Effects of Late Spring Snows in 2024 on Phenology and Survival of *Dicentra uniflora* at Carpenter Ridge and Scott's John Meadow, Butte County, Northern California

Halkard E. Mackey, Jr. (Ph.D., Retired Environmental Scientist)

Background: Schlising and Mackey (2019) provided the first detailed quantitative information from two sites, Carpenter Ridge and Scott's John Meadow, in Butte County, Northern California, on the emergence of leaves and flowers of *Dicentra uniflora,* seed production, and potential losses of flowers or fruits during the season due to herbivory. The ephemeral nature of *D. uniflora* and variation in weather phenomena from year-to-year required several years to begin to understand the life history patterns of this species. Wooden markers were used to follow the development and survival of flowering plants during the short 5 to 6 week spring season. For example, in early June 2017, Ridge was covered by 15 cm of snow and *D. uniflora* flowers emerged shortly after snowmelt which is typical. Less than a week later, a 30 cm snow covered Ridge and nearly every marked flower and many leaves were frozen and lost for 2017. Meadow was also visited in late June 2017 and numerous flowers were marked. Meadow was visited over the next 2 weeks and nearly all of the flowers and fruits were missing probably due to herbivory. Thus, 2017 was lost as a typical study year. By contrast, the spring of 2018 was a very good year for *D. uniflora* and data on seed production and survival patterns of the plants was easy to collect at both Ridge and Meadow. Therefore, 2018 will serve as a comparison year for the surveys which were conducted of *D. uniflora* in 2024, since the timing of spring emergence and phenology was very similar in both years, as well as the total amount of snowfall and precipitation. Weather data for both years are available from a station (CAR) near Ridge and a snow monitoring station near Humbug Summit (HUM).

Surveys 2024: Phenology, plant survival, seed set, and seed production data were collected in 2024 and compared for *D. uniflora* with data from 2018. Recurrent snowfall events were very different at Ridge in 2024 versus 2018. In 2024 after *D. uniflora* emerged, there were late snows at Ridge, but not at Meadow. Thus, an unexpected opportunity arose to evaluate the effect of late snows on this species. The two sites available were Carpenter **Ridge** at 1383 m elevation and Scott's John **Meadow** at 1746 m elevation. A third site, Summit, available in 2018, was destroyed by the Dixie Fire in the summer of 2021 and was not available for comparisons in 2024. Reference data for Summit will be included for comparisons for some years. Detailed descriptions of these sites are given in Schlising and Mackey (2019) and vertical views of them are shown in Figs. 1 and 2. Fig. 1 shows the 5 survey sites available at Ridge with most counts occurring at **NE**, **E**, and **S** in 2024. Counts at Meadow were conducted near a transect shown in Fig. 2. Ground views for Ridge are show in Fig. 3 and for Meadow in Fig. 4. Usually as occurred in 2018, snow melts in early April at Ridge and in early June at Meadow. No snows were found from field visits to Ridge after 9 April 2018. *Dicentra uniflora* appears following snow melt, flowers, and lasts as an ephemeral geophyte with the above ground leaves and flowers disappearing in 5 to 6 weeks. Fruit and seed production occur in this very short time frame. Late snows do not normally occur at the 2 sites after *D. uniflora* has emerged. However in 2024, Ridge was subjected to at least 2 late snows while *D. uniflora* was emerging and was already in flower. Freeze damage was noted to flowers that had emerged at the beginning of the Ridge surveys; therefore, flowers were marked (Figs. 5A, B) as to the week of the survey and status (missing, frozen, dried, or mature). Flowers were marked as they had been marked in 2018 (Fig. 5C). In addition, mature ovules of frozen and non-frozen fruits were collected and counts of aborted, immature, and mature ovules (brown or black seeds) were made from fruits collected on the last survey at Ridge on 10 May 2024. The same observations were made a month later at Meadow where late snows did not occur after *D. uniflora* had emerged. Unfortunately, it was hotter and drier after *D. uniflora* emerged at Meadow and only the status of missing, dried, or mature fruits were recorded. Also at Meadow, too few mature fruits were in good enough condition for ovule counts to be made.

