

Is there intraspecific variation in synchrony in subalpine flowering species?

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Abstract: Phenology, or the timing of biological events, are often sensitive to changes in abiotic factors. At the Rocky Mountain Biological Laboratory (RMBL), phenological events, such as first and last flowering, have shifted as a result of early snowmelt. Therefore, some species exhibit expanding flowering seasons. This could potentially impact synchrony, which is a measure of how many individuals are in bloom at the same time. I hypothesized that synchrony indices would vary between individuals. To test this hypothesis, I recorded the phenology of tagged individuals of *Delphinium nuttallianum* and *Lupinus bakeri* at the Rocky Mountain Biological Laboratory (RMBL), CO. For these species, I calculated each individual's synchrony index. I found that there is intraspecific variation in synchrony within these species. If the seasons of wildflowers shift to become more asynchronous, it is possible that these populations will decline.

Introduction: Phenology refers to the timing of biological events and may affect aspects of fitness, including reproductive success. In response to climate change, the phenology of amphibians, birds, insects, flowering plants and fungi has shifted over the years (Kausrud et al., 2012; Parmesan and Yohe, 2003). For flowering plants, previous research has primarily focused on the date of first flowering to characterize the shift in flowering distribution (Cook et al., 2012). A more recent study on subalpine flowering plants suggested that phenological shifts are much more complicated and the date of first flowering is an insufficient metric for assessing shifts in phenology (CaraDonna et al., 2014). In addition, they found that the flowering seasons have expanded by more than a month since 1974 in subalpine meadows in the Colorado Rockies (CaraDonna et al., 2014). As phenology continues to respond to warmer temperatures

by shifting earlier over time, it is unclear how these shifts will impact the temporal distribution of flowering within a population.

Synchrony in flowering species refers to the number of individuals in a population that are blooming at the same time (Gomez, 1993). For example, an individual has high synchrony when it flowers along with many other conspecifics. One possibility is that high synchrony may improve an individual's reproductive success by ensuring that the individual blooms alongside many potential mates. A previous study found that highly synchronous tropical shrubs attracted more social bees than their less synchronous counterparts (Augspurger, 1980). However, another study suggested that the pollination success of a tropical orchid declined with increased floral display and synchrony when there are few pollinators (Parra-Tabla and Vargas, 2007). Additionally, flowers with lower synchrony were visited by more pollinators and experience less damage from herbivores (Gomez, 1993). These contrasting findings demonstrate that pollinator and herbivore response to synchrony is system specific.

Delphinium nuttallianum (Ranunculaceae) and *Lupinus bakeri* (Fabaceae) are found in the meadows near RMBL, Colorado. In this study, I examined whether synchrony varied between conspecifics in *D. nuttallianum* and *L. bakeri*. I hypothesized that the synchrony indices of individuals will vary within a population. These species were chosen because they bloom at different times throughout the growing season and allow us to understand how synchrony varies between species throughout the season.

Methods:

Delphinium nuttallianum is an early blooming flower and typically flowers shortly after snowmelt. This perennial herb is self-compatible and can produce flowers for the first time after 3-7 years (Waser and Price 1991). As part of the Fabaceae, *L. bakeri* converts atmospheric nitrogen to a form that is usable to other plants (Australian Government Department of Health and Ageing, 2013). Additionally, this species is self-incompatible (Australian Government Department of Health and Ageing, 2013). Therefore, this species relies on cross-pollination as their main form of reproduction.

To test my hypothesis, I tagged at least 75 reproductive individuals of each *D. nuttallianum* and *L. bakeri*. I returned to these plants approximately every other day to record the number of open flowers, number of spent flowers, and number of fruits. To measure synchrony, I estimated the number of days that an individual's flowering overlaps with another flowering individual as described by Augspurger (1983). This value is calculated as follows:

$$X = \left(\frac{1}{n-1} \right) \left(\frac{1}{f_i} \right) \sum_{j=1}^n e_{j \neq i}$$

where n is the number of individuals in the population, f_i is the number of days that individual i is flowering, and e_j is the number of days that individual i and j are flowering synchronously. Synchrony values range from zero to one. A “zero” for synchrony indicates that an individual's bloom time does not overlap with any other recorded individual's bloom time. Whereas, a “one” indicates that specific individual's bloom time overlapped with every other flowering individual.

Results: Flowering synchrony in *D. nuttallianum* ranged from 0 to 0.37 (Figure 1). In *L. bakeri*, individual flowering synchrony ranged from 0 to 0.46 (Figure 2). In both species, there were individuals that had a synchrony index of 0 which suggests that their flowering period did not overlap with others in the population. On average, individuals of *D. nuttallianum* ($n=95$, $m=0.24$, $sd=0.14$) exhibited lower synchrony indices than *L. bakeri* ($n=92$, $m=0.31$, $sd=0.17$).

Discussion: While examining the distribution of individual flowering synchrony in *D. nuttallianum* and *L. bakeri*, I found that synchrony varies between individuals. However, all of the synchrony indices were on the lower range of possible values.

Since there is variation between the synchrony indices within a population, it is possible that natural selection can act on this trait. Higher synchrony is associated with more potential mates. Therefore, natural selection may favor highly synchronous individuals and lead to higher reproductive success. However, one study found that synchrony varies between individuals within one season and over multiple years (Ollerton and Lack, 1998). This suggests natural selection may not have a strong influence on an individual's synchrony index and other factors might determine an individual's synchrony.

