

150-Year Trends and Potential Implications in Selected Perennials in the Foothills and Mountains of Northern California, H. E. Mackey, Jr.

Overview of Results

Nine perennials (Figures A through I), mostly geophytes, were examined from the Consortium of California Herbaria online data base (CCH2) to evaluate historical patterns of changes in phenology of those species. Only those records with both a clearly identifiable date of collection and elevation were included. Years of collection ranged from 1863 to 2019. Day of the Year (DOY) ranged from 68 to 267, covering primarily early spring to early summer. Elevations ranged from 46 to 3997 meters with most collections ranging from 500 to 2500 meters (Table J). The data were divided into pre-1970 and post-1970 collections, since California has had a one to two degree F increase in temperature since 1970 (Figure L). The sample sizes for pre-1970 and post-1970 ranged considerable as well. For example, in *Dicentra pauciflora* only 63 dates were used, whereas in *Eriogonum umbellatum* var. *nevadense* 322 dates were used (Figure K). Also an approximately shift to a month earlier in snowmelt and runoff to waterways in Northern California has occurred since 1970 (Figure M). Table N shows the occurrence of these nine species at study sites or locations of observations and collections in our ongoing *Dicentra* studies from 2009 to 2021. Figure O shows the general appearances of four of our *Dicentra* study sites.

Plots of pre-1970 and post-1970 of elevation versus DOY are shown for each of the nine species in Figures A through I. These plots provided a means to calculate for each species an estimate of how many days each may have emerged earlier or later post-1970 for 1000, 1500, 2000 and 2500 meters in elevation (Figures A through I and Figure P). Of the nine species, three geophytes, *Dicentra uniflora*, *Dicentra pauciflora*, and *Claytonia lanceolata*, showed a shift to earlier collection and flowering of typically 10 to 15 days (Figures A, B, and C). Emergent, flowering, and fruit/seed production of two of these three species is closely linked to snowmelt as seen from field studies of *Dicentra uniflora* and *Dicentra pauciflora* from 2009 through 2018 in Butte County and Lassen Volcanic National Park, California (Figures Q and R). *Dicentra formosa* ssp. *formosa* showed a shift to later flowering of about 15 days, especially at higher elevations (Figure D). *Triteleia ixioides* ssp. *anilina* and *Fritillaria atropurpurea* showed little if any change from pre-1970 to post-1970 (Figures E and F). *Wyethia mollis* and *Balsamorhiza sagittata* also showed earlier trends of 6 to 12 days (Figures G and H). *Eriogonum umbellatum* var. *nevadense* showed an earlier trend at lower elevation with less change at higher elevation (Figure I).

A better understanding of the life history responses and growth of *D. uniflora*, *D. pauciflora*, *Claytonia lanceolata*, and *D. formosa* var. *formosa* to snow cover, snowmelt, and dry and wet seasons could provide information on the long-term climate change in California. These data can also provide a means to speculate on the problems and difficulties of predicting potential changes in populations of interacting species with climate changes. For example, records of historical collections and an estimate of the range of the butterfly *Parnassius clodius*, overlay generally with six of the perennials in our review utilized by either the larvae or adults of this butterfly (Figure S). *Parnassius clodius* has *D. uniflora*, *D. pauciflora* and *D. formosa* var. *formosa* as host plants on which the larvae feed (Figure S). All three species of these *Dicentra* occur at our Meadow and Summit study sites in Butte County (Table N). Adult butterflies lay overwintering eggs, often in the litter on the ground in the vicinity of *Dicentra* plants. The nocturnal larvae apparently consume *Dicentra* leaves and possibly green fruit tissue during the very short, above-ground growth period of these plants and may account for some of the herbivory that we have observed on *Dicentra uniflora* at our mid and higher elevation study sites, Meadow and Summit. *Balsamorhiza sagittata* and *Eriogonum umbellatum* var. *nevadense* have been listed or observed as nectar sources for adult butterflies of *Parnassius clodius*. In our studies, an adult male was observed on nearby *Wyethia mollis* flowers at Summit in 2018. Thus, it becomes important that the life cycle of the host plants for the larval stages be timed with the availability of their *Dicentra* food sources and that the timing of food sources for the adults be available also at the appropriate times after pupation. One would also expect that the proximity of larval and adult host species to one another such as a site like Meadow or Summit would be beneficial as well. Apparent concurrent earlier shifts of both the larval and adult food sources with this butterfly could be very important. Areas where all of these species occur near one another might require additional consideration in management planning.

