Grassland Restoration at KNZ LTER: Current research and future initiatives
Sara G. Baer, Department of Plant Biology & Center for Ecology
Southern Illinois University, Carbondale
Integration of LTER Research at KNZ

New LTER Initiatives
- Fire Reversal Exp.
- Season of Fire
- Bud Bank Demography $
- Insect Biodiversity and Ecology $
- Ecological Genomics $

Management Issues
- Bison/Cattle Grazing $
- Land Use / Land Cover Change $
- Invasive Species
- Restoration $
- Water Quality $

Climate Change
- Cross-Site, Network & International Studies $

Climate Gradient Studies
- Flux Towers CO$_2$, H$_2$O $
- Climate Gradient Studies

Extending the Inference Of Konza Studies

Spatial and Temporal Heterogeneity

Tallgrass Prairie
- Genes
- Organisms
- Populations
- Communities
- Ecosystems
- Landscapes

Plot-Level Mechanistic Studies
- Belowground Exp. Plots
- Irrigation Transects
- P Addition Experiment
- Mycorrhizae & Soil C Exp $
- LINX II Studies $
Long-term Restoration Research at KNZ

New LTER Initiatives
- Fire Reversal Exp.
- Season of Fire
- Bud Bank Demography $
- Insect Biodiversity and Ecology $
- Ecological Genomics $

Management Issues
- Bison/Cattle Grazing $
- Land Use / Land Cover Change $
- Invasive Species
- Restoration $
- Water Quality $

Climate Change
- Rainfall Manipulations $
- Experimental Stream Studies $
- Flux Towers CO$_2$, H$_2$O $
- Climate Gradient Studies

Extending the Inference Of Konza Studies

Spatial and Temporal Heterogeneity

Tallgrass Prairie
- Genes
- Organisms
- Populations
- Communities
- Ecosystems
- Landscapes

Plot-Level Mechanistic Studies
- Heterogeneity Plots
  $ NSF
PRAIRIE RESTORATION
Experimental Design
Established 1998

- Control
- +N
- +C (sawdust)
- Stone
- +N + Stone
- +C + Stone

Prairie Restoration: No Treatments
A test of the “Environmental Heterogeneity Hypothesis”
LTER V: Global Change and Grassland Dynamics

Land Use Changes
- Fire
- Grazing
- Land use legacies

Climate Change
- Rainfall timing and amount
- Temperature

Nutrient Enrichment
- Elevated N deposition

Biological Invasions
- Species introductions

Tallgrass Prairie Ecosystems
Structure
Function

Contributions:

Diversity-Productivity Theory (Baer et al. 2003, Ecology)

Dominance-Diversity Relationships (Baer et al. 2004, Oecologia; Baer et al. 2005, Restoration Ecology)

Test Positive & Negative Feedback Hypotheses (Baer and Blair, sub. Ecology)
Changes in Dominance over Time

Nutrient x Time, $P < 0.05$

Relative Cover

Panicum virgatum

1998 1999 2000 2001 2002 2003 2004 2005
Changes in Dominance over Time

**P. virgatum Relative Cover (0.25 m²)**

- Ambient N
- Enriched N
- Reduced N

**A. gerardii Relative Cover (0.25 m²)**

- Ambient N
- Enriched N
- Reduced N

**Years Restored**
Changes in Richness and Diversity

Richness (Species/0.25 m²) vs. Years Restored

Shannon's Diversity (0.25 m²) vs. Years Restored

- Ambient N
- Enriched N
- Reduced N
Total Soil C and N Accrual Rates

**Total Soil C, 0-10 cm (g/m²)**
- Ambient N
- Enriched-N

**Total Soil N, 0-10 cm (g/m²)**
- Ambient N
- C-amended
- Enriched N

**Years of Grassland Establishment**

- Ambient N SLR, $r^2 = 0.63$, $P<0.001$
- Enriched N SLR, $r^2 = 0.80$, $P<0.001$
- C-amended, SLR n.s.

