Phenology Analysis 2023

Introduction:

Since 2020, the Independence Pass Foundation has conducted a phenology survey of alpine and sub-alpine wildflowers. The diversity and strength of flower populations are precursors for the health of the larger ecosystem. This study provides data on species, population density, and blooming periods. Weather data shows the impact of precipitation and snowfall on flowering plants.

This report aims to help future analysis and provide detailed observations for the data taken thus far. Since the study is only four years old, all hypotheses are speculative. In the future, the foundation can make more conclusive observations on trends and correlations. This data will help the foundation assess the impact of climate change and other weather events on the alpine ecosystem. Also, the diversity and length of blooming periods can give insight into the apparent decline of pollinators. Lastly, this data will aid in future IPF revegetation projects by providing knowledge on which species will be most successful.

Movie of Linkin's Lake over the summer:
Preview attachment Linkin's Timelapse .mp4

Weather Data

Weather play's role in the phenological response of flowers. This analysis compares weather data with total blooms over the summer. This comparison can give insight on how blooms react to accumulative precipitation and snow depth. These insights allow the foundation to make more informed decisions on reseeding projects, as well as observations on flower/ecosystem health. Many more years of data will be needed to make confident conclusions on climate change and any change in ecosystem strength.

We sourced the weather data from the Independence Pass Snotel site #542, which sits southeast of the summit. This weather station is at Lat: 39 deg; 5 min N, Long: 106 deg; 37 min W, and an Elevation of 10,598 feet (lower than the area of study). We used the Snotel site instead of the ACGI weather station at the summit because it includes precipitation totals and is more accurate since the harsh climate causes the ACGI station to malfunction. The snowfall totals come from the summit station and are significantly higher than the snow depths at the survey area. The data was recorded during a water year, defined as a period from October 1st to September 30th.

Table 1: Weather data from station #542

	2019	2020	2021	2022	2023
Accumulative Precipitation (in) (June 1st - September 15th)		6.7	7.2	7.9	3.9
Accumulative Precipitation (in) (Water Year)	32.9	28.1	25.7	28.3	25.5
Max Snow Depth (in)	81	63	54	53	63
Melt Date	6/12/19	5/23/20	5/24/21	6/3/22	6/4/23
Percentage of Snow	87.50%	76.20%	68.50%	66.70%	87.84%
Average Temp. (June 1 - Sept 15) (DegC)		10.171962617	10.7841121	10.4607477	10.09345794

Blooming length
Flowers with the longest blooming period:
Transect 1*: Aconitum Columbianum (8 weeks), Arnica mollis (8 weeks), Rhodiola rhodanthum (8 weeks), Epilobium homemannii (6 weeks)*

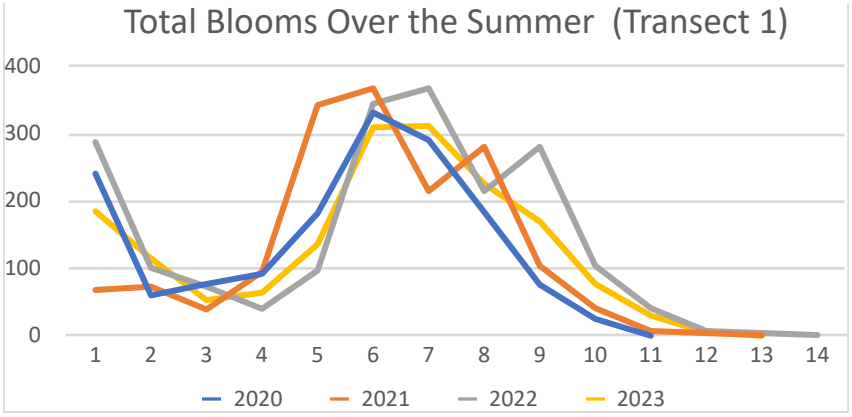
Transect 2*: Achillea millefolium (10 weeks), Heterotheca pumila (8 weeks), Arenaria congesta (5 weeks) Arnica parryi (5 weeks), Pseudocympoterus montanus (5 weeks)*

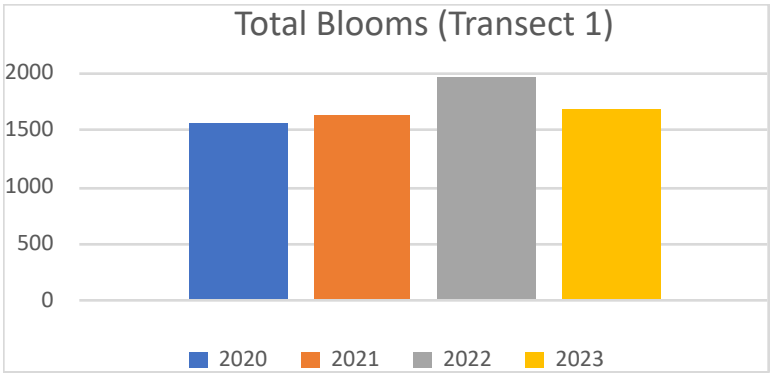
Transect 3*: Conioselinum scopulorum (7 weeks), Erigeron peregrinus (7 weeks), Gentianopsis detonsa (6 weeks), Caltha leptosepala (6 weeks), Podistera eastwoodiae (6 weeks)*