Also in forested settings, the underground portions of *D. pauciflora* grow at the interface between the overlying duff and the underlying soil and those of *D. uniflora* only slightly deeper. Therefore, these underground reproductive structures could be destroyed during forest fires. It would not be unexpected to see the distribution of these two *Dicentra* species to decline as forest fires become more common and intensify in California (Figure T, Note: Figure T does not show the over four million acres burned in California in 2020). It would be interesting to revisit past locations as recorded in the Consortium of California Herbaria online data base (CCH2) to evaluate if a declining trend is already occurring or not in these two *Dicentra* species. Non-forested, more open areas could become candidates for future protection of these species. The online CCH2 data bases can serve as a potential means to monitor and understand the complexity of changes that can occur with long-term climatic and botanical shifts in the foothills and mountains of Northern California.

References of Interest:

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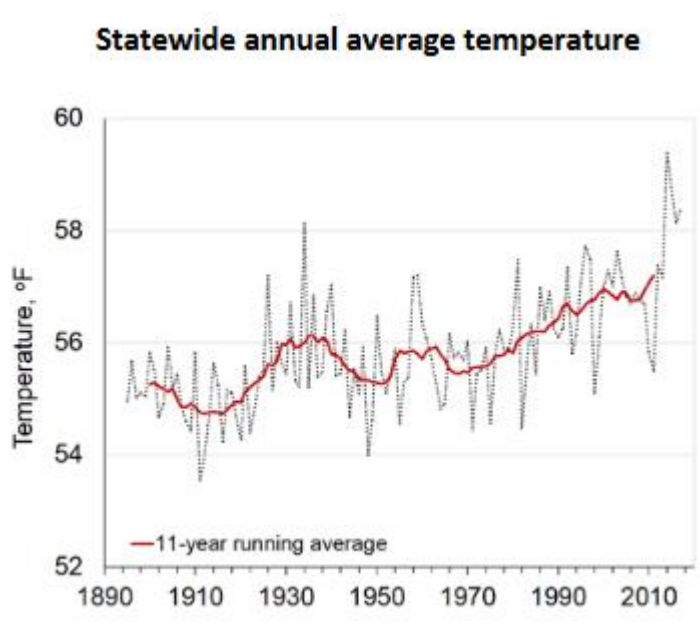


