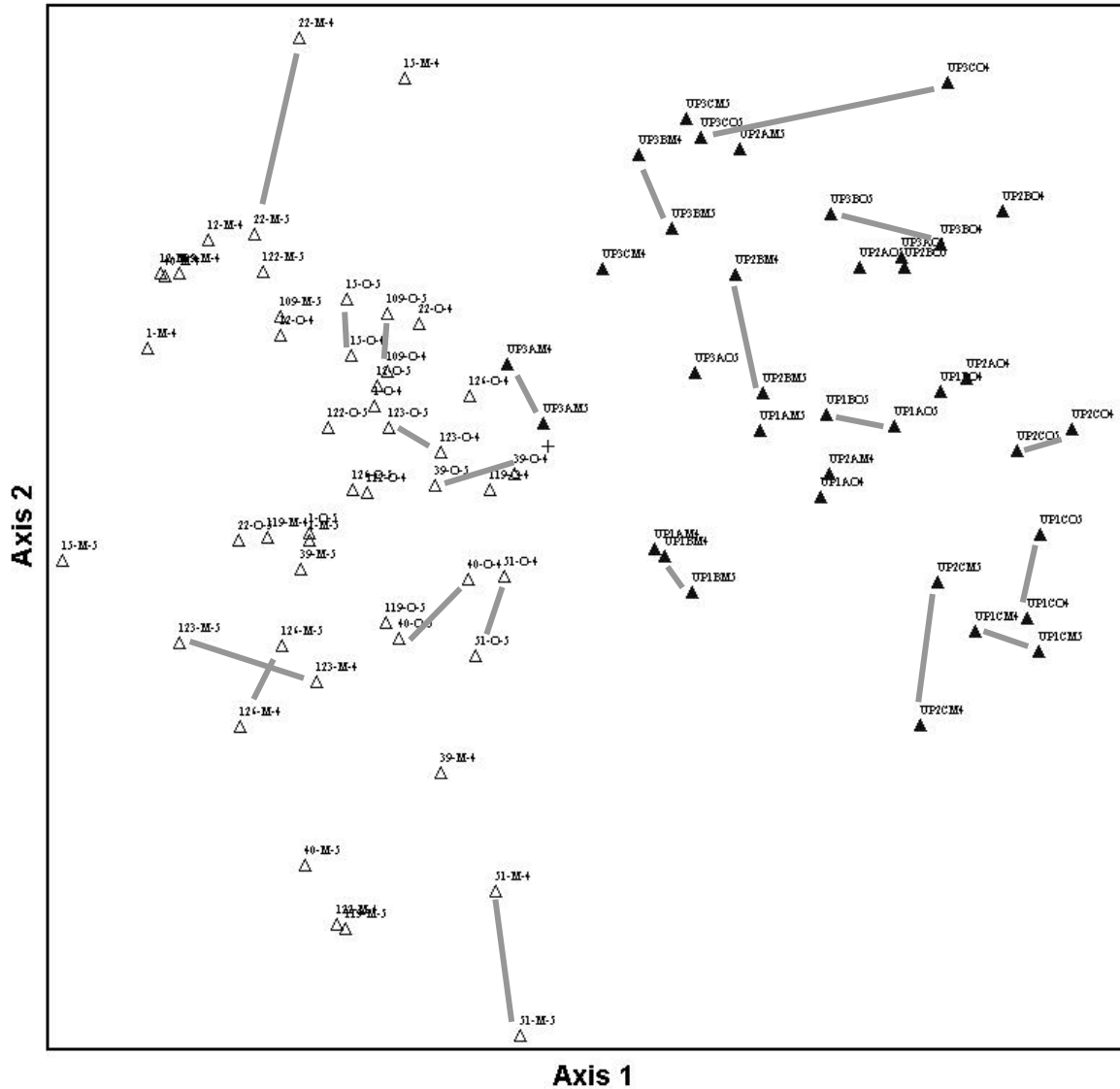
Chad Nusbaum

Dominants have strong  
host preferences

# Distributions of 30 Dominant Taxa

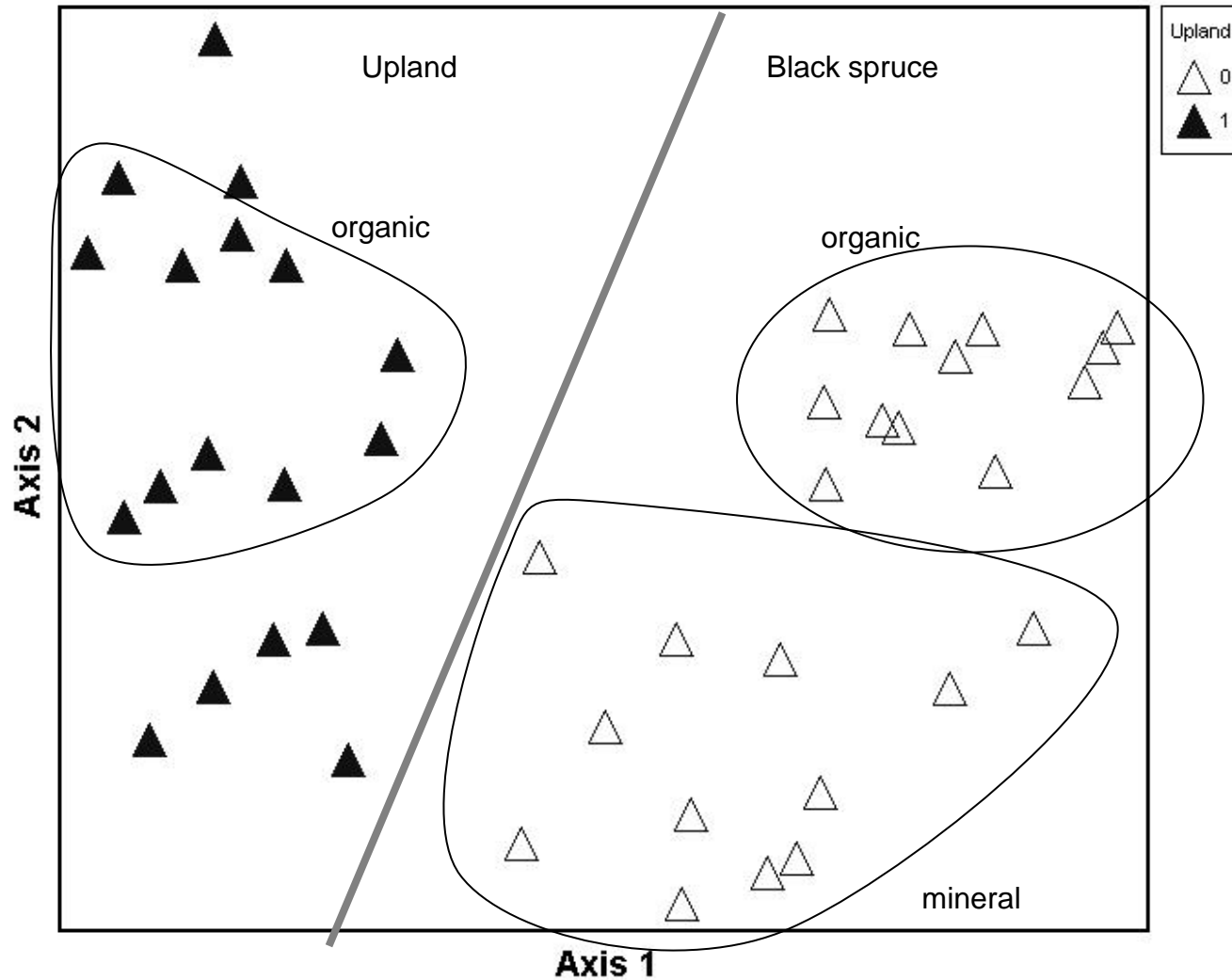


# NMS Ordination: UP and TKN black spruce sites, separate years



Low year-year  
variation within  
a site

# NMS Ordination: UP and TKN black spruce sites, years combined



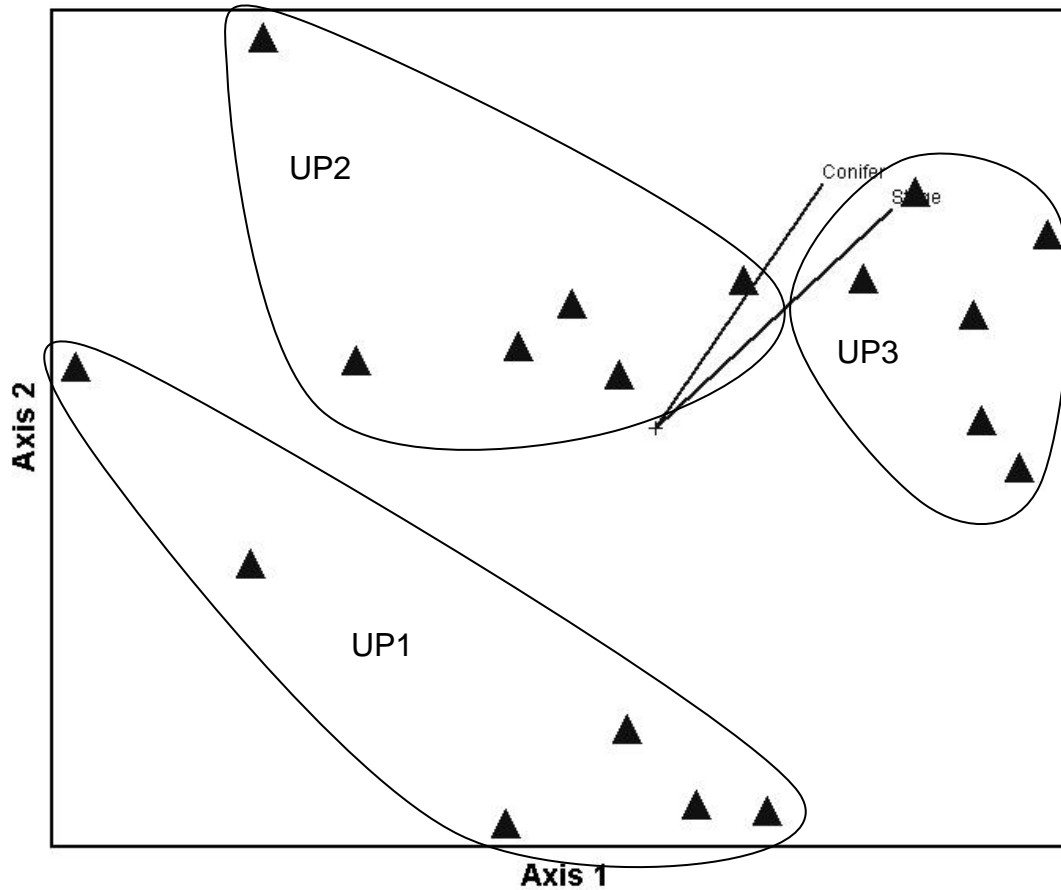