Transect 4*: Erigeron pinnatisectus (8 weeks), Minuartia obtusiloba (8 weeks), Solidago simplex (6 weeks), Antennaria rosea (6 weeks), Arctostaphylos uva-ursi (6 weeks)*

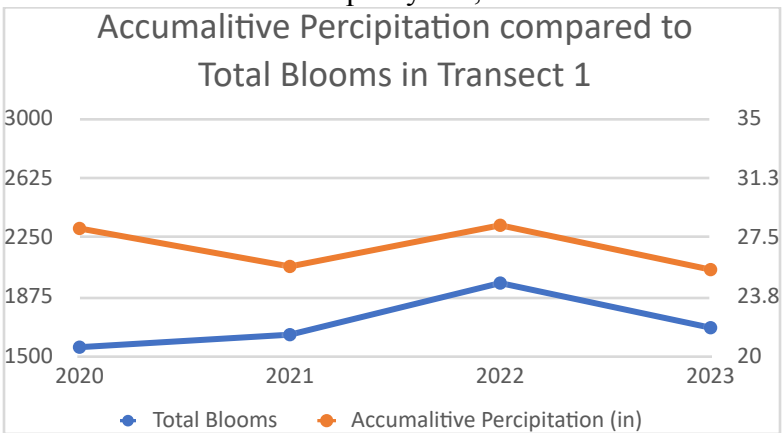
Transect 1

This plot is near the parking lot. It is adjacent to a stream which makes it a riparian biome. It contains willow shrubs and sits at an elevation of 11,722. This year, a mountain goat game trail appeared on the Northwest side of the plot. The game trail could have caused a decrease in total flowers compared to the previous year.

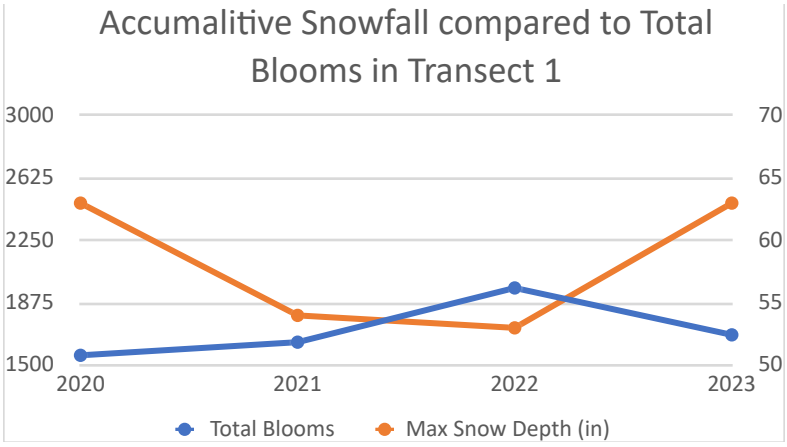




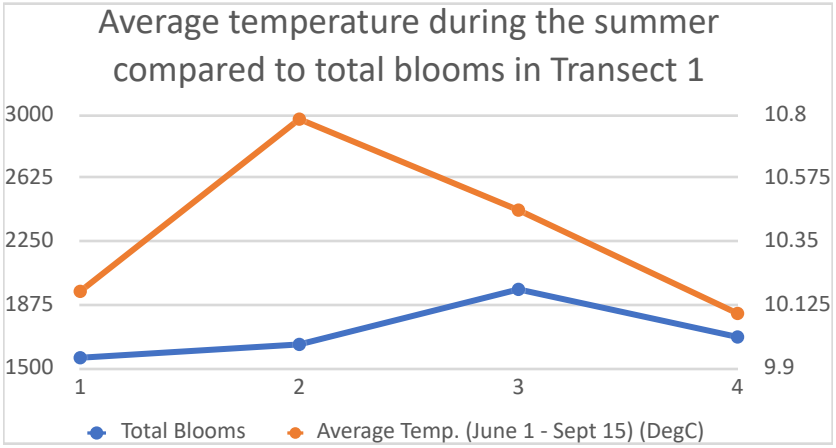
The blooms in 2023 for transect one performed like previous years. The peak appeared in late July, slightly later than previous years. There were fewer total blooms compared to 2022, but more than in 2020 and 2021. The end of the blooming period was also consistent with past years, with zero flowers in bloom on September 11th.



There is a positive correlation between precipitation and number of blooms for every year except 2020. In other words, the more rain during the summer, more flowers bloomed. The drop in rainfall compared to the previous year is a partial reason for the decline in total blooms. There was almost the same about of rainfall and total blooms in 2021 and 2023.



