# Metadata file for David Inouye's database on flowering phenology at the Rocky Mountain Biological Laboratory (RMBL)

*September 2015*

## General background

This study of flowering phenology was initiated in 1973 by a group that included Nick Waser, Graham Pyke, Susan Calder, Ruth Wagner, Bonnie Inouye, and David Inouye. We each took a different habitat and established a series of 2x2-m plots, and then counted the flowers every other day for as much of the season as we were in residence in Gothic. After 1973 I took over the plots that Pyke had started, and data have been collected from those plots and David's original set for most years since 1973. No data were collected in 1978 when I was in Austria, and in 1990 when I was working at the University of Colorado's Mountain Research Station (and collecting phenological data there). In 1989 most data were collected by Amy Seidel and Carol Ann Kearns (I was at MRS). In most other years some data were collected by other assistants or volunteers; there are usually notes in each spreadsheet file indicating when this occurred. It is not uncommon for there to have been a jump up or down in numbers of flowers counted when there was a change in the person collecting data, as sometimes slightly different subjective criteria were applied for when to count flowers as still good or not.

Data were only collected in 1973 for plots monitored by Calder and Wagner and the data may have been lost. Data for Bonnie Inouye's plots (mostly in the spruce bog on the west side of the East River across from the Enders Dining Hall) were collected until about 1980; some of these data have been transcribed into spreadsheets and all of them are on paper records in David Inouye's possession. Waser has his records on paper. All of my earlier data have been transcribed into spreadsheets (originally SuperCalc and then Excel), and through about 1990 are available as summarized paper records (which were used to generate the spreadsheets). Data through 1996 were stored in SuperCalc spreadsheets, but because this program was orphaned I began to use Excel instead, and have converted the older files to Excel (via Lotus 1-2-3 as an intermediate in order to preserve the formulas in each cell).

## David Inouye's plots

The habitat in which I established plots in 1973 was 'Rocky Meadow.' Seven plots were established in this habitat on 22 June, including one along the Copper Creek road just uphill from the Ehrlich cabin (plot RM7), and six others (RM1 – RM6) in the first clearing going north on Forest Service trail 401 (on RMBL property). Two additional plots were established on 10 July 1973 in aspen forest: Plot 9 in the forest along trail 401 between the trailhead and the meadow with plots RM1-RM6, and Plot 8 along the snowmelt stream that crosses trail 401 at the north end of the meadow with plots RM1-RM6 (even though these are in the aspen forest I usually refer to them as 'Rocky Meadow' plots as they're part of that sequence of plots. Each plot is 2x2 m, with corners marked with wooden stakes or pieces of rebar. In the spring each plot is marked with string around the corners.

Since 1974 I have also collected data from the plots established by Graham Pyke in 1973, which included 5 designated as 'Wet Meadow', 5 'Willow-Meadow Interface', and 2 '*Erythronium* Meadow.' In 1974 I also established two new plots, '*Veratrum* Removal' plots in which I pulled out all emerging stalks of *Veratrum californicum*; I have continued to remove new stalks as they appeared over the years and I think there are annotations in the spreadsheets when this occurred; the *Veratrum* has not reinvaded once the original plants ceased putting up new shoots. I established these out of curiosity to see what plants might replace the *Veratrum* and whether *Veratrum* would subsequently regrow in the plots (Given what I've since learned, that the species is clonal but only following flowering, that flowering is infrequent, and that the growth of the root is only several mm/yr, it's not surprising that they haven't re-appeared yet in the plots). The *Erythronium* and *Veratrum* Removal plots are located on John Tuttle's property, adjacent to the RMBL south boundary and on the west side of County Road 317 (between the road and the East River). In 1985 I established two "Greenhouse" plots, with 2x4 frames and plastic to cover them. I covered the plots in 1985 and 1986, but not again since then. In 1998 three additional Greenhouse plots were established, so that there is now one near each of the pairs of Wet Meadow and Willow-Meadow Interface plots. Note that the original Greenhouse Plot #1 was near Wet Meadow and Willow-Meadow plots #1, and Greenhouse plot #2 was next to Wet Meadow and Willow-Meadow plots #5. To prevent confusion about these original greenhouse plots I left their numbers alone and put Greenhouse plot #3 near WM2, Greenhouse plot #4 near WM3, and Greenhouse plot #5 near WM4. GPS locations for all plots are shown below.

In October 1984 the county road crew built up the county road a few feet in the section near the plots on Tuttle's property (to get rid of big potholes that cars got stuck in), and about 80% of Veratrum Removal plot #2 was driven over by a bulldozer, not scraped too much. There was probably a significant increase in dandelions after that.

Starting in 1987 RMBL has fenced the meadow that encloses the Wet Meadow, Willow-Meadow Interface, and Greenhouse plots, to keep cattle out in the fall.

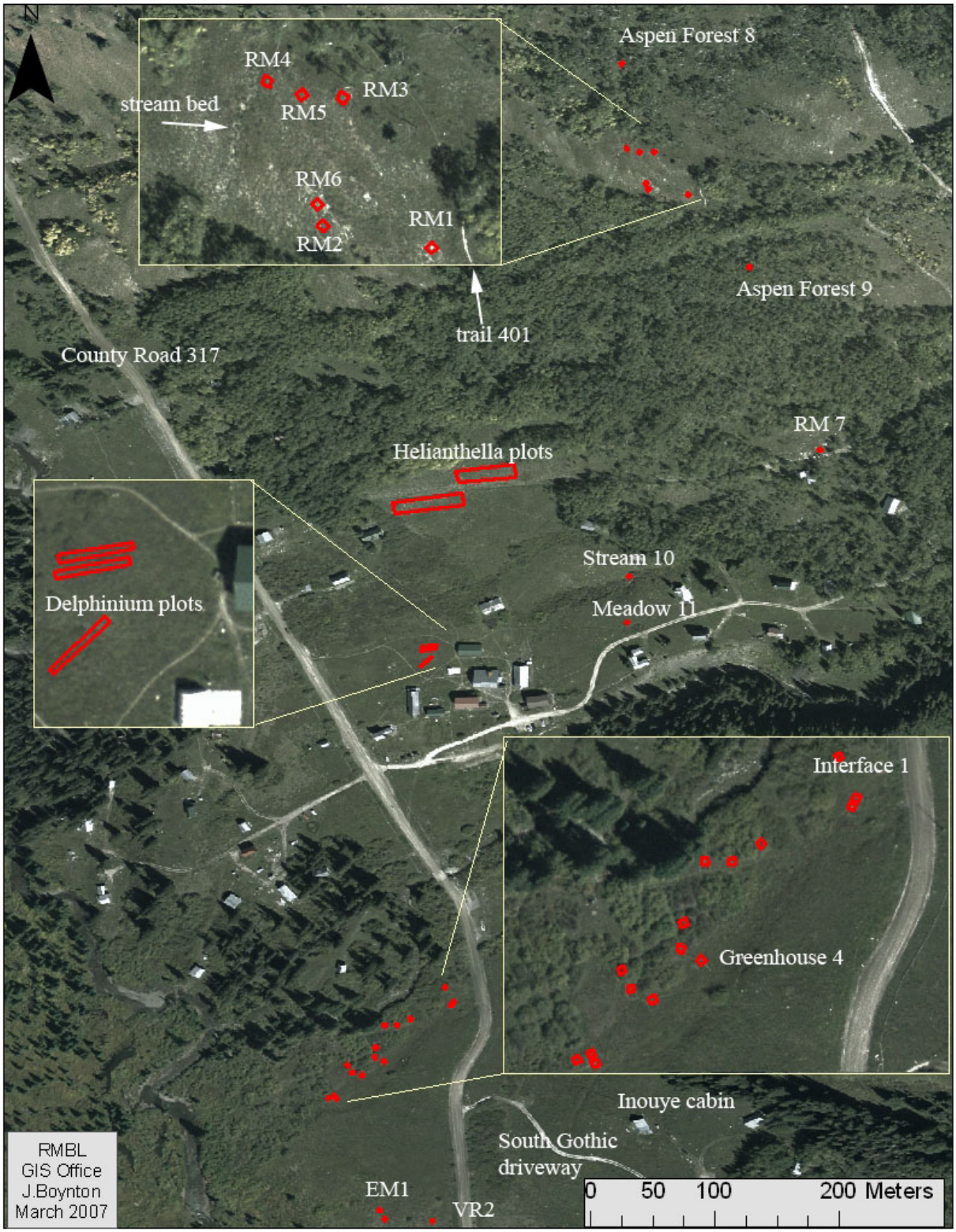
An aerial photograph with the plots indicated is shown below. The order in which I typically checked them is given in the following list, and indicated for most of these plots by the lines connecting them in the accompanying maps:

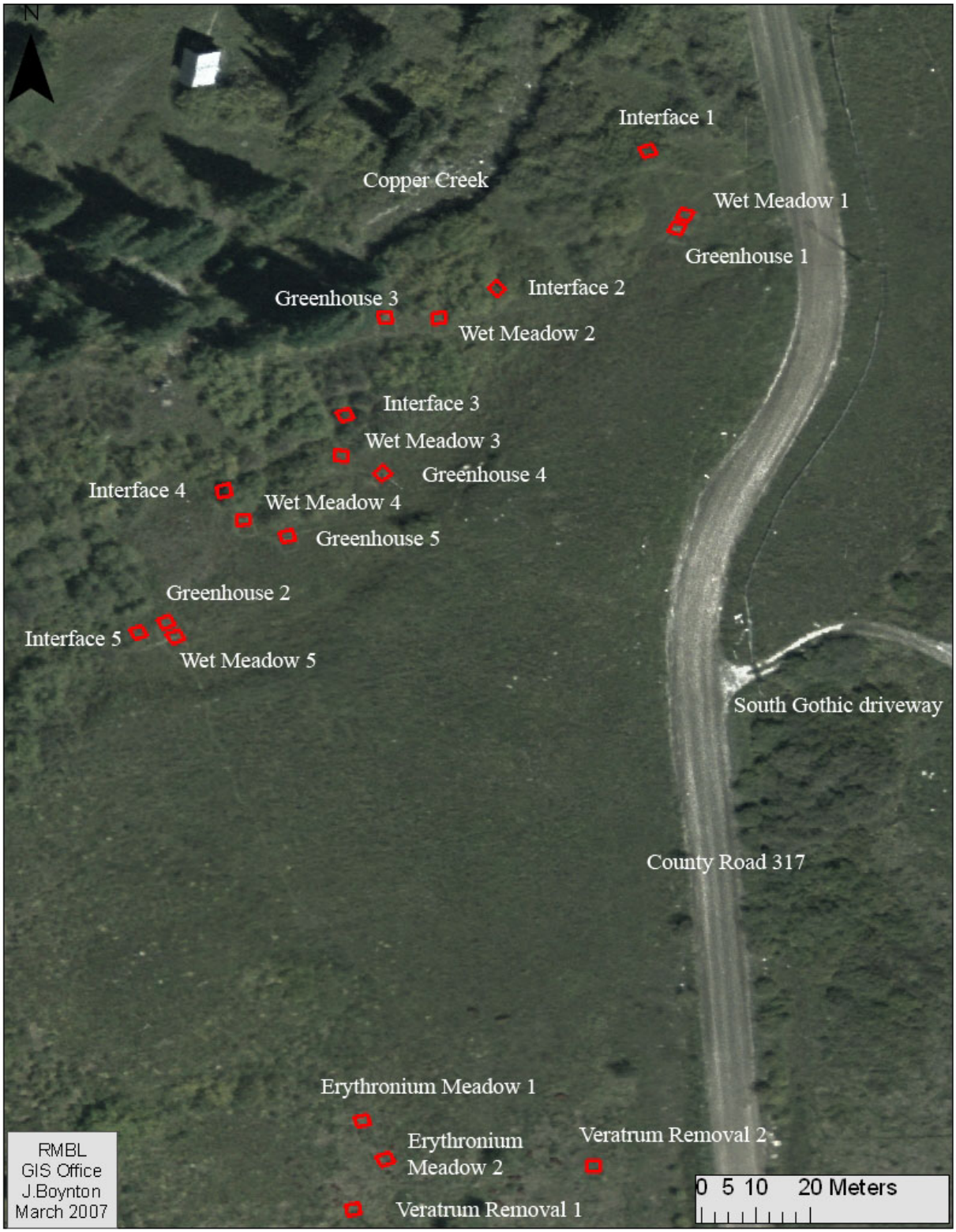
Stream plot #1
Rocky Meadow #7 (by the Ehrlich cabin on the Copper Creek trail)
Aspen Forest #9 (actually in aspen forest just west of trail 401)
Rocky Meadow #1
Rocky Meadow #2
Rocky Meadow #6
Rocky Meadow #3
Rocky Meadow #5
Rocky Meadow #4
Aspen Forest #8 (actually in aspen forest, east of trail 401)
Meadow plot #1; new in 2004, not shown on map below

Stream plot #1, established in 2004, is at the top of the stream drainage between the Ouray and Richards cabins (labeled as Stream plot #10 on aerial photo below). If you walk up the path

toward Treasury cabin, and then cut over below Ouray cabin to the willows and stream, you should find the plot. The other new plot (Meadow plot #11; also new in 2004) is near the Enders cabin. If you walk down the road from by the water treatment plant, past Mount Emmons cabin and Gates cabin (I usually cut down that way on the way back from the Rocky Meadow plots), take the path that starts near the Enders cabin and goes toward Weese lab. A few meters down that path and on the right a few meters is the plot.