Results: Phenology for 2018 and 2024 at Ridge and Meadow were similar (Fig. 6A, B, C, D, E). In both 2018 and 2024, Ridge S reached it peak flowering in mid-April and Meadow in mid-May. On Ridge, Sites SE and E emerged 2 to 3 weeks earlier than Site S (Fig. 6C). As in 2018, Meadow was not available until snow melted from that location about a month later than at Ridge (Fig., 6C, D, E). The Forest Service road to Meadow was still blocked by snow on 10 May 2024. When Meadow was available for surveys beginning on 17 May 2024, *D. uniflora* was already near peak flowering (Fig. 6C, D, E). Total rainfall and snowfall amounts were similar for water years 2017-2018 and 2023-2024 (Fig. 7). Total rainfall at the CAR station was 124.1 cm in 2018 and 150.2 cm in 2024. Total snowfall (water equivalent) was 116.7 cm in 2018 and 114.8 cm in 2024 at the HUM station. The weather patterns versus the springtime survey visits are shown for 2018 and 2024 in Fig. 8A, B, C, D. The most notable difference between the 2 years are the later snowfall events in April and May of 2024. These late snowfall events are shown in detail in Fig. 3 for Ridge. Fig. 3 also shows reference photography taken at the beginning of each survey looking northeast toward Sites E and NE. The photographs show the extent of patchy snow and on 2 dates (15 April and 05 May 2024) ground cover of late snows on Ridge. Complete survey counts were not possible on 15 April 2024 and none were possible on 04 May 2024. Fig. 5B demonstrates how plants and flowers were found on surveys with patchy snow cover. Markers were sometimes forced from the soil by freeze-thaw action and flowers/fruits were damaged from the freezing action of the snow (Fig. 5B). The number of ovules per fruit were similar in 2018 and 2024 at Ridge (Fig. 9A, B). Mean numbers of mature seeds in 2009, 2010 and 2011 ranged from a mean of 48 to 83 for samples from Butte County (Fig. 9A, B). Percent seed set ranged from 87 to 90 for samples from Butte County in 2009, 2010 and 2011 (Fig. 9A, B). Percent seed set of freeze damaged fruits was significantly lower at 53.9 % versus 90.4 % than for non-frozen fruits at Ridge in 2024 (non-frozen, N = 18, X = 90.4, Range 42.9 to 100, SE = 3.489; freeze damaged N = 16, X = 53.9, range 13 to 97.6, SE = 7.305, F = 0.007, Figs. 8, 9, and 10). Mean numbers of ovules per fruit were similar for 2018 (X = 47) and 2024 (X = 56) on Ridge and was not a significant difference between damaged and non-freeze damaged fruits in 2024 (freeze damage N = 16, X =47.1, Range 23 to 69, SE = 3.63; non-freeze damage N = 18, X = 56.4, range 26 to 90, SE = 3.43, F = 0.984) (Figs. 10, 11, 12). Percentage of flowers/fruits missing were similar on Ridge for 2018 (29 %) and 2024 (28.5 %), as well as for Meadow and Summit (Range 25 % to 45.5 %) (Fig. 13). Although Summit was not available in 2024, a survey of the fate of flowers at Summit in 2021 yielded similar data (Fig. 13). The most notable difference between 2018 and 2024 was a decrease in the percentage of seed set in frozen, versus non-frozen fruits collected at Ridge. Apparently unpredictable events such as late snows were detrimental to fruit maturation and seed production in *D. uniflora*. Although ovule and seed counts were not possible at Meadow, the numbers of missing, dried, and mature fruits were similar to those of Ridge and as reported by Schlising and Mackey (2019). In addition to lost from freezing, fruits of *D. uniflora* could have been lost from herbivory. Game cameras at survey sites in the spring of 2021 at Ridge S and at Summit recorded mule deer (*Odocoileus hemionus*) browsing in the immediate vicinity of clusters of marked plants and fruits of *D. unifora* (Fig. 14). Tracks in 2021 at Ridge Site E (Fig. 15) and pellets in 2024 at Site S on Ridge of the black-tailed jackrabbit (*Lepus californicus*) were observed in the immediate location of missing *D. uniflora* marked flowers and leaves, so it possibly that rabbits could have been feeding on this plant. A few of the markers also had "chewing" damage perhaps from rabbits. Schlising and Mackey (2019) reported the larva of the butterfly, *Parnassius clodius,* feeding on a fruit of *D. uniflora* at Summit in 2018 (Fig. 16), so it is possible that it could be present at Meadow. In addition to this larva, an immature short-horned grasshopper (Acrididae, Fig. 17) was observed at Site E on Ridge in early May 2024 and could have been feeding on *D. uniflora*. Adults of short-horned grasshoppers were seen at Ridge on 21 July 2024. Gopher activity is extensive and increasing at Meadow, but it is not know if gophers feed on underground bulblets and tubers of *D. uniflora* or are disrupted to its survival and growth. A few gopher burrows were seen on Ridge on 21 June 2024.