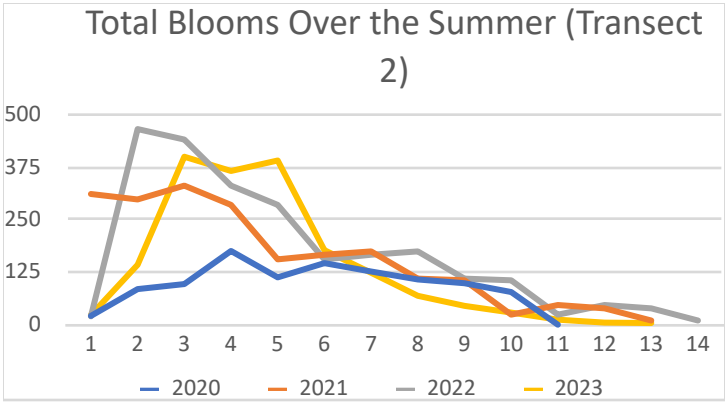
Accumulative snowfall is another indicator for total blooms. This figure shows that the more snowfall the previous winter, fewer blooms appear. There is more variability with this correlation which indicates it is a weaker factor for total flowers. The drop in total blooms compared to last year could be due to the decrease in snow fall.

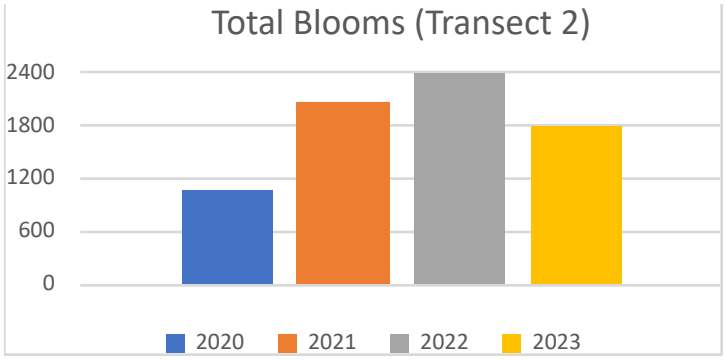


Previous studies on phenology in alpine environments propose that air temperature is a factor for the number of flowers. The average temperatures taken over the summer did not correlate with the total blooms in Transect 1. It is important to note the data for temperature is taken at a lower elevation and in a different location. The inaccurate weather data is the reason that there is no apparent correlation.

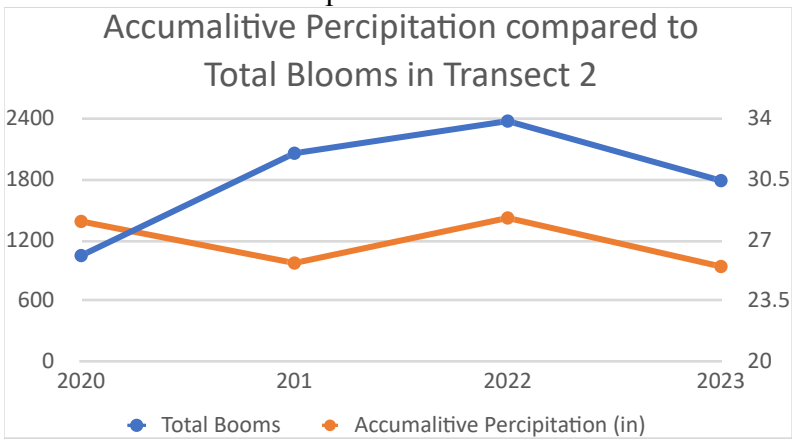
Transect 2

This plot is located further up the Likins trail on a sunny south-facing dry area. The slope of the plot is relatively steep. There are pine trees surrounding, but little non-flower vegetation within the plot. The elevation is 11,722 feet.