Figure L

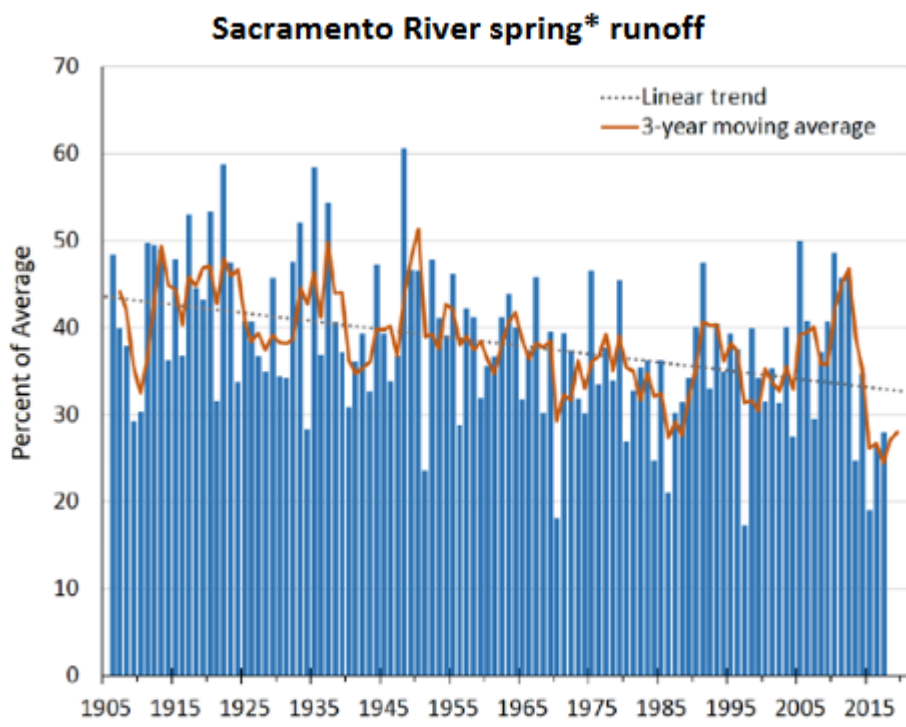


Figure M

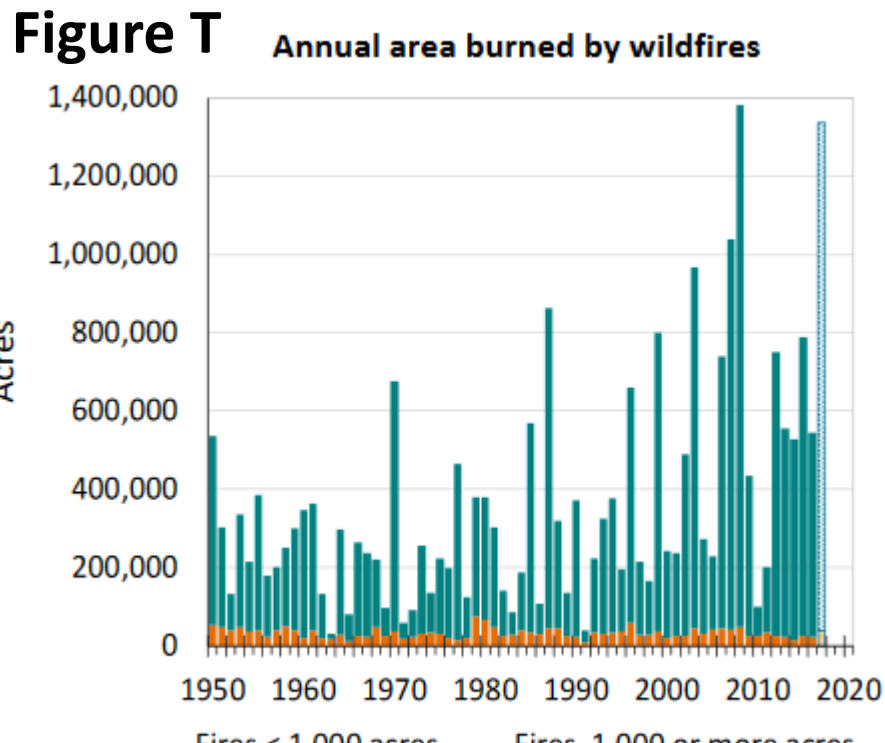


Figure T