Willow-Meadow Interface #1
Wet Meadow #1
Greenhouse #1
Willow-Meadow Interface #2
Wet Meadow #2
Greenhouse #3
Willow-Meadow Interface #3
Wet Meadow #3
Greenhouse #4
Greenhouse #5
Wet Meadow #4
Willow-Meadow Interface #4
Greenhouse #2
Wet Meadow #5
Willow-Meadow Interface #5
Erythronium Meadow #1
Erythronium Meadow #2
Veratrum Removal #1
Veratrum Removal #2


N
RM4
RM3
RM5
stream bed
RM6
RM1
RM2
Aspen Forest 8
Aspen Forest 9
trail 401
County Road 317
RM 7
Helianthella plots
Delphinium plots
Stream 10
Meadow 11
Interface 1
Greenhouse 4
Inouye cabin
South Gothic
driveway
EM1
VR2
RMBL
GIS Office
J.Boynton
March 2007
0 50 100 200 Meters


N
Interface 1
Copper Creek
Wet Meadow 1
Greenhouse 1
Interface 2
Greenhouse 3
Wet Meadow 2
Interface 3
Wet Meadow 3
Greenhouse 4
Interface 4
Wet Meadow 4
Greenhouse 5
Greenhouse 2
Interface 5
Wet Meadow 5
South Gothic driveway
County Road 317
Erythronium Meadow 1
Erythronium Meadow 2
Veratrum Removal 2
Veratrum Removal 1
RMBL GIS Office J.Boynton March 2007
0 5 10 20 Meters

**Some history about each plot**

Stream plot #1
Rocky Meadow #7 (by the Ehrlich cabin on the Copper Creek trail) – One of the original plots established in 1973 by DWI.
Aspen Forest #9 (actually in aspen forest just west of trail 401) – One of the original plots established in 1973 by DWI, a little later than other plots.
Rocky Meadow #1 – One of the original plots established in 1973 by DWI.
Rocky Meadow #2 – One of the original plots established in 1973 by DWI.
Rocky Meadow #6 – One of the original plots established in 1973 by DWI.
Rocky Meadow #3 – One of the original plots established in 1973 by DWI.
Rocky Meadow #5 – One of the original plots established in 1973 by DWI.
Rocky Meadow #4 – One of the original plots established in 1973 by DWI.
Aspen Forest #8 (actually in aspen forest, east of trail 401) – One of the original plots established in 1973 by DWI, a little later than other plots.

Meadow plot #1 – A new established in 2004 to capture a few species not already in plots, not shown on map below. Plot corners were removed in fall 2012 when road construction was going on, and plot had to be re-found in 2013.

The plots below were mostly established and counted by Graham Pyke in 1973, but then taken over by David Inouye in 1974.

Willow-Meadow Interface #1 – One of the original plots established in 1973 by Graham Pyke.
Wet Meadow #1 – One of the original plots established in 1973 by Graham Pyke.
Greenhouse #1 – One of the original plots established in 1973 by Graham Pyke.
Willow-Meadow Interface #2 – One of the original plots established in 1973 by Graham Pyke.
Wet Meadow #2 – One of the original plots established in 1973 by Graham Pyke.
Greenhouse #3 – One of the original plots established in 1973 by Graham Pyke.
Willow-Meadow Interface #3 – One of the original plots established in 1973 by Graham Pyke.
Wet Meadow #3 – One of the original plots established in 1973 by Graham Pyke.
Greenhouse #4 – One of the original plots established in 1973 by Graham Pyke.
Greenhouse #5 – One of the original plots established in 1973 by Graham Pyke.
Wet Meadow #4 – One of the original plots established in 1973 by Graham Pyke.
Willow-Meadow Interface #4 – One of the original plots established in 1973 by Graham Pyke.
Greenhouse #2 – One of the original plots established in 1973 by Graham Pyke.
Wet Meadow #5 – One of the original plots established in 1973 by Graham Pyke.
Willow-Meadow Interface #5 – One of the original plots established in 1973 by Graham Pyke.
Erythronium Meadow #1 – One of the original plots established in 1973 by Graham Pyke.
Erythronium Meadow #2 – One of the original plots established in 1973 by Graham Pyke.
Veratrum Removal #1 – Established by David Inouye in 1974 after he took over Pyke plots.
Veratrum Removal #2 – Established by David Inouye in 1974 after he took over Pyke plots.

**Data collection**

Data collection consists of visiting each plot approximately every other day for as much as the growing season as I am in residence in Gothic. In some years I have hired someone (often the winter caretakers) to collect data before or after I was in Gothic (e.g., 1995 – 2006, with funding from NSF). For some years I have data on the progression of snow melt in the plots, in order to record when the ground becomes bare. In October of 2006 I put Hobo Pendant loggers (Onset Computer Corp., measure light and temperature) in each plot in order to record dates of the beginning and end of snow cover.

During each census I record the number of flowers of every species in bloom, and make incidental notes about other events such as gopher activity, frost damage, herbivory by deer, and seed dispersal. Flowers in the plot that originate from stems outside the plot are not counted (e.g., there are often *Salix* stems in willow-meadow interface plots that can be traced back to where they emerge from the ground outside the plot; flowers on these stems aren't counted). Flowers on stems that originate in the plot but then grow outside the edges are counted. Data on flowering are usually recorded as frequency distributions of flowers open per stalk or per inflorescence, and these distributions are summarized in the spreadsheets as formulas within cells. The criteria used to decide whether or not to count a flower as open or still good depend on the species, but I typically use cues such as petal condition (wilted or not), petal coloration, presence of pollen (e.g., *Achillea millefolium*), presence of open stigmas (e.g., on florets of Asteraceae), or dehiscing anthers (e.g., grasses, *Thalictrum fendleri*). A few species are difficult, either because they don't have good morphological cues as to when they are flowering (such as *Gnaphalium uliginosum*), and some of the annual species are either small inconspicuous plants or have inconspicuous flowers (e.g., *Polygonum douglasii*, *Polygonum aviculare*, *Chaenopodium* sp., *Galium bifolium*.

It's probably best to make the counts in the morning, after sun has been on the plots long enough that flowers have opened (e.g., *Taraxacum* flowers close at night). *Linum lewisii*, for example, may start dropping petals by sometime in the afternoon, especially if it's windy. Similarly, if it's cold and rainy (or snowing) it may not be worth checking the plots as some species will not have open flowers on such days. Although the previous year's data for a plot are a good guide to what species are likely to occur in a plot in the current year, and also give a good idea about the sequence of flowering, there may be additional species that appear for the first time or after a long absence. E.g., *Orobanche fasciculata* in plot RM7, or some inconspicuous *Carex* species or small annuals.

**Spreadsheet structure**

I have created a separate spreadsheet for each plot for each year. A separate column is used for each census date, and there are typically two cells (on adjacent rows) for each species for each date. The upper of these two cells records the number of open flowers or inflorescences (e.g., grasses). After the first several years of data these numbers are shown as the calculated totals from a formula that gives the frequency distribution of flowers per some unit (typically inflorescence); the frequency distribution data from the earliest years, when data were recorded only on paper, are no longer available. For example, the formula for 12 plants (or inflorescences), each with 1 open flower, 22 plants (or inflorescences) with 2 flowers, and 43

plants (or inflorescences) with 3 open flowers is: 1*12+2*22+3*43; i.e., the first number of each pair that is multiplied is the number of open flowers and the second number is the number of plants (or inflorescences) with that number of open flowers. Additional detail is shown in the spreadsheets (e.g., about whether numbers represent inflorescences or plants). Summary calculations within each spreadsheet include the total number of flowers of all species open on a given day, the length of the flowering period for each species, and the maximum number of flowers and/or plants (or inflorescences) open on one day during the season. For some of the earlier years the spreadsheets include calculations of a diversity index (H'). The spreadsheets "published on the RMBL web site and at the Digital Repository at the University of Maryland have grass species and their data in red, and species that were outside the plots (but nearby) in blue. Species shown on the spreadsheets that were outside the plots are not include in the summary statistics.

If no data were collected on a particular census date for a particular species that was probably still in bloom, an X is entered in the appropriate cell. This happened, for example, if it was raining and flowers were not open, or if the data collector forgot to count the species. In some cases (e.g., *Salix* in some years) floral units were not counted, but the fact that they were in bloom was indicated with an X. In earlier years on some dates individual flowers weren't counted if there were a lot of them, although the number of inflorescences was counted; note that these gaps have consequences for calculations of the maximum number of flowers open on a given date, and calculations of the peak number of flowers open during the flowering period for that species. For a few species in early years (e.g., *Arenaria conjesta*, *Claytonia lanceolata*) I did not keep track of how many plants were in bloom, just total number of flowers in bloom in the plot. In some cases I did not originally count flowers on inflorescences (e.g., *Arenaria conjesta*), and only counted the number of inflorescences in bloom. In a very few cases I indicated the percentage of plants that were in bloom (or it may have been the percentage of buds that were open), but later began to count individual flowers (e.g., *Mahonia repens*).

Information is given below about individual species in the plots and how they were counted, but as generalizations:

Apiaceae – typically counted as stems with open flowers on their umbels.

Asteraceae – typically counted at the level of capitulum, or capitulum/stalk.

Poaceae – grasses are typically counted as individual flowering culms, not flowers.

If there was a gap in flowering of greater than about 8 days, two different values are usually given for the length of flowering, for the first and second flowering periods. In a few cases where the beginning of flowering was missed, I made educated guesses as to the actual length of flowering period (indicated in a separate column labeled 'best guess').