- Ambient N SLR, $r^2 = 0.65$, $P<0.001$
- Enriched N SLR, $r^2 = 0.72$, $P<0.001$
- C-amended SLR, $r^2 = 0.79$, $P<0.001$
Interactions with Community Structure

\[ r^2 = 0.73 \]
\[ P < 0.0001 \]

Legend:
- Reduced-N
- Ambient-N
- Enriched-N

Growing seasons:
- 1998
- 1999
- 2000
- 2001
- 2002
- 2003
- 2004
- 2005

Ln (Legume Cover + 1)
New Initiatives during LTER V

New LTER Initiatives
- Fire Reversal Exp.
- Season of Fire
- Bud Bank Demography
- Insect Biodiversity and Ecology
- Ecological Genomics

Management Issues
- Bison/Cattle Grazing
- Land Use / Land Cover Change
- Invasive Species
- Restoration
- Water Quality

Climate Change
- Cross-Site, Network & International Studies
- Rainfall Manipulations
- Experimental Stream Studies
- Flux Towers CO₂, H₂O
- Climate Gradient Studies

Spatial and Temporal Heterogeneity

Tallgrass Prairie
- Genes
- Organisms
- Populations
- Communities
- Ecosystems
- Landscapes

Extending the Inference of Konza Studies

Plot-Level Mechanistic Studies
- Heterogeneity Plots
  $ NSF
- Seed Source Dominance Gradient
  $ LTER
  $ SIUC
  $ NSF
Filter-Model of Community Assembly

Potential Species Pool

Abiotic Filters

Biotic Filters

Socio-Economic or Human Filter

Species in Community

Hobbs & Norton 1999
Human filters unique to restoration in community and ecosystem assembly

Population source selection
(local vs. selected genotypes)

Seed composition selection
(grass:forb)
Intraspecific Variation

Cytology
Riley & Vogel 1982
Keeler & Davis 1999

Genetic structure
Gustafson et al. 1999, 2001, 2004

Ecophysiology
Skeel & Gibson 1996, 1998
Baer et al. 2005

Hierarchical Approach:
Morphology
Physiology
Mutualism
Competition
Diversity
Productivity
Nutrient cycling

Population source selection
(local vs. selected genotypes)

Species Pool

Design Pool 1

Design Pool 2

Design Pool 3

Cultivar (selected)

Native (non-selected)

Embedded dominance
removal treatments

Riley & Vogel 1982
Keeler & Davis 1999
Gustafson et al. 1999, 2001, 2004
Skeel & Gibson 1996, 1998
Baer et al. 2005

NSF $
Source Population Selection X
Seed composition selection
Across a precipitation gradient

NSF $ & LTER $
Intraspecific Variation in BNPP
Konza vs. Cultivar Sources

Source: P = 0.043
### Root Volume in Surface 10 cm of Soil

<table>
<thead>
<tr>
<th>Species</th>
<th>A. gerardii</th>
<th>S. nutans</th>
<th>S. scoparium</th>
</tr>
</thead>
<tbody>
<tr>
<td>cm³</td>
<td>0.0</td>
<td>0.2</td>
<td>0.4</td>
</tr>
</tbody>
</table>

### Root Length in Surface 10 cm of Soil

<table>
<thead>
<tr>
<th>Species</th>
<th>A. gerardii</th>
<th>S. nutans</th>
<th>S. scoparium</th>
</tr>
</thead>
<tbody>
<tr>
<td>cm</td>
<td>0</td>
<td>500</td>
<td>1000</td>
</tr>
</tbody>
</table>

### Root Surface Area in Surface 10 cm of Soil

<table>
<thead>
<tr>
<th>Species</th>
<th>A. gerardii</th>
<th>S. nutans</th>
<th>S. scoparium</th>
</tr>
</thead>
<tbody>
<tr>
<td>cm²</td>
<td>20</td>
<td>60</td>
<td>80</td>
</tr>
</tbody>
</table>

**P = 0.03**

**Intraspecific Variation in Root Architecture**

**Konza vs. Cultivar Sources**

- **A. gerardii**
- **S. nutans**
- **S. scoparium**

R. Klopf
Intraspecific Variation in Net Photosynthesis

A. gerardii  
S. nutans  
S. scoparium

Allison Lambert
Cross-site Variation in Community Assembly

Seeded Dominance of C4 Grasses

Richness of Seeded Species (no./m²)

Total Cover of Planted Species (%)

