Connecting Differences in Phenology to Changes in Arctic Plant Communities

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Abstract

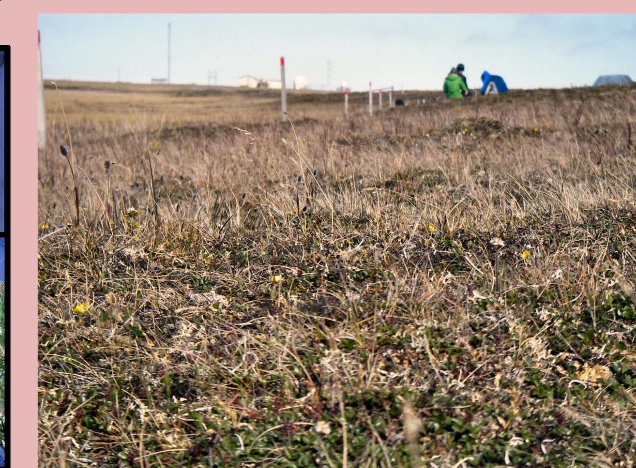
Arctic plant species have different growth and reproductive patterns; in the short Arctic growing season, some species will begin growing or flowering earlier than others. When species' growth and reproduction are triggered by temperature rather than available light, climate change can affect the timing of growth and blooming of that species. Since there is variation among species in the timing of these growth and reproductive events, change in temperature will affect different species in different ways. Using data from a long-term warming experiment in Northern Alaska, we examine whether these differences are reflected in community change.

The Experiment

A long-term tundra warming study with sites in both dry and wet Arctic communities

Sites were established at the coastal city of Barrow, Alaska (71°17′44″N 156°45′59″W) in 1994 and 1995 and at the inland village of Atqasuk (70°28′40″N 157°25′5″W) in 1996. At each location a site was established in a dry heath community and in a wet meadow community. At each of these four sites there are 24 control plots and 24 plots under Open-Topped Chambers (OTCs). The OTCs warm the experimental plots on average between 1° and 3° Celsius for the growing season, depending on the site and weather conditions for the year. They are designed to be a passive warming system, allowing weather and small animals in and out of the plots.

Location of sites in Northern Alaska



Barrow Dry Heath Site

Barrow Wet Meadow Site (*with OTC)*

Atqasuk Dry Heath Site

Atqasuk Wet Meadow Site

Phenology

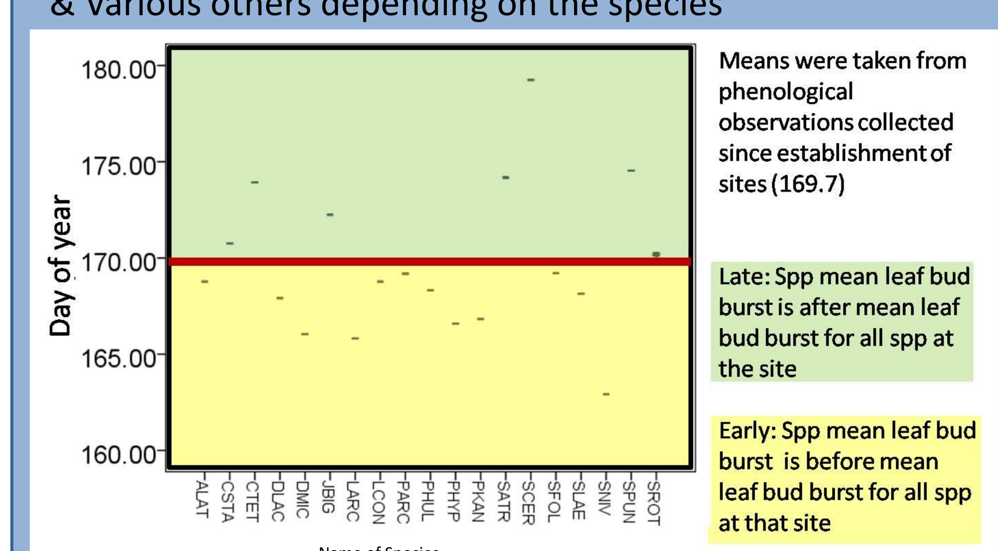
Phenology is the study of the timing of life cycle events. We studied the phenology of the plant species present in our plots. Weekly observations of several events were recorded throughout the growing season. These observations were then used to label some plants as "early" or "late" species for different events. The change in phenology as a response to warming was also used to label the species.

