

Early Snowmelt's Effects on Floral Traits and Rewards of Two Subalpine Plant Species

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ABSTRACT:

The date of spring snowmelt is advancing in numerous alpine and subalpine ecosystems due to both rising temperatures and reduced snowpack associated with climate change. Snowmelt is a critical source of water for plants in subalpine ecosystems, so changes in snowmelt timing can affect many important traits in subalpine plants. In particular, both floral traits and rewards of subalpine plants can be altered by early snowmelt. While several field studies have examined the effects of snowmelt timing on floral traits and rewards, it is vital to consider numerous species responses since there is high variability in responses to early snowmelt. Examining species that bloom at different points in the season is especially important since they may respond differently to snowmelt timing. This study focuses on two closely related species in the *Delphinium* genus that have similar floral morphologies but bloom at different points in the season. We used an experimental manipulation of snowmelt timing at a field site in the Rocky Mountains to examine the effects on floral traits and floral rewards. Floral size, nectar rewards and soil moisture were measured weekly during floral anthesis. Using three years of floral trait data, we found that snowmelt timing was associated with smaller flowers in *D. nuttallianum* and had no effect on floral size in *D. barbeyi*. The only significant changes in nectar rewards associated with early snowmelt was higher nectar volume in *D. nuttallianum* in early snowmelt plots in 2023. We also examined the correlation between soil moisture and floral traits and rewards. In 2023, soil moisture had a positive relationship with floral size and nectar volume and a negative relationship with nectar sugar concentration for both species. In 2021 and 2022, we used less precise soil moisture measurements and found less consistent results. Shifts in floral traits and rewards due to climate change could have consequences for the two *Delphinium* species and pollinator populations.

INTRODUCTION:

In montane ecosystems, the date of spring snowmelt has been advancing over the past five decades due to rising temperatures and reduced snowpack (Clow, 2010; Aldridge et al., 2011; Pederson et al., 2011). The advancement of the average snowmelt date is impacting subalpine ecosystems in numerous ways. Early snowmelt can shift the phenology, morphology, and floral rewards of subalpine plants (Inouye, 2008; Caradonna et al., 2014; Campbell et al., 2022; Powers et al., 2022). The timing of key events, such as peak flowering, has advanced for some subalpine species, and the growing season has been extended (Aldridge et al., 2011; Caradonna et al., 2014). The cumulative changes in the phenology of different species have led to the same number of flowers being spread over a longer period (Aldridge et al., 2011; Caradonna et al., 2014). Floral displays and rewards can also be altered by early snowmelt. In some subalpine flowering plants, stalk height, corolla size, and nectar volume decrease with early snowmelt (Powers et al., 2022). Early snowmelt can also cause nectar sugar concentration to increase in some species (Powers et al., 2022).

Floral display and nectar rewards are essential for maintaining the mutualistic relationship between plants and pollinators (Zambon et al., 2020). Changes in reproductive traits such as floral traits and nectar rewards can impact relationships with pollinators and the reproductive success of plant species (Gallagher and Campbell, 2017; Descamps et al., 2021; Gallagher and Campbell, 2021; Powers et al., 2022). For the vast majority of plants that require animal pollination their reproductive success is significantly affected by their ability to attract pollinators. Therefore, changes to floral traits and rewards could have intensive reproductive consequences, especially if the effects are repeated for multiple years.

Pollinator populations can also be impacted by changes to floral traits and rewards. Many pollinator species are dependent on nectar rewards as a food source (Parachnowitsch et al., 2019; Zambon et al., 2020). Changes in nectar availability could affect pollinator populations, for example, bumble bee abundance is strongly affected by the temporal distribution of floral resources (Ogilvie et al., 2017). Indirect impacts of climate change, such as changes to floral resources, may be more harmful to pollinators than direct changes, such as increased temperature (Ogilvie et al., 2017). To understand the potential impacts of snowmelt timing on pollinators, examining the impact of early snowmelt on floral traits and rewards is vital.

