**Phenology**

One man, 73 years, and 25 species. Evaluating phenological responses using a lifelong study of first flowering dates By:[Bolmgren, K](https://cuvpn.colorado.edu/,DanaInfo=0-apps.webofknowledge.com.libraries.colorado.edu+OneClickSearch.do?product=WOS&search_mode=OneClickSearch&excludeEventConfig=ExcludeIfFromFullRecPage&colName=WOS&SID=2FrGSNcCm1zDsimm6jX&field=AU&value=Bolmgren,%20K" \o "Find more records by this author) (Bolmgren, K.)**[** [**1**](https://cuvpn.colorado.edu/,DanaInfo=0-apps.webofknowledge.com.libraries.colorado.edu+full_record.do?product=WOS&search_mode=GeneralSearch&qid=1&SID=2FrGSNcCm1zDsimm6jX&page=1&doc=4#addressWOS:000317474400004-1)**,**[**2**](https://cuvpn.colorado.edu/,DanaInfo=0-apps.webofknowledge.com.libraries.colorado.edu+full_record.do?product=WOS&search_mode=GeneralSearch&qid=1&SID=2FrGSNcCm1zDsimm6jX&page=1&doc=4#addressWOS:000317474400004-2) **]** ; [Vanhoenacker, D](https://cuvpn.colorado.edu/,DanaInfo=0-apps.webofknowledge.com.libraries.colorado.edu+OneClickSearch.do?product=WOS&search_mode=OneClickSearch&excludeEventConfig=ExcludeIfFromFullRecPage&colName=WOS&SID=2FrGSNcCm1zDsimm6jX&field=AU&value=Vanhoenacker,%20D) (Vanhoenacker, D.)**[** [**3**](https://cuvpn.colorado.edu/,DanaInfo=0-apps.webofknowledge.com.libraries.colorado.edu+full_record.do?product=WOS&search_mode=GeneralSearch&qid=1&SID=2FrGSNcCm1zDsimm6jX&page=1&doc=4#addressWOS:000317474400004-3)**,**[**4**](https://cuvpn.colorado.edu/,DanaInfo=0-apps.webofknowledge.com.libraries.colorado.edu+full_record.do?product=WOS&search_mode=GeneralSearch&qid=1&SID=2FrGSNcCm1zDsimm6jX&page=1&doc=4#addressWOS:000317474400004-4) **]** ; [Miller-Rushing, AJ](https://cuvpn.colorado.edu/,DanaInfo=0-apps.webofknowledge.com.libraries.colorado.edu+OneClickSearch.do?product=WOS&search_mode=OneClickSearch&excludeEventConfig=ExcludeIfFromFullRecPage&colName=WOS&SID=2FrGSNcCm1zDsimm6jX&field=AU&value=Miller-Rushing,%20AJ) (Miller-Rushing, A. J.)**[ [5](https://cuvpn.colorado.edu/,DanaInfo=0-apps.webofknowledge.com.libraries.colorado.edu+full_record.do?product=WOS&search_mode=GeneralSearch&qid=1&SID=2FrGSNcCm1zDsimm6jX&page=1&doc=4" \l "addressWOS:000317474400004-5),**[**6**](https://cuvpn.colorado.edu/,DanaInfo=0-apps.webofknowledge.com.libraries.colorado.edu+full_record.do?product=WOS&search_mode=GeneralSearch&qid=1&SID=2FrGSNcCm1zDsimm6jX&page=1&doc=4#addressWOS:000317474400004-6) **]** INTERNATIONAL JOURNAL OF BIOMETEOROLOGY Volume: 57 Issue: 3 Pages: 367-375 DOI: 10.1007/s00484-012-0560-8 Published: MAY 2013

Links between plant species’ spatial and temportal responses to a warming climate – Amano et al 2014 Proceedings of the royal society B – Biological sciences

Maintenance of ecological niche by changing phenology – if not maintained with phenological changes then moved northward – so plants may not change their range and instead change phenology with temperature. Idea that temperature is what the plants are trying to maintain – avoid frost, keep fitness at flowering time – and this is done phonologically – earlier, or spatial, more northward…

1. 405 species, 400,000 observations (in Britain).
2. 6669 species spatial data at two census periods

If a species cannot track warming climate by advancing phenology will need to move to higher latitude (not possible if on top of mountain..)

