

The effect of temperature and photoperiod on the phenology of leafout and bird activity in The Upper Valley

<http://www.dartmouth.edu/~mpayres/hhs/>

Introduction:

Scientific studies performed around the world show that climate change is having impacts on ecosystem structure and function. For many species, there is only a short period during the year in which climatic conditions are suitable for reproduction and development. This period may also be influenced by other species at a lower trophic level. For example, a study in the Netherlands has shown that since 1985 mid spring temperatures have increased by 2°C causing caterpillar biomass to peak two weeks earlier than it did in 1985. As a result the timing of egg laying by the Great Tit (a relative of our chickadee) and the abundance of its food source (caterpillars) has become out of sync causing decreased reproductive success and declining abundance of the Great Tit. Climate change has also caused some decoupling between the time when caterpillars hatch and feed and the availability of young tender oak leaves on which they feed.

"Phenology is the study of the timing of recurring biological events, the causes of their timing with regard to biotic and abiotic forces, and the interrelation among phases of the same or different species" (US/IBP Phenology Committee, Lieth 1974). There are two chief mechanisms by which organisms adjust their phenology to maintain favorable match between themselves and their environment: photoperiod and temperature. Photoperiod is the duration of daylight, which of course changes with calendar day (Fig. 1). In this study we will investigate the roles of photoperiod and temperature in (1) the phenology of leafout in one or more common species of trees, and (2) the onset of reproductive activity by two or more common species of birds (including both winter residents and seasonal migrants).

Hypotheses:

- H1: The timing of leafout is primarily a function of temperature, specifically the accumulation of degree days (thermal sum).
- H2: The time when birds initiate reproductive activity (indicated by singing) is primarily a function of photoperiod but is also influenced by the timing of leafout.
- H3: The phenology of reproductive activity by migratory birds is mainly a function of photoperiod while the phenology of winter-resident birds is more sensitive to plant phenology.

Fig. 1. Photoperiod vs. calendar date at 43.75° north latitude

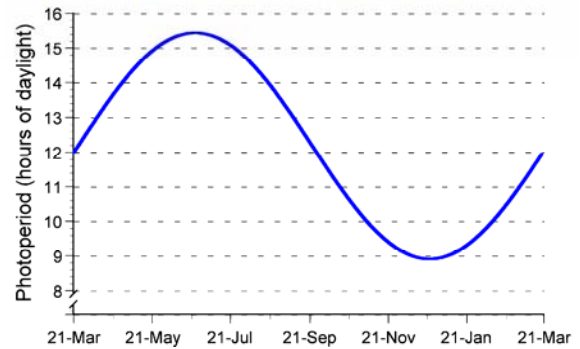


Fig. 2. Air temperature vs. elevation in Hubbard Brook Forest

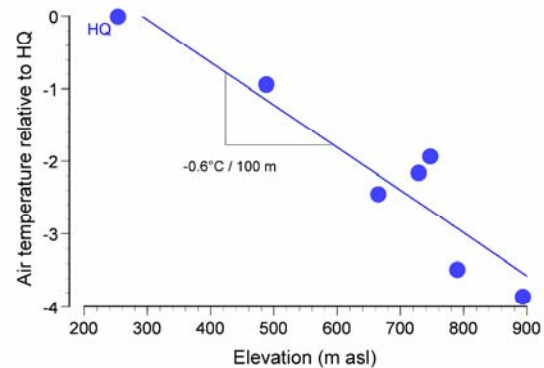
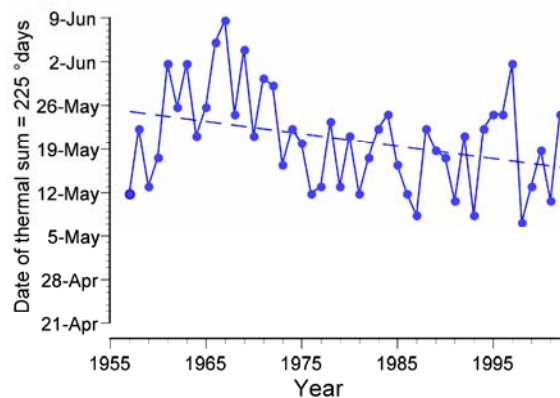


Fig. 3. Estimated leafout at Hubbard Brook Forest (253 m asl)



If Hypotheses 1 and 2 are true, then the recent tendency for warmer springs (Fig. 3) will disrupt the historical match between tree phenology and bird reproduction, possibly with negative effects on the birds. If Hypothesis 3 is also true, then the negative effects will be greater for migratory birds than for winter-resident birds.

Research plan:

Select species of study trees. Each student should report the tree species in or around their yard. In particular, look for one or more sugar maple trees that have branches accessible from the ground. Based on the lists, we will select for study one or more tree species that can be found by all, or most, students. We anticipate that virtually everyone should be able to locate a suitable sugar maple for observation.