The changes in floral traits and rewards due early snowmelt may be caused by water limitation (Powers et al., 2022). Flowers and rewards are expensive for a plant to produce, therefore they may sacrifice the number, size or rewards of flowers they produce if they are water-limited (Descamps et al., 2021). Early snowmelt can increase the length of the mid-season dry period, limiting the water available to subalpine plants and causing drought-stress responses in some species (Blankinship et al., 2014; Sloat et al. 2015; Powers et al., 2022). The mid-season

dry period is becoming prolonged by increased temperatures, reduced snowpack and earlier spring snowmelt without a consistent shift in monsoon rains (Aldridge et al., 2011; Sloat et al. 2015). Subalpine plants in the Rocky Mountains generally obtain water from snowmelt in the spring and monsoon rains in the summer. The timing of a plant's life history events will therefore affect the amount of water limitation that a plant is subjected to. There may be fewer changes to floral traits in plants that bloom late in the summer when precipitation is plentiful due to the monsoons.

Several studies have examined the impacts of snowmelt timing on floral traits and rewards; however, the research is limited by the number of species examined (Inouye, 2008; Gallagher and Campbell, 2017; Powers et al., 2022). The impacts of early snowmelt timing on subalpine plants can vary between species, particularly between species with different seasonal flowering timing (Caradonna et al., 2014). Consequently, it is necessary to examine the impacts of snowmelt timing on a variety of species that flower at differing points across the season. This study aims to contribute to the understanding of the impacts of snowmelt timing on floral traits and rewards by focusing on two long-lived perennial species that have different flowering phenologies. One of the study species (*Delphinium nuttallianum*) flowers early in the growing season, and the other (*Delphinium barbeyi*) flowers mid-late in the season.

The study took place in a subalpine ecosystem near Rocky Mountain Biological Laboratory (RMBL) in Gunnison County, Colorado, where the spring snowmelt date has been advancing by about 3.5 ± 2.0 days per decade since the 1970s (Pederson et al., 2011; Iler et al., 2013; Sloat et al., 2015; Wadgyamar et al., 2018). There have been phenological, morphological, and physiological changes associated with snowmelt timing in several species of subalpine forbs in the area near RMBL (Miller-Rushing and Inouye, 2009; Caradonna et al., 2014; Gallagher and Campbell, 2017; Gallagher and Campbell, 2021; Powers et al., 2022). Between 1974 and 2012, the spring peak in floral abundance near RMBL advanced by 20.7 days and the summer peak in floral abundance advanced by 12.9 days (Caradonna et al., 2014). Fewer flowers are blooming overall during late spring than there were historically because of the change in the temporal distribution of flowers throughout the growing season (Caradonna et al., 2014). With fewer flowers blooming during late spring, those that do, such as *Delphinium nuttallianum*, provide critical food sources for pollinators.

The timing of first and peak blooms of *D. nuttallianum* advance in response to earlier snowmelt, but the phenology of *D. barbeyi* does not change in response to earlier snowmelt (Inouye, 2008; Caradonna et al., 2014). However, *D. barbeyi* can be severely impacted by frost damage, which is more frequent in early snowmelt years (Inouye, 2008). Late spring frost events can cause all buds on *D. barbeyi* to fail (Inouye, 2008); this occurred on six of the monitored *D. barbeyi* plants in our plots in 2022. Snowmelt date can also affect the abundance of flowers on *D. barbeyi*; there are generally fewer flowers in early snowmelt years, which may be due to increased frost damage (Inouye, 2008). Additional effects of advanced snowmelt on *D. nuttallianum* and *D. barbeyi* are yet to be established.

While floral traits and nectar rewards can be extremely plastic in some species, they are resistant to change in other species (Parachnowitsch et al., 2019; Descamps et al., 2021). *Delphinium* species may conserve their floral traits and nectar rewards under stress in order to reproduce. Both *D. nuttallianum* and *D. barbeyi* rely on animal pollination to reproduce, therefore they may prioritize using resources to attract pollinators through floral traits and rewards (Pyke, 1978; Parachnowitsch, 2019).

