Spring 1972

# Phenology and microclimate

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## PHENOLOGY AND MICROCLIMATE

This study was undertaken in the Fairy Chasm State Scientific Area, administered by The Wisconsin Chapter of the Nature Conservancy since 1970. Fairy Chasm includes a relict community harboring many northern species of vegetation which became established soon after the retreat of the last glacial ice 10,000 years ago.

The Fairy Chasm Scientific Area encompasses twenty acres at the Lake Michigan end of a series of ravines that begin approximately 1¼ miles west of the shore of Lake Michigan in Ozaukee County. These ravines vary from sixty to one hundred feet in depth and have some slopes greater than $45^{\circ}$. The protection of the slopes, the cool air draining down them, and the cool winds coming off the lake, create a microclimate suitable for many northern species of plants.

White pine, white cedar, balsam poplar, and paper birch are present throughout the ravine areas. A few yellow birch can still be found and, eastern hemlock, no longer present, once thrived here.

Today, most northern tree species are losing ground and show little reproduction; species of the deciduous forest appear destined to replace them. The invaders are characteristic upland hardwoods and include sugar maple, beech, basswood, and shagbark hickory.

Northern shrubs such as leatherwood, buffalo berry, and beaked hazelnut are found with many northern herbaceous plants including orchids, pyrolas, dwarf scouring rush, sphagnum moss, and pine drops. Orange hawkweed flourishes along the uncut roadsides surrounding the ravines.

This study examined the effects of different microclimates on the phenology of several plant species. A second objective involved testing the applicability of the duration-summation temperature method of heat accumulation (Lindsey and Newman 1956) to an area of diverse topography.

Three weather stations were established in Fairy Chasm in late fall of 1970; locations were chosen so that there would be marked differences between stations. Station 1 was placed in a level, moderately wooded area of second growth sugar maple, beech, ash, and basswood. Stations 2 and 3 were placed 50 meters apart in the ravine and less than 100 meters from station 1. Station 2 was located midway from the base of the 20 meter deep ravine on a slope of $31^{\circ}$ and had a direct southerly exposure. Station 3 was situated on a $23^{\circ}$ north-facing slope directly to the south and on the same level as station 2. Both slopes were dominated by white cedar, paper birch, and sugar maple. Balsam poplar grows along the stream which bisects the ravine and white pine grows along the upper edges.

Although the arboreal vegetation was very similar on both slopes, the lower vegetation differed greatly, with the greatest differences occurring in the fern and bryophyte stratum. Sphagnum and other mosses, *Equisitum scirpoides,* and various ferns flourished on the north-facing slope; these species were absent from the south-facing slope.

Special instrument shelters (with instrument level at 0.5 meters) were placed at each location. Each shelter housed a recording hygrothermograph from March 7 through June 21. Before March 7 the shelters had been equipped with Taylor maximum-minimum thermometers. Mercury thermometers were used to obtain weekly soil temperature readings.

*Hepatica acutiloba* D.C. and *Corylus cornuta* Marsh. (beaked hazelnut) were present at all stations and were selected as primary species for observation. A threshold temperature of 40° F was used throughout. This coincides with the threshold temperature determined for *Hepatica* by Lindsey and Newman (1956). Lindsey and Newman used a 45° F threshold for all shrubs; however, I found the 45° F threshold too high for *Corylus* in Wisconsin.

## *RESULTS AND DISCUSSION*

### *Microclimate*

Temperatures at the three stations showed marked differences. Greatest differences occurred between average maximum temperatures (Table 1) as a result of differences in duration of insolation and the angle at which it is received. The results are comparable to those obtained by Cantlon (1953) on north and south-facing slopes in central New Jersey and follow the pattern of temperature differences during the growing season found by Mowbray and Oosting (1968) in a gorge in the Southern Appalachians. Average temperatures at station 1 were compared with those recorded at two U.S. Weather Service stations: the Port Washington Weather Station, 14 miles north of Fairy Chasm and 200 meters from the shore of Lake Michigan and; the General Mitchell Field station in Milwaukee, 17 miles south of Fairy Chasm and three miles inland.