Phenologcial Data Collection

Each plot was visited at least once weekly from the time of snowmelt until the third week of August. For each species present in the plot, the date is recorded when the following events are observed:

- •Leaf green
- •Inflorescence appears
- •Flower burst
- •Flower wither
- •Seed set
- •Seed dispersal
- •Leaf wither

& Various others depending on the species



From these data we can determine mean leaf bud burst date and mean flower burst date. Species whose mean is before the all-species mean are labeled "early" species. Species whose mean is after the all-species mean are labeled "late" species. A species is not necessarily an "early" species for both leaf and flower labels, and a species may vary from site to site. We used control data only for these labels.

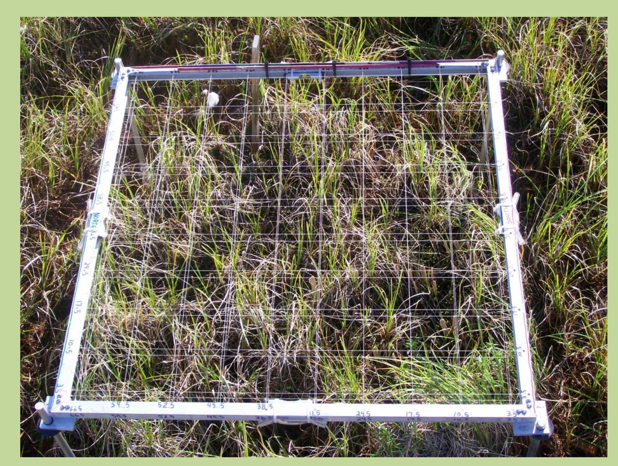
We include the data from experimental plots when we are labeling the plants based on the changes in their pheonology as a response to the warming treatment. The species are labeled as having a positive phenological response to warming, a negative phenological response to warming, an inconsistent response to warming, or no response. These responses are again kept separate by site, and could vary from site to site. There was not sufficient data for some species to determine the phenological response to warming, so those species were not included.

The table to the right shows the response for the 33 species that had sufficient data at least one site to determine response to warming.

P = strong positive response
p= weak positive response
N= strong negative response
n=weak negative response
U= unresponsive
I = inconsistent
…=not sufficient data to label at this site
X= not present or not measured at this site

Species	Atqasuk Dry	Atqasuk Wet	Barrow Dry	Barrow Wet
Arctagrostis latifolia	X	X	U	X
Carex aquatilis	X	U	X	U
Cardamine pratensis	X	X	X	P
Cassiope tetragona	…	X	U	X
Diapensia lapponica	U	X	X	X
Draba lactea	X	X	i	U
Draba micropetala	X	X	U	X
Dupontia fisheri	X	n	X	n
Dupontia psilosantha	X	n	X	X
Eriophorum angustifolium	X	U	X	U
Eriophorum russeolum	X	U	X	U
Eriophorum scheuchzeri	X	i	X	X
Hierochloe alpina	U	X	X	X
Hierochloe pauciflora	X	X	X	U
Juncus biglumis	X	X	X	U
Ledum palustre	U	X	X	X
Luzula arctica	U	X	U	U
Luzula confusa	i	X	p	U
Luzula wahlenbergii	X	i	X	X
Papaver hultenii	X	X	p	X
Pedicularis sudetica	X	U	X	X
Petasites frigidus	X	X	X	X
Poa arctica	X	X	U	i
Polygonum bistorta	U	X	X	X
Potentilla hyparctica	X	X	p	X
Salix rotundifolia	X	X	i	X
Saxifraga cernua	X	X	X	U
Saxifraga foliolosa	X	X	…	p
Saxifraga hieracifolia	X	X	X	U
Saxifraga hirculus	X	X	X	n
Saxifraga punctata	X	X	U	X
Senecio atropurpureus	X	X	U	X
Stellaria laeta	X	X	p	U