This study examined three main research questions.

Q1. How does snowmelt timing impact floral traits and rewards, including corolla size, nectar volume, and sugar concentration?

H1. In the early snowmelt plots, corolla size will decrease, nectar volume will decrease and sugar concentration will increase.

Q2. Does the impact of snowmelt timing on floral traits change based on seasonal flowering timing?

H2. Snowmelt timing will have a greater impact on the early flowering species, *D. nuttallianum*.

Q3. How does soil moisture impact both floral traits and rewards?

H3. Soil moisture will have a positive correlation with corolla size and nectar volume and a negative correlation with sugar concentration.

METHODS:

Data Collection

Experimental snowmelt plots were established near the Rocky Mountain Biological Laboratory in Gunnison County, Colorado (elevation approximately 9600 ft) by Dr. Amy Iler in 2020, with additional plots established in 2021 and 2022 by PhD candidate Elsa Godtfredsen. There are eight experimental blocks, each of which contains one control plot and one early snowmelt plot. In the early snowmelt plots the snow was melted early using black cloth attached to poles to increase solar radiation. In 2023, the average difference in snowmelt date between the experimental and control plots was 6.25 days.

Each plot contains three 5x1.2-meter subplots and 0.7-meter walkways. We monitored sixty individuals of each study species (30 in experimental plots and 30 in control plots). After locating all the reproductive individuals of each species inside plots, we randomly selected 60 of each species. Within each block, the number of plants selected in the treatment plot were matched as closely as feasible with plants in the control plot. We assigned a number and a tag to each selected individual. Each of the study species for this project are present and monitored in three of the experimental blocks established by Dr. Amy Iler and Elsa Godtfredsen. During the flowering phase of each species, we recorded the floral traits of all tagged individuals on a weekly basis.

Each week, we randomly selected one flower stalk per tagged plant (during floral anthesis) and bagged it to exclude pollinators for 24 hours in preparation for nectar measurements. For each selected stalk we counted all the viable flowers and buds. Then, we randomly selected one open flower in the top half of the viable open flowers and one open flower in the lower half of the viable open flowers for the measurement of floral traits and rewards. The position of each flower was denoted as a fraction with the numerator being the position counted up from the bottom flower (the bottom flower being one) and the denominator being the total number of flowers and buds. Higher flowers are expected to have less nectar than lower flowers so we needed to control for position (Pyke, G. H., 1978; Parachnowitsch et al., 2019).

We measured floral width (corolla width) and nectar spur length to assess floral size and nectar volume and sugar concentration to quantify floral rewards. We measured the nectar volume using a 2-microliter Drummond brand microcapillary tube. We recorded the length (in millimeters) of nectar in the microcapillary tube, and converted the length to volume in microliters. We quantified the nectar sugar concentration in percent sucrose by mass (% BIX) using a refractometer. We also noted the time of day the nectar was collected to account for daily temporal variation (Parachnowitsch et al., 2019).

During 2023 we measured the soil moisture with a 6 cm probe at bare soil near the base of each plant when the floral traits of the individuals are measured. The probe measured volumetric moisture content (VMC), allowing for quantitative analysis of the effects of soil moisture on floral traits and rewards and for the examination of effects from early snowmelt outside of water limitation because the effects from soil moisture are accounted for. Data on floral traits and rewards have been collected at the same site for the past two years by PhD candidate Elsa Godfredsen. The data from the past two years were also used in multi-year analyses of the impacts of early snowmelt on floral traits and rewards. Measurements of floral size and rewards have been taken using the same methods so the data is consistent and comparable. The soil moisture was taken at the sub-plot level for the past two years, but not at the plant level. Soil moisture analyses were done for individual years only, because the precision of the readings are not consistent.

Statistical Analyses

We analyzed each individual year from 2021 to 2023 and the combination of all three years. To analyze our data, we used mixed effects models that accounted for the random effects of block, plot, plant number, flower position, day of year, and year. We analyzed the association between early snowmelt and floral length, floral width, nectar volume, nectar sugar concentration and soil moisture. We also analyzed the relationships between soil moisture and floral length, floral width, nectar volume, and nectar sugar concentration.