Higher minimum temperatures and lower maximums in the spring suggest a strong influence of Lake Michigan (Kopec 1967) on the Port Washington record. The Milwaukee weather station, inland at Mitchell Field, does not show the moderating effects of the lake felt at Fairy Chasm and Port Washington. The differences between the three stations in the Fairy Chasm area and those at Milwaukee and Port Washington demonstrate the climatic diversity which complicates accurate phenological forecasting. In addition, June data suggest that during the summer, both slopes of the ravine may possess cooler maximum temperatures than the surrounding level areas. Thus, one reason for the continued existence of the northern relict community may be the relatively low maximum temperatures during the summer.

Soil temperatures showed a gradual increase compared to the rapid increase in air temperature. The -10 cm level was warmer than the -20 cm level until mid-April when conditions were reversed. Soil temperature levels on the south-facing slope were five days in advance of those in the upper wooded area through the month of May; north-facing slope temperatures were nearly ten days behind those of the upper wooded area. Snow persistence roughly paralleled the time lag exhibited by soil temperature. The last snow persisted on the north-facing slope until April 11, while snow was gone on the south-facing slope on March 31.

Early plant development appears to be most closely related to the amount of heat energy received by the dormant or growing plant (Wang 1963). The unit used in many phenological studies is the degree hour, i.e., the number of units of heat

| | Upper Woods | South Facing Slope | Relative Difference (%) | North Facing Slope | Relative Difference (%) |
|---|---|---|---|---|---|
| | | | MARCH 8-31 | | |
| MAX. | 37.7 | 38.8 | + 2.9 | 33.4 | - 11.4 |
| MIN. | 22.7 | 23.3 | + 2.6 | 20.8 | - 8.4 |
| MEAN | 30.2 | 31.1 | + 3.0 | 27.1 | - 10.3 |
| | | | APRIL | | |
| MAX. | 51.4 | 54.5 | + 6.0 | 47.7 | - 7.2 |
| MIN. | 30.0 | 30.7 | + 2.3 | 30.0 | — |
| MEAN | 40.7 | 42.6 | + 4.7 | 38.8 | - 4.7 |
| | | | MAY | | |
| MAX. | 63.3 | 63.7 | + 0.6 | 59.4 | - 6.1 |
| MIN. | 38.0 | 38.5 | - 1.3 | 37.8 | - 0.5 |
| MEAN | 50.6 | 51.1 | + 1.0 | 48.6 | - 4.0 |
| | | | JUNE 1-15 | | |
| MAX. | 72.0 | 70.1 | - 2.6 | 67.1 | - 6.8 |
| MIN. | 52.1 | 52.5 | + 0.8 | 51.7 | - 0.8 |
| MEAN | 62.1 | 61.3 | - 1.3 | 59.4 | - 4.3 |

Table 1. Average maximum, minimum, and mean temperature ($^{o}$F) recorded in level woods, south facing slope, and north facing slope and the percentage that the temperature of either slope differs relative to the wooded area.

for one hour (over a certain threshold temperature) that the plant receives. A method of determining threshold temperatures is explained by Lindsey and Newman (1956).

A 40$^{o}$ threshold was used to determine the actual number of degree hours and also to estimate the number of degree hours by the duration-summation method. Values for the duration-summation technique were obtained from Lindsey and Newman's (1956) master chart. Lindsey and Newman based their work on an equation employing the daily minimum and maximum and the threshold temperature to delimit a triangular area which approximates the daily total of degree hours. This method has proven to be more successful than others previously used (Lindsey

1963). For comparison, I measured the actual total of degree hours shown on the hygrothermograph charts. The two sums were compared and differences determined between actual and estimated values for the north and south-facing slopes and the level station (Table 2).

