Presentation Outline

• Overview: Origin of Grasslands
• Co-evolution of grazers and grasslands
• Fire in the Prairie Peninsula
• Fire, Bison, and Deer Effects on Prairie Diversity
Common Features of Grasslands

- Periodic droughts and high rates of evaporation
- Periodic fires
Common Features of Grasslands

- Rolling to nearly level landscapes
- Dominance by burrowing and grazing animals
Grass Form Adaptation

Protection of perennating organs beneath the soil surface
Expansion of Grasslands is related to appearance of C4 Photosynthesis

- C3 Plants
  - Cool, moist climates
  - Low water use efficiency
  - High levels of CO2 > 500 ppm/v
  - Low light saturation
  - Low photosynthesis rate
  - Exhibit Photorespiration

- C4 Plants
  - Warm, arid climates
  - High water use efficiency
  - Selected advantage at low levels of CO2
  - High light saturation
  - High photosynthetic rate
  - No Photorespiration
Atmospheric Carbon Dioxide Relative to Present

Million Years Before Present

-----Paleozoic-------------|--Mesozoic-----|Cenozoic

32 MaBP CO2 levels favor C4 Plant Evolution (Early Miocene to Late Oligocene)

Grass Evolution 65 MaBP?
Expansion of C4 Plants

Rapid adaptive radiation in grassland animals (1) cursorial and saltational (jumping) body forms and (2) (hypsodonty)

Grasslands Replace Forests And Woodlands

$\rho CO_2$ (ppmv)

MaBP

5 6 7 8 9 10 11 12 13 14 15 16
There has been coevolution among grassland organism resulting in many complex interactions.
Hypsodonty

- Brachydonty Initial crown emergence complete from jaw
- Hypsodonty delayed complete emergence
  - Initial emergence from the jaw is partial
  - Later emergence as the teeth are worn down
  - High crowned teeth
    - Not necessarily harder
    - Molars and premolars
- Degrees of hypsodonty —
  - Hypsodonty Index = unworn crown length/width or length
- Associated with grasslands —
  - grass has silica bodies
  - Lot of dirt consumption in grasslands
- Paleoecology — relate degrees of hypsodonty to presumed historic vegetation
Relationship of mean hypsodonty index (HI) to diet and habitat type based upon 133 species of living ungulates of known dietary and habitat preference.

- **Grazer** = ≥90% grass in the diet;
- **Mixed/Grazer (Mixed/G)** = 50–89% grass in the diet;
- **Mixed/Browser (Mixed/B)** = 11–49% grass in the diet;
- **Browser** = ≤10% grass in the diet.

Hypsodonty indices of North American fossil equids (plus Recent Old World equids).

**Grassland Expansion & Adaptive Radiation**

- **DIETS IN RELATION TO LEVEL OF HYPSODONTY**
  - Mostly grass
  - Grass + browse
  - Browse + grass
  - Mostly browse

- Inception of grasslands

- Ma 55, 50, 45, 40, 35, 30, 25, 20, 15, 10, 5, 0

- NALMA: Wa, Br, Ui, Du, Ch, Or/Wh, Ar1-2, Ar3-4, He, Ba, Cl, Hh, Bl, Pleist.

<table>
<thead>
<tr>
<th>E</th>
<th>M</th>
<th>L</th>
<th>E</th>
<th>L</th>
<th>E</th>
<th>M</th>
<th>L</th>
<th>PLIO-CENE</th>
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<td>PLIO-CENE</td>
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Climate and the Central Grassland

<table>
<thead>
<tr>
<th>Annual Rainfall</th>
<th>16”</th>
<th>27”</th>
<th>35-40”</th>
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<tbody>
<tr>
<td>Grass Height</td>
<td>0.5 – 1.5’</td>
<td>2-4’</td>
<td>5-10’</td>
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</table>

- **Short Grass Prairie**
- **Mid-Grass Prairie**
- **Tall Grass Prairie**
Prairie Peninsula
Edgar Nelson Transeau
Fire is necessary for Prairies to Survive

• Control woody plant invasion
• Helps control introduced invasive species
• Increase prairie grass Production
Relative effect of fire, climate, and grazing on ANPP as a function of Mean Annual ppt.

- Grazing
- Fire
- Climate
Why does burning increase productivity of tallgrass prairie?
Average Annual Number of Lightning Caused Forest Fires Per Million Acres

Ignition Source of Prairie Fires

Peak season for Midwestern forest fires is spring. Dry litter from the previous growing season is abundant, and new spring growth has not yet begun.