KS, P<0.001, r²=0.47
IL, P=0.0201, r²=0.09

Kansas P<0.001, r²=0.53
Illinois P<0.001, r²=0.71

Ryan Campbell & Ryan Klopf
New Initiatives for LTER VI

New LTER Initiatives
- Fire Reversal Exp.
- Season of Fire
- Bud Bank Demography $
- Insect Biodiversity and Ecology $
- Ecological Genomics $

Management Issues
- Bison/Cattle Grazing $
- Land Use / Land Cover Change $
- Invasive Species
- Restoration $
- Water Quality $

Climate Change
- Cross-Site, Network & International Studies $

Extending the Inference Of Konza Studies

Spatial and Temporal Heterogeneity

Tallgrass Prairie
- Genes
- Organisms
- Populations
- Communities
- Ecosystems
- Landscapes

Management Issues
- Bison/Cattle Grazing $
- Land Use / Land Cover Change $
- Invasive Species
- Restoration $
- Water Quality $

Climate Change
- Rainfall Manipulations $
- Experimental Stream Studies $
- Flux Towers CO₂, H₂O $
- Climate Gradient Studies

Maintenance
- Plot-Level Mechanistic Studies
- Heterogeneity Plots $NSF$
- Seed Source Dominance Gradient $LTRER$, $SIUC$, $NSF$

New Initiatives for LTER VI
- Season of Fire
- Bud Bank Demography $
- Insect Biodiversity and Ecology $
- Ecological Genomics $

Management Issues
- Bison/Cattle Grazing $
- Land Use / Land Cover Change $
- Invasive Species
- Restoration $
- Water Quality $

Climate Change
- Cross-Site, Network & International Studies $

Extending the Inference Of Konza Studies

Spatial and Temporal Heterogeneity

Tallgrass Prairie
- Genes
- Organisms
- Populations
- Communities
- Ecosystems
- Landscapes

Management Issues
- Bison/Cattle Grazing $
- Land Use / Land Cover Change $
- Invasive Species
- Restoration $
- Water Quality $

Climate Change
- Rainfall Manipulations $
- Experimental Stream Studies $
- Flux Towers CO₂, H₂O $
- Climate Gradient Studies

Maintenance
- Plot-Level Mechanistic Studies
- Heterogeneity Plots $NSF$
- Seed Source Dominance Gradient $LTRER$, $SIUC$, $NSF$

New Initiatives for LTER VI
- Season of Fire
- Bud Bank Demography $
- Insect Biodiversity and Ecology $
- Ecological Genomics $

Management Issues
- Bison/Cattle Grazing $
- Land Use / Land Cover Change $
- Invasive Species
- Restoration $
- Water Quality $

Climate Change
- Cross-Site, Network & International Studies $

Extending the Inference Of Konza Studies

Spatial and Temporal Heterogeneity

Tallgrass Prairie
- Genes
- Organisms
- Populations
- Communities
- Ecosystems
- Landscapes

Management Issues
- Bison/Cattle Grazing $
- Land Use / Land Cover Change $
- Invasive Species
- Restoration $
- Water Quality $

Climate Change
- Rainfall Manipulations $
- Experimental Stream Studies $
- Flux Towers CO₂, H₂O $
- Climate Gradient Studies

Maintenance
- Plot-Level Mechanistic Studies
- Heterogeneity Plots $NSF$
- Seed Source Dominance Gradient $LTRER$, $SIUC$, $NSF$

New Initiatives for LTER VI
- Season of Fire
- Bud Bank Demography $
- Insect Biodiversity and Ecology $
- Ecological Genomics $

Management Issues
- Bison/Cattle Grazing $
- Land Use / Land Cover Change $
- Invasive Species
- Restoration $
- Water Quality $

Climate Change
- Cross-Site, Network & International Studies $

Extending the Inference Of Konza Studies

Spatial and Temporal Heterogeneity

Tallgrass Prairie
- Genes
- Organisms
- Populations
- Communities
- Ecosystems
- Landscapes

Management Issues
- Bison/Cattle Grazing $
- Land Use / Land Cover Change $
- Invasive Species
- Restoration $
- Water Quality $

Climate Change
- Rainfall Manipulations $
- Experimental Stream Studies $
- Flux Towers CO₂, H₂O $
- Climate Gradient Studies