For analyses of the effects of snowmelt timing on floral size we used linear mixed effects models to compare size measurements with treatment as the predictor. For analyses of the effects of snowmelt timing on nectar sugar concentration, we used linear mixed models with treatment

as the predictor. To determine if there was a difference in soil moisture between early snowmelt and control plots during the floral anthesis of each species, we analyzed the association between treatment and soil moisture using linear mixed effects models with treatment as the predictor.

For analyses of the effects of snowmelt timing on nectar volume we used measurements of nectar volume (length in millimeters of nectar in the microcapillary tube) rounded to the nearest whole number so that we could use generalized linear mixed effects models with a poisson family. We used the length measurements in millimeters of nectar inside microcapillary tubes, because these measurements could be rounded to the nearest integer (unlike the volume measurements in microliters); the integer values allowed us to use a poisson family to compensate for zero inflated data. We also examined binary nectar presence data using generalized linear mixed models with a binomial family. We tried using generalized linear mixed effects models with a negative binomial family and the unrounded nectar volume measurements. However, using qq plots and residual plots we found that the data did not fit this model.

For analyses of the effects of soil moisture on floral traits and rewards, we used mixed effects models that accounted for the random effects of block, plot, plant number, flower position, and day of year. For 2021 and 2022 we used measurements of soil moisture at the sub plot level (the average of two readings) taken within a few days of the floral trait measurements. For 2023 we used measurements of soil moisture that were taken near the base of each plant on the same days that floral traits and rewards were measured. For analyses of the effects of soil moisture on floral size, we used linear mixed effects models to compare size measurements with VMC as the predictor. For analyses of the effects of soil moisture on nectar volume we used measurements of nectar volume (length in millimeters of nectar in the microcapillary tube) rounded to the nearest whole number so that we could use generalized linear mixed effects models with a poisson family (to compensate for zero-inflated data). For analyses of the effects of soil moisture on nectar sugar concentration, we used linear mixed models to compare measurements of percent sucrose by mass with VMC as the predictor.

RESULTS:

Impacts of Snowmelt Timing on Floral Traits and Rewards:

The only significant difference in floral size between early snowmelt and control treatments was *D. nuttallianum* corolla width using data from all three years (with yearly variation accounted for as a random effect); *D. nuttallianum* corolla widths were smaller in early snowmelt plots ($p < 0.008$). There was also a marginally significant difference between early snowmelt and control treatments in *D. nuttallianum* corolla width in 2022 ($p = 0.0624$). Early snowmelt had no significant effects on floral size for either species in any individual year.

The treatment effects on nectar volume varied across the years. In 2021, both species had marginally significant, higher, nectar volumes in early snowmelt plots compared to control plots (*D. nuttallianum*: $p < 0.051$, *D. barbeyi*: $p < 0.059$). In 2022, there was no significant difference in nectar volumes between treatments for either species. In 2023, *D. nuttallianum* had higher

nectar volume in early snowmelt plots compared to control plots ($p < 0.01$) and *D. barbeyi* had no difference. In multi-year analyses, there were no significant differences in nectar volume between early snowmelt and control treatments. Snowmelt timing did not appear to have an effect on sugar concentration. There were no significant differences in sugar concentration between early snowmelt and control treatments in any individual years or multi-year analyses.

The only significant difference in soil moisture between early snowmelt and control plots was during the floral anthesis of *D. barbeyi* in 2021, when the soil moisture was higher in early snowmelt plots. For every other period of floral anthesis there was no significant difference in the soil moisture of early snowmelt and control plots.

Impacts of Soil Moisture on Floral Traits and Rewards:

Soil moisture did have significant correlations with floral traits and rewards for both species. In 2021, *D. nuttallianum* floral length had a positive relationship with soil moisture ($p < 0.0011$), but there was no significant relationship between soil moisture and *D. barbeyi* floral size. In 2022, *D. barbeyi* floral width had a significant negative relationship with soil moisture ($p < 0.002$), but there was no significant relationship between soil moisture and *D. nuttallianum* floral size. In 2023 floral length had a positive relationship with soil moisture for both species (*D. nuttallianum*: $p < 0.0001$, *D. barbeyi*: $p < 0.021$, Figure 1). There was no significant relationship between soil moisture and floral width in 2023.

