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Title: Bridging past and present: a methodology for interpreting flowering time from herbarium specimens

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Abstract

Premise—Understanding the timing of plant flowering is crucial for gaining insights into climate responses, particularly in the face of global climate change. Utilizing herbarium records presents a promising avenue for studying phenology, yet their interpretation has been hindered by the diverse phenological phases and collection sites of specimens.

Methods—We introduce a novel method for interpreting flowering timing from herbarium specimens, focusing on the species *Arthropodium strictum* R.Br. This method determines the difference between the collection date and the date of a chosen earlier flowering phase, basing the difference on the timing, (in days), of the transition of one flowering phase to the next observed on living plants. Using this difference to place herbarium observations onto an intra-annual timeline enables true comparison among specimens. We coupled the timeline placed observations with temporally and spatially appropriate climatic and elevation data for phenoclimatic assessment. The climatic and elevation variables were modelled against the time-line placed flowering dates.

Results—At the few sites where repeat sampling has occurred, we detected changes in flowering timing. However, the spatial heterogeneity among the remaining collections prevents direct detection of change elsewhere. Higher winter temperatures were associated with earlier flowering timing. Most late-year flowering occurred at higher elevations compared to early-year flowering.

Conclusions—Our methodology provides a clearer understanding of historical flowering timing and facilitates comparison with contemporary observations. This method establishes a framework for phenological data collection that could be applied to other species and will have defined, meaningful and interpretable results, because it enables realistic estimates of the timing of the individual phases of historic flowering events. Furthermore, it allows revisiting sites corresponding to the herbarium collection to collect contemporary observations for comparison with a single visit.

Key words: Climate change, phenology, herbarium specimen