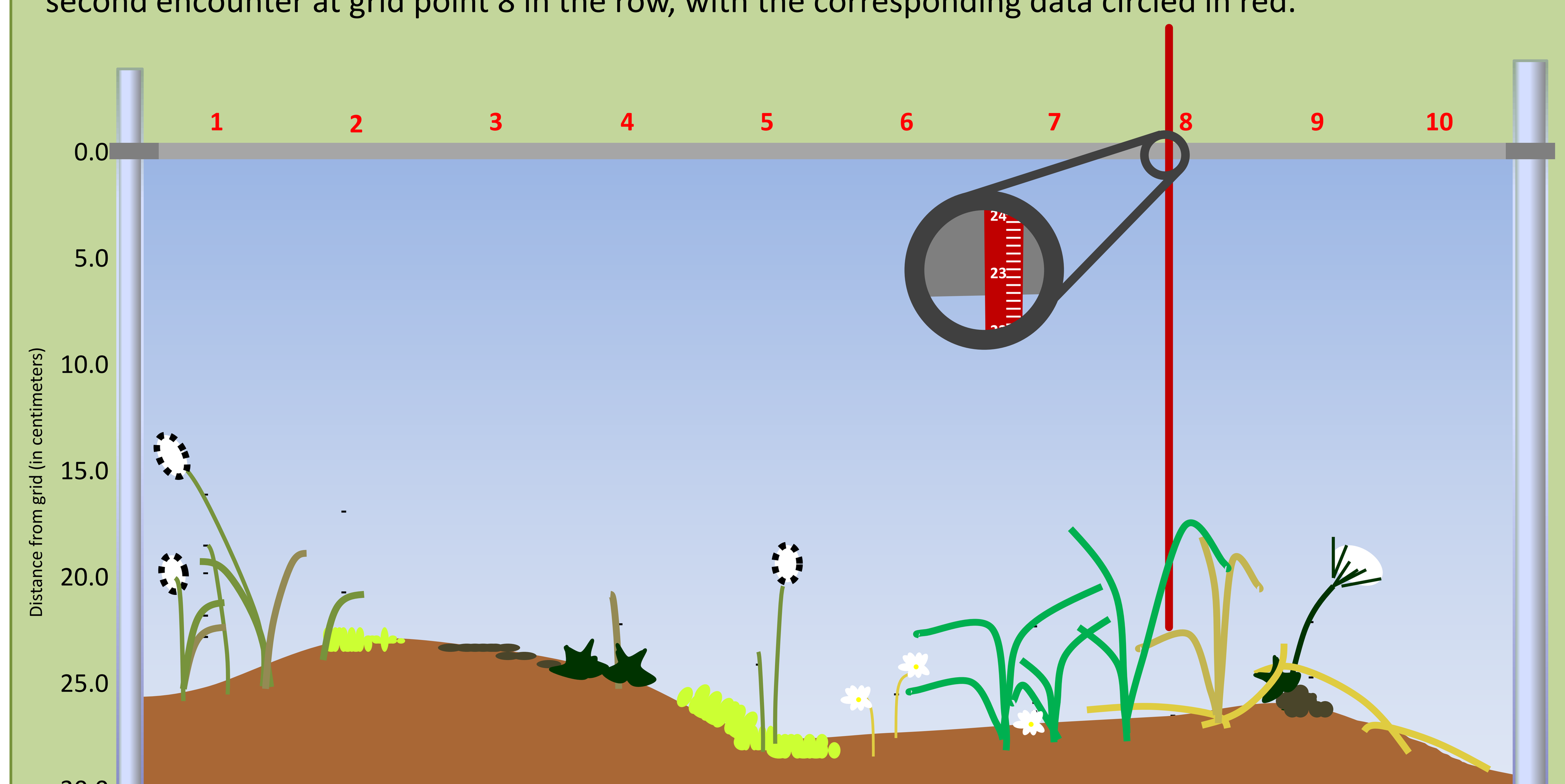
Community



The plant community is measured using a point-frame method of cover assessment. Both control plots and warmed plots are measured. Previous studies have shown that warmed plots have more and larger vegetation overall, but differences exist in how each species changes in response to warming. Some species increase in absolute cover, some species decrease in absolute cover, and some remain the same. The phenology data will be used to look for differences.

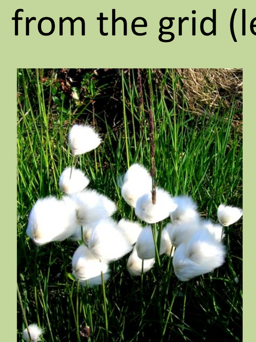
Point-frame Method of Cover Assessment

Plant community data was collected using a point frame method in 2007 and 2008. A 75 cm x 75 cm grid (pictured above) was leveled over each of 96 control plots and 96 experimental plots. At each of 100 intersections of the grid, a ruler was dropped. Every time the ruler touched something, it was identified by species (or by abiotic material) and recorded as alive or dead. Each encounter was recorded, as well as the ground height. Below is a simplified illustration of what a cross-section of one row of the grid might look like, using an example of the data, also shown. The ruler is shown at the second encounter at grid point 8 in the row, with the corresponding data circled in red.