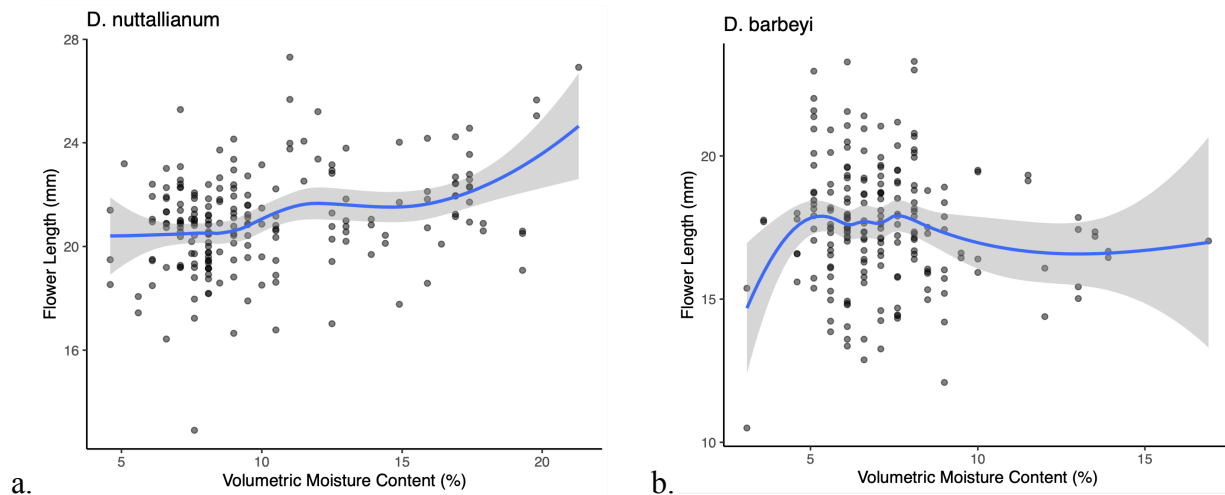


Figure 1: The relation between soil moisture in VMC and floral length in mm for *D. nuttallianum* ($p < 0.0001$) and *D. barbeyi* in 2023. For both species there is a positive correlation between VMC and floral length. For *D. nuttallianum* $p < 0.0001$, and for *D. barbeyi* $p < 0.021$.

In 2021, there was a positive relationship between soil moisture and nectar volume for both species (*D. nuttallianum*: $p < 0.0001$, *D. barbeyi*: $p < 0.0052$). In 2022, there was a negative relationship between soil moisture and nectar volume in *D. nuttallianum* ($p < 0.0001$), and no relationship for *D. barbeyi*. In 2023, there was a positive relationship between soil

moisture and nectar volume for both species (*D. nuttallianum*: $p < 0.0064$, *D. barbeyi*: $p < 0.0001$, Figure 2).