Maintenance
- Plot-Level Mechanistic Studies
- Heterogeneity Plots $NSF$
- Seed Source Dominance Gradient $LTRER$, $SIUC$, $NSF$

New Initiatives for LTER VI
- Season of Fire
- Bud Bank Demography $
- Insect Biodiversity and Ecology $
- Ecological Genomics $

Management Issues
- Bison/Cattle Grazing $
- Land Use / Land Cover Change $
- Invasive Species
- Restoration $
- Water Quality $

Climate Change
- Cross-Site, Network & International Studies $

Extending the Inference Of Konza Studies

Spatial and Temporal Heterogeneity

Tallgrass Prairie
- Genes
- Organisms
- Populations
- Communities
- Ecosystems
- Landscapes

Management Issues
- Bison/Cattle Grazing $
- Land Use / Land Cover Change $
- Invasive Species
- Restoration $
- Water Quality $

Climate Change
- Rainfall Manipulations $
- Experimental Stream Studies $
- Flux Towers CO₂, H₂O $
- Climate Gradient Studies

Maintenance
- Plot-Level Mechanistic Studies
- Heterogeneity Plots $NSF$
- Seed Source Dominance Gradient $LTRER$, $SIUC$, $NSF$

New Initiatives for LTER VI
- Season of Fire
- Bud Bank Demography $
- Insect Biodiversity and Ecology $
- Ecological Genomics $

Management Issues
- Bison/Cattle Grazing $
- Land Use / Land Cover Change $
- Invasive Species
- Restoration $
- Water Quality $

Climate Change
- Cross-Site, Network & International Studies $

Extending the Inference Of Konza Studies

Spatial and Temporal Heterogeneity

Tallgrass Prairie
- Genes
- Organisms
- Populations
- Communities
- Ecosystems
- Landscapes

Management Issues
- Bison/Cattle Grazing $
- Land Use / Land Cover Change $
- Invasive Species
- Restoration $
- Water Quality $

Climate Change
- Rainfall Manipulations $
- Experimental Stream Studies $
- Flux Towers CO₂, H₂O $
- Climate Gradient Studies

Maintenance
- Plot-Level Mechanistic Studies
- Heterogeneity Plots $NSF$
- Seed Source Dominance Gradient $LTRER$, $SIUC$, $NSF$

New Initiatives for LTER VI
- Season of Fire
- Bud Bank Demography $
- Insect Biodiversity and Ecology $
- Ecological Genomics $

Management Issues
- Bison/Cattle Grazing $
- Land Use / Land Cover Change $
- Invasive Species
- Restoration $
- Water Quality $

Climate Change
- Cross-Site, Network & International Studies $

Extending the Inference Of Konza Studies

Spatial and Temporal Heterogeneity

Tallgrass Prairie
- Genes
- Organisms
- Populations
- Communities
- Ecosystems
- Landscapes

Management Issues
- Bison/Cattle Grazing $
- Land Use / Land Cover Change $
- Invasive Species
- Restoration $
- Water Quality $

Climate Change
- Rainfall Manipulations $
- Experimental Stream Studies $
- Flux Towers CO₂, H₂O $
- Climate Gradient Studies

Maintenance
- Plot-Level Mechanistic Studies
- Heterogeneity Plots $NSF$
- Seed Source Dominance Gradient $LTRER$, $SIUC$, $NSF$

New Initiatives for LTER VI
- Season of Fire
- Bud Bank Demography $
- Insect Biodiversity and Ecology $
- Ecological Genomics $

Management Issues
- Bison/Cattle Grazing $
- Land Use / Land Cover Change $
- Invasive Species
- Restoration $
- Water Quality $

Climate Change
- Cross-Site, Network & International Studies $

Extending the Inference Of Konza Studies

Spatial and Temporal Heterogeneity

Tallgrass Prairie
- Genes
- Organisms
- Populations
- Communities
- Ecosystems
- Landscapes

Management Issues
- Bison/Cattle Grazing $
- Land Use / Land Cover Change $
- Invasive Species
- Restoration $
- Water Quality $

Climate Change
- Rainfall Manipulations $
- Experimental Stream Studies $
- Flux Towers CO₂, H₂O $
- Climate Gradient Studies