At the level station, values from the estimated duration-summation method and the measured or actual totals are comparable, deviations range from -2.8% to +1.3%. This is not the case for the slope stations. Degree hours on the south-facing slope are continually overestimated and those for the north-facing slope, underestimated, from maximum and minimum values. These results indicate serious discrepancies when using the duration-summation method in areas of diverse micro-topography.

| *Period of Measurement* | | | | *Cumulative Total* | |
|---|---|---|---|---|---|
| *Dates* | *Actual* | *Duration-Summation* | *Monthly Relative Difference (%)* | *Actual* | *Duration-Summation* |
| March 8-31 | 179 | 241 | + 34.6 | 179 | 241 |
| April | 3,340 | 3,176 | - 4.9 | 3,519 | 3,417 |
| May | 8,021 | 8,281 | - 3.2 | 11,540 | 11,698 |
| June 1-15 | 7,855 | 7,956 | + 1.3 | 19,395 | 19,654 |
| | | | *SOUTH-FACING SLOPE* | | |
| March 8-31 | 284 | 371 | + 23.4 | 284 | 371 |
| April | 3,804 | 3,976 | + 4.5 | 4,088 | 4,347 |
| May | 8,136 | 8,498 | + 4.4 | 12,224 | 12,845 |
| June 1-15 | 7,385 | 7,656 | + 3.7 | 19,609 | 20,501 |
| | | | *NORTH-FACING SLOPE* | | |
| March 8-31 | 57 | 51 | - 10.5 | 57 | 51 |
| April | 2,360 | 2,104 | - 10.8 | 2,417 | 2,155 |
| May | 6,930 | 6,865 | - 1.0 | 9,347 | 9,020 |
| June 1-15 | 6,876 | 6,984 | + 1.5 | 16,223 | 16,004 |

Table 2. Comparison of actual degree hours and the duration-summation total of degree hours in 1971. Per cent differences are arrived at using the total degree hours accumulated for each month above a 40°F. threshold.

| *SPECIES* | *EVENT* | *DATE* |
|---|---|---|
| Basswood *Tilia americana* | Budbreak | May 2 |
| Spring Cress *Cardamine Douglassii* | First Flower | May 2 |
| Yellow Trout Lily *Erythronium americanum* | First Flower | May 9 |
| Wood Anemone *Anemone quinquefolia* | First Flower | May 9 |
| Large Flowered Trillium *Trillium grandiflorum* | First Flower | May 13 |
| Jack-in-the-Pulpit *Arisaema Triphyllum* | Emergence | May 15 |
| Paper Birch *Betula papyrifera* | Leaf Emergence | May 18 |
| Wild Strawberry *Fragaria virginiana* | First Flower | May 18 |
| Poison Ivy *Toxicodendron rydbergii* | Leaf Emergence | May 18 |
| Shagbark Hickory *Carya ovata* | Budbreak | May 27 |
| Red Osier Dogwood *Cornus stolonifera* | First Flower | June 7 |
| Orange Hawkweed *Hieracium auranticum* | First Flower | June 7 |

Table 3. Calendar of phenological events occurring in the level woods at Fairy Chasm in 1971.

*PHENOLOGY*

*Hepatica* exhibited a fourteen day difference in first flowering (first evidence of petal opening) from the south to the north-facing slope; on the level area first flower occurred 7 days later than on the south-facing slope (Fig. 1). The estimated mean total $^{o}$hr requirement for first flower using the duration-summation method was 2149 ($\pm$ 163) $^{o}$hrs; the actual (measured) mean $^{o}$hr was 2285 ($\pm$ 228) $^{o}$hrs.

Dates of peak flowering of *Hepatica* (based on the largest number of *Hepatica* plants flowering at a station at one time) are 16 days apart between the south and the north-facing slope. The mean degree hours and standard deviation are 4072 $\pm$ 58 and 4055 $\pm$ 175 for the duration-summation value and the measured total, respectively. The difference between the degree hour means arrived at by the duration-summation method and the actual total are negligible (0.4%) as a result of combining of the overestimated values of the south-facing slope with the underestimated values of the north-facing slope. Peak flowering date appears more reliable for prediction purposes than the use of date of first flower. The actual values to which the degree requirements at all three stations correspond indicate a fairly reliable degree hour estimation for the future prediction of both the date of first flower and of peak flowering of *Hepatica.*

Three clones of *Corylus cornuta* were observed at each station. The shrubs varied in age, and the height of catkin-bearing branches ranged from 1 to 2.5m above the soil surface. Three different threshold levels, 35$^{o}$, 40$^{o}$, and 45$^{o}$ F were used in an attempt to correlate catkin opening, pollination, stigma emergence, and bud break with degree hour totals. No significant correlation was found, suggesting the lessening of temperature differences farther away from the soil surface as compared to the temperature recorded in the instrument shelters only 0.5m above the surface. Likewise, basswood trees showed bud break and leaf emergence on the same days at all three stations, beech followed the same pattern.