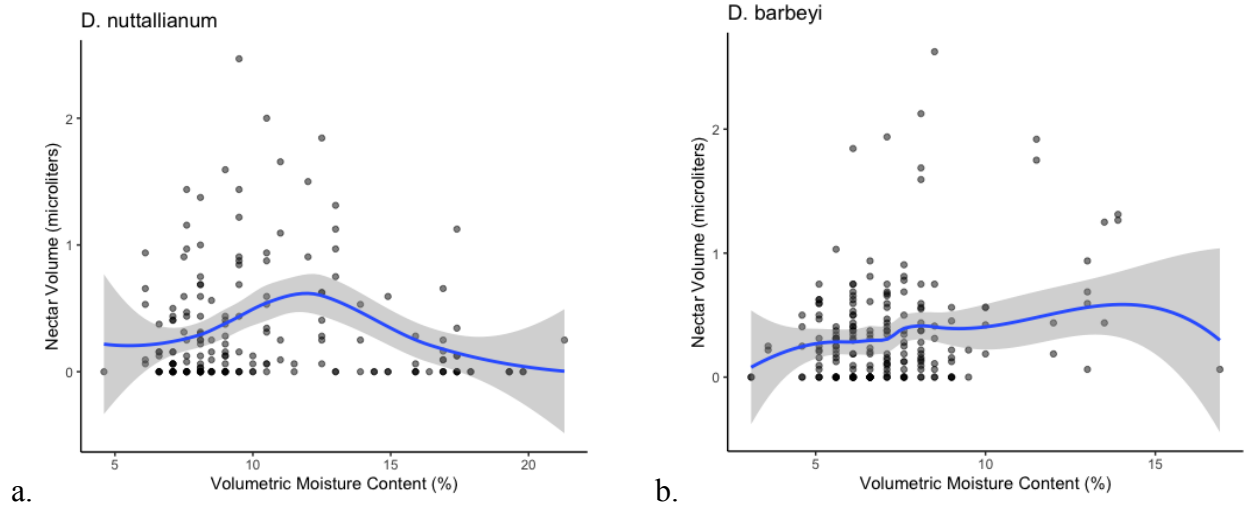


Figure 2: The relation between soil moisture in VMC and nectar volume in microliters for *D. nuttallianum* and *D. barbeyi* in 2023. For both species there is a positive correlation between VMC and nectar volume. For *D. nuttallianum* $p < 0.0064$, and for *D. barbeyi* $p < 0.0001$.

In 2021, there was a negative relationship between soil moisture and nectar sugar concentration for *D. barbeyi* ($p < 0.012$), and no relationship for *D. nuttallianum*. In 2022, there was a negative relationship between soil moisture and nectar sugar concentration for *D. nuttallianum* ($p < 0.023$), and no relationship for *D. barbeyi*. In 2023, there were negative relationships between soil moisture and sugar concentration for both species (*D. nuttallianum*: $p < 0.015$, *D. barbeyi*: $p < 0.032$, Figure 3).

