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# MONITORING OF SPRING FLOWER PHENOLOGY IN NOVA SCOTIA: COMPARISON OVER THE LAST CENTURY

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ABSTRACT - Since 1996, Nova Scotia Plantwatch has collected earliest flower dates for 12 plant species at 200 sites in Nova Scotia. The initial results for 1996-1998 are compared with records collected by MacKay between 1892 and 1923. Although the Mackay data were from a colder climatic interval in the Northern Hemisphere, most flowering dates are not significantly different from the present warmer (+0.5 – 0.7ºC) period except during the 1998 season of record warmth. The only two species that showed significant differences are *Epigaea repens* and *Syringa vulgaris*. While *E. repens* showed significant later recent dates of first bloom, *S. vulgaris* showed earlier dates. Some of the variation within the province may be linked to oceanic influence; other variation reflects latitudinal gradients. These phenological results are compatible with other evidence that the average spring climate of the Atlantic Canada region has remained cool since 1948, but the early flowering in 1998 may be a response to a warming trend in the western part of the region.

## INTRODUCTION

Stresses on ecosystems can be of many types, with various amplitudes, some being difficult to detect in the short term (Rapport and Whitford 1999). Since ecosystems are affected by irreversible impacts, it is crucial to document any sign of distress (Rapport and Whitford 1999). For example, without urgent measures to control $CO_2$ and other greenhouse emissions, according to the global circulation simulation models (GCMs), the global climate may be rapidly and radically modified (Mooney et al. 1991). Trends toward warming have already been reported on a global scale (Jones et al. 1999) and in some parts of Canada (Skinner and Gullett 1993). However, climate records for the Atlantic region of Canada (i.e., Nova Scotia, New Brunswick, Prince Edward Island, and Newfoundland) have shown a warming trend from 1885-1947 and a cooling trend (-0.7 ºC) from 1948-1995 (Environment Canada 1998). The large-scale grouping of four Atlantic provinces for climatic studies, unfortunately results in merging of data from almost 10

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degrees of latitude (~43.5 - 52° N), ranging from subarctic areas in the north to temperate forests in the southwest. For example, in Nova Scotia alone, there is a steep gradient in mean annual temperature from 7.1 °C in the Southwest to 5.5°C in the Northeast (Environment Canada 1998).

The main purpose of the study here is to examine the evidence for the reported Atlantic region cooling on a more sensitive provincial scale, using the flowering phenology of selected plants collected in Nova Scotia at intervals over the past century, in addition to temperature records. Among the periodical phenomena (phenology) of plants that can be monitored easily and are sensitive to spring temperatures, time of flowering is one of the most evident. Jackson (1966) established the sensitivity of spring flowering dates to air temperatures on a microclimatic level in a small study area. In recent years, province-wide flowering phenology has also received more attention because of its relation to plant fitness and sensitivity to environmental change (e.g., Beaubien and Johnson 1994). Although there is a genetic component influencing the time of flowering, it is usually closely linked to the environment (Rees 1987), thereby representing a useful tool for ecological monitoring (Klaveness and Wielgolaski 1996). Price and Wasser (1998) also showed that early season warming and snowmelt may advance flowering by 7 days. Collections of large phenological data sets are particularly valuable when they can be compared with historical data from the same region, such as the 1736-1947 Marsham record for the county of Norfolk in England (Sparks and Carey 1995). In our study, we are able to compare modern and historical data collected from 12 counties throughout the province of Nova Scotia.

**Nova Scotia Plantwatch**

In 1996, the Nova Scotia Plantwatch initiated a long-term phenological survey of flowering events of 12 common plant species. Almost 1000 dates of flowering events throughout the province were collected. The present study has two objectives: 1) to improve public education and awareness about our flora, the importance of its conservation, and the effects of environmental changes (such as global warming) on their survival; and 2) to compare the present plant phenological data with historical data collected a century ago by MacKay (1899). From about 1892 to 1923, Alexander H. MacKay, the superintendent of schools of Nova Scotia, collected and published yearly phenological observations from teachers and students from about 1000 schools in the province (MacDonald 1973, MacKay 1899). For each year of the MacKay database, 100 phenological observations were made, including first flowering and fruiting of 50 native and cultivated plants, first appearances of migratory birds, and dates of hay-cutting and sheep-shearing along with weather events such as hurricanes and hailstorms.

Eight of the plant species monitored in our study are the same as those in MacKay's database. It is therefore possible to compare the pre-1924 and modern flowering dates in the different parts of the province. The modern data set covers a time when Northern Hemisphere temperatures have increased by 0.1 – 0.5ºC (Jones et al. 1999).