Figure S

Adult, Larva, and Distribution Of *Parnassius clodius* In California

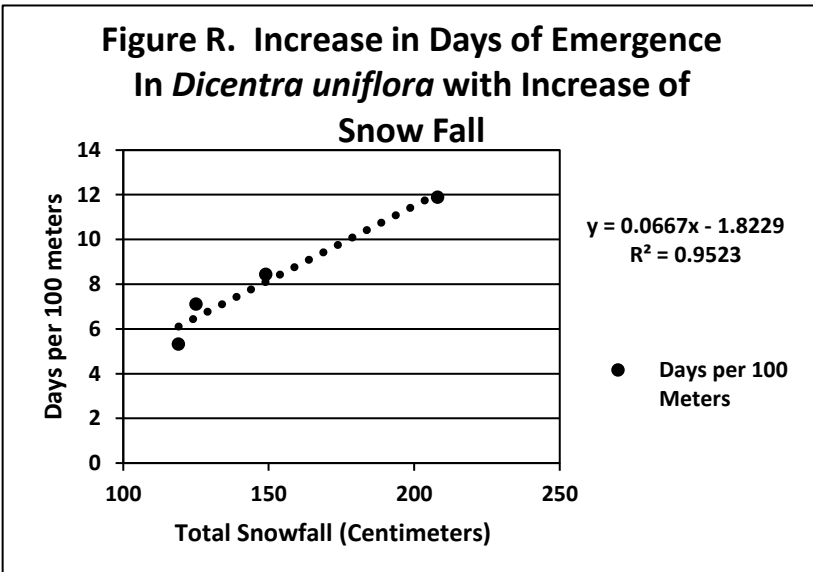