Events were recorded for thirty-five different species, many present at only one of the climatic stations (Table 3). Where herbaceous species occurred at two or all three of the stations the results closely parallel that of *Hepatica.* Towards the end of May and the beginning of June, the effect of the south-facing slope in advancing phenological events disappeared and, in some cases, events on the south-facing slope became delayed and compared to those at the level wooded station. The climate of the north-facing slope continued to retard phenological events in comparison to those on the level.

On the average, the difference in flowering time between the south and north-facing slopes was fourteen days, equivalent to 242 miles difference in latitude or 1400 feet in elevation (Hopkins 1938).

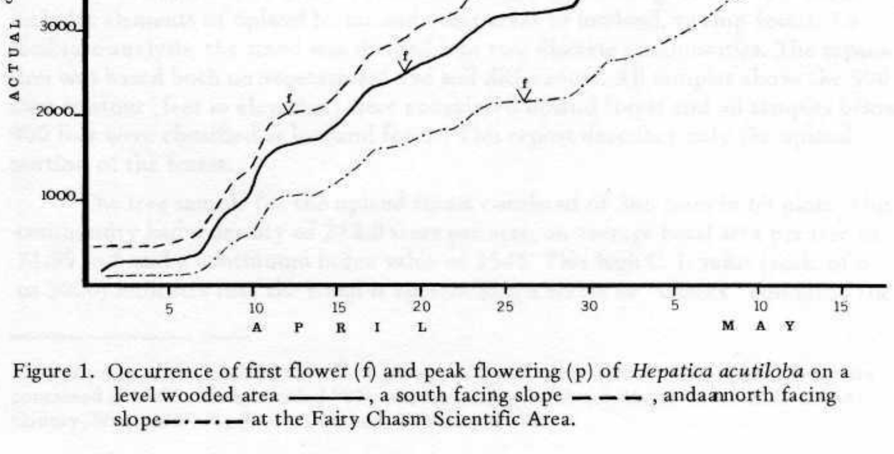


Figure 1. Occurrence of first flower (f) and peak flowering (p) of *Hepatica acutiloba* on a level wooded area ———, a south facing slope — — — , andaanorth facing slope—·—·— at the Fairy Chasm Scientific Area.

## LITERATURE CITED

Cantlon, J. E. 1953. Vegetation and microclimates on north and south slopes of Cushetunk Mountain, New Jersey. Ecol. Monogr. 23:241-270.

Geiger, R. 1965. The climate near the ground. Harvard University Press, Cambridge. 611p.

Hopkins, A. D. 1938. Bioclimatics, A science of life and climate relations. U.S. Dept. Agr. Misc. Publ., 280. 188pp.

Jackson, M. T. 1966. Effects of microclimate on spring flowering phenology. Ecology. 47:407-415.

Kopec, R. J. 1967. Effects of the Great Lakes' thermal influence on freeze-free dates in spring and fall as determined by Hopkins' Bioclimatic Law. Agr. Meteorol. 4:241-253.

Lindsey, A. A. and J. E. Newman 1956. Use of official weather data in springtime-temperature analysis of an Indiana phenological record. Ecology 37:812-823.

Lindsey, A. A. 1963. Accuracy of duration temperature summing and its use for *Prunus serrulata*. Ecology. 44:149-155.

Mowbray, T. B. and H. J. Oosting. 1968. Vegetation gradients in relation to environment and phenology in a southern Blue Ridge Gorge. Ecol. Monogr. 38:309-344.

Wang, J. M. 1963. Agricultural meteorology. Pacemaker Press, Milwaukee, Wisconsin 693p.

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