Used daily mean temperature (central England temperature (CET).

“Only native species (native

status ¼ N or NH in the PLANTATT database [24]) whose indices

exceeded 19 years were used in this analysis, based on an

earlier study which reported that, in most species, relatively accurate

estimates of the relationship between flowering dates and

temperature can be obtained with 20-year data” – “one man, 73 years, and….”

Mean daily CET in the week starting from the first flowering date estimated by the species-level index for each year and species.

Looked at each month – what responsible for first bloom..

* Alpine species that are not changing their phenology with changing temperature may be at risk of climate change driven extinction because they cannot track northward??
* Mean they don’t have the phenotypic plasticity to survive change without range change?

Phenological plasticity will not help all species adapt to

climate change

ANNE DUPUTI\_E1 , 2 \* , ALEXIS RUTSCHMANN2 , 3 \* , OPH\_EL I E RONCE 4 and ISABELLE CHUINE2

2015

Advanced spring events due to phnotypic plasticity. Some of these plastic shifts are adaptive but some can be maladaptive.

Mean temperature of coldest month, mean temp of wamest month, numbr of chilling days, drought index, GDD above 5°C. total precipitation, precipitation during growing season, coefficient of variation of precipitations among season

Title: [Nonlinear flowering responses to climate: are species approaching their limits of phenological change?](https://cuvpn.colorado.edu/,DanaInfo=apps.webofknowledge.com+full_record.do?product=WOS&search_mode=GeneralSearch&qid=8&SID=1CmKcESlHrmd2KpZu5G&page=4&doc=40)

Author(s): Iler, Amy M.; Hoye, Toke T.; Inouye, David W.; et al.

Source: PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B-BIOLOGICAL SCIENCES  Volume: 368   Issue: 1624     Article Number: UNSP 20120489   DOI: 10.1098/rstb.2012.0489   Published: AUG 19 2013

Times Cited: [2](https://cuvpn.colorado.edu/,DanaInfo=apps.webofknowledge.com+CitingArticles.do?product=WOS&SID=1CmKcESlHrmd2KpZu5G&search_mode=CitingArticles&parentProduct=WOS&parentQid=8&parentDoc=40&REFID=454260126) (from Web of Science)

Title: [Long-term monitoring at multiple trophic levels suggests heterogeneity in responses to climate change in the Canadian Arctic tundra](https://cuvpn.colorado.edu/,DanaInfo=apps.webofknowledge.com+full_record.do?product=WOS&search_mode=GeneralSearch&qid=8&SID=1CmKcESlHrmd2KpZu5G&page=4&doc=39)

Author(s): Gauthier, Gilles; Bety, Joel; Cadieux, Marie-Christine; et al.

Source: PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B-BIOLOGICAL SCIENCES  Volume: 368   Issue: 1624     Article Number: UNSP 20120482   DOI: 10.1098/rstb.2012.0482   Published: AUG 19 2013

Times Cited: [1](https://cuvpn.colorado.edu/,DanaInfo=apps.webofknowledge.com+CitingArticles.do?product=WOS&SID=1CmKcESlHrmd2KpZu5G&search_mode=CitingArticles&parentProduct=WOS&parentQid=8&parentDoc=39&REFID=454260122) (from Web of Science)

Title: Growing degree-days: one equation, two interpretations

Gregory S. McMaster W.W. Wilhelm

Agricultural and Forest Meteorology 87 (1997) 291-300

Calculations of GDD differ and impact simulation models for duration of process. Depends on how the base temperature is incorporated into the equation.