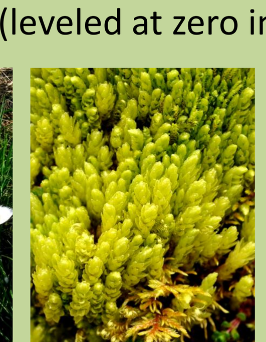


Grid Point 1	Grid Point 2	Grid Point 3	Grid Point 4	Grid Point 5	Grid Point 6	Grid Point 7	Grid Point 8	Grid Point 9	Grid Point 10
ERIRUS, A : 16.1 ERIRUS, D: 18.5 ERIRUS, A: 19.8 ERIRUS, A: 21.8 ERIRUS, D: 22.8	ERIRUS,A: 16.9 ERIRUS, A: 20.7 AULTUR, A: 22.7	GYMINF, A: 23.2	ERIRUS, D: 22.2 PETFRI, D: 24.5	ERIRUS, A: 24.1 AULTUR, A: 27.4	STELAE, A: 25.5	CARAQU, A: 22.3 CARAQU, A: 25.9 STELAE, A: 26.3	CARAQU, A: 18.5 CARAQU, D: 22.6 LITTER, D: 26.5	PETFRI, A: 22.1 LITTER, D: 24.7 GYMINF, A: 25.9	LITTER D: 28.5
Ground ---: 25.3	Ground ---: 25.3	Ground ---: 23.4	Ground ---: 24.7	Ground ---: 27.6	Ground ---: 27.6	Ground ---: 27.1	Ground ---: 26.7	Ground ---: 26.1	Ground ---: 28.7

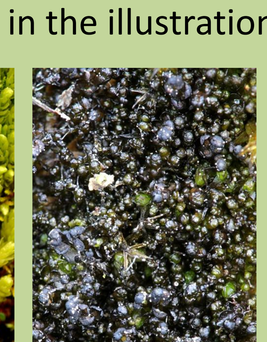
Above are the data used for the cross-section illustration. The format for each entry follows this pattern: SPECIES, A/D: ##.#. The species codes (six letters) used in the data sample are defined with photos and complete names below. The letters "A" and "D" indicate alive/dead status, and the number is the distance from the grid (leveled at zero in the illustration). Last is ground-to-grid distance.