Comments: Varying weather conditions in 2024 provided a rare opportunity to evaluate loss of plants and seed production from unexpected weather events, i.e., late snows. There appears to have been a decrease in percentage of seed set in *D. uniflora* on Ridge in 2024. Schlising and Mackey (2019) reported that there appears to be fewer mature seeds per fruit at lower elevations than at higher elevations were *D. uniflora* occurs (Fig. 18). Perhaps more unpredictable weather events at lower elevations in the springtime versus higher elevations immediately after initial snowmelt may be playing a role in reduced seed production in fruits at these lower elevations. *D. uniflora* has two modes of reproduction, bulblets and seeds. Seeds can be scattered on the ground as the fruits become prostrate and begin dehiscing seeds. Ants are also attracted to the elaiosomes of the seeds and can carry them away and possibly burying them at shallow depths in the ground. Field studies of germination of bulk burial and individual burial of seeds have yielded higher germination rates, typically in the range of 20 to 70 %, versus 4 to 7 % for germination in scattered seed plots (unpublished data Mackey). Underground portions survive for reproduction also. However, there appears to be a trend for possible decline of plants from high soil temperatures in mid- to late summer of over 45 degrees centigrade at E and SE on Ridge since 2009. Lost from intense fires at Summit from the Dixie Fire in 2021 almost eliminated the population of *D. uniflora* there. Thus, it is difficult, given the complexity of factors, likely to occur with a changing environment of (1) unpredictable weather patterns in the spring (late snows), (2) higher summer time (soil) temperatures, (3) drier autumns with less and later precipitation, and (4) extremes from fires to know what the future of this ephemeral geophyte will be long term. This is especially true, since it may require as long as 2 or more decades for *D. uniflora* to reach maturity and flower (Mackey, unpublished data) and maintain a viable seed source at lower elevations within its range in Northern California.

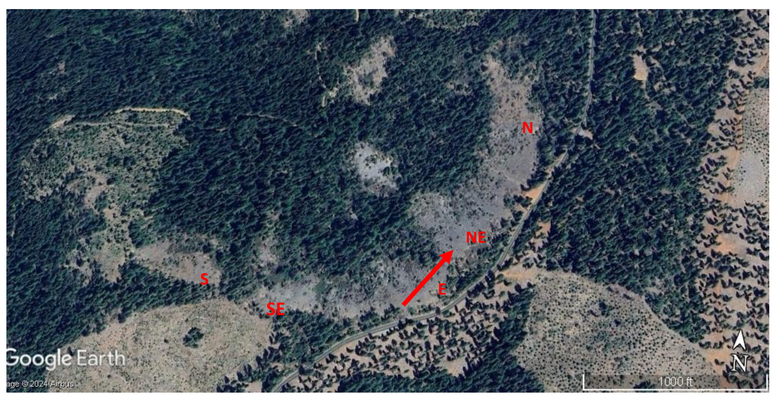
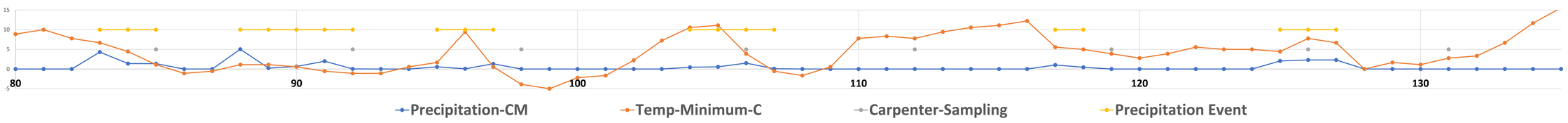


Fig. 1. Aerial view from Google Earth of Carpenter Ridge. The five study sites adjacent to the steep rocky outcrop are indicated by the letters N, NE, E, SE and S. Most samples were taken at NE, E, and S. The arrow indicates the location and direction that reference ground photograph were taken with each survey as presented in Fig. 3 .