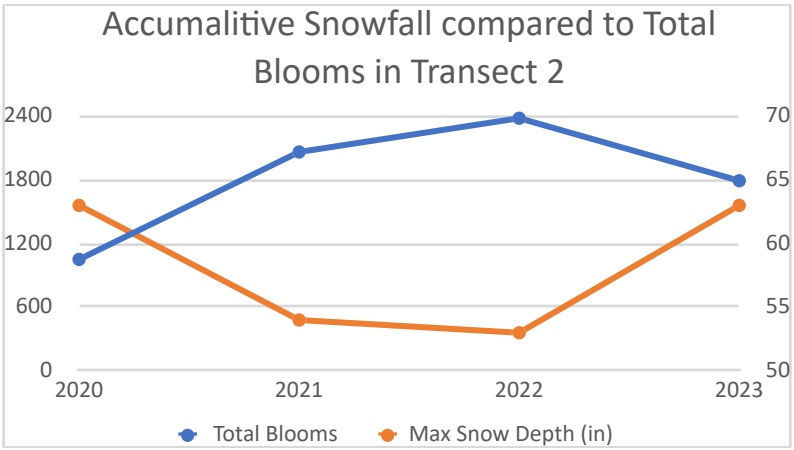




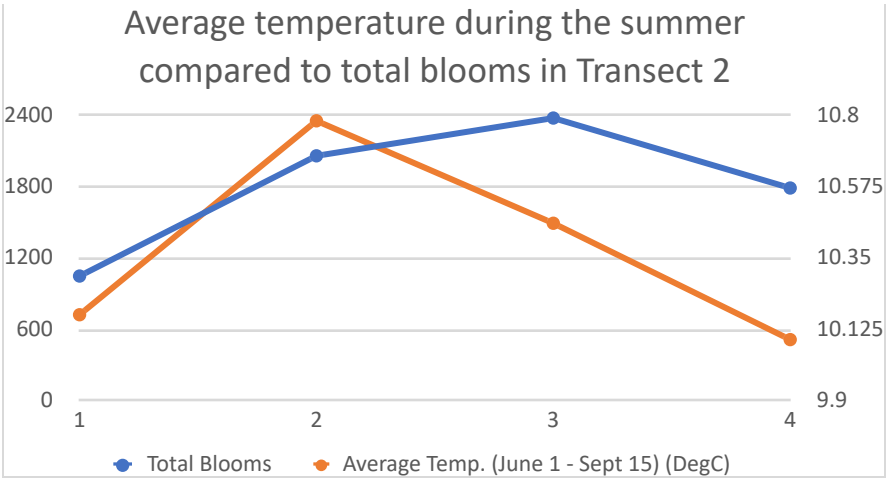
The total blooms in this transect performed like the previous year. The peak appeared in late June and then again in mid-July. This peak is slightly later than the previous years. The only year that produced fewer blooms than 2023 was 2020. The end of the blooming period was a week or two before past years, with four blooms on September 11th.



There appears to be a strong correlation between rainfall and total blooms for Transect 2. There was the same amount of rainfall in 2021 and 2023, but fewer blooms in 2023. The decline in blooms could be due to the inconsistent rainfall over the summer of 2023. It was a particularly wet spring followed by a dry summer. Even though the cumulative rainfall was the same, the inconsistency could be the reason for the decline in total blooms in 2023. This trend indicates a dry, steep location relies on consistent rainfall, more than other plots.



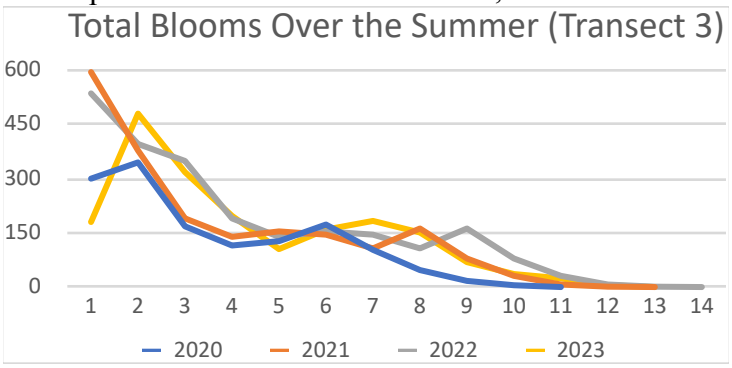
Snowfall appears to be a factor for total blooms in this plot. The increase in snowfall could be a reason for the decline in total blooms. Snow did not cover the plot at the beginning of the study, but it could have delayed the germination of the flowers if it kept the ground colder for a longer period.

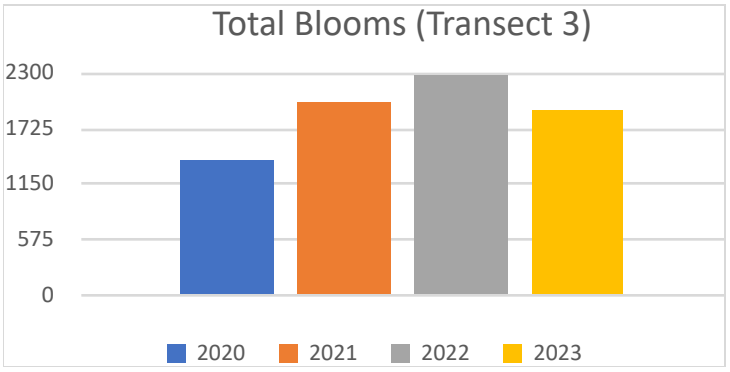


There appears to be a weak correlation between temperature and total blooms for 2022 and 2023. This data shows the lower temperature leads to fewer blooms. The temp data in this figure was taken in a different location and at a lower elevation, so conclusions on this correlation are very speculative.

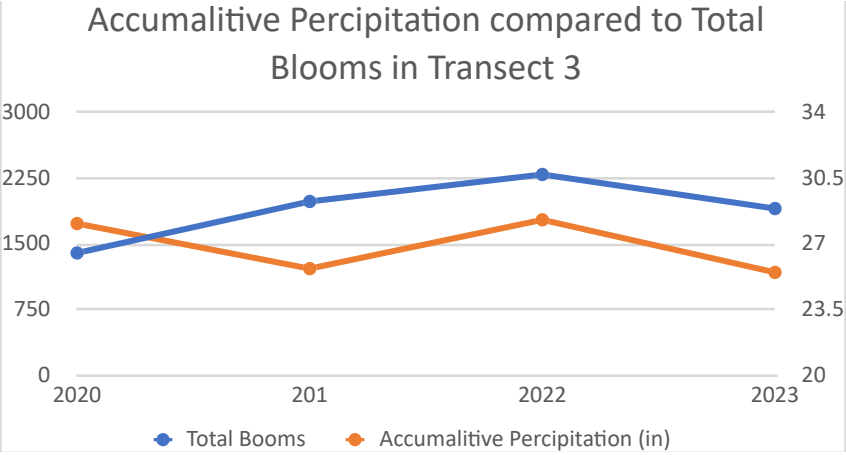
Transect 3

This plot is located next to Linkins, near alpine wetlands, and is a riparian biome. Willows, small pine trees and a few alpine pools were inside the plot. It sits at an elevation of 12,031 ft.