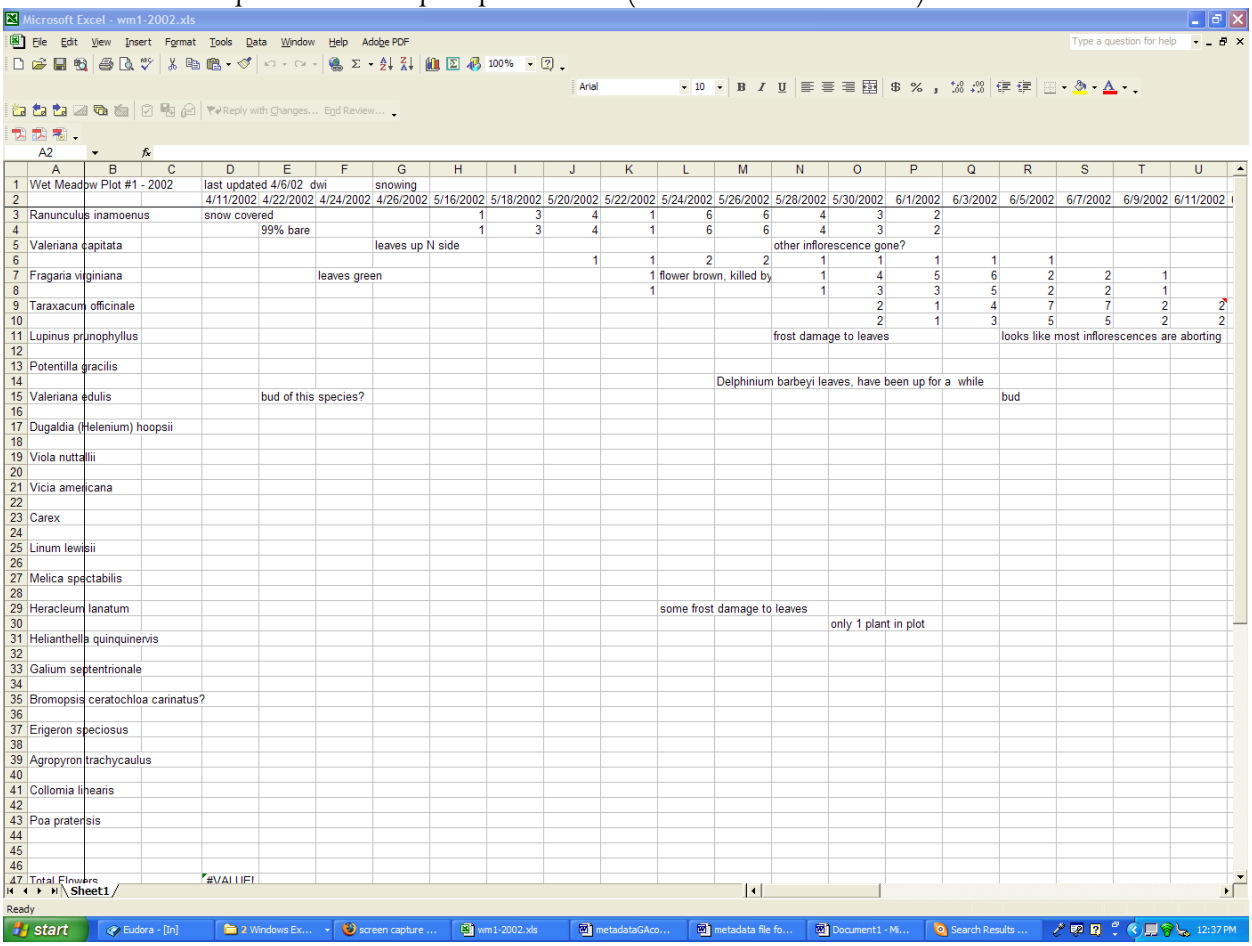
There are occasional notes about weather, e.g., whether it was snowing or raining on a particular census date; these are typically in a cell below the one with the date. In later years, when either I was in residence for the winter or hired an assistant to begin monitoring as the snow melted, there are records of snowpack depth in the plots and the date when snow melted is indicated. There are also notes about who assisted with data collection (in later years, the dates when this occurred are indicated), and after the first few years, estimates of the total amount of plot area covered by gopher dumps deposited in the winter. In plots not protected from grazing, there may also be notes about the deposition of cowpies (typically I did not remove them). Rocky Meadow Plot #8 has a temporary snow-melt stream that runs through

it, and I usually have notes about when the stream dried up. The same stream runs just below Rocky Meadow Plot #4, and I usually have notes about when the stream dries up at that point. In a few cases I removed dead branches that fell in plots, and in a few years I trimmed some of the willow branches to maintain the interface plots as part uncovered meadow; these events are typically noted.

I have used color in the Excel spreadsheets (which also shows in the PDF files of those spreadsheets): grasses are shown in red, and species that were outside the plot are shown in blue. Data for species outside the plot are not included in summary statistics (e.g., number of flowers on each date, number of species in bloom on each date). I have also used the note feature of Excel in some cases, and these notes do not show up in the PDF files. I have not yet found a convenient way to include that information in an ASCII version of the files.

I have additional summary spreadsheets for each species that include data on first date of flowering, maximum number of flowers and stalks/plants, and length of flowering period.

Here's a screen capture of a sample spreadsheet (for data 1973 to 2009):



**Policy on use of these data**

I collected many years of these data mostly as a side project while concentrating on other projects at RMBL. NSF funding I have received for this project includes an LTREB grant from 1995 – 1997, another from 2003 – 2008, and a current one that was awarded in 2009. My intention is to publish, either on my own or in collaboration with my graduate students (e.g, Inouye et al. 2003), postdoctoral associates (e.g., Inouye and McGuire 1991, Inouye et al. 2002, Aldridge et al. 2011), or others, a variety of types of analyses of the available data. I am open to collaboration with anyone on any aspect of the dataset, but would like to have the option of co-authorship in recognition of my effort in collecting and summarizing the data.

**Publications using these data, as of July 2015 (n = 28):**


Inouye, D. W. 1988. Natural variation in plant and animal populations, and its implications for studies of recovering ecosystems. Pages 39-50 in Cairns, J., editor. Rehabilitating Damaged Ecosystems. CRC Press. Second edition 1995.

Inouye, D. W., and G. H. Pyke. 1988. Pollination biology in the Snowy Mts. of Australia, with comparisons with montane Colorado, U.S.A. Australian Journal of Ecology 13:191-210.

Inouye, D. W., W. A. Calder and N. M. Waser. 1991. The effect of floral abundance on feeder censuses of hummingbird populations. Condor 93:279-285.

Inouye, D. W. and A. D. McGuire. 1991. Effects of snowpack on the timing and abundance of flowering in *Delphinium nelsonii*: implications for climate change. American Journal of Botany 78(7):997-1001.

Inouye, D. W., M. Morales, and G. Dodge. 2002. Variation in timing and abundance of flowering by *Delphinium barbeyi* Huth (Ranunculaceae): the roles of snowpack, frost, and La Niña, in the context of climate change. Oecologia 130: 543-550.

Inouye, D. W., F. Saavedra, and W. Lee-Yang. 2003. Environmental influences on the phenology and abundance of flowering by *Androsace septentrionalis* L. (Primulaceae). American Journal of Botany 90(6):905-910.

Saavedra, F., D. W. Inouye, M. V. Price and J. Harte. 2003. Changes in flowering and abundance of *Delphinium nuttallianum* (Ranunculaceae) in response to a subalpine climate warming experiment. Global Change Biology 9: 885-894.

Inouye, D. W., and F.-E. Wielgolaski. 2003. Phenology of high-altitude climates. Pages 195-214 in: Phenology: An Integrative Environmental Science (M. D. Schwartz, ed.) Kluwer Academic.

Morales, M. A., G. J. Dodge, and D. W. Inouye. 2005. A phenological mid-domain effect in flowering diversity. Oecologia (published online 6 August 2004) 142(1): 83-89.

Inouye, D. W. 2008. Consequences of climate change for phenology, frost damage, and floral abundance of sub-alpine wildflowers. Ecology 89(2): 353-362.

Miller-Rushing, A. J. and D. W. Inouye. 2009. Variation in the impact of climate change on flowering phenology and abundance: An examination of two pairs of closely related wildflower species. American Journal of Botany 96:1821-1829.

Forrest, J., D. W. Inouye, and J. D. Thomson. 2010. Flowering phenology in subalpine communities: Does climate variation reshuffle species assemblages? Ecology 91(2):431-440.

Lambert, A., A. J. Miller-Rushing, and D. W. Inouye. 2010. Changes in snowmelt date and summer precipitation affect the flowering phenology of *Erythronium grandiflorum* Pursh (glacier lily, Liliaceae). American Journal of Botany 97(9): 1431–1437.

Aldridge, G., D. W. Inouye, J. R. K. Forrest, W. A. Barr, and A. J. Miller-Rushing. 2011. Emergence of a mid-season period of low floral resources in a montane meadow ecosystem associated with climate change. Journal of Ecology. DOI: 10.1111/j.1365-2745.2011.01826.x

Inouye, D. W. 2011. Effects of frost on wildflowers: an unexpected consequence of climate change. EcoEd Digital Library http://ecoed.esa.org/ [collection of 22 photographs and graphs]

Boggs, C. L., and D. W. Inouye. 2012. A single climate driver has direct and indirect effects on pollinator numbers. Ecology Letters 15(5):502-508. [Rated "must read" by Faculty of 1000]

Anderson, J. T., D. W. Inouye, A. McKinney, and T. Mitchell-Olds. 2012. Phenotypic plasticity and adaptive evolution contribute to advancing flowering phenology in response to climate change. Philosophical Transactions of the Royal Society 279(1743): 3843-3852. [Rated "must read" by Faculty of 1000]

McKinney, A. M., P. J. CaraDonna, D. W. Inouye, b. barr, D. Bertelson, and N. M. Waser. 2012. Asynchronous changes in phenology of migrating Broad-tailed Hummingbirds and their early-season nectar resources. Ecology 93(9):1987-1993.

Pyke, G. H., D. W. Inouye, and J. D. Thomson. 2012. Local geographic distributions of bumble bees near Crested Butte, Colorado: Competition and community structure revisited. Environmental Entomology 41(6):1332-49.

Iler, A. M., and D. W. Inouye. 2013. Effects of climate change on mast-flowering cues in a clonal montane herb, *Veratrum tenuipetalum* (Melanthiaceae). Amer. J. Bot. 100:1-7.

Iler, A. M., T. T. Høye, D. W. Inouye, and N. M. Schmidt. 2013. Long-term trends mask variation in the direction and magnitude of short-term phenological shifts. Amer. J. Bot. 100(7): no pages yet.

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Mazer, S. J., S. E. Travers, B. I. Cook, T. J. Davies, K. Bolmgren, N. J. B. Kraft, N. Salamin, and D. W. Inouye. 2013. Flowering date of taxonomic families predicts phenological sensitivity to temperature: Implications for forecasting the effects of climate change on unstudied taxa. Amer. J. Bot. 100(7):1381-1397.

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CaraDonna, P. J., A. M. Iler, and D. W. Inouye. 2014. Shifts in flowering phenology reshape a subalpine plant community. Proc. Nat. Acad. Sci. (USA) 111(13): 4916-4921. [Recommended by Faculty of 1000]

Fagan, W. F., S. Bewick, S. Cantrell, C. Cosner, I. G. Varassin, and D. W. Inouye. 2014. Phenologically explicit models for studying plant-pollinator interactions under climate change. Theoretical Ecology 7:289-297.

Wright, Karen W., K. L. Vanderbilt, D. W. Inouye, C. D. Bertelsen, and T. M. Crimmins. 2015. Turnover and reliability of flower communities in extreme environments: Insights from long-term phenology data sets. Journal of Arid Environments 115:27-34.

CaraDonna, P. J. and D. W. Inouye. 2015. Phenological responses to climate change do not exhibit phylogenetic signal in a subalpine plant community. Ecology 96(2):355-361.

**Published abstracts**

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Inouye, D. W. 1987. The relative contributions of different components of flowering phenology to overall variation in flowering. American Journal of Botany 74(5):652.

Inouye, D. W. 1989. Environmental control of variation in flowering by two *Delphinium* species in montane Colorado. American Journal of Botany 76 (supplement):108-109.

Inouye, D. W. and A. D. McGuire. 1990. Environmental control of the timing and abundance of flowering of *Delphinium nelsonii* (Ranunculaceae) in subalpine meadows of Colorado. Bulletin of the Ecological Society of America 71(2):197-198.

Inouye, D. W. 1991. Quantitative variation in flowering by *Delphinium barbeyi* (Ranunculaceae): environmental determinants and consequences for flower visitors. American Journal of Botany 78(6 supplement):57-58.