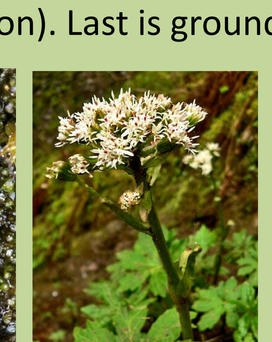
ERIRUS =
Eriophorum russeolum



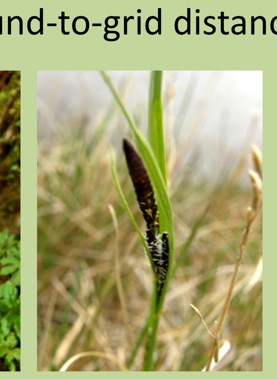
AULTUR =
Aulacomnium turgidum



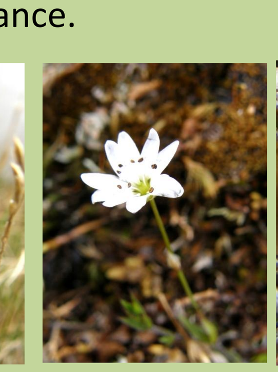
GYMINF =
Gymnocolea inflata



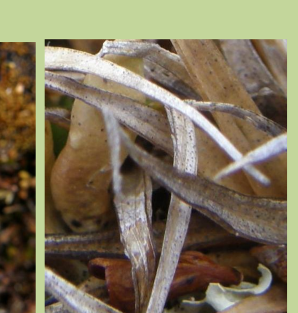
PETFRI=
Petasites frigidus



CARAQU =
Carex aquatilis

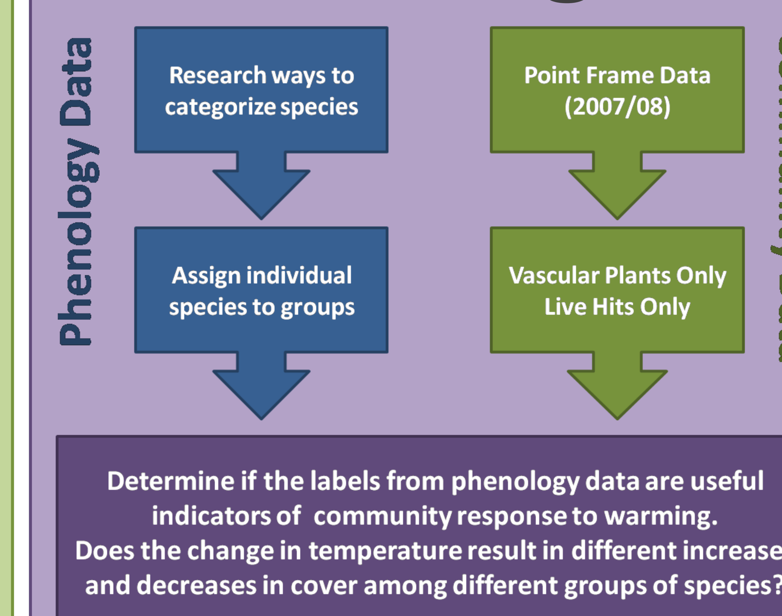


STELAE =
Stellaria laeta



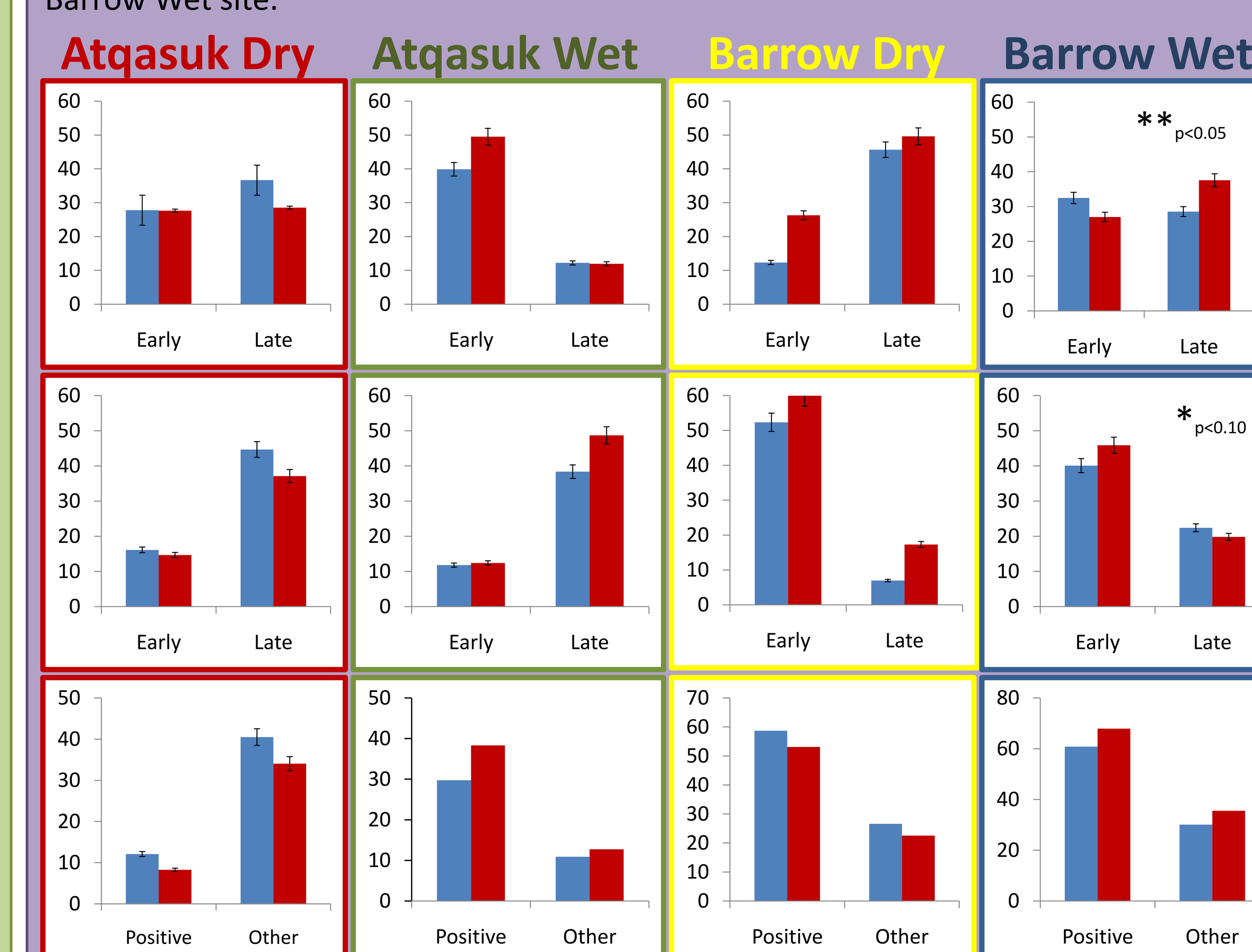
LITTER =
Leaf litter

Connecting



We used community data from the cover assessment (see green box), labeled the species using phenology data (see blue box) and compared the control plots to the warmed plots (see red box). In this way we were using differences in phenology to look for ways to explain changes in the community. We used a two-way ANOVA as a statistical measure of whether the phenology labels explained community changes. Each site was analyzed individually, due to differences in community composition.

Only two of the tests showed that the phenological label was a useful indicator of how the community changes. In both the Leaf Burst analysis and the Flower Burst analysis there was a significant result at the Barrow Wet site.



Early vs Late Leaf Burst

Significant response for Barrow Wet.

Early vs Late Flower Burst

Significant response for Barrow Wet.

Positive vs Any Other Response to Warming

No significant response.

Conclusions

Our results show that the date of different events in a plant's development could be useful for predicting change, though phenological response to warming is not a good indicator of cover change. However, a weak spot in analyzing plants by phenological response is that we did not have sufficient data to use this label for all the species at the site. Further assessment of species' phenological response could make this approach useful.

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