Arizona leads the nation in lightning-caused forest fires, with August being the peak month.
Fires on Natural USA Land 1980-2003
Average yearly counts of lightning flashes per sq. km based on data collected by NASA satellites between 1995 and 2002.
Plant Diversity on the tallgrass prairie

• C4 grasses are the dominant species

• Forbs contribute most species richness

• Many forbs are C3 plants
• Frequent burns can reduce the abundance of forbs
Bison diet is 90-95% Grass, they consume few forbs, and they can offset effects of frequent burns.
Key Features of Bison Grazing

- Diet Primarily 90-95% grass
- Graze in two patterns
  - Extensive grazing lawns > 400 m²
  - Grazing patches 20-50 m²
- Prefer previous grazed to ungrazed sites
  - Higher nitrogen
  - More palatable
  - No dead tissue
Production on grazed and ungrazed patches

- Initially photosynthesis is higher on grazed patches
  - Physiologically younger tissue
  - Higher nitrogen
  - More moisture
  - Higher light
- Eventually production declines on grazed patches
  - Nitrogen withdrawn from belowground
- Repeated grazing selects for non-palatable species
  - Encourages shifting to other areas
  - 6-7% of patches abandoned each year
Non-palatable forb – Prairie Bushclover
Affects nutrient Cycling

• Grazing offsets nitrogen loss with burning
  – Less litter to burn

• Reduces microbial immobilization of nitrogen
  – Litter has lower C:N ratio

• Grazing increases plant uptake of nitrogen
  – Increases the rate of mineralization of organic nitrogen (Urea to Ammonia)
Enhance Habitat Diversity

• Reduces fire intensity and makes patchy fires
  – Favors fire sensitive species (e.g. Insects)

• Increases spatial heterogeneity
  – Increases bird diversity
Bison can increase Bird Diversity

- Grassland birds require a continuum of habitats from short grass with bare spaces to dense tall grass.
- Bison can provide that continuum.
Upland Sand Piper Midewin National Tallgrass Prairie
Influence of White-tailed Deer Browsing on Tallgrass Prairie
Questions We Asked

• How did species of forbs respond to browsing?
• How was forb diversity affected by deer browsing?
• How was floristic quality affected by deer browsing?
• How did deer browsing and burning affect flowering
Location of study area

Goose Lake Prairie State Park
Study Design

Sampling Forbs and Graminoids

Exclosure  Unexclosed

Unexclosed  Exclosure

48 m

32 m

1  4  8  12 m

1m  3  5  7  9  11  13  15  17  19  21  23
# Local deer density by year

<table>
<thead>
<tr>
<th>Year</th>
<th>deer/km²</th>
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<tr>
<td>1992</td>
<td>32</td>
</tr>
<tr>
<td>1993</td>
<td>50</td>
</tr>
<tr>
<td>1994</td>
<td>34</td>
</tr>
<tr>
<td>1995</td>
<td>32</td>
</tr>
<tr>
<td>1996</td>
<td>32</td>
</tr>
<tr>
<td>1997</td>
<td>No count - hunting in fall</td>
</tr>
<tr>
<td>1998</td>
<td>9</td>
</tr>
<tr>
<td>1999</td>
<td>7</td>
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Solidago canadensis

DCA1 Axis Deer Browsing Intensity

Stem Count

0 50 100 150 200
Species Responding Positively to intense deer browsing

<table>
<thead>
<tr>
<th>Species</th>
<th>Correlation Coefficient</th>
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<tbody>
<tr>
<td>Monarda fistulosa</td>
<td>+ 0.736**</td>
</tr>
<tr>
<td>Heuchera richardsonii</td>
<td>+ 0.706**</td>
</tr>
<tr>
<td>Solidago canadensis</td>
<td>+ 0.678**</td>
</tr>
<tr>
<td>Silphium integrifolium</td>
<td>+ 0.634*</td>
</tr>
<tr>
<td>Amorpha canescense</td>
<td>+ 0.572*</td>
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P<0.05, r= 0.532, P<0.01, r= 0.661
Veronicastrum virginicum