Inouye, D. W. 1995. Long-term studies of flower abundance and floral diversity: How long is long enough? Supplement to Bulletin of the Ecological Society of America 76(2):128.

Lee, W. and D. W. Inouye. 1997. Temporal and quantitative variation in a long-term study of flowering by *Androsace septentrionalis* L. (Primulaceae). Supplement to Bulletin of the Ecological Society of America 78(4):129.

Inouye, D. W. 1999. The effects of winter snowpack and frost on timing and abundance of flowering by *Erigeron speciosus*, a long-lived perennial from the Colorado Rocky Mountains. Abstracts of the 84th Annual Meeting, Ecological Society of America.

Inouye, D. W. 2000. The effects of late spring frosts on the diversity and abundance of flowering in sub-alpine meadows. Abstracts of the 85th Annual Meeting, Ecological Society of America.

Boggs, C. L., and D. W. Inouye. 2000. Weather-driven resource availability controls butterfly population dynamics. Abstracts of the 85th Annual Meeting, Ecological Society of America.

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Inouye, D. W. 2000. Loss of synchrony between high- and low-altitude flowering phenology due to climate change. **And**, The phenological consequences of climate change for high- altitude hibernating and migratory species. Presentation and poster at "Progress in Phenology – Monitoring, Data Analysis, and Global Change Impacts". Held 4-6 October in Freising, Germany (Technisches Universität München).

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Inouye, D. W. 2014. ESA Annual Meeting. Long-term data provide context for interpretation of ecological interactions.

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**Related data sets**

I have monitored flowering by *Helianthella quinquenervis* (Asteraceae; Aspen sunflower) in two plots in Gothic since 1974.

Inouye, D. W. and O. R. Taylor. 1979. Annual variation in flower production and predation on *Helianthella quinquenervis*, a temperate region ant-plant. Bulletin of the Ecological Society of America 60: 116-117.

I have monitored flowering by *Frasera speciosa* (Gentianaceae; Monument plant) in the East River valley since 1979, and by *Veratrum californicum* in an area near South Gothic since 1984.

I have created a spreadsheet summarizing a variety of weather data from the Crested Butte weather station for the months May – September since 1967. This weather station is about 9 km (5.7 miles) from RMBL (38°52'N / 106°59'W), at altitude 2702.1m (8865') above s/l. The spreadsheet also has some summaries of billy barr's winter snowpack data at the Rocky Mountain Biological Laboratory, and data from the Forest Service manual snowcourse on Mt. Crested Butte and the Snow-Tel on Mt. Crested Butte (an automated system for measuring water content of the snowpack). I have used these data for most of my analyses of the effects of environmental variables on the timing and abundance of flowering.

**GPS coordinates and altitudes for the plots**.

GPS coordinates and altitudes for David W. Inouye's phenology plots at the Rocky Mountain Biological Laboratory. Plots are 2x2m. Location data were recorded on 1 August 2006 by Jessica Boynton (RMBL GPS/GIS technician), Patty Coffin (research assistant) and David Inouye, using a TopCon Hiper Pro, a survey-grade GPS unit with RTK (real-time kinematic) millimeter precision. (Jessica Boynton writes: "The specs for precision are 10-15mm, but I have found that typically you get around 20mm.) Latitude (north) and Longitude (east) are reported as decimal degrees. Readings were taken on top of the steel (typically half-inch concrete

reinforcement rod - "rebar"), which are at various heights above ground level, but typically 10-20 cm); this may contribute in part to the variation in altitude among plot corners, but most of the Rocky Meadow plots are on uneven terrain.

Rocky Meadow plot #7 (only 3 corners marked with steel stakes; one doesn't have enough soil to hold a stake). Just above the Copper Creek trail, close to the Ehrlich cabin.

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 205 | Rocky Meadow 7 | Southwest | 9604.516 | 2927.46 | 38.96007556 | 106.98564488 |
| 206 | Rocky Meadow 7 | Northwest | 9605.620 | 2927.79 | 38.96009195 | 106.98565317 |
| 207 | Rocky Meadow 7 | Southeast | 9604.938 | 2927.59 | 38.96008211 | 106.98562372 |

Aspen Forest plot #9 (may sometimes have been referred to as Rocky Meadow plot #9 as it is part of the Rocky Meadow set of plots, but it is in aspen understory a few m west of Forest Service trail 401 on property of the Rocky Mountain Biological Laboratory). The wide range in altitude of plot corners is probably an artifact of a smaller number of satellites used due to interference from the surrounding trees.

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 233 | Aspen Forest 9 | Northwest | 9703.737 | 2957.70 | 38.96141987 | 106.98615420 |
| 234 | Aspen Forest 9 | Northeast | 9705.699 | 2958.30 | 38.96141858 | 106.98613776 |
| 235 | Aspen Forest 9 | Southeast | 9712.341 | 2960.32 | 38.96139902 | 106.98612296 |
| 236 | Aspen Forest 9 | Southwest | 9709.846 | 2959.56 | 38.96141092 | 106.98616737 |

Jessica Boynton (RMBL GPS/GIS technician) wrote: In terms of the points w/varying elevations, I believe that points 233 and 234 are more accurate (based on viewing them on a map) than 235 and 236. I think that 235 is the least accurate point.

Rocky Meadow plot #1.

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 208 | Rocky Meadow 1 | Southwest | 9730.166 | 2965.75 | 38.96192152 | 106.98659164 |
| 209 | Rocky Meadow 1 | Northwest | 9732.400 | 2966.44 | 38.96193295 | 106.98660717 |
| 210 | Rocky Meadow 1 | Northeast | 9733.978 | 2966.92 | 38.96194489 | 106.98659060 |
| 211 | Rocky Meadow 1 | Southeast | 9731.739 | 2966.23 | 38.96193290 | 106.98657440 |

Rocky Meadow plot #2 (only 3 corners marked with steel stakes; one doesn't have enough soil to hold one).

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 212 | Rocky Meadow 2 | Southwest | 9731.867 | 2966.27 | 38.96196089 | 106.98687850 |
| 213 | Rocky Meadow 2 | Northwest | 9732.662 | 2966.52 | 38.96197211 | 106.98689632 |
| 215 | Rocky Meadow 2 | Northeast | 9734.362 | 2967.03 | 38.96198395 | 106.98688072 |

Rocky Meadow plot #6 (only 3 corners marked with steel stakes; one doesn't have enough soil to hold one).

| Point # | Plot name | Corner (compass | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|

| | | direction) | | | | |
|---|---|---|---|---|---|---|
| 216 | Rocky Meadow 6 | Southwest | 9735.003 | 2967.23 | 38.96200457 | 106.98689527 |
| 217 | Rocky Meadow 6 | Northwest | 9734.954 | 2967.21 | 38.96201794 | 106.98691076 |
| 218 | Rocky Meadow 6 | Northeast | 9736.682 | 2967.74 | 38.96203011 | 106.98689487 |

Rocky Meadow plot #3

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 219 | Rocky Meadow 3 | Southwest | 9744.735 | 2970.20 | 38.96222557 | 106.98683031 |
| 220 | Rocky Meadow 3 | Southeast | 9744.106 | 2970.00 | 38.96224163 | 106.98681930 |
| 221 | Rocky Meadow 3 | Northeast | 9744.380 | 2970.09 | 38.96225100 | 106.98683978 |
| 222 | Rocky Meadow 3 | Northwest | 9745.150 | 2970.32 | 38.96223433 | 106.98685016 |

Rocky Meadow plot #5

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 223 | Rocky Meadow 5 | Southest | 9744.349 | 2970.08 | 38.96224050 | 106.98692617 |
| 224 | Rocky Meadow 5 | Southwest | 9743.834 | 2969.92 | 38.96223000 | 106.98694455 |
| 225 | Rocky Meadow 5 | Northwest | 9743.764 | 2969.90 | 38.96224414 | 106.98695823 |
| 226 | Rocky Meadow 5 | Northeast | 9744.487 | 2970.12 | 38.96225538 | 106.98693969 |

Rocky Meadow plot #4

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 227 | Rocky Meadow 4 | Southeast | 9740.397 | 2968.87 | 38.96225706 | 106.98702683 |
| 228 | Rocky Meadow 4 | Southwest | 9738.723 | 2968.36 | 38.96226236 | 106.98704792 |
| 229 | Rocky Meadow 4 | Northwest | 9739.740 | 2968.67 | 38.96227966 | 106.98704417 |
| 230 | Rocky Meadow 4 | Northeast | 9741.138 | 2969.10 | 38.96227461 | 106.98702234 |

Aspen Forest plot #8 (may sometimes have been referred to as Rocky Meadow plot #8 as it is part of the Rocky Meadow set of plots, but is in fact aspen understory northeast of Forest Service trail 401 on property of the Rocky Mountain Biological Laboratory).

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 231 | Aspen Forest 8 | Southeast | 9752.097 | 2972.44 | 38.96286048 | 106.98706971 |
| 232 | Aspen Forest 8 | Northwest | 9755.397 | 2973.45 | 38.96289257 | 106.98707155 |
| 237 | Aspen Forest 8 | Northeast | 9754.430 | 2973.15 | 38.96288083 | 106.98705429 |
| 238 | Aspen Forest 8 | Southwest | 9755.151 | 2973.37 | 38.96287847 | 106.98708526 |

Stream plot #10

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 100 | Stream plot | Northwest | 9477.987 | 2888.89 | 38.95916790 | 106.98703187 |
| 101 | Stream plot | Northeast | 9479.319 | 2889.30 | 38.95918393 | 106.98702148 |
| 102 | Stream plot | Southwest | 9477.576 | 2888.77 | 38.95916009 | 106.98701160 |
| 103 | Stream plot | Southeast | 9479.491 | 2889.35 | 38.95917612 | 106.98700135 |

Meadow plot (Enders) #11

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 201 | Meadow (Enders) | South | 9483.003 | 2890.42 | 38.95882712 | 106.98702622 |
| 202 | Meadow (Enders) | West | 9482.520 | 2890.27 | 38.95883442 | 106.98704710 |
| 203 | Meadow (Enders) | North | 9482.983 | 2890.41 | 38.95885037 | 106.98703825 |
| 204 | Meadow (Enders) | East | 9483.393 | 2890.54 | 38.95884314 | 106.98701714 |

Willow-Meadow Interface plot #1

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 104 | Willow-Meadow Interface #1 | Southeast | 9417.541 | 2870.47 | 38.95619637 | 106.98833352 |
| 105 | Willow-Meadow Interface #1 | Southwest | 9417.420 | 2870.43 | 38.95618950 | 106.98835438 |
| 106 | Willow-Meadow Interface #1 | Northwest | 9417.722 | 2870.52 | 38.95620670 | 106.98836226 |
| 107 | Willow-Meadow Interface #1 | Northeast | 9418.011 | 2870.61 | 38.95621261 | 106.98834085 |

Wet Meadow plot #1

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 108 | Wet Meadow plot #1 | Northwest | 9417.316 | 2870.40 | 38.95610579 | 106.98829272 |
| 109 | Wet Meadow plot #1 | Northeast | 9417.486 | 2870.45 | 38.95609916 | 106.98827150 |
| 110 | Wet Meadow plot #1 | Southeast | 9417.380 | 2870.42 | 38.95608281 | 106.98828025 |
| 111 | Wet Meadow plot #1 | Southwest | 9417.150 | 2870.35 | 38.95608975 | 106.98830124 |

Greenhouse plot #1

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 112 | Greenhouse plot #1 | Northwest | 9417.160 | 2870.35 | 38.95608371 | 106.98830571 |
| 113 | Greenhouse plot #1 | Northeast | 9417.541 | 2870.47 | 38.95607717 | 106.98828502 |
| 114 | Greenhouse plot #1 | Southeast | 9417.420 | 2870.43 | 38.95606136 | 106.98829379 |
| 115 | Greenhouse plot #1 | Southwest | 9417.178 | 2870.36 | 38.95606720 | 106.98831527 |