# Tests for fungal community differentiation: multiple response permutation procedure

<b>Factor</b>	<b>Effect size, <math>A</math></b>	<b>Significance, <math>p</math></b>
Horizon (Mineral vs. Organic)	0.03074 992	< 0.00000001
Stand (Upland vs black spruce)	0.06293 753	< 0.00000001
Year	-0.00067788	0.57493 865

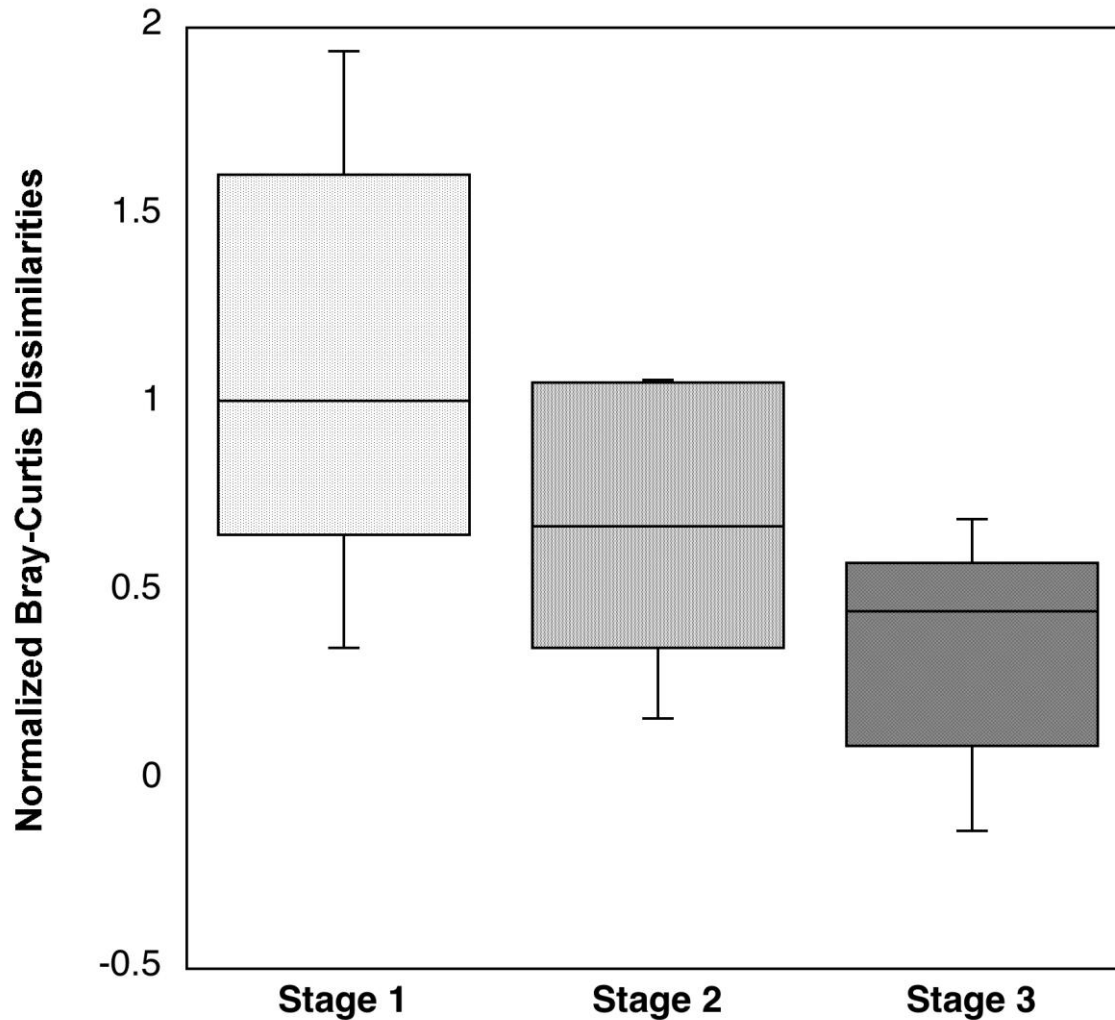
Upland + black spruce differ; horizons  
differ; year-year variation insignificant