1. where if (tmax+tmin/2) < tbase then use tbase.
2. If Tmax < tbase then tmax = tbase

Temperature Thresholds and Growing-Degree-Day Models for Red Sorrel (Rumex acetosella) Ramet Sprouting, Emergence, and Flowering in Wild Blueberry Scott N. White, Nathan S. Boyd, and Rene C. Van Acker 2015

Cumulative GDD = sum 1 to n (Tmean – Tbase) and when Tmean < tbase then GDD = 0 citing Gordon and Bootsma (1993)

Bases and limits to using ‘degree.day’ units. Bonhomme 2000

Mathematical formulae for calculating the base temperature for growing degree days. Yang et al 1995

Selecting temperature at which below growth and development will cease.

Evaluation of several degree-day estimation methods in California climates. Roltsch et al 1999

Allen JC. 1976 A modified sine wave method for calculating degree days. Environ. Entomol. 5, 388 – 396. (doi:10.1093/ee/5.3.388)

Grasshopper community response to climatic change: variation along an elevational gradient. 2010. Nufio, Cesar R. McGuire Chris R. Bowers M. Deane Guralnick Robert P.

For detailed review of the concept of GDD, see Arnold (19601, Pruess (19831, Wang (19601, and Zalom et al. (1983).

**Papers citing Gallagher et al. 2009**

Chambers et al. 2013. PLOS ONE. Phenological Changes in the Southern Hemisphere. Meta-analysis of phenological drivers; advance in timing of spring events; temperature most frequently identified as primary driver (though in many cases that was only one considered); when precipitation considered, often played key role but direction of variation difficult to predict.

Li et al. 2013. Biodiversity and Conservation. Species-level phonological responses to ‘global warming’ as evidenced by herbarium collections in the Tibetan Autonomous Region. Growing realization that herbarium-based collections offer baseline data; looked at average flowering time; used mixed model with randomized blocks for 41 species (909 specimens), with altitude as the block and year and temp fixed effects and flowering time was the response variable; found earlier flowering time (0.5 days per year).

Keatley and Hudson. 2012. Austral Ecology. Detecting change in an Australian flowering record: Comparisons of linear regression and cumulative sum analysis change point analysis. CUSUM can detect multiple change points but linear regression cannot; but two methods agreed 84.6% of the time.

Diskin et al. 2012. International Journal of Biometeorology. The phenology of Rubus fructicosus in Ireland: herbarium specimens provide evidence for the response of phenophases to temperature, with implications for climate warming. Looked at temp vs date of first flower, full flower, first fruit, and full fruit with linear regression; supports use of multiphase approach to using herbarium specimens since prior work validated single phenophase work. Only one of five species examined had enough data to yield statistically significant results with temperature.

Panchen et al. 2012. American Journal of Botany. Herbarium specimens, photographs, and field observations show Philadelphia area plants are responding to climate change. Used regression analysis of date of flowering with year or with temp; 16 days earlier over 170 year period and 2.7 days earlier per 1C rise in temp; woody plants with short flowering duration best indicator of warming climate.

Proenca et al. 2012. Ecography. Phenological Predictability Index in BRAHMS: a tool for herbarium-based phenological studies. The main focus of such studies have been phenological changes which accompany warmer spring and autumn temperatures in northern temperate (Robbirt et al. 2011) or southern hemisphere alpine plants (Gallagher et al. 2009, Gaira et al. 2011, Zalamea et al. 2011).

Gaira et al. 2011. Biodiversity and Conservation. Potential of herbarium records to sequence phonological pattern: a case study of Aconitum heterophyllum in the Himalaya. Used herbarium records to look at flowering times along elevational gradient and through time; also compared to maximum winter temp and mean winter temp; used general additive model (GAM)

Robbirt, et al. 2011. Journal of Ecology. Validation of biological collections as a source of phenological data for use in climate change studies: a case study with the orchid Ophrys sphegodes. Rigorous test of validity of using herbarium specimens for phonological studies by comparing peak flowering time to climate from both herbarium and field observations, used mean spring temp. herbarium data corresponded closely with field observations.