Willow-Meadow Interface plot #2

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 116 | Willow-Meadow Interface #2 | Southeast | 9411.643 | 2868.67 | 38.95597158 | 106.98858374 |
| 117 | Willow-Meadow Interface #2 | Southwest | 9412.169 | 2868.83 | 38.95595835 | 106.98859909 |
| 118 | Willow-Meadow Interface #2 | Northwest | 9413.021 | 2869.09 | 38.95597232 | 106.98861380 |
| 119 | Willow-Meadow Interface #2 | Northeast | 9412.668 | 2868.98 | 38.95598444 | 106.98859959 |

Wet Meadow plot #2

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 120 | Wet Meadow #2 | Southeast | 9411.271 | 2868.5 | 38.95591461 | 106.98868370 |
| 121 | Wet Meadow #2 | Southwest | 9411.393 | 2868.59 | 38.95591369 | 106.98870659 |
| 122 | Wet Meadow #2 | Northwest | 9411.593 | 2868.65 | 38.95593087 | 106.98870759 |
| 123 | Wet Meadow #2 | Northeast | 9411.708 | 2868.69 | 38.95593224 | 106.98868477 |

Greenhouse plot #3

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 124 | Greenhouse plot #3 | Southeast | 9410.662 | 2868.37 | 38.95591479 | 106.98877263 |
| 125 | Greenhouse plot #3 | Southwest | 9410.199 | 2868.23 | 38.95591380 | 106.98879607 |
| 126 | Greenhouse plot #3 | Northwest | 9410.631 | 2868.36 | 38.95593199 | 106.98879676 |
| 127 | Greenhouse plot #3 | Northeast | 9411.011 | 2868.48 | 38.95593307 | 106.98877453 |

Willow-Meadow Interface plot #3

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 128 | Willow-Meadow Interface #3 | Northwest | 9408.525 | 2867.72 | 38.95576514 | 106.98886672 |
| 129 | Willow-Meadow Interface #3 | Southwest | 9408.326 | 2867.66 | 38.95574957 | 106.98885740 |
| 130 | Willow-Meadow Interface #3 | Northeast | 9408.377 | 2867.67 | 38.95577275 | 106.98884572 |
| 131 | Willow-Meadow Interface #3 | Southeast | 9409.198 | 2867.92 | 38.95575597 | 106.98883695 |

Wet Meadow plot #3

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 132 | Wet Meadow #3 | Northeast | 9408.502 | 2867.71 | 38.95570210 | 106.98884669 |
| 133 | Wet Meadow #3 | Southeast | 9408.219 | 2867.63 | 38.95568391 | 106.98884800 |
| 135 | Wet Meadow #3 | Southwest | 9408.227 | 2867.63 | 38.95568611 | 106.98887012 |
| 136 | Wet Meadow #3 | Northwest | 9408.048 | 2867.57 | 38.95570385 | 106.98886910 |

Greenhouse plot #4

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 137 | Greenhouse plot #4 | North | 9410.259 | 2868.25 | 38.95567700 | 106.98878927 |
| 138 | Greenhouse plot #4 | East | 9409.094 | 2867.89 | 38.95566385 | 106.98877312 |
| 139 | Greenhouse plot #4 | South | 9410.315 | 2868.26 | 38.95565208 | 106.98879034 |
| 140 | Greenhouse plot #4 | West | 9409.815 | 2868.11 | 38.95566463 | 106.98880545 |

Greenhouse plot #5

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 141 | Greenhouse plot #5 | Northeast | 9406.475 | 2867.09 | 38.95557111 | 106.98894020 |
| 142 | Greenhouse plot #5 | Southeast | 9406.546 | 2867.12 | 38.95555370 | 106.98893402 |
| 143 | Greenhouse plot #5 | Southwest | 9406.578 | 2867.12 | 38.95554889 | 106.98895635 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 144 | Greenhouse plot #5 | Northwest | 9406.189 | 2867.01 | 38.95556605 | 106.98896256 |

Wet Meadow Plot #4

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 145 | Wet Meadow #4 | Southeast | 9406.021 | 2866.96 | 38.95557836 | 106.98900924 |
| 146 | Wet Meadow #4 | Southwest | 9406.036 | 2866.96 | 38.95557695 | 106.98903133 |
| 147 | Wet Meadow #4 | Northwest | 9406.138 | 2866.99 | 38.95559474 | 106.98903250 |
| 148 | Wet Meadow #4 | Northeast | 9405.714 | 2866.86 | 38.95559595 | 106.98901019 |

Willow-Meadow Interface plot #4

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 149 | Willow-Meadow Interface #4 | Southwest | 9407.376 | 2867.37 | 38.95562350 | 106.98906203 |
| 150 | Willow-Meadow Interface #4 | Northwest | 9406.898 | 2867.22 | 38.95564098 | 106.98906556 |
| 151 | Willow-Meadow Interface #4 | Northeast | 9406.794 | 2867.19 | 38.95564664 | 106.98904515 |
| 152 | Willow-Meadow Interface #4 | Southeast | 9406.050 | 2866.96 | 38.95562829 | 106.98904060 |

Greenhouse plot #2

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 153 | Greenhouse plot #2 | Northeast | 9404.114 | 2866.37 | 38.95542763 | 106.98914374 |
| 154 | Greenhouse plot #2 | Northwest | 9403.928 | 2866.32 | 38.95542031 | 106.98916419 |
| 155 | Greenhouse plot #2 | Southwest | 9402.422 | 2865.86 | 38.95540474 | 106.98915504 |
| 156 | Greenhouse plot #2 | Southeast | 9403.382 | 2866.15 | 38.95541201 | 106.98913401 |

Wet Meadow plot #5

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 157 | Wet Meadow plot #5 | Northeast | 9403.276 | 2866.12 | 38.95540373 | 106.98912861 |
| 158 | Wet Meadow plot #5 | Southeast | 9403.001 | 2866.03 | 38.95538790 | 106.98911818 |
| 159 | Wet Meadow plot #5 | Southwest | 9402.786 | 2865.97 | 38.95538103 | 106.98913880 |
| 160 | Wet Meadow plot #5 | Northwest | 9402.538 | 2865.89 | 38.95539629 | 106.98914986 |

Willow-Meadow Interface plot #5

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 161 | Willow-Meadow Interface #5 | Southeast | 9401.957 | 2865.72 | 38.95539367 | 106.98918016 |
| 162 | Willow-Meadow Interface #5 | Southwest | 9401.312 | 2865.52 | 38.95538839 | 106.98920097 |
| 163 | Willow-Meadow Interface #5 | Northeast | 9402.492 | 2865.88 | 38.95540978 | 106.98918993 |
| 164 | Willow-Meadow Interface #5 | Northwest | 9401.861 | 2865.689 | 38.95540433 | 106.98921185 |

*Erythronium* Meadow plot #1

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 165 | *Erythronium* Meadow #1 | Northwest | 9399.319 | 2864.91 | 38.95459301 | 106.98883648 |
| 166 | *Erythronium* Meadow #1 | Northeast | 9399.835 | 2865.07 | 38.95459741 | 106.98881568 |
| 167 | *Erythronium* Meadow #1 | Southeast | 9399.351 | 2864.92 | 38.95458126 | 106.98880969 |
| 168 | *Erythronium* Meadow #1 | Southwest | 9399.334 | 2864.92 | 38.95457596 | 106.98883095 |

*Erythronium* Meadow plot #2

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 169 | *Erythronium* Meadow #2 | Northwest | 9399.016 | 2864.82 | 38.95452700 | 106.98880070 |
| 170 | *Erythronium* Meadow #2 | Southwest | 9398.707 | 2864.73 | 38.95451113 | 106.98879050 |
| 171 | *Erythronium* Meadow #2 | Southeast | 9398.150 | 2864.56 | 38.95451840 | 106.98876933 |
| 172 | *Erythronium* Meadow #2 | Northeast | 9398.931 | 2864.79 | 38.95453454 | 106.98877989 |

*Veratrum* Removal plot #1

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 173 | *Veratrum* Removal #1 | Northeast | 9397.083 | 2864.23 | 38.95445052 | 106.98882967 |
| 174 | *Veratrum* Removal #1 | Southeast | 9397.816 | 2864.45 | 38.95443300 | 106.98882594 |
| 175 | *Veratrum* Removal #1 | Southwest | 9397.563 | 2864.38 | 38.95442905 | 106.98884756 |
| 176 | *Veratrum* Removal #1 | Northwest | 9397.766 | 2864.44 | 38.95444593 | 106.98885225 |

*Veratrum* Removal plot #2

| Point # | Plot name | Corner (compass direction) | Altitude (feet) | Altitude (meters) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 177 | *Veratrum* Removal #2 | Southwest | 9400.339 | 2865.22 | 38.95450226 | 106.98844966 |
| 178 | *Veratrum* Removal #2 | Northwest | 9400.301 | 2865.21 | 38.95451991 | 106.98845026 |
| 179 | *Veratrum* Removal #2 | Northeast | 9399.891 | 2865.09 | 38.95452022 | 106.98842747 |
| 180 | *Veratrum* Removal #2 | Southeast | 9400.583 | 2865.30 | 38.95450239 | 106.98842779 |

This is a list of the species commonly encountered in the phenology plots, with brief descriptions of the methods and criteria I use in making the flower counts. I use Weber and Whittman (2012) "Colorado flora: western slope" (fourth edition) as the authority on plant names. For most species I have included the Taxonomic Serial Number from the Integrated Taxonomic Information System (National Museum of Natural History, Washington, D.C.; http://www.itis.usda.gov/index.html, accessed 2007); in a few cases their names don't agree with those used by Weber and Wittman, so I have indicated the ITIS names as well.

*David Inouye, 2015*

*Achillea millefolium* (ITIS Taxonomic Serial No.: 35423) (Asteraceae): Look for yellow anthers in the middle of the florets. Count the number of stalks with open florets. The petals remain white for a long time after the anthers are done, and in early years I counted them as flowering for longer than I should have. See the yellow pollen in this picture:

*Achnatherum lettermanii* (syn. *Stipa lettermanii*; ITIS Taxonomic Serial No.: 507946) (Poaceae): needlegrass (has long awns). Look for fresh anthers and white stigmas. Count the number of stalks with fresh flowers.

*Aconitum columbianum* (ITIS Taxonomic Serial No.: 18416) (Helleboraceae/Ranunculaceae): Count the number of open flowers per stalk. Look for exposed anthers and stigmas, and fresh petals.

*Agastache urticifolia* (ITIS Taxonomic Serial No.: 3450) (Lamiaceae): look or fresh anthers or stigmas. Count the number of open flowers per stalk.

*Agoseris aurantiaca* (ITIS Taxonomic Serial No.: 36488) (Asteraceae): They only flower a day or two, and are easy to miss. It's pretty easy to tell when they are flowering – look for fresh petals and anthers. Count the number of heads with open florets per plant (typically one).

*Agoseris glauca* (ITIS Taxonomic Serial No.: 36490) (Asteraceae): They only flower a day or two, and are easy to miss. It's pretty easy to tell when they are flowering – look for fresh petals and anthers. Count the number of heads with open florets per plant (typically one).

*Amelanchier alnifolia* (syn. *Amelanchier pumila*; ITIS Taxonomic Serial No.: 182049) (Rosaceae): Look for fresh white open petals and yellow anthers. Count the number of flowers per branch (stem).

*Amerosedum lanceolatum* (syn. *Sedum lanceolatum*; ITIS Taxonomic Serial No.: 24127) (Crassulaceae): Look for fresh yellow flowers, don't count them after they start to fade. Count the number of flowers per stalk.

*Androsace septentrionalis* (ITIS Taxonomic Serial No.: 23935) (Primulaceae): Sometimes the flowers are hard to spot, particularly if they are in open sun. Shading parts of the plot with a clipboard, or your shadow, helps to spot them. Mature buds show white but are easy to tell apart from open flowers. Where possible I count the number of flowers per plant, but if the plants are dense the long stems sometimes overlap and make it difficult unless you reach down and separate the plants. Thus the total count of flowers per plot is more accurate than the count of flowers per plant, or than count of plants per plot. Most plants are indeterminate winter annuals, but some survive to flower a second year and have many more flowers. Summer precipitation affects both the length of the flowering period and probability of survival.

