Plant and Soil Consequences of A Long-Term Climate Change Simulation

Michael E. Loik, Dept. of Environmental Studies, University of California, Santa Cruz, CA 95064, mloik@ucsc.edu
precipitation magnitude, timing, variation

tree encroachment

carbon storage

fire risk

conservation

hydrology
Precipitation Scenarios & Model Uncertainty

Canadian Global Climate Model 1 (CGCM1)

Hadley Centre for Climate Prediction
HadCM2

Hadley Centre for Climate Prediction
HadCM3

(annual changes compared to 1961 – 1990)
Valentine Eastern Sierra UC Reserve, Mammoth Lakes, CA
For Mammoth Lakes, CA...

CGCM1 predicts
+ >100%

HadCM2 predicts
+80%

HadCM3 predicts
–10%

(annual changes compared to 1961 – 1990)
Approach

- use of 50 year old snow fences along a 50 km transect to cause snow depth forcing
Snow Fences

- used by highway departments, ski areas, and railroads for snow control
- also by water districts for water management
Prevailing wind accumulation ablation
US Hwy 395 ca. 100 m
Incorporating Climate Model Uncertainty

HadCM2 predicts +80\% (simulated by the snow accumulation zone)

HadCM3 predicts −10\% (simulated by the snow ablation zone)

Prevailing wind

accumulation

ablation
- Inyo NF, BLM, LADWP
- headwaters for Owens River (Los Angeles)
- land use: recreation, grazing, timber
- invasive species; fire risk
- recreation: 12 million visitor days per year
- increasing development and population in Mammoth Lakes
Hypotheses

1. Snow depth in the non-growing season affects photosynthesis during the subsequent growing season.

2. Long-term changes in snow depth (increases and decreases) alter plant community patterns.

3. Results in 1 & 2 lead to altered litter production, decomposition, and soil C and N content.
snow depth

soil water content

photosynthesis

community structure

ANPP

litter quality, quantity

root production

SOM

decomposition

N mineralization

surface CO₂ flux

root production

ANPP

photosynthesis

community structure

litter quality, quantity

N mineralization

surface CO₂ flux
Snow fence

Depth = D
Depth = ca. 2D
Depth = ca. 0.7D

Control zone
Accumulation zone
Ablation zone

50 m
100 m
5 m
10 m
35 m

100 m
100 m
100 m

Prevailing wind direction
Hypothesized Response

(assuming that snow depth impacts soil water content, community patterns, and ecosystem processes.)
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April, 2004 following snowmelt
Artemisia tridentata  
(Asteraceae)  
Great Basin Sagebrush  

Purshia tridentata  
(Rosaceae)  
Antelope Bitterbrush
Artemisia tridentata, $P = 0.09$

Water potential (MPa)

-4 -3 -2 -1 0

Location: upwind +snow -snow

$Artemisia tridentata$, $P = 0.09$

Purshia tridentata, $P = 0.03$

Water potential (MPa)

-4 -3 -2 -1 0

Location: upwind +snow -snow

$Purshia tridentata$, $P = 0.03$
Stomatal conductance (mmol m\(^{-2}\) s\(^{-1}\))

**Artemisia tridentata**

- Control
- +snow
- -snow

**Purshia tridentata**

- Control
- +snow
- -snow
CO₂ assimilation (μmol m⁻² s⁻¹)

**Artemisia tridentata**

- Control
- +snow
- -snow

**Purshia tridentata**

- Control
- +snow
- -snow

Location
Hypotheses

1. Snow depth in the non-growing season affects photosynthesis during the subsequent growing season.

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Species Richness

One-way ANOVA: \( F = 2.84, \ P = 0.09 \)
<table>
<thead>
<tr>
<th>Location</th>
<th>Relative % cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up</td>
<td>Artemisia tridentata: ~60, Purshia tridentata: ~50</td>
</tr>
<tr>
<td>Acc</td>
<td>Artemisia tridentata: ~40, Purshia tridentata: ~50</td>
</tr>
<tr>
<td>Abl</td>
<td>Artemisia tridentata: ~30, Purshia tridentata: ~60</td>
</tr>
</tbody>
</table>

Decreased albedo on – snow plots?
Location control +snow -snow

Leaf area index (unitless)

P = 0.066

Location

control +snow -snow
Location control +snow -snow

Leaf area index (unitless)

control +snow -snow

Location
Leaf area index (unitless)

Location

control  +snow  -snow

going to reproduction?

going to wood?

snow pressure?

snow mold?

going to roots/soil?
Location upwind +snow -snow

Albedo

<table>
<thead>
<tr>
<th>Location</th>
<th>Albedo</th>
</tr>
</thead>
<tbody>
<tr>
<td>upwind</td>
<td>0.25</td>
</tr>
<tr>
<td>+snow</td>
<td>0.30</td>
</tr>
<tr>
<td>-snow</td>
<td>0.22</td>
</tr>
</tbody>
</table>
Hypotheses

1. Snow depth in the non-growing season affects photosynthesis during the subsequent growing season.

2. Long-term changes in snow depth (increases and decreases) alter plant community patterns.

3. Results in 1 & 2 lead to altered litter production, decomposition, and soil C and N content.
Mortality (shrub skeletons)

Artemisia tridentata
higher mortality on -snow plots

Purshia tridentata
no difference
Soil C and N (to date)

- organic C is higher in ambient, compared to +snow and –snow plots

- higher at 10 compared to 30 cm depth

- no differences for nitrogen content
Winter 2004 - 2005
- eight months of snow
57 cm SWE at fences

(25 feet on Tioga Pass)
Work in Progress

Litter production
Decomposition
Soil Organic Matter
Work in Progress

- need to examine potential for “fertile island” effect

Do C, N, and other nutrients vary under the canopy of *A. tridentata* or *P. tridentata*, compared to open, inter-canopy sites?
Work in Progress

Soil moisture & temperature probes at 10, 25, 50, 75, and 100 cm depth

Bulk density, NPK, roots, SOM
Work in Progress

Seasonal water relations, gas exchange, LAI, NDVI, albedo

From snowmelt (May) to dormancy (Sept?)
2005
Annual growth rings

+ snow

- snow

$^{13}\text{C}$ reconstruction of long-term WUE
Many thanks…

VALENTINE EASTERN SIERRA RESERVE

Alden Griffith, Holly Alpert, Dan Dawson and the Valentine Eastern Sierra Reserve staff, David and Jody Holl

M. Theo Kearney
Foundation for Soil Science

Inyo National Forest
<table>
<thead>
<tr>
<th>Snow fence complex</th>
<th>Number snow fences</th>
<th>Elev (m)</th>
<th>Soil</th>
<th>Depth Vadose Zone (cm)</th>
<th>Infiltration rate (cm h(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>June Lake</td>
<td>3</td>
<td>2320</td>
<td>Cozetica</td>
<td>&gt;150</td>
<td>15 - 50</td>
</tr>
<tr>
<td>Deadman</td>
<td>8</td>
<td>2290</td>
<td>Vitrandic Xerorthent; Cryopsammet</td>
<td>100</td>
<td>15 - 50</td>
</tr>
<tr>
<td>Mammoth</td>
<td>10</td>
<td>2325</td>
<td>Haypress</td>
<td>&gt;150</td>
<td>15 - 50</td>
</tr>
<tr>
<td>Hot Creek</td>
<td>1</td>
<td>2175</td>
<td>Torriothentic Haploxeroll</td>
<td>&gt;150</td>
<td>5 - 15</td>
</tr>
</tbody>
</table>