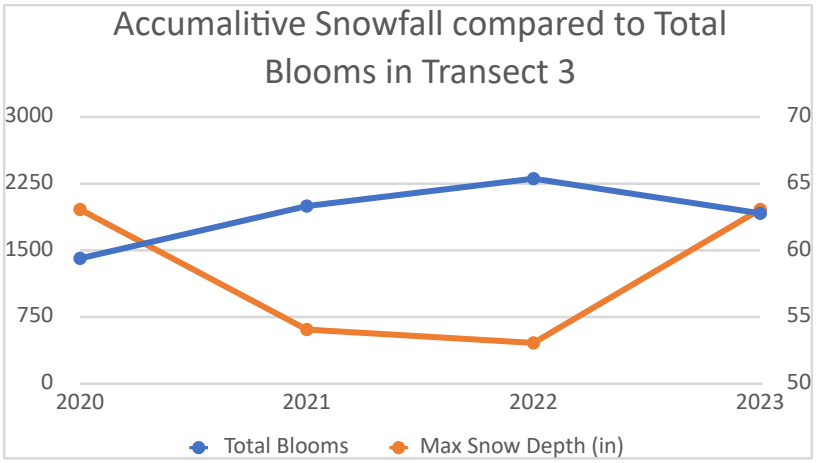




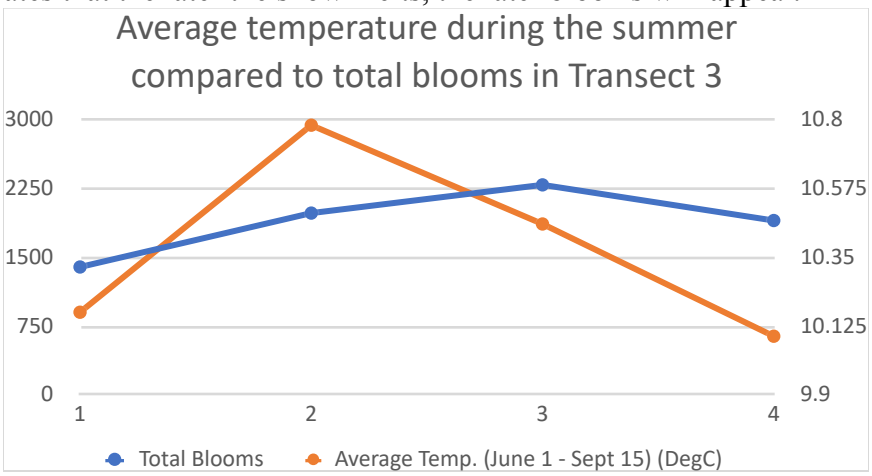
There was a decline in total blooms compared to 2022. There were almost the same number of total blooms in 2021 and 2023. Peak blooms appeared in late June, which is later than previous years. There were zero blooms reported on September 11th, which is consistent with the past two years.



Accumulative precipitation positively correlates with total blooms. There was less rainfall this summer and fewer blooms compared to 2022. There was the same amount of rainfall and almost the same number of blooms in 2021 and 2023.



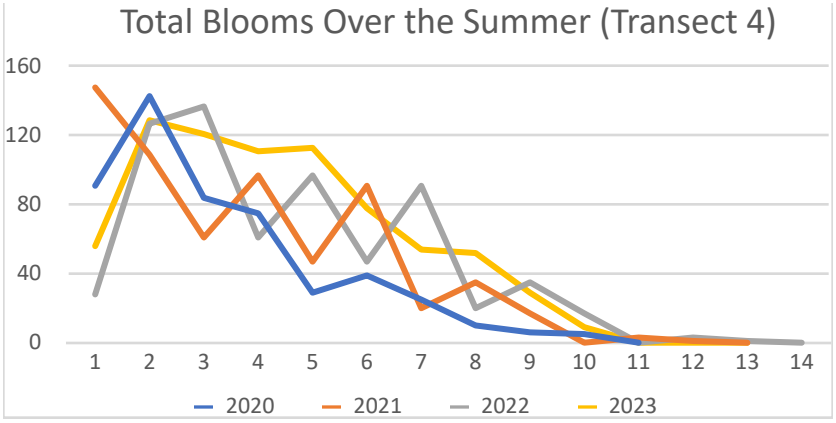
At the start of the survey there was a large amount of snow around the plot. Fewer blooms were present at the beginning of the study compared to 2022 and 2021. The peak was also later this year than all previous years. This relationship indicates that the later the snow melts, the later blooms will appear.