Deploy temperature loggers. Each student should use a GPS to record the latitude, longitude, and elevation of their home. Then we will select a subset of homes, dispersed in space and elevation, at which to deploy automated data loggers for recording hourly air temperatures throughout the study. Loggers should be placed so that they are 1-2 meters above ground, protected from direct sunlight, and in the vicinity of study trees. It is especially critical to sample temperatures across the full range of elevations because air temperature is negatively correlated with elevation (adiabatic effects, Fig. 2), and we will later develop a predictive equation from the sites where we recorded temperature to estimate the temperatures at all study sites.

Monitor phenology of leafout. Each student should select for observation five leaf buds on their study tree. To make it easier to relocate each individual bud, mark them with a twist tie (labeled 1-5) on the branch next to the bud. Examine each bud three times per week and record on a datasheet the date of observation and the developmental status of each bud (or leaf) with one of the following categories:

- 0 no change from winter conditions unexpanded buds only
- 1 bud swelling noticeable
- 2 budbreak; small leaves becoming evident but <1 cm long
- 3 leaf 1-3 cm in length
- 4 leaf 3-6 cm in length
- 5 leaf >6 cm length but still expanding
- 6 leaf fully expanded

Monitor phenology of bird singing. On three mornings per week, each student should listen for singing birds near their study tree for 5-10 minutes. Record the date and time of observation, and note any of the focal bird species that were heard singing and/or seen. Data sheet should indicate whether birds were heard, seen, or heard and seen. Everyone should learn the robin and cardinal songs. The other species are optional. Pictures and recordings of calls are available at the associated weblinks.

*American Robin	http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/American_Robin.html
*Northern Cardinal	http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/Northern_Cardinal.html
Eastern Phoebe	http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/Eastern_Phoebe.html
Winter Wren	http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/Winter_Wren.html
Hermit Thrush	http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/Hermit_Thrush.html
Veery	http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/Veery.html
Ovenbird	http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/Ovenbird.html
White-throated Sparrow	http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/White-throated_Sparrow.html
Song sparrow	http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/Song_Sparrow.html

Analyze data and evaluate hypotheses:

We will work as a group to determine how to efficiently summarize, visualize, and interpret our data such that we are able to test hypotheses 1-3. Ideally, the results will either falsify or support each hypothesis. Also, we will consider whether it would be valuable to continue these studies in subsequent years.

Some potentially useful background information:

Adiabatic lapse. Air temperatures will be predictably cooler at sites that are on hills compared to the valley. Based on the physics of adiabatic cooling, air cools by ~ 0.5 – 0.7°C / 100 meters of increase in elevation (Fig. 2; exact coefficient depends upon moisture content and air movement patterns). Thus, we can expect that we will have a range of temperatures across our study sites because there will be a range of elevations. Consider how we can use temperature data from a subset of sites to estimate air temperatures at other sites of known elevation in the Upper Valley.

Degree days and thermal sum. Biological events that are primarily driven by temperature can frequently be predicted based upon the accumulation of degree days (thermal sum). For example, leafout in the nearby Hubbard Brook Experimental Forest (<http://www.hubbardbrook.org/>), which is one of the best studied forests in the world, has ranged from early May to early June over the last 40 years, but generally tends to occur on about the day when the thermal sum above a 5°C base reaches 225 °days (Fig. 3). Thermal sum can be calculated as:

$$Tsum_d = \sum_{i=1}^d [(T_i - Base) \text{ if } T_i > Base \text{ else } 0]$$

Where the thermal sum on day d ($Tsum_d$) = sum of all positive differences between previous daily mean temperatures (T_i) and the lowest temperature at which the biological process of interest proceeds ($Base$). Trees in our area tend to have a developmental threshold ($Base$) of ~ 5°C. Thus a day when the average temperature is 11°C adds 6 °days to the thermal sum (11 - 5), a day when the average temperature is 23°C adds 18 °days to the thermal sum (23 - 5), and the thermal sum after these two days is 24 °days (6 + 18). Days when the temperature does not exceed the base neither add to nor subtract from the accumulating thermal sum.

Recent regional trend toward earlier springs. At the Hubbard Brook Experimental Forest, the average date when the thermal sum reached 225 °days has advanced by ~ one week since 1960 (Fig. 3). This has also been reflected in a tendency for the ice on Mirror Lake at Hubbard Brook Forest to break free earlier in the spring (Likens 2000*). Probably the same pattern has been true in the Upper Valley but we know of no analyses.

Long term data for the Upper Valley. Daily maximum and minimum temperature records have been recorded at a NOAA climate station in Hanover (behind the Co-op) since 1948 and are available online.

<http://www4.ncdc.noaa.gov/cgi-win/wwwcgi.dll?wwDI~StnSrch~StnID~20018671>

We have recently rediscovered historical data on the average timing of spring arrival by migrant birds in the Upper Valley from 1910 – 1957 that were compiled by E.M. Sherrard and E. A. Sanborn. These will also be made available online.

*Likens, G.E. 2000. A long-term record of ice cover for Mirror Lake, NH: Effects of global warming? *Verhandlungen der Internationalen Vereinigung für Theoretische und Angewandte Limnologie* 27: 2765-2769. <http://www.hubbardbrook.org/research/current/discipline/climate/vadeboncoeur06.htm>