Maintenance
- Plot-Level Mechanistic Studies
- Heterogeneity Plots $NSF$
- Seed Source Dominance Gradient $LTRER$, $SIUC$, $NSF$
New Initiatives for LTER VI

New LTER Initiatives:
- Fire Reversal Exp.
- Season of Fire
- Bud Bank Demography
- Insect Biodiversity and Ecology
- Ecological Genomics

Management Issues:
- Bison/Cattle Grazing
- Land Use / Land Cover Change
- Invasive Species
- Restoration
- Water Quality

Climate Change:
- Rainfall Manipulations
- Experimental Stream Studies
- Flux Towers $CO_2$, $H_2O$
- Climate Gradient Studies

Spatial and Temporal Heterogeneity

Tallgrass Prairie:
- Genes
- Organisms
- Populations
- Communities
- Ecosystems
- Landscapes

Extending the Inference of Konza Studies

INCREASE:
- Cross-Site, Network & International Studies

MAINTAIN:
- Plot-Level Mechanistic Studies

INCREASE:
- Seed Source Dominance Gradient
- Seed Source $LTER$
- Seed Source $SIUC$
- Seed Source $NSF$

MAINTAIN:
- Heterogeneity Plots $NSF$
New Initiatives for LTER VI

New LTER Initiatives
- Fire Reversal Exp.
- Season of Fire
- Bud Bank Demography$
- Insect Biodiversity and Ecology$
- Ecological Genomics$

Management Issues
- Bison/Cattle Grazing$
- Land Use/Land Cover Change$
- Invasive Species
- Restoration$
- Water Quality$

INCREASE
- Cross-Site, Network & International Studies$

Climate Change
- Rainfall Manipulations$
- Experimental Stream Studies$
- Flux Towers CO₂, H₂O$
- Climate Gradient Studies

Extending the Inference Of Konza Studies

Spatial and Temporal Heterogeneity

Tallgrass Prairie
- Genes
- Organisms
- Populations
- Communities
- Ecosystems
- Landscapes

INCREASE
- Plot-Level Mechanistic Studies
- Heterogeneity Plots
  - NSF
- Seed Source Dominance Gradient
  - LTER
  - SIUC
  - NSF

MAINTAIN
- Management Issues
  - Bison/Cattle Grazing$
  - Land Use/Land Cover Change$
  - Invasive Species
  - Restoration$
  - Water Quality$

INITIATE
- Fire
- Grazing
- Climate
New Restoration Initiative

Establish large-scale restoration plots with fire and grazing treatments TO:

1) Broaden tests of ecological drivers and community assembly theory.

2) Expand inference from WS studies to restored grasslands.

3) Further contribute to the management objective of KNZ LTER.

4) Foster collaboration, as larger plots more conducive to studying higher trophic levels.

5) Increase education and outreach.

6) Initiate cross-site studies along a climate gradient using the Grassland Restoration Network…
Grassland Restoration Network

“A consortium of restoration practitioners, scientists, and land managers interested in integrating the best science and management practices into large scale grassland restoration projects.”

- Kankakee Sands (7,200 ac)
- Midewin National Tallgrass Prairie (19,165 ac)
- Nachusa (2,500 ac)
- Sauk Prairie (77,000 ac)
- Neal Smith Wildlife Refuge (8,000 ac)
- Rocky Mountain Arsenal (8,000 ac)
- Grand River Grasslands (70,000 ac)
- Nickel Preserve (15,000 ac)
- Glacial Ridge (35,000 ac)
- Central Platte (1,000 ac)
- Midewin National Tallgrass Prairie (19,165 ac)
- Kankakee Sands (7,200 ac)
- Neal Smith Wildlife Refuge (8,000 ac)
Expanding Our Perception of Restoration

Expanding Our Perception of Restoration

Degraded Intact Ecosystem State

Ecosystem Attribute

Fully Functional Grassland

Non-Functional Grassland

Requires physical modification

Requires biological modification

Requires improved management

Woody removal

Inter-seeding

Prescribed Fire

Modified from Hobbs and Harris (2001)
Acknowledgements

Graduate Students
Ryan Klopf
Ryan Campbell
Allison Lambert
Lewis Reed

Past & Current Undergraduates
Robin Garcia
David Dalzotto
Luke Koett
Dana Carver
Meredith Mendola
Stephanie Welsh