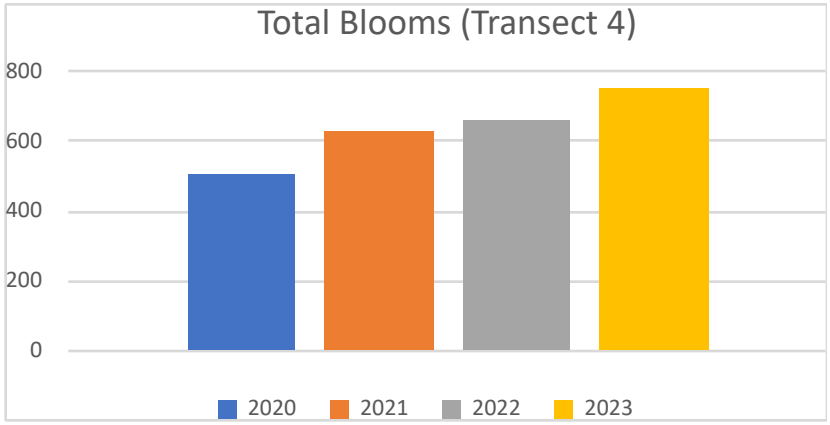


There appears to be a weak correlation between temperature and total blooms for 2022 and 2023. This data shows the lower temperature leads to fewer blooms. The temp data in this figure was taken in a different location and at a lower elevation, so conclusions on this correlation are very speculative.

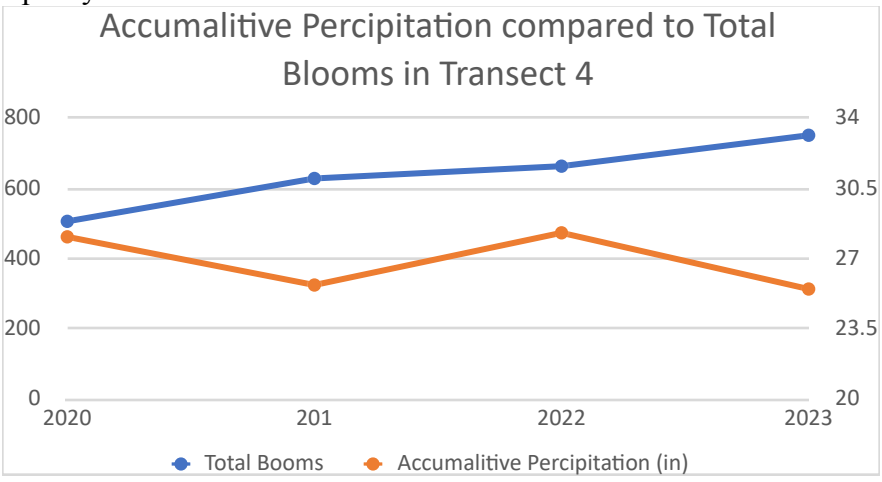
Transect 4

This plot is above tree line and is the highest in the survey at an elevation of 12,204. It is dry, rocky, steep, south-facing and receives lots of sun.