# NMS Ordination: UP only, years combined



- 1) Strong structure by stage
- 2) Greatest variation in early stage

# Community dissimilarities by successional stage



Greatest variation  
in early succession

$F = 4.17, p = 0.036$

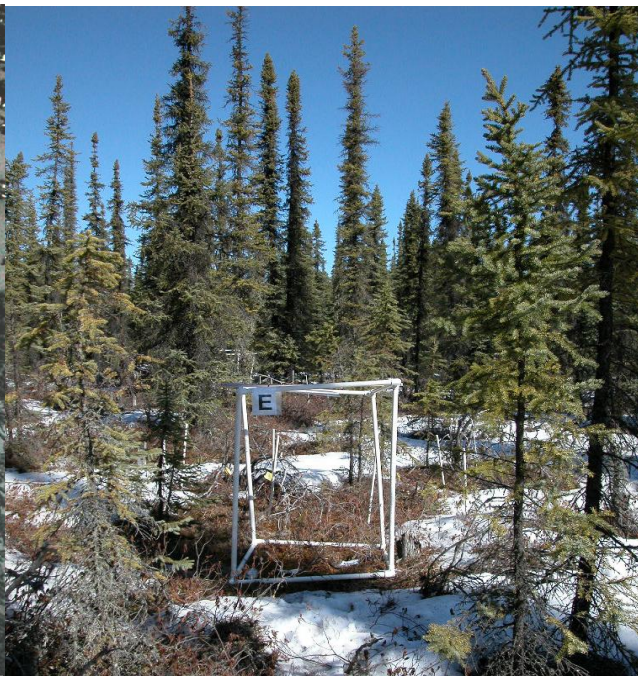
# Summary of Three Fungal Community Structure Studies

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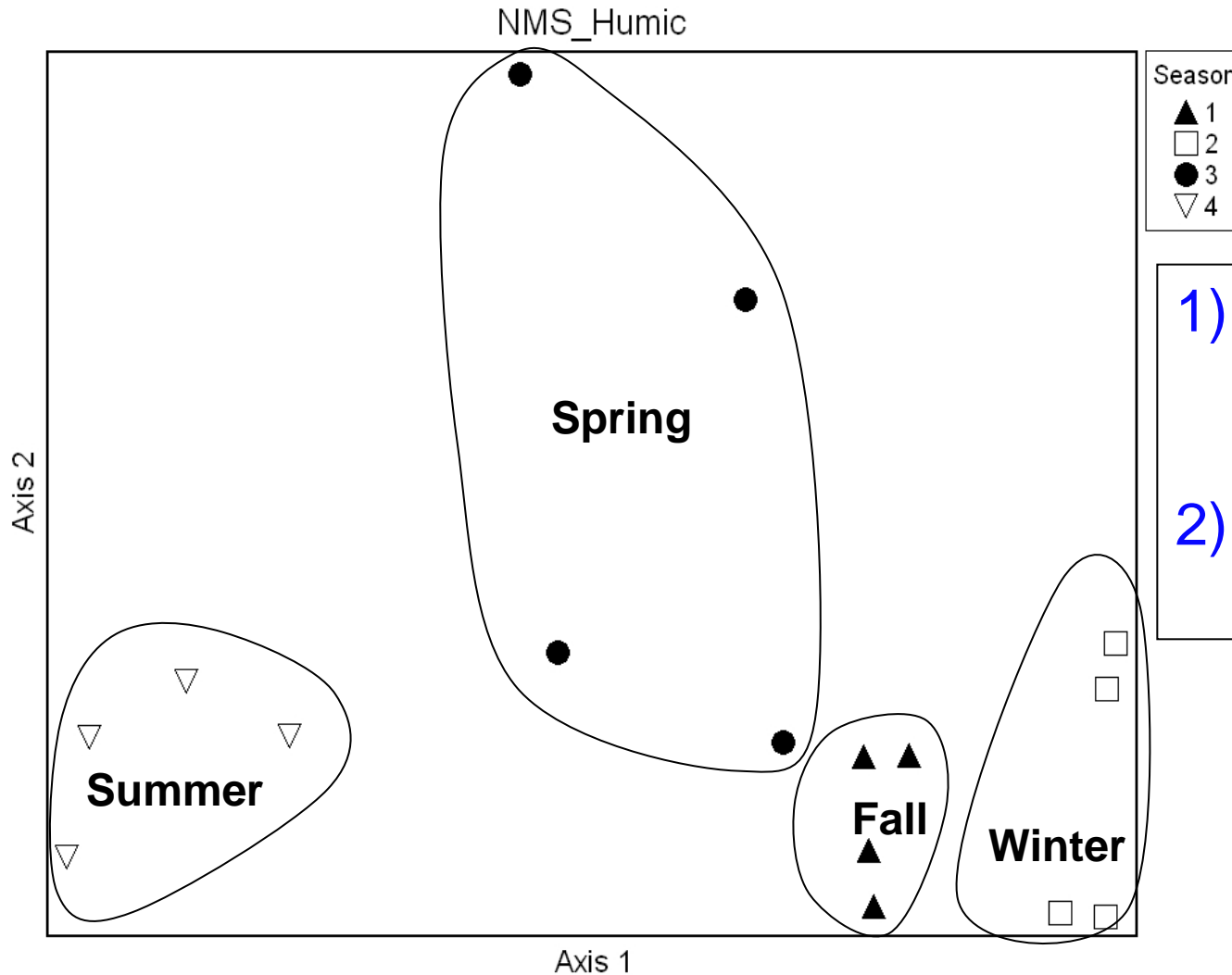
## Part 2: Seasonal Dynamics?

- Sampled 1 site (white/black spruce) : August '04, October '04, February '05 and May '05
- cores into: Litter, Humic, Mineral
- 10 pooled cores per sampling date
- ~9500 clones analyzed

*Ian Herriott  
Niall Lennon  
Chad Nusbaum  
D. Lee Taylor*



# NMS Ordination: Humic horizon

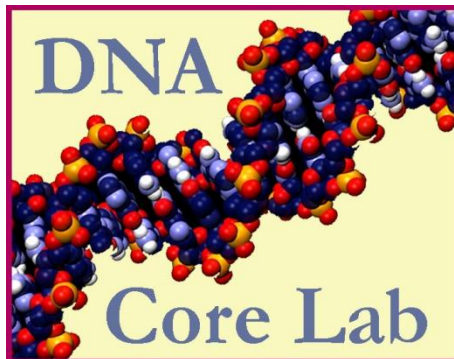
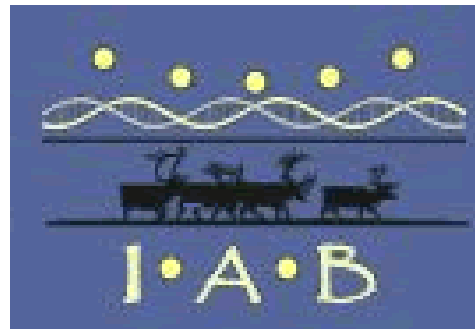


- 1) Seasons have different communities
- 2) Summer most distinct

# Summary of Three Fungal Community Structure Studies

- I. Broad surveys, 1) UP and 2) TKN black spruce sites
  - a. Inter-annual variation - resilience
  - b. Successional dynamics - strong habitat and horizon prefs, most variable early
- II. 3) Intra-annual variation - detectable dynamics
- III. Conclusions