*Antennaria pulcherrima* (ITIS Taxonomic Serial No.: 36751) (Asteraceae): This one is problematic, as it appears to be apomictic and doesn't seem to expose anthers or stigmas. I look for heads that seem to have expanded maximally and have exposed brush-like parts that are still white, and stop counting the heads when the tips start to turn brown. Count the number of open heads per stalk.

*Anticlea elegans* (syn. *Zigadenus elegans*; ITIS Taxonomic Serial No.: 508927; they also use *Zigadenus elegans*, (ITIS Taxonomic Serial No.: 524838) (Liliaceae; Weber and Wittman put it in Melanthiaceae): Count the number of open flowers per inflorescence. Look for fresh petals and stigmas.

*Aquilegia coerulea* (ITIS Taxonomic Serial No.: 565004) (Ranunculaceae): Look for open, fresh flowers. Count the number of flowers per stalk.

*Boechera stricta* (syn. *Arabis drummondii*; ITIS Taxonomic Serial No.: 22689) (Brassicaceae): Count the number of flowers per inflorescence. Older plants may have multiple inflorescences. Most plants have white flowers, are pretty easy to spot, but some have violet-colored petals about the same size as the white ones, and occasional plants have much smaller, usually darker (magenta) and are more difficult to spot (at least by the flowers; the bolting stalk is usually conspicuous). These latter plants have such different flowers that I wonder whether it's the same species.

*Eremogone congesta* (syn. *Arenaria congesta*; ITIS Taxonomic Serial No.: 20243) (Caryophyllaceae): Look for anthers sticking out of white flowers; count the number of okay flowers per stalk. Check the petals too, and don't count flowers that have wilted petals.

*Oligosporus dracunculus* (syn. *Artemisia dracunculus*; ITIS Taxonomic Serial No.: 35462) (Asteraceae): One of the less conspicuous flowers. Look for open florets on the small heads. It's pretty easy to tell when they have finished flowering. Count the number of stalks with open florets. Sometimes stalks develop buds that don't open (remain small).

*Artemisia tridentata* (ITIS Taxonomic Serial No.: 35498) (Asteraceae): sage brush in RM plots. Look for open florets on flower heads, but just count the number of stalks with open florets. At some point the yellowish flowers start to fade; don't count them after this stage.

*Symphyotrichum foliaceum* (syn. *Aster foliaceus*; ITIS Taxonomic Serial No. 193134 for *Symphyotrichum foliaceum* (Lindl. ex DC.) Nesom var. *parryi* (D.C. Eat.) Nesom) (Asteraceae): Late flowering. Look for good florets; sometimes there aren't many florets. Count the number of open heads per stalk. I don't think they clone, so each inflorescence is a separate plant. Some assistants have confused this with *Erigeron speciosus*; note the wider petals, also fewer and broader bracts on back. It also starts flowering after *E. speciosus*.

*Bromelica spectabilis* (syn. *Melica spectabilis*; ITIS Taxonomic Serial No.: 41861) (Poaceae): Usually the first grass to flower. Individual stalks. Look for white stigmas and fresh anthers. They don't stay in bloom very long. Count the number of stalks with fresh flowers.

*Bromopsis inermis* (syn. *Bromus inermis* var. *inermis*; ITIS Taxonomic Serial No.: 566598) (Poaceae): Look for fresh anthers (or less visible, stigmas). Smooth brome, an introduced species but common around Gothic. Outer bract usually smooth. Count the number of stalks with fresh flowers.

*Bromopsis pumpelliana* (*Bromus inermis* var. *pumpellianus*; ITIS Taxonomic Serial No.: 566600) (Poaceae): Nodding hairy brome, native. Look for fresh anthers (or less easily spotted, stigmas). Spikelets are rounder than those of the other brome. Count the number of stalks with fresh flowers.

*Calochortus gunnisonii* (ITIS Taxonomic Serial No.: 42849) (Liliaceae): It's pretty obvious when to count these: after they open, and before they start to fall apart. Count the number of open flowers per plant.

*Campanula rotundifolia* (ITIS Taxonomic Serial No.: 34497) (Campanulaceae): These are easy to spot and it's easy to tell when they're open and fresh. Count the number of open flowers per plant.

*Cardamine cordifolia* (ITIS Taxonomic Serial No.: 22789) (Brassicaceae): Look for fresh petals, anthers. Count the number of open flowers per stalk.

*Carex sp.* (Cyperaceae): Some of these are inconspicuous and you may want to look at previous years' data sheets for a plot to see whether there are *Carex* in them, and if so, when they typically flower so you can know when to look carefully. Look for fresh anthers (usually yellow) or stigmas (usually white; if they turn brown I don't count them). Individual inflorescences may be male, female, or both at the same time. In this picture of *Carex geyeri*, the plant on the lift is female (stigmas only) and the one on the right is male and female. Count the number of female, male, or bisexual stalks with fresh stigmas and/or anthers.

Maybe *Carex nigricans* on the left (stream plot #1); *Carex aurea* (?) in the middle (same plot); and a common species (unknown) from the Interface and Wet Meadow plots.

*Castilleja linariifolia* (ITIS Taxonomic Serial No.: 33138) (Scrophulariaceae): Look for fresh stigmas. Count the number of flowers per inflorescence.

*Castilleja sulphurea* (ITIS Taxonomic Serial No.: 33083) (Scrophulariaceae): Look for fresh stigmas. Count the number of flowers per inflorescence.

*Ceratochloa carinata* (syn. *Bromus carinatus*; ITIS Taxonomic Serial No.: 40481) (Poaceae): Look for fresh anthers (or less easily spotted, stigmas), but note that this species is at least partially cleistogamous so not all stalks will display reproductive parts. Spikelets are flattened, not hairy. Count the number of stalks with fresh flowers.

*Chamerion danielsii* (syn. *Chamerion angustifolium*; ITIS Taxonomic Serial No.: 566019) (Onagraceae): There have been several plants that are vegetative but not flowering in recent years (2007 – DWI). Count the number of open flowers per stalk.

*Chenopodium album* (ITIS Taxonomic Serial No.: 20592) (Chenopodiaceae): small plant (most years, unless there's a lot of rain), tiny inconspicuous flowers, and I probably miss flowering most of the time, but it's not very common (although in the wet summer of 2006 plants got much larger than they do in most years). Count the number of open flowers per stalk.

*Cirsium* species (Asteraceae): Look for fresh florets and count the number of capitula with good florets on each stalk.

*Claytonia lanceolata* (ITIS Taxonomic Serial No.: 20390) (Portulacaceae): Try to count all the flowers open per plant. This can be time consuming when there are hundreds of plants in a plot. Subdividing the plot with string helps to keep track of which plants you've counted. If you run out of time, at least count all the open flowers in the plot. This plant has 3 open flowers, buds, and one finished flower:

*Collomia linearis* (ITIS Taxonomic Serial No.: 31041) (Polemoniaceae): Little pink flowers, and there's not much question about whether they're open or not. Count the number of open flowers per plant.

*Delphinium nuttallianum* (syn. *Delphinium nelsonii*; ITIS Taxonomic Serial No.: 18483) (Helleboraceae/Ranunculaceae): Count the number of open flowers on each inflorescence. Sometimes old flowers may just lose a petal or two but not fall completely off the stem; don't count these. When the white petals start to turn brown, don't count those flowers.

*Delphinium barbeyi* (ITIS Taxonomic Serial No.: 18539) (Helleboraceae/Ranunculaceae): Count the number of open flowers on each inflorescence. I haven't kept track of how many inflorescences there are per plant (how many plants are in a plot), but that would be useful information. The buds are susceptible to frost damage. Sometimes old flowers may just lose a petal or two but not fall completely off the stem; don't count these. When the white petals start to turn brown, don't count those flowers.

*Descurainia incana* (syn. *D. richardsonii*; ITIS Taxonomic Serial No.: 22839) (Brassicaceae): A weedy mustard with small flowers. Look for open, fresh flowers per inflorescence. Can be very variable in height (short in dry years) and number of flowers. Count the number of open flowers per stalk.

*Dodecatheon pulchellum* (ITIS Taxonomic Serial No.: 23945) (Primulaceae): It's pretty easy to tell when buds open (the petals reflex). Stop counting when the petals wilt. Count the number of open flowers per stalk.

*Draba aurea* (ITIS Taxonomic Serial No. 22863) (Brassicaceae): Look for fresh petals, anthers. Count the number of open flowers per stalk. As the flowers age they start to face sideways; I usually count just those that are facing up.

*Draba nemorosa* (ITIS Taxonomic Serial No. 22894) (Brassicaceae): A small annual, alien, with yellow flowers. Look for fresh petals, and fresh-looking anthers/stigma. Count the number of open flowers in the inflorescence.

*Dugaldia hoopesii* (syn. *Hymenoxys hoopsii*; ITIS Taxonomic Serial No.: 507616) (Asteraceae): Look for open florets that still look fresh, and count the number of heads per stalk that have open florets. In some late-flowering individuals the florets seem to dry out and it can be a little difficult to tell whether to count a capitulum as still having good florets or not.

*Elymus elymoides* (ITIS Taxonomic Serial No.: 525111) (Poaceae): Squirreltail grass. Count the number of stalks with fresh flowers.

*Elymus trachycaulus* (ITIS Taxonomic Serial No.: 502282) (Poaceae): Wild rye. Look for fresh anthers (or less easily spotted, stigmas). Count the number of stalks with fresh flowers.

*Epilobium brachycarpum* (ITIS Taxonomic Serial No.: 27309) (Onagraceae): Look for fresh, open flowers. Count the number of open flowers per stalk.

*Erigeron coulteri* (ITIS Taxonomic Serial No.: 35845) (Asteraceae): Look for fresh florets. Count the number of heads with open florets. The white petals remain fresh looking long after the disk florets are done.

*Erigeron elatior* (ITIS Taxonomic Serial No.: 35857) (Asteraceae): Not in any of the plots, but I have kept track of its flowering between plots. Note the wooly involucres. Look for fresh florets on a head. Count the number of open heads per stalk.

*Erigeron flagellaris* (ITIS Taxonomic Serial No.: 35865) (Asteraceae): Look for fresh florets on a head. Count the number of open capitula per plot.

*Erigeron speciosus* (ITIS Taxonomic Serial No.: 35950) (Asteraceae): Look for fresh florets on a head. Susceptible to drought, and may dry up before florets open. Also susceptible to frost as early buds. Count the number of open capitula per plant (clump). When they turn brown (as in the lower flower in this picture) don't count them. Some RAs have confused this with *Aster foliaceus*; note the narrower petals, also more numerous and narrower bracts. Sometimes it's rather arbitrary to define the separate clumps (genets?) in a plot.

*Eriogonum umbellatum* (ITIS Taxonomic Serial No.: 21266) (Polygonaceae): Count the number of inflorescences with open flowers on them. Look for open petals, stigmas and anthers to determine when the flowers are good. These inflorescences are smaller and greener than those of *E. subalpinum.*

*Eriogonum subalpinum* (syn. *Eriogonum umbellatum* var. *majus*; ITIS Taxonomic Serial No.: 528020) (Polygonaceae): Count the number of inflorescences with open flowers on them. Look for open petals, stigmas and anthers to determine when the flowers are good.

*Erysimum capitatum* (ITIS Taxonomic Serial No.: 22932) (Brassicaceae): These plants seem to hold their petals past the time when I suspect they still have pollen or receptive stigmas. If the outer flowers in the inflorescence have started to change to a lighter shade of yellow, I usually don't count them. Count the number of open flowers per stalk.

*Erythrocoma triflorum* (*Geum triflorum*; ITIS Taxonomic Serial No.: 195836) (Rosaceae): Typically the middle flower opens first, followed by the ones on the side. You'll have to lift the flowers up to look and see when they open. Count the number open per stalk.

