What makes an arctic plant predictable?

Rob Slider & Bob Hollister, GVSU
Predicting plant responses to warming is important

- Arctic plants play critical roles in local and global systems
- Predicting plant responses to climatologic factors can improve models of these systems

Arctic food web

Thawing carbon source
Study Questions:
Since predicting plant responses to warming is important…

Which abiotic factors can we use to predict them?

Why may a factor predict traits for one species but not for another?
Study Sites

Barrow

Atqasuk
Arctic growing season

- Spring
- Summer (Snow melt)
- Fall (Freeze-up)

Ground layers:
- Frozen Ground
- Thawed Ground

Snow conditions:
- Snow
Arctic growing season

from a plant’s perspective

- Spring
- Summer
- Fall

Leaf burst & growth
Inf. growth
Flowering starts
Flowering ends
Root growth
Leaf length (vegetative plants)

Repro. effort
(# Inf.’s or flowers produced)

Flower burst date

Spring Summer Fall

Leaf length (vegetative plants)
Abiotic factors examined

- Canopy height temperature (10 cm)
- Soil temperature (10 cm)
- Thaw depth
- Snowmelt date
- Freeze-up date
- Growing season length

Spring Summer Fall
Methods

- Control plot data (5-24 plots)
- 4 sites x 5 years
  (Years all climatologic factors were collected)
- Collected flowering data 1-3x / week
- Leaf length & Inflorescence height at the end of the season (after peak)
- Calculating degree days from snowmelt
  - Various base temp (-5 °C to 2 °C)
  - Two periods:
    - Spring & Summer, Fall (just soil)
- Linear regressions in R (α = 0.05)
### Species used

#### Deciduous Shrubs

<table>
<thead>
<tr>
<th>Species</th>
<th>Site</th>
<th>Traits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salix rotundifolia (F)</td>
<td>BD</td>
<td>Fl,RE,In</td>
</tr>
<tr>
<td>Salix rotundifolia (M)</td>
<td>BD</td>
<td>RE,Le</td>
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</tbody>
</table>

#### Evergreen Shrubs

<table>
<thead>
<tr>
<th>Species</th>
<th>Site</th>
<th>Traits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassiope tetragona</td>
<td>AD</td>
<td>RE,Le</td>
</tr>
<tr>
<td>Cassiope tetragona</td>
<td>BD</td>
<td>RE,Le</td>
</tr>
<tr>
<td>Diapensia lapponica</td>
<td>AD</td>
<td>Fl,RE,In,Le</td>
</tr>
<tr>
<td>Ledum palustre</td>
<td>AD</td>
<td>Fl,RE,Le</td>
</tr>
<tr>
<td>Vaccinium vitis-idaea</td>
<td>AD</td>
<td>Fl,RE,Le</td>
</tr>
</tbody>
</table>

#### Forbs

<table>
<thead>
<tr>
<th>Species</th>
<th>Site</th>
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</thead>
<tbody>
<tr>
<td>Draba lactea</td>
<td>BW</td>
<td>Fl,RE,In</td>
</tr>
<tr>
<td>Papaver hultenii</td>
<td>BD</td>
<td>Fl,RE,In</td>
</tr>
<tr>
<td>Pedicularis sudetica</td>
<td>AW</td>
<td>Le</td>
</tr>
<tr>
<td>Polygonum bistorta</td>
<td>AD</td>
<td>RE,In,Le</td>
</tr>
<tr>
<td>Potentilla hyparctica</td>
<td>BD</td>
<td>Fl,RE,In,Le</td>
</tr>
<tr>
<td>Saxifraga cernua</td>
<td>BW</td>
<td>Le</td>
</tr>
<tr>
<td>Saxifraga foliolosa</td>
<td>BW</td>
<td>In</td>
</tr>
<tr>
<td>Saxifraga hieracifolia</td>
<td>BW</td>
<td>RE,In,Le</td>
</tr>
<tr>
<td>Saxifraga hirculus</td>
<td>BW</td>
<td>RE,In,Le</td>
</tr>
<tr>
<td>Saxifraga punctata</td>
<td>BD</td>
<td>Fl,RE,In,Le</td>
</tr>
<tr>
<td>Senecio atropurpureus</td>
<td>BD</td>
<td>In,Le</td>
</tr>
<tr>
<td>Stellaria laeta</td>
<td>BD</td>
<td>Fl,RE,In,Le</td>
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</tbody>
</table>