# Funding Sources and Supporting Agencies





# *Thanks!*

Michelle Augustyn

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Ina Timling

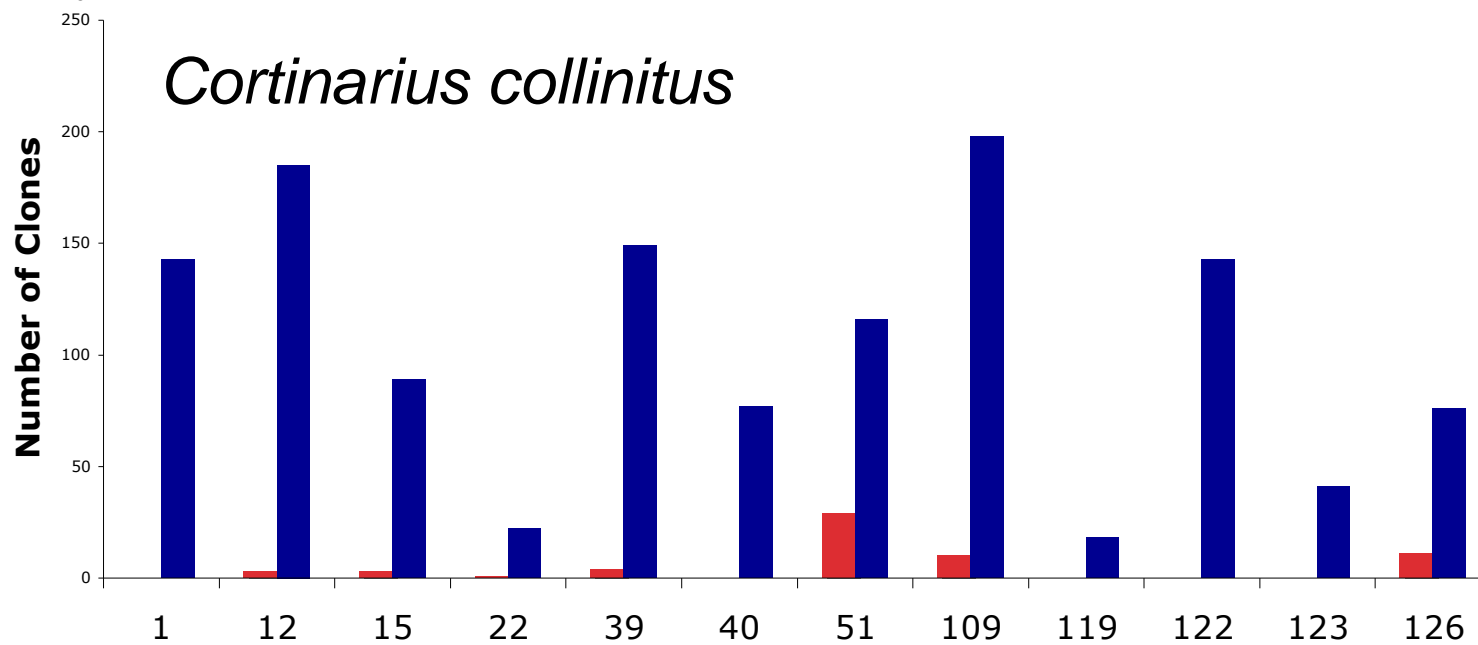
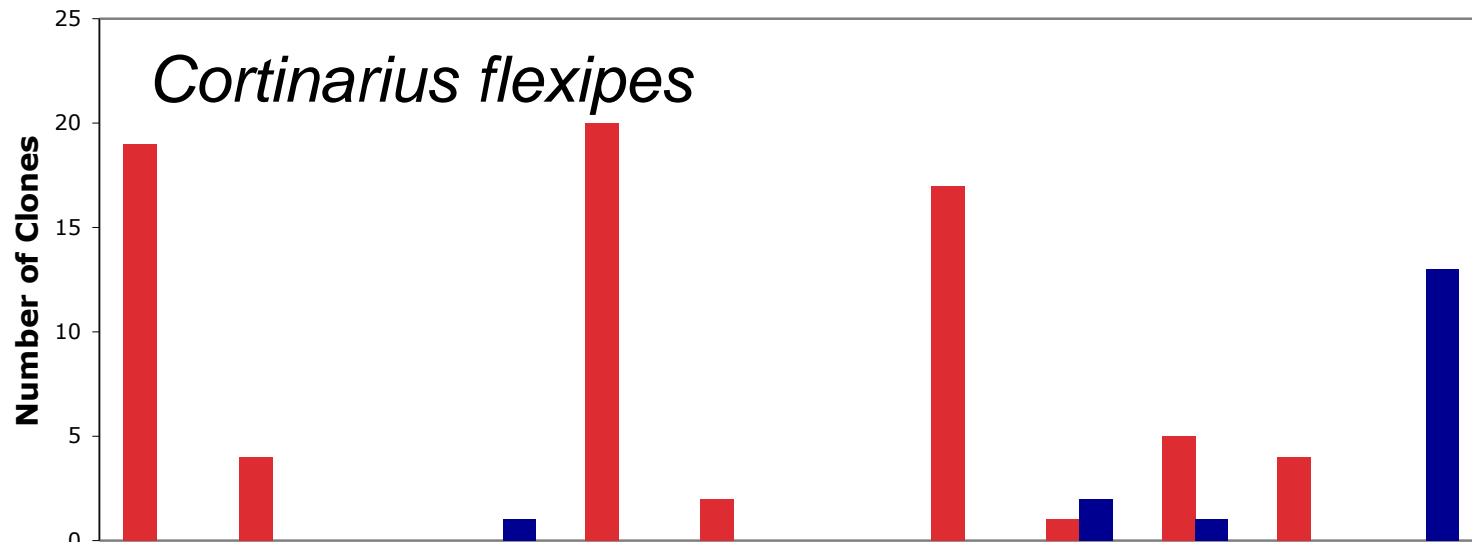
# Indicator species status among the 10 most frequent OTUs in the seasonal study

<b>Indicator Species Blast ID</b>	<b>Rank Abundance</b>	<b>Indicator of</b>	<b>Ecology</b>	<b>Subphylum</b>	<b>Family</b>
<b>Seasonal indicator species in the Humic Horizon</b>					
<i>Tricholoma orirubens</i>	1	Winter	ECM	Agaricomycotina	Tricholomataceae
<i>Piloderma lanatum</i>	4	Spring	ECM	Agaricomycotina	Atheliaceae
<i>Orbilia auricolor</i>	6	Summer	Sap	Pezizomycotina	Orbiliaceae
<i>Piloderma lanatum</i>	7	Summer	ECM	Agaricomycotina	Atheliaceae
<i>Cortinarius erythrinus</i>	8	Spring	ECM	Agaricomycotina	Cortinariaceae
<b>Seasonal indicator species in the Mineral Horizon</b>					
<i>Tricholoma orirubens</i>	1	Summer	ECM	Agaricomycotina	Tricholomataceae
<i>Piloderma lanatum</i>	4	Summer	ECM	Agaricomycotina	Atheliaceae
<i>Cortinarius erythrinus</i>	8	Summer	ECM	Agaricomycotina	Cortinariaceae
<i>Orbilia auricolor</i>	10	Spring	Sap	Pezizomycotina	Orbiliaceae