*Erythronium grandiflorum* (ITIS Taxonomic Serial No.: 196372) (Liliaceae): There's usually not much question about whether to count these, as the flowers wither quickly when done. Count the number of open flowers per inflorescence (plant). This plant has one bud and one open flower.

*Festuca thurberi* (ITIS Taxonomic Serial No.: 40828) (Poaceae): Look for fresh anthers (or less easily spotted, stigmas). Count the number of stalks with fresh flowers. A bunchgrass but I haven't kept track of numbers of bunches.

*Fragaria virginiana* (ITIS Taxonomic Serial No.: 24639) (Rosaceae): Look for fresh white petals and yellow anthers. Don't count if they have started to wither or turn brown. Count the number of flowers per inflorescence (typically 1-2).

*Galium bifolium* (ITIS Taxonomic Serial No.: 34826) (Rubiaceae): Tiny little flowers and I often miss flowering by this annual. Sometimes I spot the little fruits, and then note that the plants were present in the plot but flowering was missed. Count the number of flowers per plant.

*Galium septentrionale* (*Galium boreale*; ITIS Taxonomic Serial No.: 565204) (Rubiaceae): look for fresh anthers and petals. Count the number of stalks with flowers.

*Gayophytum ramosissimum* (ITIS Taxonomic Serial No.: 27679) (Onagraceae): Tiny flowers. Look for fresh open corolla. Count the number of flowers per plant.

*Pneumonanthe parryi* (syn. *Gentiana parryi*; ITIS Taxonomic Serial No.: 29980) (Gentianaceae): One of the last species to bloom, large flowers (bumble bees climb down into them) that don't open when it's raining. Look for open flowers with fresh petals. Count the number of open flowers per stalk.

*Gentianella acuta* (syn. *Gentianella amarella* ssp. *acuta*; ITIS Taxonomic Serial No.: 30060) (Gentianaceae): may not be in any plots, but I've tracked it outside plots. Look for fresh, open corollas. Count the number of flowers per stalk.

*Gentianopsis thermalis* (syn. *Gentianopsis detonsa*; ITIS Taxonomic Serial No.: 30090) (Gentianaceae): Look for open, fresh corolla. Count the number of flowers per plant.

*Geranium richardsonii* (ITIS Taxonomic Serial No.: 29118) (Geraniaceae): Look for fresh open petals. Count the number of flowers per plant.

*Helianthella quinquenervis* (ITIS Taxonomic Serial No.: 37597) (Asteraceae): Count capitula with fresh florets. I usually note whether it is terminal or axillary capitula that are flowering, and count the number on each flower stalk.

*Heliomeris multiflora* (syn. *Viguiera multiflora*; ITIS Taxonomic Serial No.: 37603) (Asteraceae): Count the number of capitula with good florets, and if possible, make separate counts for each plant (clump).

*Heracleum sphondylium* (syn. *Heracleum maximum*; ITIS Taxonomic Serial No.: 502953) (Apiaceae): I don't take the time to count individual flowers, just whether an umbel has open flowers or not. Count the number of umbels with open flowers.

*Heterotheca villosa* (syn. *Chrysopsis villosa*; ITIS Taxonomic Serial No.: 37689) (Asteraceae): Count the number of capitula with good florets, and if possible, make separate counts for each plant (stalk).

*Heuchera parviflora* (ITIS Taxonomic Serial No.: 24365) (Saxifragaceae): Doesn't flower in any plots but I've counted it near some of the Wet Meadow plots (it occurs a little further south). Look for fresh petals and anthers. Count the number of flowers per stalk.

*Hydrophyllum capitatum* (ITIS Taxonomic Serial No.: 31391) (Hydrophyllaceae): Look for flowers with fresh corollas and exerted stamens and stigmas. Sometimes a single stem will have two heads of flowers. In later years I have kept track of the numbers on each of the heads separately, indicated by two numbers within parentheses (e.g., (4+5)), but still counting that as one plant in the count of number of plants flowering. Here's an example of a plant with two flower heads.

*Hydrophyllum fendleri* (ITIS Taxonomic Serial No.: 31392) (Hydrophyllaceae): Look for flowers with fresh corollas and exerted stamens and stigmas. Count the number of flowers per plant.

*Ipomopsis aggregata* (ITIS Taxonomic Serial No.: 31192) (Polemoniaceae): Look for open petals. Count the number of flowers per plant.

*Koeleria macrantha* (ITIS Taxonomic Serial No.: 503284) (Poaceae): Look for anthers and stigmas. The inflorescences are very tight to the stalk while in bud, and spread open a few days before flowering. Count the number of stalks with fresh flowers.

*Lathyrus leucanthus* (syn. *Lathyrus lanszwertii* var. *leucanthus*; ITIS Taxonomic Serial No.: 528691) (Fabaceae): Usually pretty easy to spot and count, although in bright sun they may be surprisingly hard to see. Shading parts of the plot with a clipboard, or your shadow, sometimes helps. Count the number of flowers per cluster (e.g, 2 below). If they aren't still all white and not wilted, don't count them.

*Ligularia bigelovii* (syn. *Senecio bigelovii*; ITIS Taxonomic Serial No.: 530300) (Asteraceae): You may have to bend the stalk over to look at the faces of the down-ward facing capitulate. Look for fresh florets, and count the number of heads flowering on each stalk. E.g., on this plant, I would count the two flowers on the right but not the bud on the left.

*Ligusticum porteri* (ITIS Taxonomic Serial No.: 29532) (Apiaceae): I haven't taken the time to count individual flowers on inflorescences, so I just count each stalk that has an inflorescence with open flowers (look for open petals, exposed stigmas and anthers). Some plants may have multiple (usually no more than two I think) umbels. Sometimes the inflorescences are killed by frost while in bud.

*Limnorchis hyperborea* (syn. *Platanthera hyperborea* var. *hyperborea*; ITIS Taxonomic Serial No.: 196402) (Orchidaceae): Look for open flowers with yellow pollinia. They turn brown with age. Count the number of flowers per stalk.

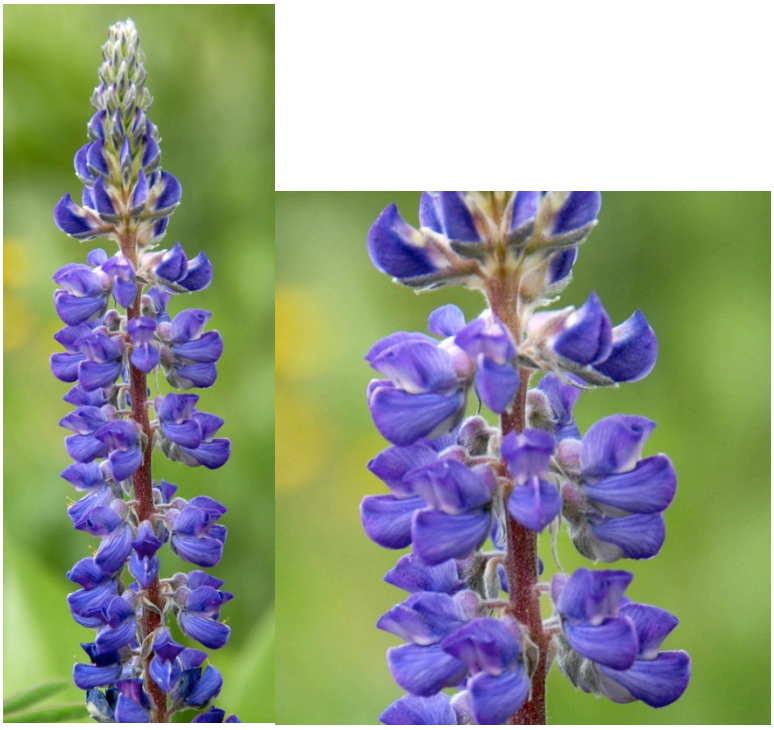
*Adenolinum lewisii* (syn. *Linum lewisii*; ITIS Taxonomic Serial No.: 29214) (Linaceae): Big flowers, easy to count, although if there are a lot of plants in a plot sometimes it's a little tricky to keep track of flowers per plant. If you count late in the day some flowers will have lost some (or possibly all) of their petals, especially if it's windy. They may not open in rainy weather. In a few cases (starting in 2007) I have indicated the number of genets with inflorescences by putting in parentheses in the spreadsheet formula the number of inflorescences in each genet. For example, this formula "=(1*3+2)+(1*2)+1*2" indicates that there was one genet with three inflorescences with a single open flower and one with two, another genet with two inflorescences with a single open flower, and two other plants with single open flowers.

*Lithophragma glabrum* (ITIS Taxonomic Serial No.: 24395) (Saxifragaceae): Has sometimes flowered in Rocky Meadow Plot #4, but I've often noted its presence nearby but outside the plot.

*Lomatium dissectum* (ITIS Taxonomic Serial No.: 503534) (Apiaceae): Inconspicuous, so you may have to look carefully for these early-flowering plants. Look for individual flowers with anthers or stigmas exserted. Count the number of umbels in the plot (I don't think there are ever more than one per plant, and not all plants flower).

*Distegia involucrata* (syn. *Lonicera involucrata*; ITIS Taxonomic Serial No.: 35927) (Caprifoliaceae): Not in any plots, but nearby a few of them so I've collected data in some (not very many) years. Look for exerted stigmas and fresh corollas.

*Lupinus argenteus* (ITIS Taxonomic Serial No.: 503575) (Fabaceae): Lupine flowers are usually easy to count, but don't count them if they have started to wither, e.g., to the point that stigmas are exposed. They seem to be subject to frost damage so sometimes the buds never develop very far. This species has smaller flowers than the following one, reddish stems, and is much less common. Count the number of flowers per stalk.



*Lupinus polyphyllus* var. *prounophilus* (syn. *Lupinus prunophilus*; ITIS Taxonomic Serial No.: 26097) (Fabaceae): Lupine flowers are usually easy to count, but don't count them if they have started to wither, e.g., to the point that stigmas are exposed. They seem to be subject to frost damage so sometimes the buds never develop very far. This is the common lupine species around Gothic. Count the number of flowers per stalk.

*Mahonia repens* (ITIS Taxonomic Serial No.: 195045) (Berberidaceae): It's pretty obvious when the flowers open. Look for fresh petals when deciding when to stop counting. Count the number of open flowers per stem.

*Maianthemum stellatum* (ITIS Taxonomic Serial No.: 503656) (Lilaceae): Look for fresh flowers – white petals, not wilted, fresh anthers. Not very hard to tell which to count; count the number of open flowers per plant.

*Medicago lupulina* (ITIS Taxonomic Serial No.: 503721): doesn't occur in any of the plots but I have recorded its flowering by looking at plants along the Copper Creek trail above and below Rocky Meadow plot #7. Count the number of flowers per stalk.

*Mertensia fusiformis* S. Wats. (ITIS Taxonomic Serial No.: 31680) and *M. ciliata* (ITIS Taxonomic Serial No.: 31668; picture on the right) (Boraginaceae): Count the number of open flowers per stalk (inflorescence). Don't count flowers if they have started to wilt and don't look fresh; usually they drop off by then but sometimes they don't. Occasionally there is a lepidopteran larva that webs inflorescences, which can make it difficult to count flowers. I think that many RMBL researchers have used the name *Mertensia fusiformis* for what Weber calls *brevistyla*, which is also a synonym with *oblongifolia* (KTZ). Kathy Darrow reports (pers. Comm..) that Hartman/Nelson lists *M. fusiformis* as the contemporary leading name.

*Moehringia lateriflora.* (ITIS Taxonomic Serial No.: 20017) (Caryophyllaceae). Just outside NE corner of Willow-Meadow Interface plot #3 in 2009 (and probably other earlier years).

*Muhlenbergia sp.* Only occurs in one plot, Rocky Meadow #6, on east edge. Possibly *Muhlenbergia montana.* (ITIS Taxonomic Serial No.: 41927) The only C4 (warm season) grass around Gothic, I think (you can see the bundle sheaths in a cross section of a leaf). Count the number of stalks with fresh flowers.