Fig. 2. Aerial View of Meadow showing the location of the transect were most of the marked flowers were located in 2018 and 2024 surveys. The surveys occurred in semi-open areas adjacent to the more open, wetter areas of Scott's John Meadow. The transect received less intense fire in the summer of 2021 versus the surrounding forests which were heavily burned.

Fig. 4. View along the sampling transect at Meadow in spring 2024

Fig. 3. Weather patterns and sampling on Carpenter Ridge in spring 2024. Precipitation and minimum temperatures are shown for the sampling dates. Reference photographs showing snow are presented. Of special interest are snow cover on 15 April and 05 May



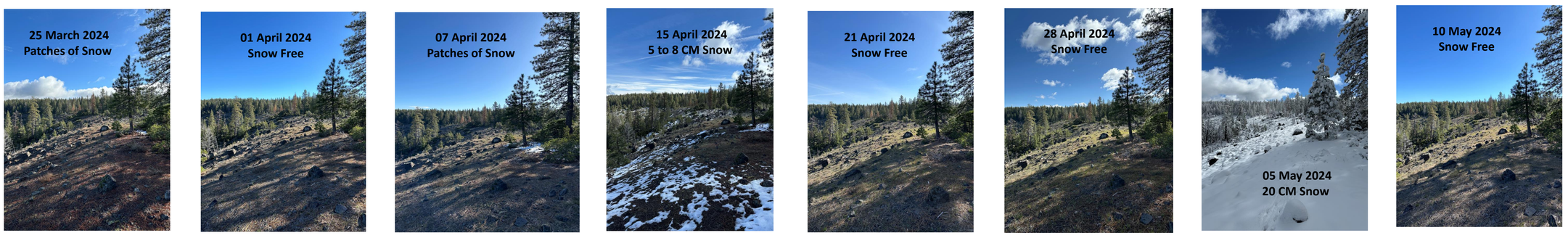


Fig. 6A. Phenology New Flowers 2018

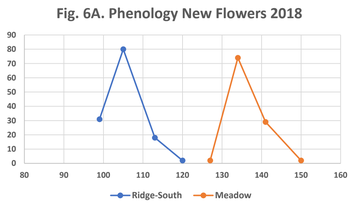


Fig. 6B. Total Number of Flowers 2018

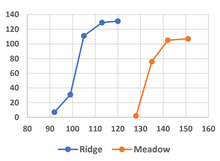


Fig. 6C. Phenology New Flowers 2024

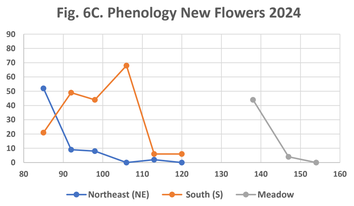
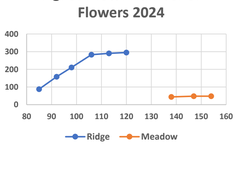


Fig. 6D. Total Number of Flowers 2024



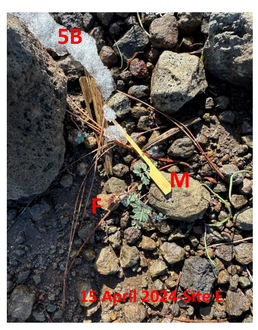


Fig. 5A and B. A shows the general snow cover on 15 April 2024.
M indicates a marker that was freeze-thawed from the soil.
F indicates a flower with freeze damage.

Fig. 5C. Markers were numbered for the week of collection and used in 2018, as shown here, and in 2024 to track the status of *Dicentra uniflora* flowers.