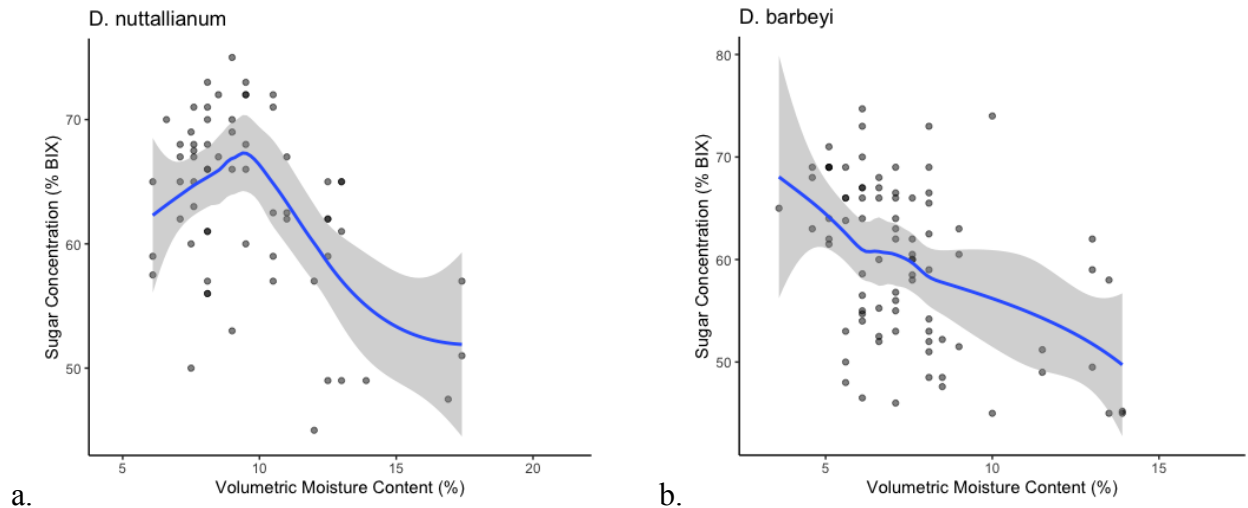


Figure 3: The relation between soil moisture in VMC and nectar sugar concentration in percent for *D. nuttallianum* and *D. barbeyi* in 2023. For both species there is a positive correlation between VMC and nectar volume. For *D. nuttallianum* $p < 0.015$, and for *D. barbeyi* $p < 0.032$.

DISCUSSION:

Impacts of Snowmelt Timing on Floral Traits and Rewards:

During the three years of this experiment, the effects of snowmelt timing on the floral traits and rewards of *D. nuttallianum* and *D. barbeyi* were less extensive than expected. Snowmelt timing did not have a significant effect on floral size for either species in any individual year, however in multi-year analyses there was a significant difference in *D. nuttallianum* floral width. The floral widths in early snowmelt plots were about 1.3 mm smaller on average than floral widths in control plots. This difference in flower size in *D. nuttallianum* could have reproductive consequences if the size change affects pollinator preference. The difference may not have been significant in individual years because the sample size was not sufficient to confirm a difference so small in comparison to the total variation in floral width.

Snowmelt timing did not have a large effect on nectar rewards. The only significant difference in nectar rewards associated with early snowmelt was increased nectar volume in *D. nuttallianum* in 2023. There was also marginally significant increased nectar associated with early snowmelt in both species in 2021. This contradicts prior research on another subalpine species (*Ipomopsis aggregata*) that showed a reduction in nectar volume associated with early snowmelt (Powers et al., 2022). Early snowmelt could facilitate increased nectar production because it lengthens the growing season, allowing the plants a longer period to grow and access resources. Alternatively, the longer growing season may compensate for the stress caused by an early snowmelt, leading to a lack of significant effects. Nectar rewards may also be conserved due to their importance in reproduction, resulting in no significant difference in rewards between early snowmelt and control plots (Parachnowitsch et al., 2019).

The nature of individual years may have affected the impacts of snowmelt timing on floral traits and rewards because of varying snowmelt timing, precipitation patterns, and treatment effects. There was not a significant relationship between snowmelt timing and soil moisture across either individual flowering period during any year. These analyses only used soil moisture data from the periods of floral anthesis, and may have missed a period of significant difference in soil moisture prior to *D. nuttallianum* flowering. However, if the difference in soil moisture between the early snowmelt and control plots only lasted for a short period, there may not have been enough of a difference in conditions to cause significant differences in floral traits and rewards. Furthermore, 2021 was an early snowmelt year across the study area, so the earlier than average snowmelt may have impacted the control plots as well. In 2022, there was a very small difference in snowmelt timing between the early snowmelt and control plots, which could have diminished the treatment effect.

Comparison of Species:

The only statistically significant differences between early snowmelt and control plots were smaller floral widths and larger nectar volumes in early snowmelt plots; these differences were only significant in *D. nuttallianum*, the earlier-blooming species. There were no significant differences between early snowmelt and control plots for *D. barbeyi*, the later blooming species. Therefore, it appears that early snowmelt has a larger effect on the earlier blooming species. This trend is similar to the phenological responses of the two species to early snowmelt. Early snowmelt affects the flowering phenology of *D. nuttallianum* but not *D. barbeyi* (Caradonna et al. 2014). *D. nuttallianum* reproduction may be more responsive to changes in snowmelt timing due to its dependence on water from snowmelt during its reproductive period. *D. barbeyi* may be less impacted by early snowmelt because it blooms several months after spring snowmelt.

Because both species' floral traits and rewards appear to be sensitive to changes in soil moisture, we would expect them both to react to snowmelt timing if it affected soil moisture. We found no significant difference in the soil moisture of early snowmelt and control plots during the floral anthesis of either species in any year. However, there may have been a difference in soil moisture before *D. nuttallianum* started blooming, which could have driven the decrease in floral width.