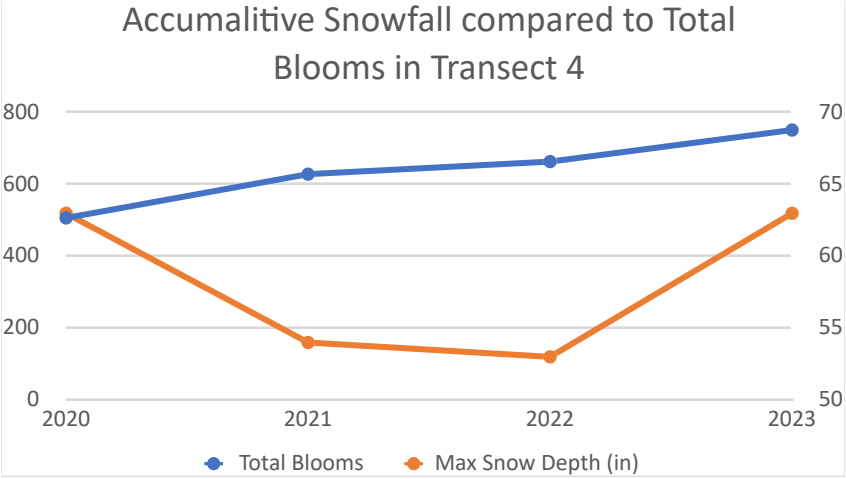




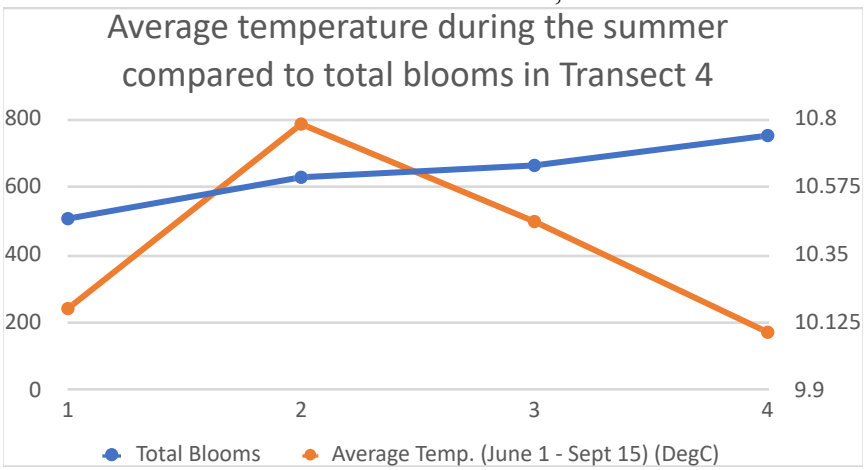
This plot showed the most variability from year to year. There has been a consistent increase in total blooms peaking in 2023. Peak total blooms happened in mid-June which was consistent with previous years. There was a steady decline in total blooms after the peak. This decline after the peak bloom is unlike 2021 and 2022, which showed various minor peaks throughout the summer. The blooming period ended on August 29th, earlier than all other plots and past years.



Unlike the other transects, there is no correlation between rainfall and total blooms. Even with less rain in 2022, there was still an increase in blooms. This relationship indicates rainfall affects the total blooms in transect four less than plots at a lower elevation. The species of flowers may be more resilient to inconsistent rain which is why the population did not decline.



Again, unlike other transects snowfall did not correlate with total blooms. There were more blooms at the start of the survey in 2021 but less blooms at the start in 2022 which indicates snowmelt did not affect the start of the blooming period. There was a similar amount of snowfall in 2021, but far fewer total blooms.



With zero observed correlations between rain and snowfall, temperature could be the determining factor for total blooms. An impact from temperature was not shown by our data. This is most likely due to the source the temp data was taken from. The temperatures over the past four years have not significantly varied, but they may have at that specific location. The correlation between higher temperatures and longer blooming periods is supported by a different study completed at high elevations (Arroyo, 2021).

Biodiversity

Measuring biodiversity in flower studies is crucial for assessing the stability and functionality of ecosystems and understanding the relationship between flowers and pollinators. The more biodiverse an ecosystem is, the more pollinators it can support. We used Simpson's Diversity Index to measure the four transects biodiversity.

The Simpson's Diversity Index is a statistical measure used to assess the diversity of an ecosystem. It considers both the number of different species (or types) present and their relative abundances. The index provides a single numerical value that reflects the probability that two individuals selected at random from the community will belong to different species.

The closer the Simpson's Diversity Index is to 1, the more diverse and evenly distributed the species are within the community, while a value closer to 0 suggests lower diversity and a more imbalanced distribution of species abundances. This number is used comparatively so from one sample to another sample.

Biodiversity Index (Simpson's Diversity Index)	2020	2021	2022	2023
Plot 1	0.88	0.89	0.88	0.9
Plot 2	0.85	0.83	0.88	0.77
Plot 3	0.8	0.91	0.9	0.73
Plot 4	0.84	0.82	0.81	0.91

Our data shows that all plots are relatively diverse and are equal in diversity. The lowest biodiversity was in Plot 3 in 2023. The highest biodiversity was in Plot 4 in 2023 and Plot 3 in 2021. This statistical measure will be a good to use as years go by to measure the health of each ecosystem as they respond to climate change.

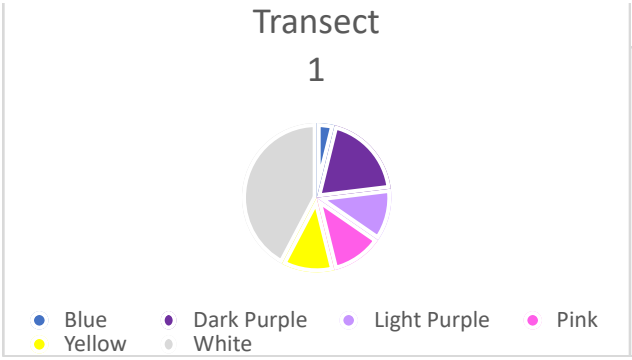
Conclusions

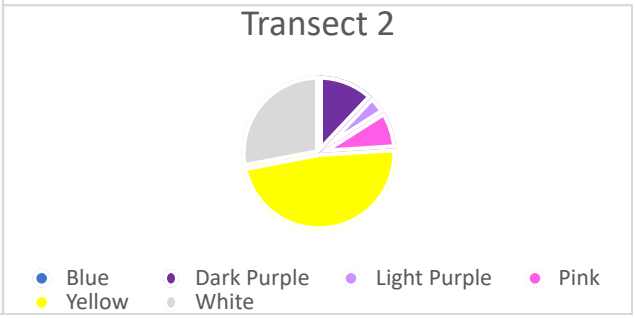
- There has been little variability in temperature over the past four years. The temperature data was taken at a different location than the survey, which makes correlations inconclusive.
- There are fewer blooms in 2020 because the blooming period stopped two weeks before all other years. The reason for the short blooming period is unknown.
- Transect 1 and Transect 3 had a similar response to cumulative rainfall, likely due to their riparian biome.
- Dry sloped areas like Transect 2 rely on consistent rainfall.
- There is a positive correlation with rain and total blooms in all transects except Transect 4.
- There is an inverse correlation with snowfall and total blooms in all transects except Transect 4. The snow melt date for 2023 was the latest out of all four years and resulted in a later peak and start of the blooming period compared to past years. The time of snowmelt, however, did not affect the total blooms.
- The blooms peak sooner at higher elevations.
- Biodiversity is not currently under threat, nor is there a particular site that is underperforming.