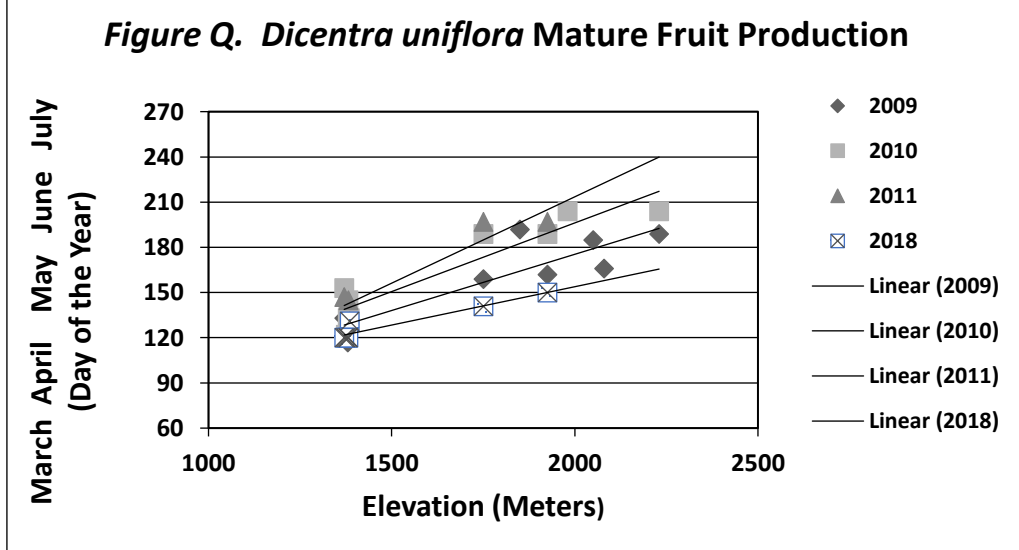
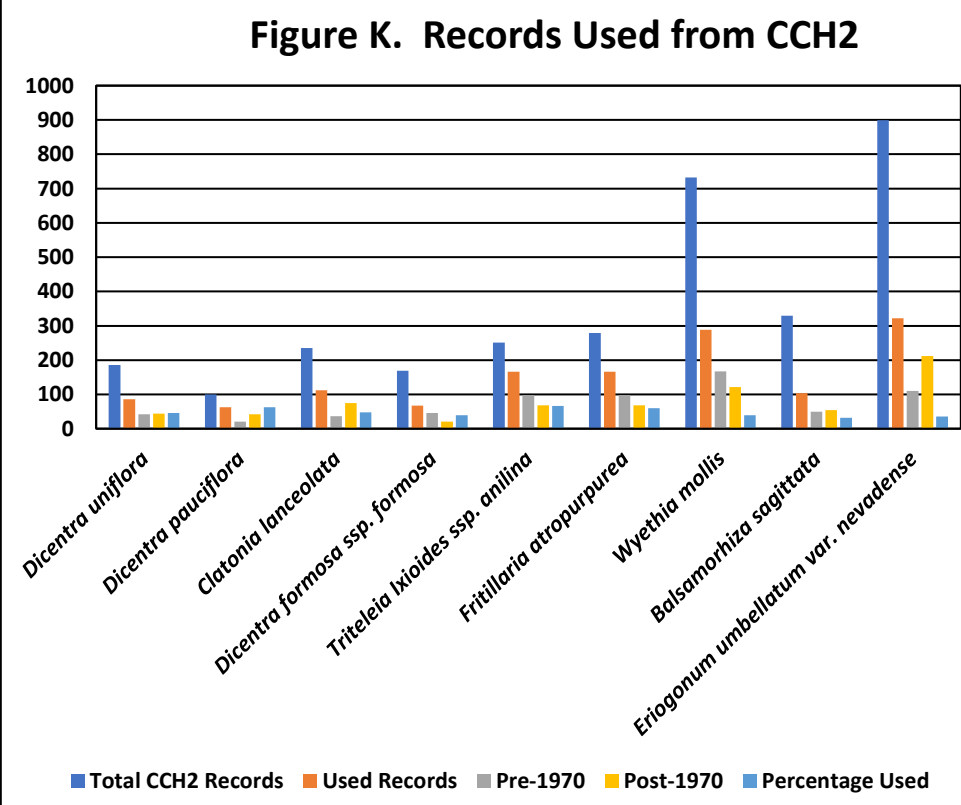
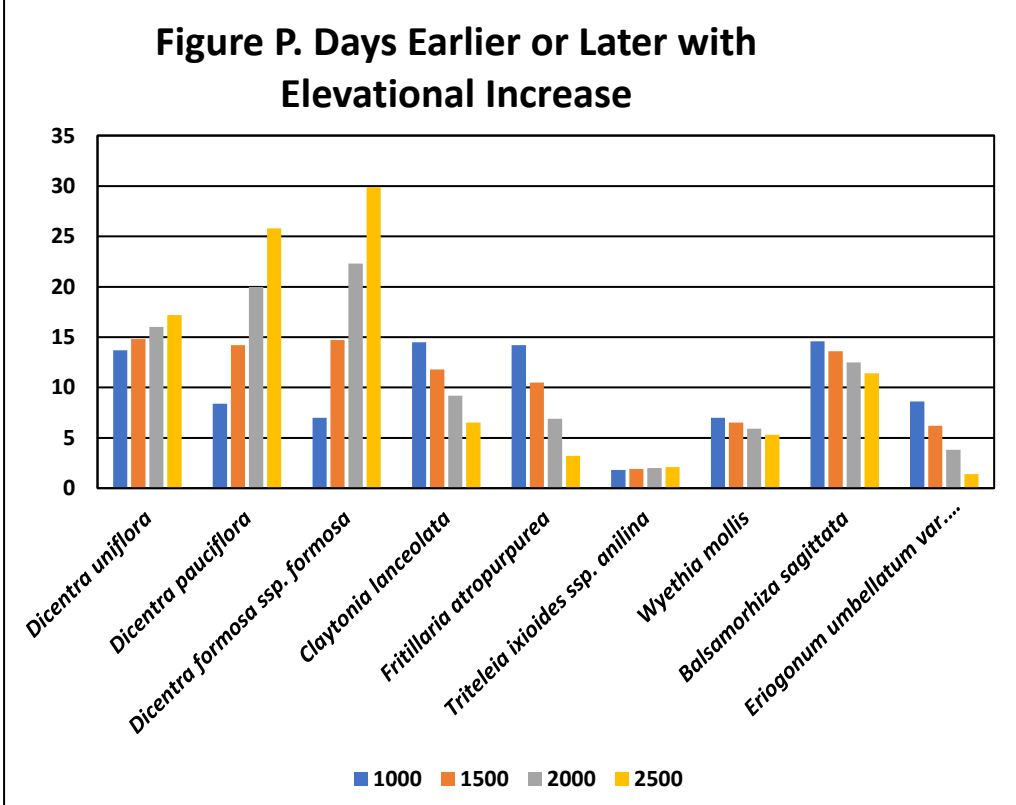