Stem Counts vs. DCA1 Axis Deer Browsing Intensity
<table>
<thead>
<tr>
<th>Species</th>
<th>Correlation Coefficient</th>
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<tbody>
<tr>
<td><em>Tradescantia ohiensis</em></td>
<td>-0.871**</td>
</tr>
<tr>
<td><em>Veronicastrum virginicum</em></td>
<td>-0.847**</td>
</tr>
<tr>
<td><em>Commandra richardsonii</em></td>
<td>-0.826**</td>
</tr>
<tr>
<td><em>Helianthus mollis</em></td>
<td>-0.768**</td>
</tr>
<tr>
<td><em>Stachys palustris</em></td>
<td>-0.700**</td>
</tr>
<tr>
<td><em>Aster azerus</em></td>
<td>-0.700**</td>
</tr>
<tr>
<td><em>Rosa carolina</em></td>
<td>-0.654**</td>
</tr>
<tr>
<td><em>Rudbeckia subtomentosa</em></td>
<td>-0.552*</td>
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</table>

P<0.05, r = 532. P<0.01, r = 0.661
Effect of Deer Browsing and Fire on Flowering

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>Belt Transect</th>
<th>Belt Transect</th>
<th>Belt Transect</th>
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</table>

Three Belt Transect Per Transect

- 2 m x 12 m

Counted Number of stems by species bearing buds, flowers, or fruits
Leading Species on Study Plots

Unprotected

- Rosinweed (*Silphium integrifolium*) 9052
- Wild Quinine (*Parthenium integrifolium*) 3462
- Early Goldenrod (*Solidago juncea*) 2043

Protected

- Ashy sunflower (*Helianthis mollis*) 5637
- Culver’s Root (*Veronicastrium virginicum*) 3908
- Wild Quinine (*Parthenium integrifolium*) 3839
- Rosinweed (*Silphium integrifolium*) 3251
- Spiderwort (*Tradescantia ohiensis*) 2248
- Early Goldenrod (*Solidago juncea*) 1832
- Sweet Black-eyed Susan (*Rudbeckia subtomentosa*) 1342

*Species with more than 1,000 flowering stems counted on either the protected or unprotected plot during the study are included in the list of leading species.*
Effect of Fire and Deer Browsing on Forb Flowering

Mean ± SE No. Flowering Stems Per Plot

YEAR

1998 1999 2000 2001

Protected

Unprotected
Snout-beetle *Rhynchites hirtus* feeds on rosinweed inflorescences
### Species Richness

<table>
<thead>
<tr>
<th>Year level</th>
<th>Protected</th>
<th>Unprotected</th>
<th>$\chi^2$</th>
<th>$P$-</th>
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<tbody>
<tr>
<td>1998</td>
<td>29</td>
<td>22</td>
<td>0.960</td>
<td>$p&gt;0.1$</td>
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<tr>
<td>1999</td>
<td>36</td>
<td>31</td>
<td>0.373</td>
<td>$p&lt;0.9$</td>
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<tr>
<td>2000</td>
<td>38</td>
<td>26</td>
<td>2.250</td>
<td>$p&gt;0.1$</td>
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<tr>
<td>2001</td>
<td>40</td>
<td>32</td>
<td>0.888</td>
<td>$p&lt;0.5$</td>
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## Evenness

<table>
<thead>
<tr>
<th>Year</th>
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<tr>
<td>1998</td>
<td>0.656</td>
<td>0.553</td>
<td>0.931</td>
<td>$p&lt;0.5$</td>
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<tr>
<td>1999</td>
<td>0.625</td>
<td>0.374</td>
<td>6.306</td>
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<tr>
<td>2000</td>
<td>0.530</td>
<td>0.540</td>
<td>0.009</td>
<td>$p&gt;0.90$</td>
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<tr>
<td>2001</td>
<td>0.614</td>
<td>0.491</td>
<td>2.245</td>
<td>$p&gt;0.10$</td>
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Shannon Diversity Index $H'$

<table>
<thead>
<tr>
<th>Year</th>
<th>Protected</th>
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<th>P-level</th>
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<tbody>
<tr>
<td>1998</td>
<td>2.21</td>
<td>1.70</td>
<td>$P&lt;0.001$</td>
</tr>
<tr>
<td>1999</td>
<td>2.24</td>
<td>1.28</td>
<td>$P&lt;0.001$</td>
</tr>
<tr>
<td>2000</td>
<td>1.92</td>
<td>1.77</td>
<td>$p&lt;0.001$</td>
</tr>
<tr>
<td>2001</td>
<td>2.26</td>
<td>1.70</td>
<td>$p&lt;0.001$</td>
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