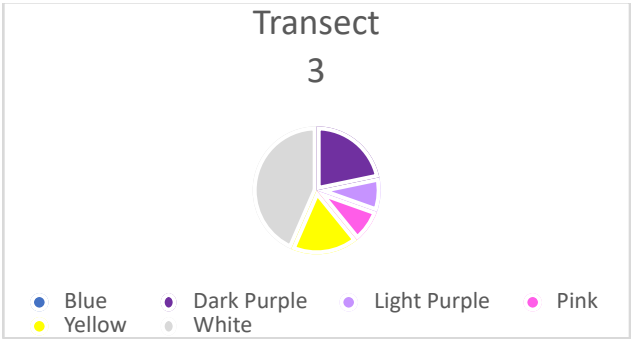
Colors

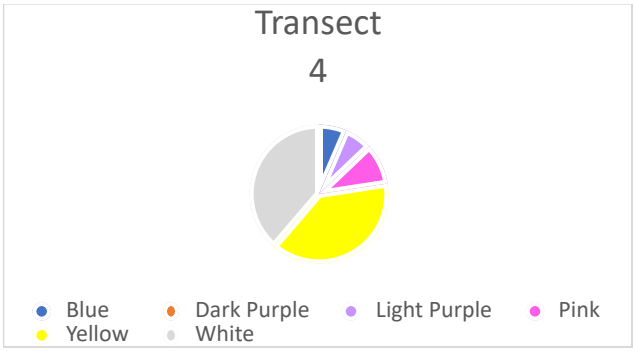
While completing the survey, I became curious on the role flower colors play in each plot. Bloom color is a key factor for pollination. Different insect species are attracted to different colors because their eyes pick up a variety of color wavelengths. For example, flies lack color vision, so they are attracted to yellow and white flowers because they contrast against the green surroundings (Long, 2022). Bees cannot see red but can pick up purple, violet, and blue very well (Maxwell, 2022). Birds, like hummingbirds, are more attracted to red and orange flowers. Keep this in mind for later. Color is not the only variable when it comes to pollination success. The diversity of flower shapes also attracts specific pollinators and is another way flowers create relationships with specific pollinators (U.S. Department of the Interior, 2015). Even though flower shape plays an important role, I focused on color.

For this analysis, I grouped the species in each plot into six color groups: White, Yellow, Blue, Pink, Light Purple, and Dark Purple. I then took the percentage of each color within a plot and displayed it on a pie chart. It is important to note that all my observations are speculative. There is not enough data to make confident conclusions. Here are the results:









In every plot, white and yellow were the most common colors. Transect one and three have more purple flowers than Transect two and four. Purple flowers may be more common in vegetated riparian environments where yellow and white flowers do well on bare, sunny slopes. These results indicate that flies prefer hot, less vegetated areas, and bees stick to denser, colder areas.

One study completed by the horticultural department at the University of Wisconsin found the most common pollinators in alpine environments are bumble bees, solitary bees, flies, and moths (Brunet, 2009). This study can show why apline flowers are mostly white, yellow, purple, and pink.

In 2023, most rainfall came in the early summer. It was then dry until some storms came through in August. The first flowers that bloom are often white and yellow when flies are at their peak (Long, 2022). The early rainfall could have played a role in the large percentage of yellow and white flowers.

Pink flowers are found in every transect but are not as common. Pink is very close to red on the color wheel and could attract a smaller variety of pollinators. Blue is the least common color. There were only two flowers in this category: Forget-Me-Nots and Alpine Bluebells. I do not know why true blue is a rare color in the alpine, but it does make those two flowers more unique.

References:

Arroyo, M. T., Tamburrino, Í., Pliscoff, P., Robles, V., Colldecarrera, M., & Guerrero, P. C. (2021). Flowering Phenology Adjustment and flower longevity in a South American alpine species. *Plants*, *10*(3), 461. https://doi.org/10.3390/plants10030461

Brunet, J. (2009). Pollinators of the Rocky Mountain Columbine: Temporal variation, functional groups and associations with floral traits. *Annals of Botany*, *103*(9), 1567–1578. https://doi.org/10.1093/aob/mcp096

Long, D. L. (2022, March 24). *Why are the first flowers of spring often white or yellow?*. The Earth is Good . https://donnallong.com/first-flowers-of-spring-often-white-or-yellow/

Maxwell , D. (2022, March). *Which Flower Colors Best Attract Pollinators and Birds?* . Illinois Extension . https://extension.illinois.edu/sites/default/files/what_are_the_best_flower_colors_to_attract_pollinators-1.pdf

U.S. Department of the Interior. (n.d.). *Pollinators*. National Parks Service. https://www.nps.gov/romo/learn/nature/pollinators.htm