Table J

Elevation (Meters)	<i>Dicentra uniflora</i>	<i>Dicentra pauciflora</i>	<i>Claytonia lanceolata</i>	<i>Dicentra formosa</i> ssp. <i>formosa</i>	<i>Triteleia ixioides</i> ssp. <i>anilina</i>	<i>Fritillaria atropurpurea</i>	<i>Wyethia mollis</i>	<i>Balsamorhiza sagittata</i>	<i>Eriogonum umbellatum</i> var. <i>nevadense</i>
0-500	none	none	none	low	low	low	none	none	none
501-1000	none	none	none	small	low	low	low	low	low
1001-1500	low	low	low	low	X	small	X	X	X
1501-2000	X	X	X	low	X	X	X	X	X
2001-2500	X	low	X	low	X	X	X	X	X
2501-3000	low	low	X	low	low	low	X	low	X
3001-3500	low	none	low	none	none	low	none	none	low

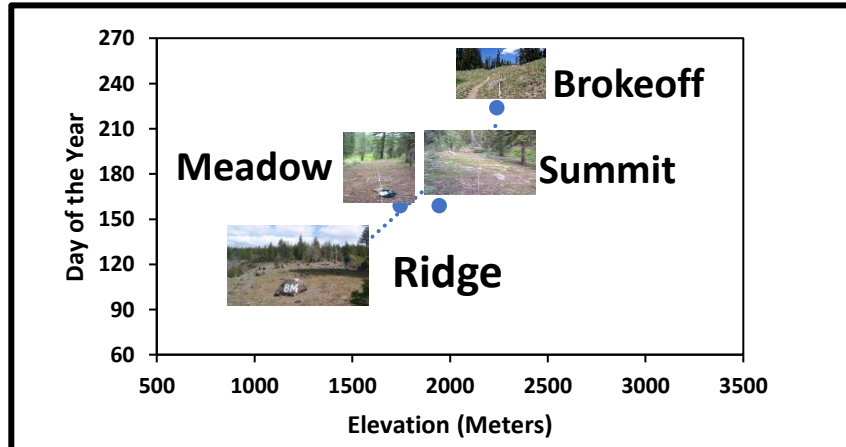


Figure O

Table N

Species	Sites	Ridge	Meadow	Canopy	Summit	Brokeoff-LVNP
<i>Dicentra uniflora</i>	X	X	X	X	X	X
<i>Dicentra pauciflora</i>	X	X	X	X	X	X
<i>Claytonia lanceolata</i>	X	X	X	X	X	X
<i>Dicentra formosa</i> ssp. <i>formosa</i>	X	X	X	X	X	X
<i>Triteleia ixioides</i> ssp. <i>anilina</i>	X	X	X	X	X	X
<i>Fritillaria atropurpurea</i>	X	X	X	X	X	X
<i>Wyethia mollis</i>	X	X	X	X	X	X
<i>Balsamorhiza sagittata</i>	X	X	X	X	X	X
<i>Eriogonum umbellatum</i> var. <i>nevadense</i>	X	X	X	X	X	X

Special thanks to Dr. Robert A. Schlising, Samantha Hillaire, Shawna Burns, Simone Burdick, and the Chico State Herbarium without who's assistance, this project would not have been possible.