Impacts of Soil Moisture on Floral Traits and Rewards:

In 2021 and 2022, the relationships between soil moisture and floral traits and rewards were not consistent. There were fewer correlations overall in both years than in 2023, and in 2022, there were some unexpected relationships. In 2021, *D. nuttallianum* nectar volume and floral size had positive relationships with soil moisture as expected (Gallagher and Campbell, 2017; Descamps et al., 2021; Gallagher and Campbell, 2021; Powers et al., 2022), but *D. nuttallianum* nectar sugar concentration had no relationship with soil moisture. The relationship between soil moisture and nectar sugar concentration can vary, some studies have shown negative relationships (Powers et al., 2022), while others have shown no relationship (Gallagher and Campbell, 2017; Descamps et al., 2021; Gallagher and Campbell, 2021). In 2021 *D. barbeyi* nectar volume and nectar sugar concentration reacted to soil moisture as expected, but there was no relationship with floral size. In 2022, *D. nuttallianum* nectar sugar concentration had a negative relationship with soil moisture as expected (Powers et al, 2022), but there were also several relationships that were unexpected; *D. nuttallianum* nectar volume and *D. barbeyi* floral width both had negative relationships with soil moisture. Nectar volume and floral width generally have positive relationships with soil moisture in subalpine plants (Gallagher and Campbell, 2017; Descamps et al., 2021; Gallagher and Campbell, 2021; Powers et al., 2022). The less precise measurements of soil moisture taken in these years (at the subplot level) may have led to less accurate results. Additionally, 2022 was a particularly heavy rain year, therefore it is possible that soil moisture reached above optimum levels.

In 2023, both species appear to react to soil moisture as expected. The relationship between soil moisture and floral traits was similar to the relationships previously established in other subalpine species (Gallagher and Campbell, 2017; Descamps et al., 2021; Gallagher and Campbell, 2021; Powers et al., 2022). Lower water availability can decrease photosynthetic rate

and thereby inhibit a plant's ability to produce floral traits and rewards (Gallagher and Campbell, 2017). Increased access to water could enable plants to produce larger flowers and nectar volumes; it also can lead to diluted nectar with lower sugar concentrations. These relationships suggest that *Delphinium* floral traits and rewards are sensitive to changes in soil moisture.

The apparent relationship between soil moisture and *Delphinium* floral traits and rewards suggests that other climatic variables, such as temperature, that affect soil moisture could have impacts on *Delphinium*. The increased temperatures associated with climate change can lower water availability and therefore may lead to changes in floral traits and rewards (Gallagher and Campbell, 2017). Some of the changes in floral traits attributed to early snowmelt in long-term observational studies may actually be driven by the higher temperatures associated with early snowmelt.

CONCLUSIONS:

In our system, *Delphinium* species appear to be relatively resilient to changes in snowmelt timing and may be able to conserve some of their floral traits. A larger sample size and longer study could provide further insight into the effects of snowmelt timing on the floral traits and rewards of *Delphinium* species. These species are long-lived perennials, and more years of early snowmelt may be required to stress them enough that they sacrifice their floral traits and rewards. If the amount of stress caused by early snowmelt is small, effects on the floral traits of either species may not be apparent for multiple years. Alternatively, these species could be prioritizing reproduction at the expense of other traits, such as leaf size and number. Further study of the physiological, morphological, and demographic effects of snowmelt timing is essential to understanding the responses of these species to early snowmelt.

Subsequent research should include temperature and precipitation manipulations on *Delphinium*. While the floral traits and rewards of *Delphinium* seem to be relatively resilient to snowmelt timing, their sensitivity to soil moisture suggests that they may be affected by changes in temperature and precipitation. A long-term study examining the relationship between temperature and *Delphinium* floral traits and rewards would be invaluable to understanding the implications of climate change. In order to predict the impacts of climate change on plant and pollinator communities, it is essential to further examine the effects of climatic shifts on the floral traits and rewards of flowering plants.

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