Future studies should examine the relationship between synchrony and reproductive success since this study primarily examines variation in synchrony. A previous study has suggested that there is a relationship between plant size and reproductive success (Ollerton and Lack, 1998). Therefore, these studies should incorporate size as a covariate to account for

that relationship. To fully understand the potential implications of shifts in synchrony, future studies should examine how pollinators and herbivores respond to lower synchrony.

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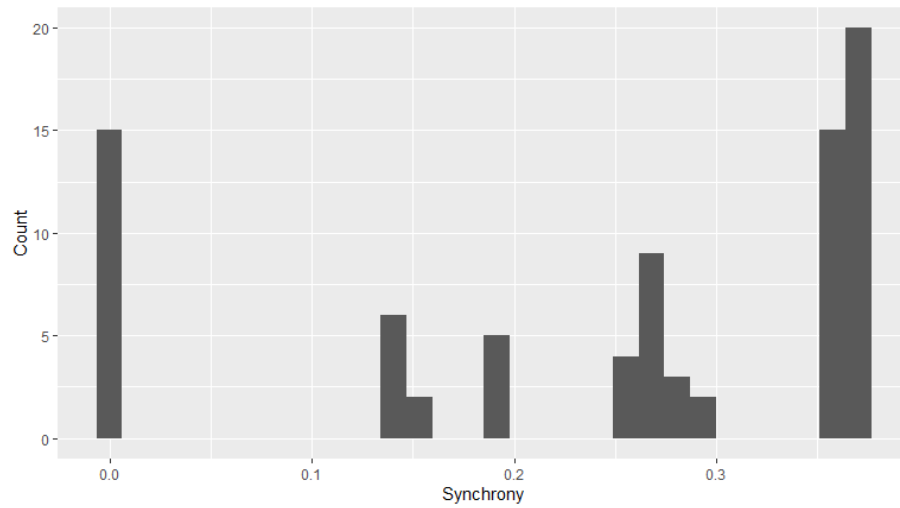
Figures

Figure 1. The distribution of *Delphinium nuttallianum* individual flowering synchrony.

Synchrony indices varied between individuals ($n=95$, $m=0.24$, $sd=0.14$).

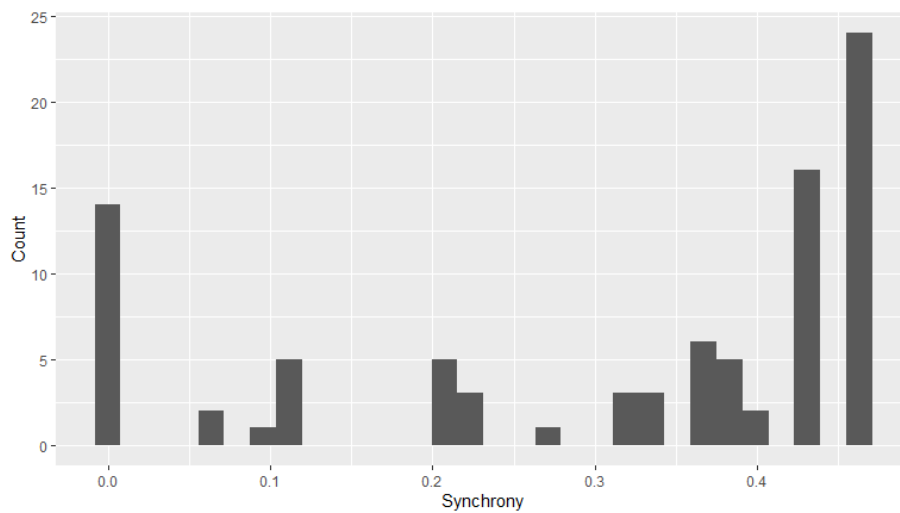


Figure 2. The distribution of *Lupinus bakeri* individual flowering synchrony. Synchrony indices

varied between individuals ($n=92$, $m=0.31$, $sd=0.17$).

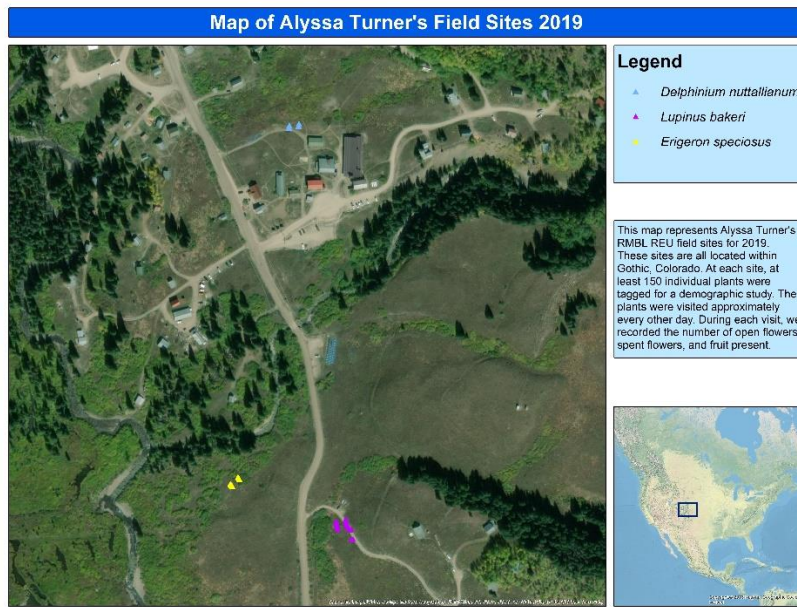


Figure 3. Location of field sites for *Delphinium nuttallianum* (blue), *Lupinus bakeri* (purple), and *Erigeron speciosus* (yellow).