*Noccaea fendleri* (syn. *Noccaea montanum*, *Thlaspi montanum*; ITIS Taxonomic Serial No.: 23423) (Brassicaceae): Count the number of open flowers per flower stalk. This species has been declining in the plots since about 2000. Sometimes flowers seem to keep their petals after they may no longer have fresh anthers or stigmas, so look for that and then don't count such flowers.

*Oreochrysum parryi* (*Haplopappus parryi*; ITIS Taxonomic Serial No.: 517938) (Asteraceae): Look for good florets, and count the number of capitula flowering on each inflorescence. Until 2008 I mistook *Solidago multiradiata* for this species, which may not actually occur in any of the plots. So probably any records of this species prior to 2008 are actually *Solidago multiradiata*. Picture here with *Solidago multiradiata* on the right. *O. parryi* has bigger bracts in multiple levels, fewer heads per inflorescence, and each capitulum has its own stalk.

*Aphyllon fasciculatum* (syn. *Orobanche fasciculata*; ITIS Taxonomic Serial No.: 34290) (Orobanchaceae): This species hasn't occurred in the plots for many years (DWI 2008); I think it has only appeared in Rocky Meadow Plot #7, but is not too rare in the general Gothic area (e.g., above and below Copper Creek trail in Gothic, and the Deer Creek trail).

*Orthocarpus luteus* (ITIS Taxonomic Serial No.: 3347) (Scrophulariaceae): This species hasn't flowered in the plots for quite a few years (DWI 2008). My recollection is that the yellow flowers are easy to count, and that it's easy to tell which ones are appropriate to count. Count the number of flowers per stalk.

*Osmorhiza occidentalis* (ITIS Taxonomic Serial No.: 29792) (Apiaceae): Look for fresh flowers; count number of flowering plants (stems) with good flowers. Presence of fresh anthers is a good indicator.

*Oxypolis fendleri* (ITIS Taxonomic Serial No.: 29546) (Apiaceae): Look for open flowers with fresh petals and stigmas/anthers. Count the number of inflorescences. I usually keep track of whether there are one or two umbels open on individual stalks.

*Paxistima myrsinites* (ITIS Taxonomic Serial No.: 504149) (Celastraceae): These flowers are very small and easy to overlook. In the one plot where they occur (Rocky Meadow #2), the plant is overgrown by *Artemisia tridentata*) so you have to peer a bit through that to find the *Paxistima*. I stop counting them after they start to fade in color. Count the number of flowers per plant.

*Pedicularis bracteosa* (ITIS Taxonomic Serial No.: 33361) (Scrophulariaceae): Look for opening of the petals and appearance of stigmas. Stop counting when the petals start to wilt and/or stigma is no longer visible. Count the number of open flowers per inflorescence.

*Pedicularis groenlandica* (ITIS Taxonomic Serial No.: 33377) (Scrophulariaceae): Look for expansion of the petals (elephant's ears) and emergence of the stigma from the end of the elephant's trunk. I think this species was in some of Bonnie Inouye's plots in the spruce bog across the river from the Enders dining hall, but not in the current set of plots. Count the number of flowers per stalk.

*Phacelia heterophylla* (ITIS Taxonomic Serial No.: 504271) (Hydrophyllaceae): Look for white petals and fresh anthers or stigmas. Don't count them after they start turning brown. Shown here with *Bombus flavifrons* worker. Hasn't flowered in any of the plots, but I've kept track of plants near or on the way to some of them. Count the number of flowers per stalk.

*Phleum commutatum* (timothy grass) (syn. *Phleum alpinum*; ITIS Taxonomic Serial No.: 41063) (Poaceae): look for fresh anthers or stigmas. Count the number of stalks with fresh flowers.

*Poa arctica* (ITIS Taxonomic Serial No.: 41077) (Poaceae): Look for fresh anthers and stigmas. Only in a few of the willow-meadow interface plots. Taller than *Poa pratensis*, and seems to stay in bloom longer.

*Poa pratensis* (ITIS Taxonomic Serial No.: 41088) (Poaceae): Look for fresh anthers (or less easily spotted, stigmas). See purple anthers on this picture:

*Polygonum aviculare* (ITIS Taxonomic Serial No.: 20876) and *P. douglasii* (ITIS Taxonomic Serial No.: 20891) (Polygonaceae): *douglasii* is much more common, has pinkish flowers, usually facing sideways or down. *aviculare* flowers are white, typically face up, have a more crowded inflorescence. Flowers don't open up much in either species, and often don't open at all; I think mostly they self. Count the number of open flowers per plant.

*Bistorta vivipara* (syn. *Polygonum viviparum*; ITIS Taxonomic Serial No.: 20864) (Polygonaceae). These plants had few flowers, mostly bulbils, and have been only in the Stream plot. Count the number of stalks with open flowers.

*Pentaphylloides floribunda* (syn. *Potentilla fruticosa*, *Dasiphora fruticosa*; ITIS Taxonomic Serial No.: 24711) (Rosaceae): The shrubby species. Look for fresh petals, anthers. Count the number per shrub.

*Potentilla hippiana* (ITIS Taxonomic Serial No.: 24718) (Rosaceae): The herbaceous species characteristic of the dry rocky meadow habitat, like the Rocky Meadow plots. Leaf is more elongated than that of *Potentilla pulcherrima* X *hippiana*. RM Plot #4 has both species, although I failed to differentiate them prior to 2009. Count the number of flowers per plant.

*Potentilla pulcherrima* (ITIS Taxonomic Serial No.: 504586) (Rosaceae): The common species around the Lab. There are typically too many plants in a plot to keep track of flowers per plant, so I just count the number open per cluster of flowers or flowers on the same stem (typically 1-3). If you count them late in the day sometimes there will be a petal or two missing, but I usually count those flowers anyway. Look for fresh anthers (not brown).

*Pseudocymopterus montanus* (ITIS Taxonomic Serial No.: 29837) (Apiaceae): You can tell when the flowers are open when you see anthers or stigmas stick up up past the floret petals. I haven't tried to count individual flowers, just umbels.

*Pyrrocoma crocea* (syn. *Haplopappus croceus*; ITIS Taxonomic Serial No.: 504695) (Asteraceae): These capitula seem to have a surprisingly short lifespan. Look for good florets. On this flower, note the finished florets on the outside, buds in the center, and fresh florets in between. Count the number of flowers per stalk.

*Ranunculus inamoenus* (ITIS Taxonomic Serial No.: 18616) (Ranunculaceae): The flowers seem to get smaller during the course of the flowering period. There are few enough plants in the plots that it's easy to keep track of individuals and their flowers. Look for both yellow petals and fresh-looking anthers.

*Rosa woodsii* (ITIS Taxonomic Serial No.: 24847) (Rosaceae): Count the number of flowers per plant.

*Salix* species (Salicaceae): Look for fresh yellow anthers on male catkins, and fresh green stigmas on female catkins. Count the number of male or female catkins per plot.

*Tolmachevia integrifolia* (syn. *Rhodiola integrifolia*, *Sedum integrifolium*; ITIS Taxonomic Serial No.: 520043) (Crassulaceae): Fresh anthers are probably the most reliable cue for which flowers to count. Count the number of flowers on each head.

*Senecio integerrimus* (ITIS Taxonomic Serial No.: 36148) (Asteraceae): Look for open florets, and count the number of capitula per inflorescence with open florets.

*Ligularia pudica* (syn. *Senecio pudicus*; ITIS Taxonomic Serial No.: 36172) (Asteraceae): Look for fresh florets, count the number of capitula per stalk. Not in any of the plots, but I've counted a plant along the Copper Creek trail about 13m below the water treatment plant.

*Senecio serra* (ITIS Taxonomic Serial No.: 36182) (Asteraceae): Look for open florets with fresh stigmas or anthers. Not in any of the plots, I think, but I've counted plants a few times along the Copper Creek trail.

*Silene antirrhina* (ITIS Taxonomic Serial No.: 20045) (Caryophyllaceae): This one is easy to overlook as it's not very conspicuous. I've often not seen it until after it was finished flowering, or at least after it started. Look for fresh petals. Count the number of flowers per stalk.

*Solidago multiradiata* (ITIS Taxonomic Serial No.: 36279) (Asteraceae): Until 2008 I mistakenly called this *Oreochrysum* (*Haplopapus*) *parryi*. Look for good florets, and count the number of capitula flowering on each inflorescence. Here's an inflorescence at peak bloom.

*Stellaria longifolia* (ITIS Taxonomic Serial No.: 20185) (Caryophyllaceae): Look for open white flowers. Only in Stream Plot below Ouray cabin. Count the number of flowers per plant.

*Swertia perennis* (ITIS Taxonomic Serial No.: 30118) (Gentianaceae): Look for open fresh petals. Count the number of open flowers per inflorescence.

*Taraxacum officinale* (ITIS Taxonomic Serial No.: 36213) (Asteraceae): The only tricky thing about counting these is that they may not open in rainy/cloudy weather and sometimes it's a judgment call if they are partway open. There aren't very many of these in the plots so it's not difficult to identify individual plants and their flowers.

*Thalictrum fendleri* (ITIS Taxonomic Serial No.: 18670) (Ranunculaceae): Count the number of male and female plants. Look for fresh stigmas on female flowers (see below), and anthers that are dehiscing on males. Stop counting when ovaries start to enlarge (a bit arbitrary) or anthers are done.

*Thlaspi arvense* (ITIS Taxonomic Serial No.: 23422) (Brassicaceae): Introduced weed that seems to be becoming more common around Gothic as of 2008. Not in any plots as of 2009, but in between Vertrum Removal plots. Count the number of flowers per stalk.

*Tragopogon dubius* (ITIS Taxonomic Serial No.: 38564) (Asteraceae): Individual flowers don't stay in bloom long. Look for expanded fresh ray florets (petals). Count the number of flowers per plant.

*Trifolium pratense* (ITIS Taxonomic Serial No.: 26313) (Fabaceae): Along the Copper Creek trail and Virginia Mine road. Count the number of inflorescences with good flowers per stalk.

*Trifolium repens* (ITIS Taxonomic Serial No.: 26206) (Fabaceae): Along the Copper Creek trail and Virginia Mine road. Count the number of inflorescences with good flowers per stalk.

*Trisetum spicatum* (ITIS Taxonomic Serial No.: 41294) (Poaceae): lots of short awns. Look for fresh anthers. Count the number of stalks with fresh flowers.

*Valeriana occidentalis* (ITIS Taxonomic Serial No.: 35362) (Valerianaceae): Look for good florets and then count the number of heads with good florets. Fresh anthers or stigmas (some plants are female) are probably the most reliable indicator.

*Valeriana edulis* (ITIS Taxonomic Serial No.: 35359) (Valerianaceae): Look for good florets and then count the number of heads with good florets. Fresh anthers or stigmas are probably the most reliable indicator. This plant is a favorite food of deer, and it's common for flower stalks to be eaten while in bud or flowering. I record the number of stalks eaten.

*Veratrum tenuipetalum* (ITIS Taxonomic Serial No.: 505649) (Lilaceae; Weber and Wittman put it in Melanthiaceae): I have sometimes counted open flowers (fresh anthers and/or stigmas) on individual stalks, if there aren't too many plants flowering. Look for fresh anthers and stigmas.

*Vicia americana* (ITIS Taxonomic Serial No.: 26331) (Fabaceae): Not much question about when to count these, as it's obvious when the petals open and they wither quickly when finished. It may be difficult to identify individual plants, so count the number of open flowers per cluster (1-3).

*Viola adunca* (ITIS Taxonomic Serial No.: 22032) (Violaceae): Not in any of the plots, but I have recorded them near Aspen Forest plot #8.

*Viola praemorsa* (ITIS Taxonomic Serial No.: 505717) (Violaceae): Usually plants are pretty well separated so it's not difficult to count how many open flowers are on each. I don't count flowers that have started to wither.