## Take-Home Messages:

- Inter-annual stability of communities (resilience)
- Extreme structure by soil horizon
- Divergence in horizon preferences among closely related taxa (fine niche-partitioning => lower resilience)
- Detectable seasonal shifts in structure (resilience)



■ Mineral Clones  
■ Organic Clones



Black Spruce Site

# Summary of Coring and Sequencing Efforts

<b>Study, Site Description</b>	<b>Site Codes</b>	<b>Col. Year</b>	<b>Soil Horizons</b>	<b># of Soil Cores</b>	<b># of DNAs</b>	<b>Clones Sequenced</b>
White Spruce, seasonal study, DNA	UAF	2004-5	litter, humic, mineral	160	20	9216
White Spruce, seasonal study, RNA-DNA	UAF	2007	humic	1	2	4,224
Early successional upland mixed forest	UP1a, UP1b, UP1c	2004, 2005	organic, mineral	300	12	18048
Mid-successional upland mixed forest	UP2a, UP2b, UP2c	2004, 2005	organic, mineral	300	12	12288
Late successional upland mixed forest	UP3a, UP3b, UP3c	2004, 2005	organic, mineral	300	12	12288
Dry acidic black spruce	TKN0012	2004, 2005	organic, mineral	100	4	9216
Dry acidic black spruce	TKN0122	2004, 2005	organic, mineral	100	4	9216
Dry acidic black spruce	TKN0001	2004, 2005	organic, mineral	100	4	9216
Moist acidic black spruce	TKN0015	2004, 2005	organic, mineral	100	4	9216
Moist acidic black spruce	TKN0022	2004, 2005	organic, mineral	100	4	9216
Moist acidic black spruce	TKN0109	2004, 2005	organic, mineral	100	4	9216
Dry nonacidic black spruce	TKN0039	2004, 2005	organic, mineral	100	4	9216
Dry nonacidic black spruce	TKN0123	2004, 2005	organic, mineral	100	4	9216
Dry nonacidic black spruce	TKN0126	2004, 2005	organic, mineral	100	4	9216
Moist nonacidic black spruce	TKN0051	2004, 2005	organic, mineral	100	4	9216
Moist nonacidic black spruce	TKN0119	2004, 2005	organic, mineral	100	4	9216
Moist nonacidic black spruce	TKN0040	2004, 2005	organic, mineral	100	4	9216
<b>TOTALS</b>				2160	90	162,432*

# Study I: Fungal diversity in 0.25g of boreal forest soil



Co-conspirators:

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*Jack McFarland*

*Ian Herriott*

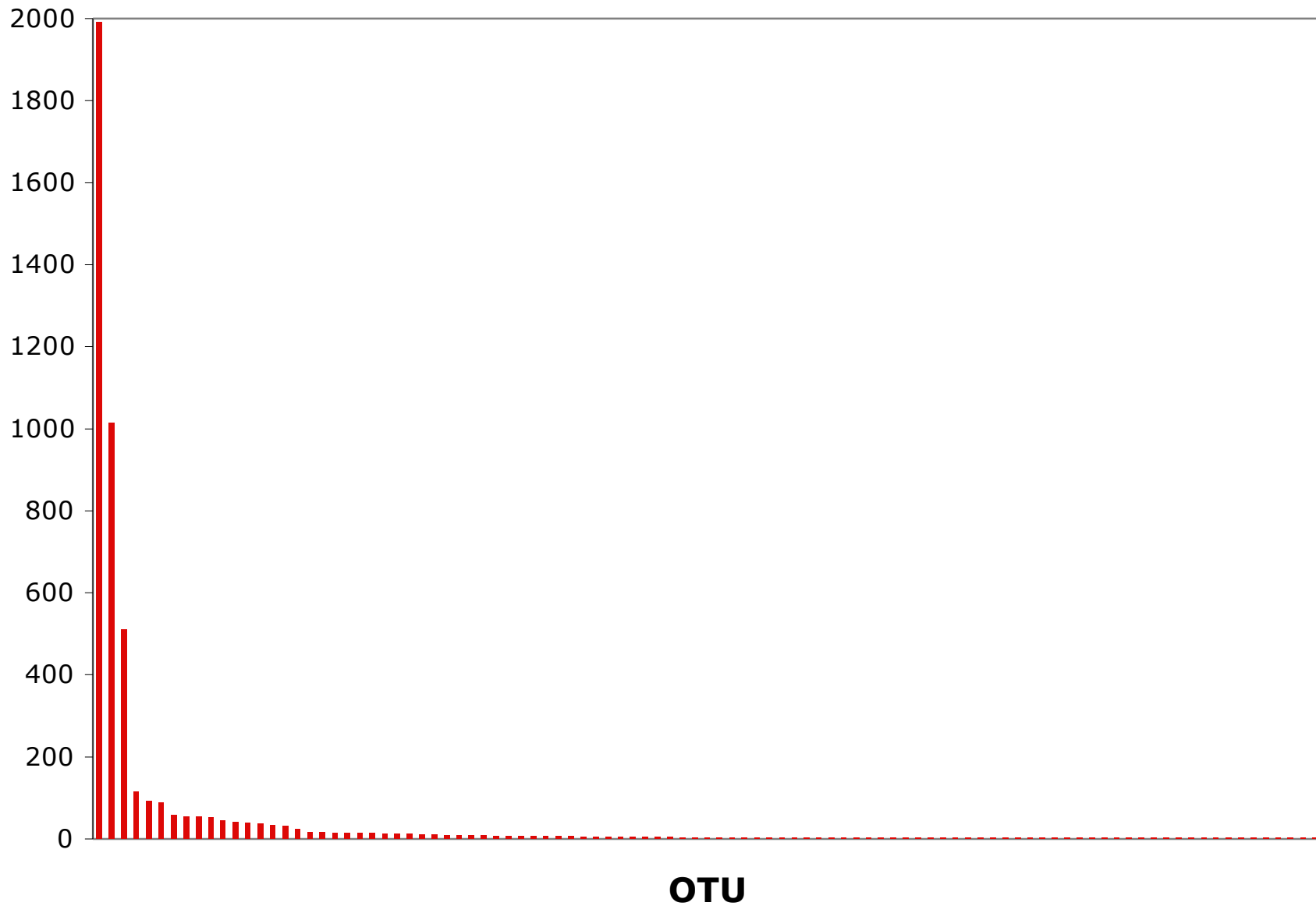
*Roger Ruess*

*Niall Lennon*

*Chad Nusbaum*

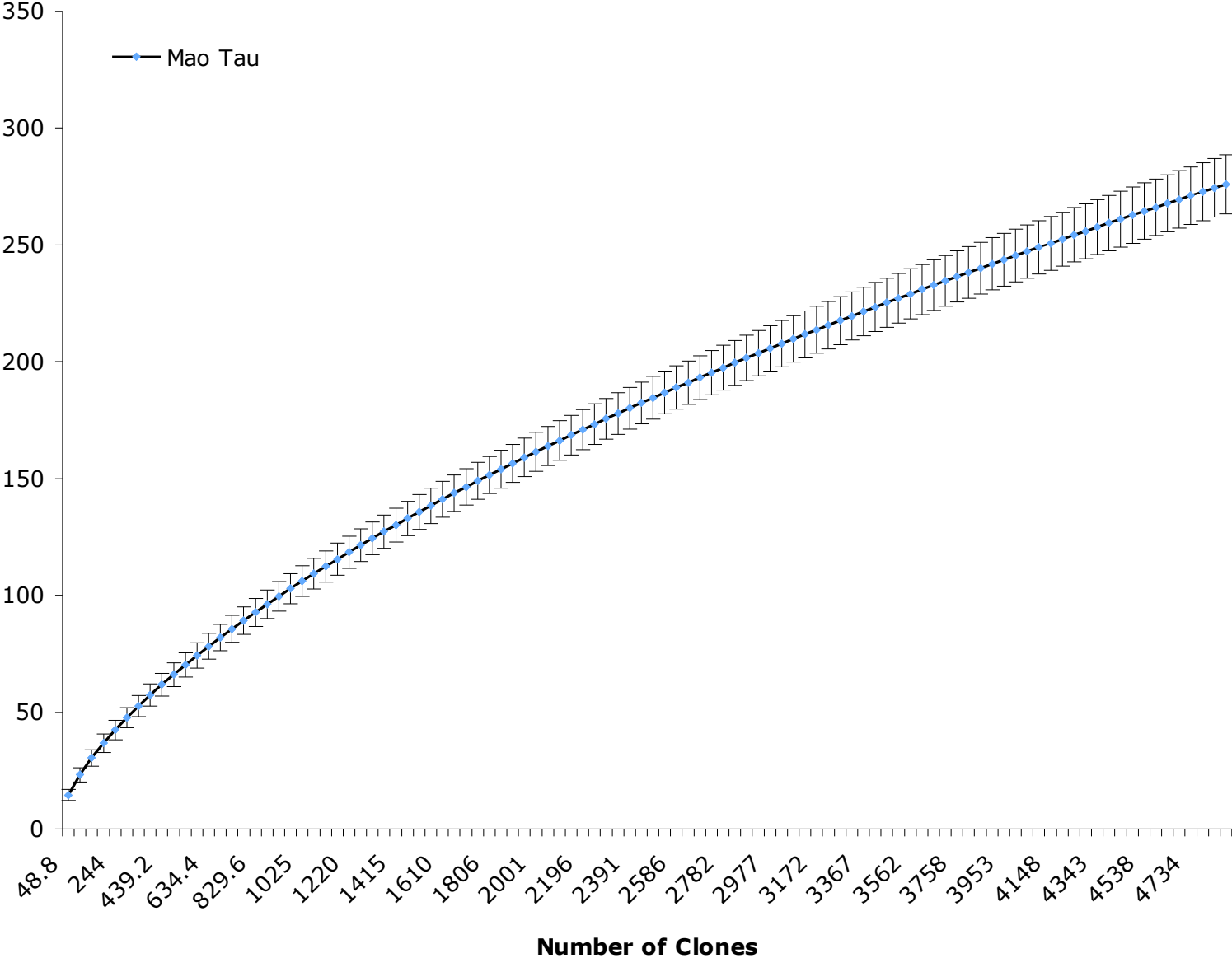
# Summary Stats

# Rank Abundance Plot, Core D8

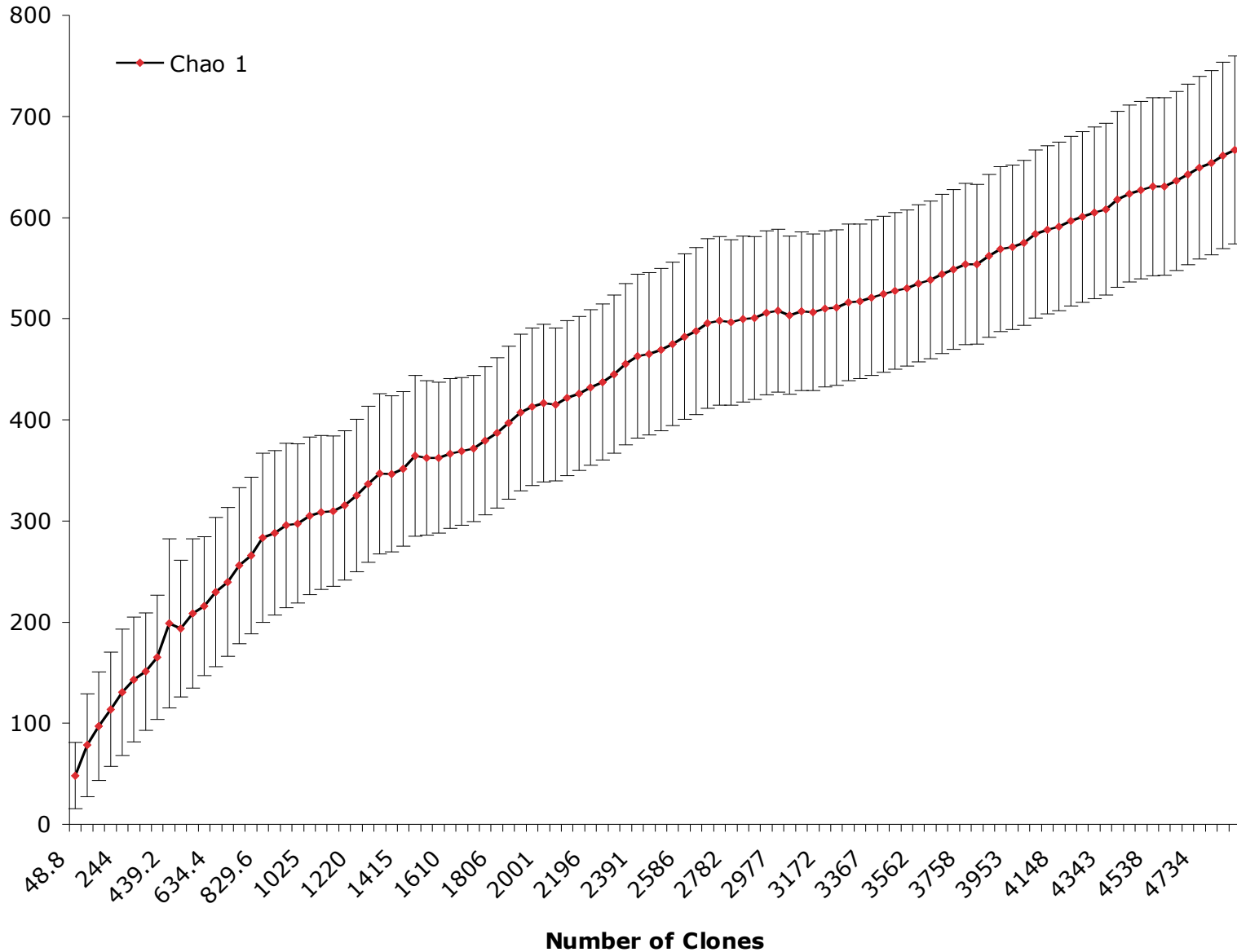