#### Graminoids

<table>
<thead>
<tr>
<th>Species</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Arctagrostis latifolia</td>
<td>BD</td>
<td>RE,In,Le</td>
</tr>
<tr>
<td>Carex aquatilis</td>
<td>AD</td>
<td>Fl,RE,In,Le</td>
</tr>
<tr>
<td>Carex bigelowii</td>
<td>AD</td>
<td>Le</td>
</tr>
<tr>
<td>Carex stans</td>
<td>BW</td>
<td>Fl,RE,In,Le</td>
</tr>
<tr>
<td>Dupontia fisheri</td>
<td>AW</td>
<td>Le</td>
</tr>
<tr>
<td>Dupontia fisheri</td>
<td>BW</td>
<td>Fl,RE,In,Le</td>
</tr>
<tr>
<td>Eriophorum angustifolium</td>
<td>AW</td>
<td>RE,In,Le</td>
</tr>
<tr>
<td>Eriophorum russeolum</td>
<td>AW</td>
<td>RE,In,Le</td>
</tr>
<tr>
<td>Eriophorum russeolum</td>
<td>BW</td>
<td>Le</td>
</tr>
<tr>
<td>Eriophorum triste</td>
<td>AW</td>
<td>RE,In,Le</td>
</tr>
<tr>
<td>Hierochloe alpina</td>
<td>AD</td>
<td>Fl,RE,In,Le</td>
</tr>
<tr>
<td>Hierochloe pauciflora</td>
<td>BW</td>
<td>Fl,RE,In,Le</td>
</tr>
<tr>
<td>Juncus biglumis</td>
<td>AD</td>
<td>RE,In,Le</td>
</tr>
<tr>
<td>Luzula arctica</td>
<td>BD</td>
<td>Fl,RE,In,Le</td>
</tr>
<tr>
<td>Luzula arctica</td>
<td>BW</td>
<td>Fl,RE,In,Le</td>
</tr>
<tr>
<td>Luzula confusa</td>
<td>AD</td>
<td>Fl,RE,In,Le</td>
</tr>
<tr>
<td>Luzula confusa</td>
<td>BD</td>
<td>RE</td>
</tr>
<tr>
<td>Poa arctica</td>
<td>BD</td>
<td>RE,In,Le</td>
</tr>
<tr>
<td>Poa arctica</td>
<td>BW</td>
<td>RE,In,Le</td>
</tr>
<tr>
<td>Trisetum spicatum</td>
<td>AD</td>
<td>Le</td>
</tr>
</tbody>
</table>

### Trait Key

- **Fl** = Flowering date
- **RE** = Reproductive effort
- **In** = Inflorescence height
- **Le** = Leaf length
Including a variety of abiotic factors increased number of species predicted & amount of variation explained.
### Flowering date

<table>
<thead>
<tr>
<th>Condition</th>
<th>Tailored to Species</th>
<th>DD’s 0 °C</th>
<th>DD’s -2 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r^2$ avg</td>
<td>0.73</td>
<td>0.65</td>
<td>0.62</td>
</tr>
<tr>
<td>% Species predicted</td>
<td>0.24 - 0.89</td>
<td>0.19 - 0.89</td>
<td>0.14 - 0.88</td>
</tr>
</tbody>
</table>

### Leaf length

<table>
<thead>
<tr>
<th>Condition</th>
<th>Tailored to Species</th>
<th>DD’s 2 °C</th>
<th>DD’s -2 °C</th>
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<tr>
<td>$r^2$ avg</td>
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<td>0.14</td>
<td>0.19</td>
</tr>
<tr>
<td>% Species predicted</td>
<td>0.06 - 0.62</td>
<td>0.04 - 0.47</td>
<td>0.05 - 0.55</td>
</tr>
</tbody>
</table>

### Inflorescence height

<table>
<thead>
<tr>
<th>Condition</th>
<th>Tailored to Species</th>
<th>Prv. GS length</th>
<th>DD’s 2 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r^2$ avg</td>
<td>0.22</td>
<td>0.19</td>
<td>0.18</td>
</tr>
<tr>
<td>% Species predicted</td>
<td>0.06 - 0.58</td>
<td>0.05 - 0.55</td>
<td>0.05 - 0.45</td>
</tr>
</tbody>
</table>

### Reproductive effort

<table>
<thead>
<tr>
<th>Condition</th>
<th>Tailored to Species</th>
<th>Prv. DD’s -5 °C</th>
<th>Prv. Soil DD’s 0°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r^2$ avg</td>
<td>0.18</td>
<td>0.18</td>
<td>0.16</td>
</tr>
<tr>
<td>% Species predicted</td>
<td>0.05 - 0.60</td>
<td>0.07 - 0.58</td>
<td>0.08 - 0.49</td>
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</tbody>
</table>
The ability of an abiotic factor to predict a species’ traits relates to its ecological behavior

**Example:** *Cassiope tetragona* uses resources from previous year for reproduction this year
Summary of main points

1) Including a variety of abiotic factors increased number of species predicted & amount of variation explained
   - Using all climatologic factors generally increased # spp predicted
   - Using all factors increased avg. $r^2$ values for ALL traits

2) The ability of a abiotic factor to predict a species’ traits relates to its ecological behavior
   - Repro. effort predicted using previous year’s factors
   - Ability of a factor to predict a trait related to leaf & flowering phenology
Which factor to use?