Fig. 7. Snow and Rain Fall Data in CM for Water Years 2017-2018 Through 2023-2024 (June 2024)

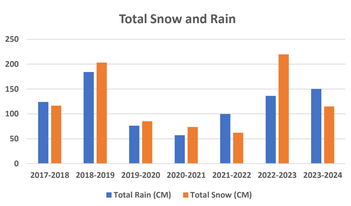


Fig. 8A. Precipitation (cm) Ridge 2018

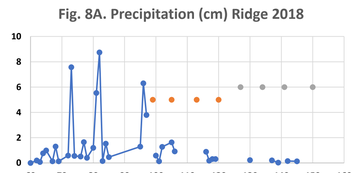


Fig. 8B. Precipitation (cm) Ridge 2024

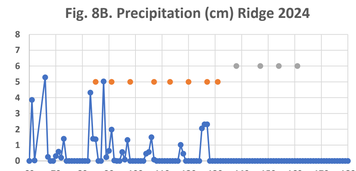


Fig. 8C. Humbug Snow Fall (cm) 2018

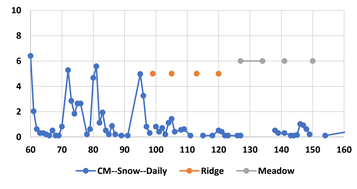


Fig. 8D. Humbug Snow Fall (cm) 2024

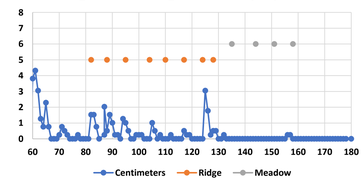


Fig. 6E. Phenology 2024

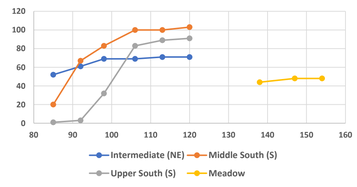


FIG. 9A. NUMBER OF OVULES AND % SEED SET

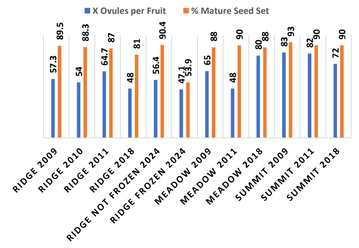


FIG. 10. COMPARISON FROZEN AND NON-FROZEN FRUITS 2024

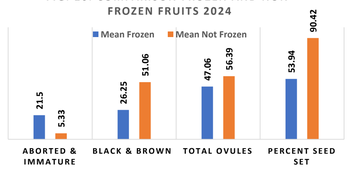


FIG. 13. FRUIT STATUS FOR SITES IN 2018, 2021 AND 2024

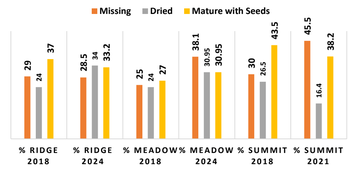


Fig. 18. Number of Seeds versus Elevation

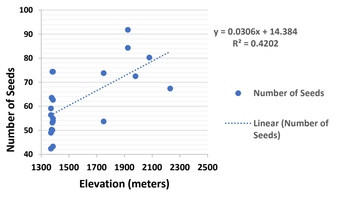


Fig. 9B. Number Ovules per Fruit and % Seed Set

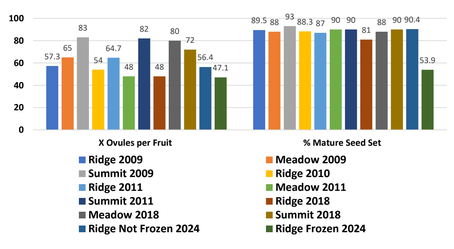


Fig. 12. F Values for Frozen and Non-Frozen Ovule Status

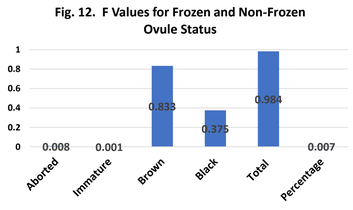


Fig. 14. Mule deer browsing near marked *D. uniflora* flowers.

Fig. 15. Track of black-tailed rabbit at E in 2021

Fig. 16. Adult butterfly of *Parnassius clodius* and larva feeding on leaf of *D. uniflora* at Summit, Butte County, CA.

Fig. 17. Immature of short-horned grasshopper seen on Ridge 2024

Reference of Interest: SCHLISING, R. A. and H. E. Mackey, Jr. 2019. Biology of the ephemeral geophyte, steer's head (*Dicentra uniflora*, Papaveraceae) in the southernmost Cascade Range, Butte County, California. Madroño 66:148-163.

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