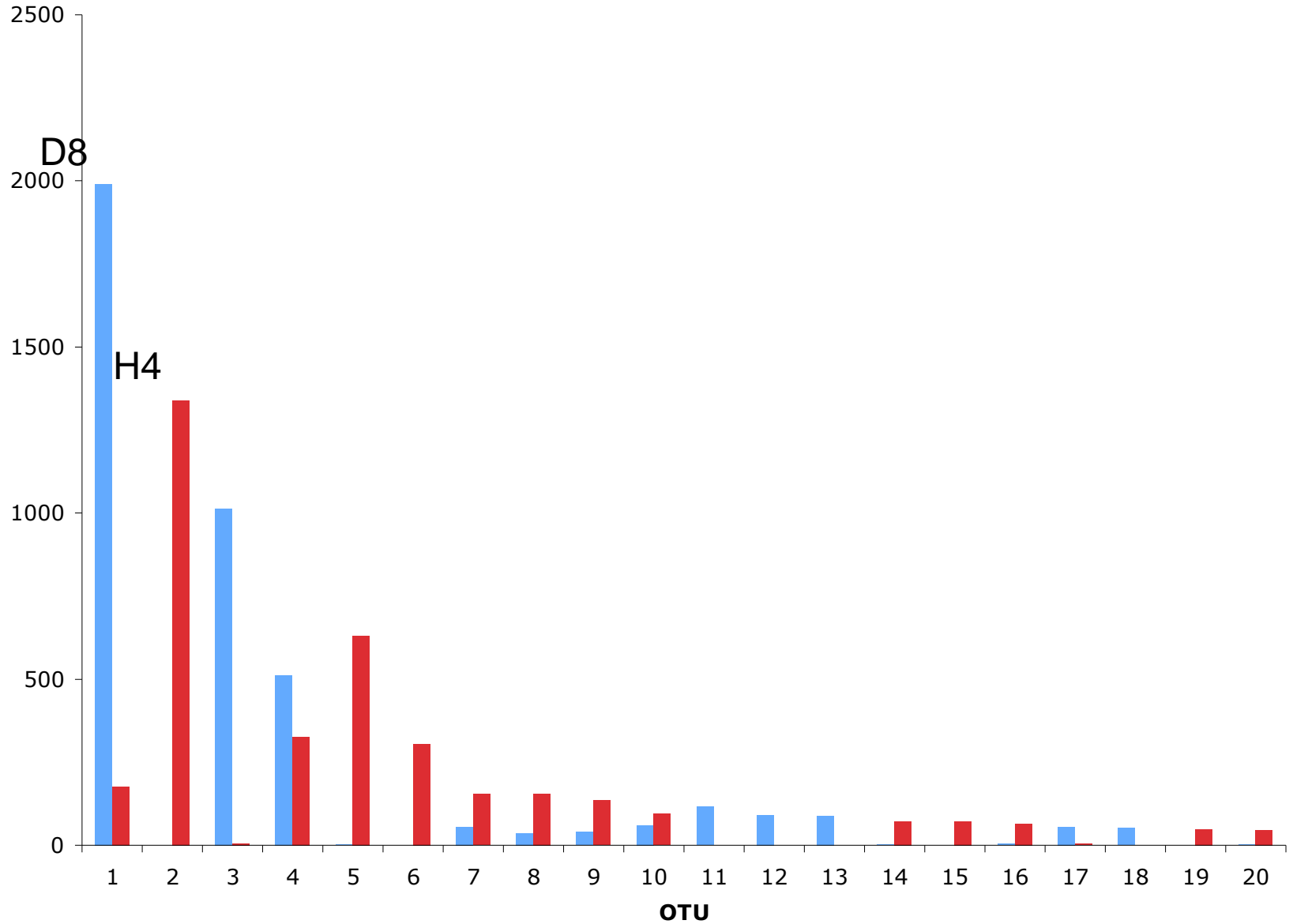
# D8 Species Accumulation Curve



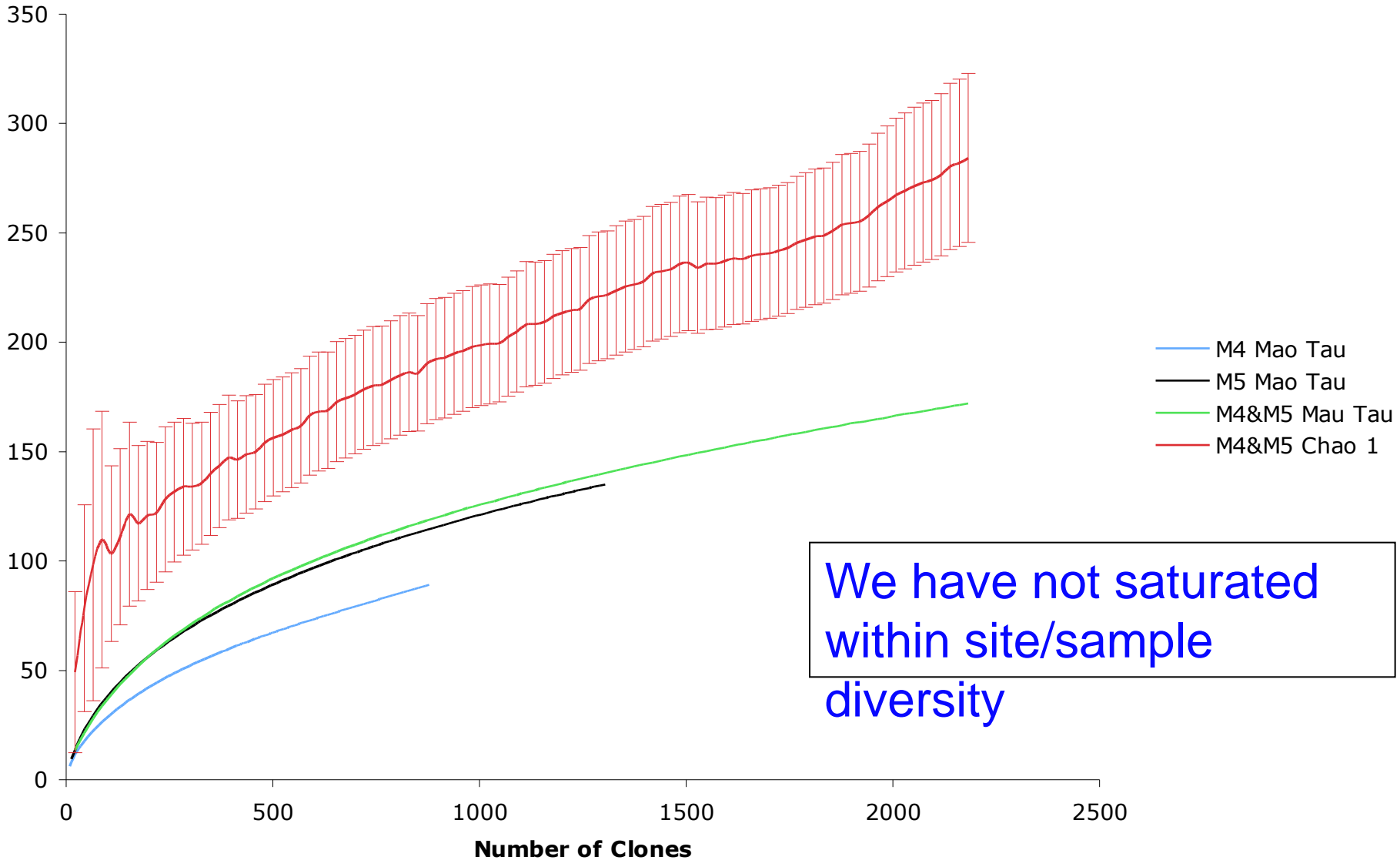
# Estimated Actual Number of Species



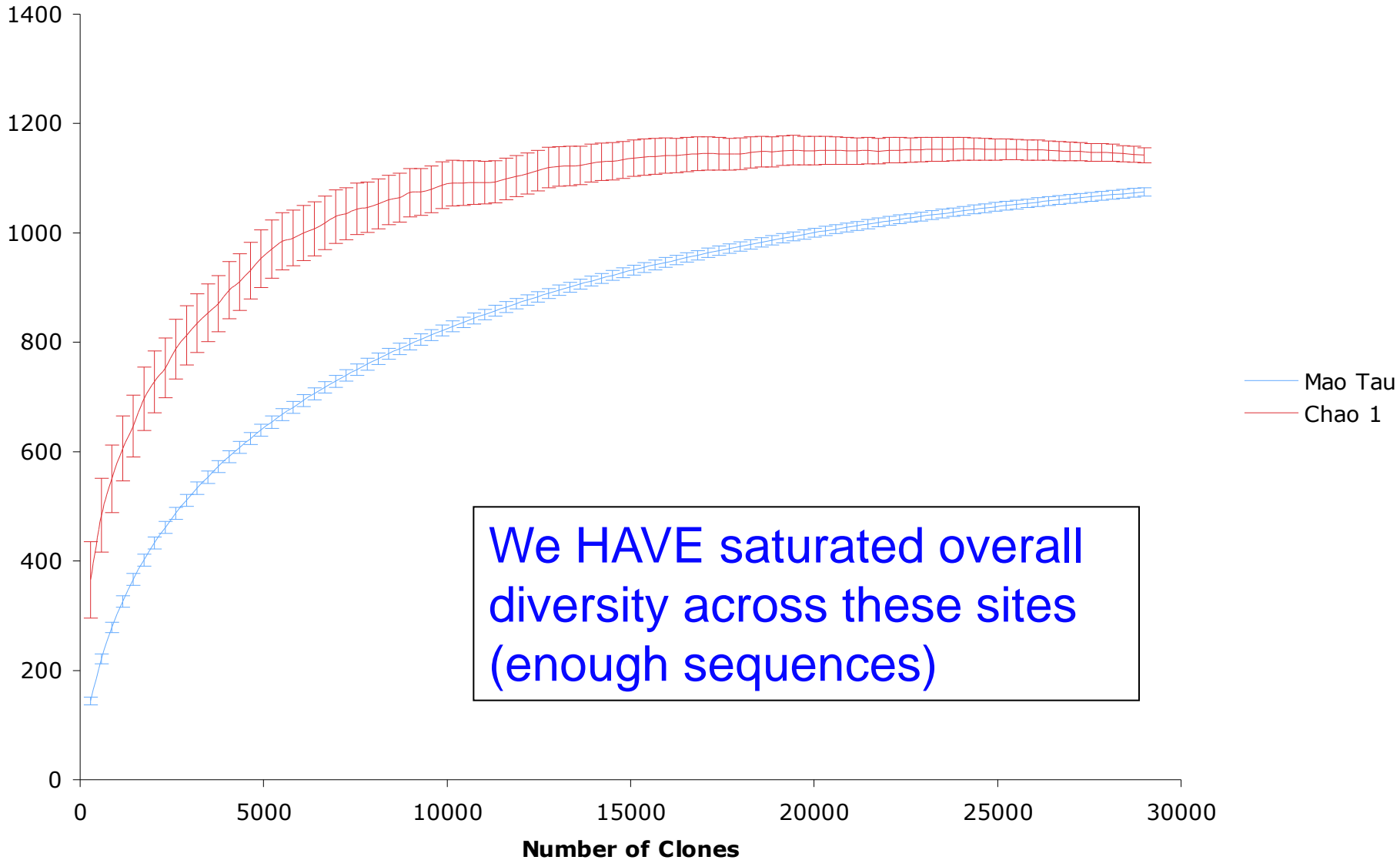
# Dominants from soil cores ~1m apart



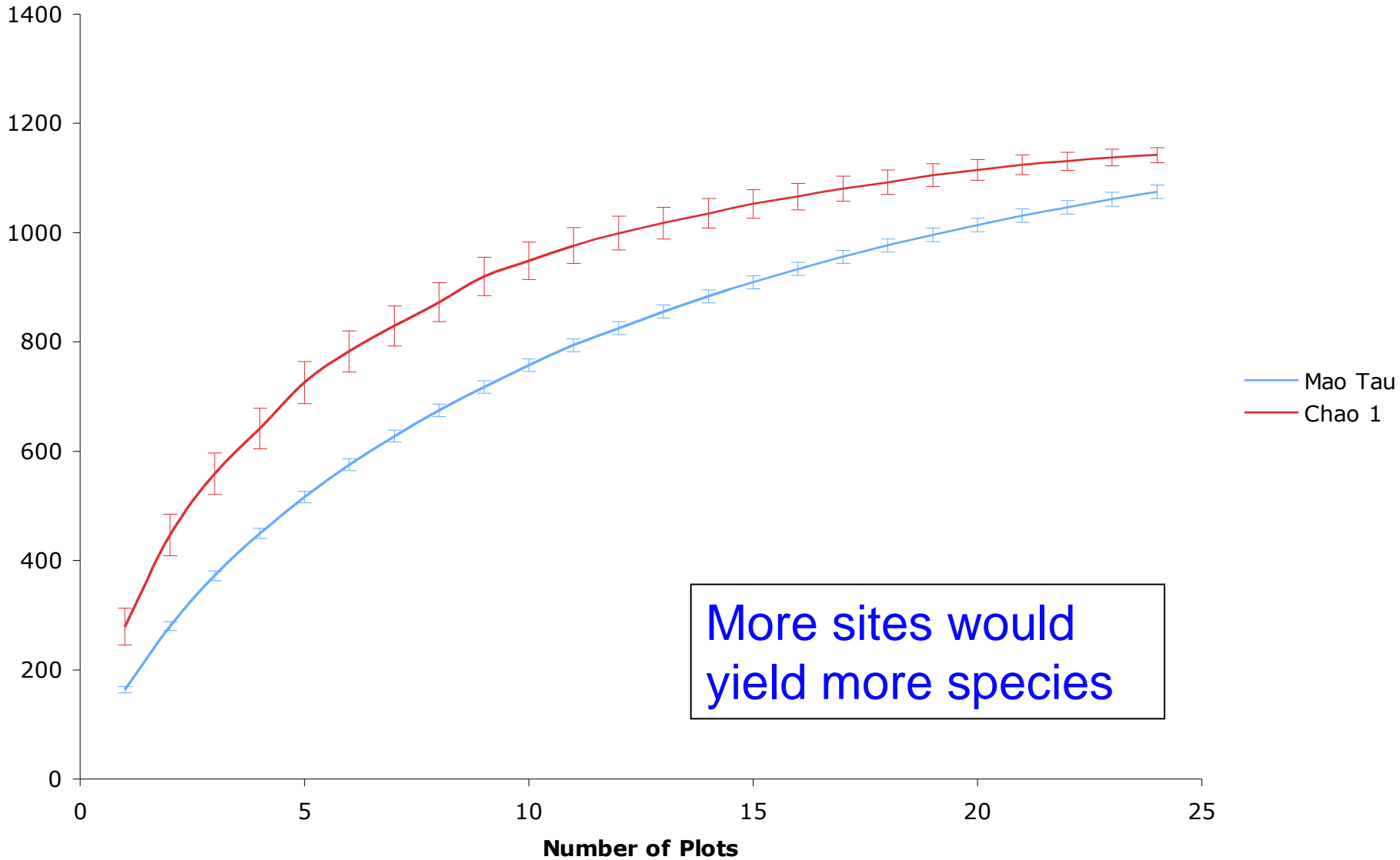
# 0109M4&M5 Rarefaction Curves



# All Sites Rarefaction Curve



# All Sites by Plot Rarefaction Curve





Ephemeral, clumped, large + small genets, appearance unpredictable



Diverse, intermixed, clumped to over-dispersed

???



# Soil Microbial Seasonal Dynamics Plot