Check using this year’s air temps. above 2 °C for predicting my height!

Check last fall’s soil temps if you wanna know how much I’ll be reproducing!
Implications & Future work

• If modeling arctic plant responses to climate change use several abiotic factors

• Plant predictability is tied to ecological behavior

• Knowing which behaviors to base predictions on will improve our ability to predict how climate change will affect the Arctic
Sources


Acknowledgements

GVSU Arctic Ecology Program
- Jeremy May, Jenny Liebig, Kelsey Kremers, Jean Galang, Michael Lothschutz, Amanda Snyder
Any questions?
The ability of a climatologic factor to predict a species’ traits relates to its ecological behavior

**Example:** Sexual reproduction is “expensive”!
*Warmer temperatures may make it more affordable*
Senecio atropurpureus
Flowering date

- All Factors: $r^2$ avg: 0.73, 0.24 - 0.89
- DD's 0 °C: $r^2$ avg: 0.65, 0.19 - 0.89
- DD's -2 °C: $r^2$ avg: 0.62, 0.14 - 0.88

Leaf length

- All Factors: $r^2$ avg: 0.21, 0.06 - 0.62
- Deg. Days 2 °C: $r^2$ avg: 0.14, 0.04 - 0.47
- Deg. Days -2 °C: $r^2$ avg: 0.19, 0.05 - 0.55

Inflorescence height

- All Factors: $r^2$ avg: 0.22, 0.06 - 0.58
- Prv. Season length: $r^2$ avg: 0.19, 0.05 - 0.55
- DD's 2 °C: $r^2$ avg: 0.18, 0.05 - 0.45

Reproductive effort

- All Factors: $r^2$ avg: 0.18, 0.05 - 0.60
- Prv. DD's -5 °C: $r^2$ avg: 0.18, 0.07 - 0.58
- Prv. Soil DD's -0 °C: $r^2$ avg: 0.16, 0.08 - 0.49
The Arctic is warming and is predicted to continue warming.

Rapid & dramatic warming
(4 - 8°C)
predicted over next century
(IPCC 2007)
Summary of results
(with proposed explanations)

1) Across plant traits, more species were predicted by degree days than seasonal event dates (e.g. snowmelt date)
   – Degree days incorporate time & temperature

2) The number of species predicted & amount of variability explained by degree days depended on base temperature
   – Temp. requirements for growth & reproduction vary by species & trait

3) Some traits were better predicted using the previous year’s climatic factors rather than the current year’s
   – Previous year’s conditions affect resources availability in current year

4) Species’ responses to climatic factors could be explained by timing of resource acquisition & utilization
   – Ecological behavior should determine which
2) The number of species predicted & amount of variability explained by degree days depended on base temperature

- Just show current year’s degree days for inLn, flower date, and leaf length with r2 values
- Point out lower DD’s predict more spp for leaf-out while higher do for repro traits (repro effort not included)
3) Some traits were better predicted using the previous year’s climatic factors rather than the current year’s

- Show regression of CTET BD
  - Previous year’s soil tdd
  - Current year’s soil tdd
4) Species’ responses to climatic factors could be explained by timing of resource acquisition & utilization

• Refer to previous thing w/CTET
• Case study with DFIS
  – Leaves by current & previous
  – Inf’s by current mostly
Findings in context: degree day base temp. matters

Base temp: \(-2^\circ C\)
- \(p = 0.01\)
- \(R^2 = 0.92\)

Base temp: \(5^\circ C\)
- \(p = 0.12\)
- \(R^2 = 0.62\)

\(Potentilla hyparctica\)
Findings in context: repro. effort better predicted using previous year’s temps.

Critical period for determining flowering
Arctic growing season

- **Spring** (Mid-June to Late June)
- **Summer** (July to Mid-August)
- **Fall** (Mid-August to Late Sept.)

**Diagram:**
- **Snow melt**
- **Thawed Ground**
- **Frozen Ground**
- **Freeze-up**

**Legend:**
- Snow
- Frozen Ground
- Thawed Ground
Base Temp: 0 °C

Base Temp: 1 °C
• Repro effort: 9 (27.27%) species predicted using previous season’s abiotic factors