## METHODS

Dates of flowering were collected at various sites across Nova Scotia from 1996 to 1998. The species (and their common names) in this study are *Populus tremuloides* (trembling aspen), *Epigaea repens* (mayflower), *Syringa vulgaris* (purple lilac), *Acer rubrum* (red maple), *Cornus canadensis* (bunchberry), *Rhododendron canadense* (rhodora), *Clintonia borealis* (bluebead), and *Houstonia caerulea* (bluets). The other species currently monitored but not included in this study are: *Larix laricina* (hackmatack or larch), *Tussilago farfara* (coltsfoot), and *Forsythia suspensa* (weeping forsythia), *Trientalis borealis* (starflower), *Taraxacum officinale* (dandelion), and *Fragaria americana* (wild strawberry). For each species, the dates were recorded when 10% (i.e. either a few flowers on the same plant, or a few herbs in the survey area, were opened), 50% (half of the flowers were blooming or open flowers were common), and 90% (most of the flowers on a same plant or in the area were opened). Mean annual temperature was obtained from averages of the monthly means compiled for 12 weather stations in 12 of the 15 Nova Scotian counties (Gerard Morin, Environment Canada, pers. comm. 1999).

MacKay's data included 100-300 observations for most years. The surveys recorded only the "first flowering" (presumably ~10%) and "common flowering" (50% bloom). These two sets of data were used for the comparison of flowering dates in MacKay's time and the present Nova Scotia Plantwatch surveys. Temperature data for the MacKay series were annual averages of records for Yarmouth, Halifax and Sydney. Although there is some heterogeneity between the pre-urbanisation and modern records from the city of Halifax, it has been shown that this does not significantly affect the trend in temperature change compared to neighbouring non-urban weather stations (Richards et al. 1991). For this preliminary study of historical and present phenological data, statistical comparisons were made using the Wilcoxon test (SPSS Version 10.0, 2000) since the data were not normal and the samples were unbalanced.

## RESULTS

Despite the difference in the global average temperatures at the time of the historical and modern surveys, there were no statistically significant overall differences in flowering dates between the histori-

Table 1. Mean (standard deviations) dates of flowering between 1898 and 1926 and in 1996-1998 for the province of Nova Scotia. Dates are transformed in day of the year for better comparisons. The last row includes the Wilcoxon comparison tests significant levels for the comparison that were performed between the dates of first bloom of MacKay's observations and the "1990s" data.

| Year | Bloom | Flowering sequence (Julian days) | | | | | | | | *Mean annual temperature* |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Populus tremuloides* | *Epigaea repens* | *Syringa vulgaris* | *Acer rubrum* | *Cornus canadensis* | *Rhododendron canadense* | *Clintonia borealis* | *Houstonia caerulea* | (ºC) |
| 1892-1897 | First | 124(5) | 104(4) | 158(4) | | | | | | 6.4(0.3) |
| 1898-1904 | First | 113(8) | 100(6) | 159(2) | 123(5) | 150(5) | 145(1) | 152(5) | 134(9) | 6.6(0.7) |
| | 50% | 118(5) | 112(4) | 166(2) | 129(5) | 155(6) | 153(1) | 157(4) | 140(1) | |
| 1911-1917 | First | 122(4) | 109(5) | 161(5) | 130(5) | 152(4) | 150(6) | 155(5) | | 6.3(0.6) |
| | 50% | 128(2) | 118(5) | 165(5) | 136(5) | 158(3) | 156(7) | 162(4) | | |
| 1918-1923 | First | 120(6) | 109(6) | 158(6) | 131(5) | 150(3) | 147(4) | 152(2) | | 6.0(0.5) |
| | 50% | 126(6) | 119(4) | 164(6) | 136(5) | 156(3) | 151(3) | 159(4) | | |
| 1996 | First | 123(14) | 121(12) | 143(10) | 125(13) | 146(9) | 143(8) | 142(11) | 131(8) | 6.7 |
| | 50% | 132(14) | 129(15) | 149(9) | 134(9) | 147(8) | 146(9) | 147(8) | 140(13) | |
| 1997 | First | 130(12) | 125(6) | 156(10) | 128(4) | 155(7) | 156(8) | 160(9) | 140(9) | 6.5 |
| | 50% | 137(6) | 130(7) | 160(8) | 136(5) | 159(10) | 160(11) | 163(7) | 139(10) | |
| 1998 | First | 107(7) | 109(8) | 142(7) | 115(8) | 144(5) | 138(8) | 145(4) | 126(8) | 7.7 |
| | 50% | 116(9) | 116(8) | 146(9) | 121(6) | 148(8) | 143(6) | 147(5) | 132(7) | |
| Wilcoxon test | | 0.477 | 0.010 | 0.019 | 0.648 | 0.929 | 0.127 | 0.408 | 0.989 | |

cal and modern data sets for most Nova Scotian species and temperatures (Table 1). In recent years, most species tended to flower at almost the same time in spring as they did between 1892 and 1923 and the average temperatures were not significantly different from the historical time interval. For example, the range of time for first bloom of poplar was similar between the two study periods, although the 1998 value was among the earliest ever recorded (Fig. 1a). However,

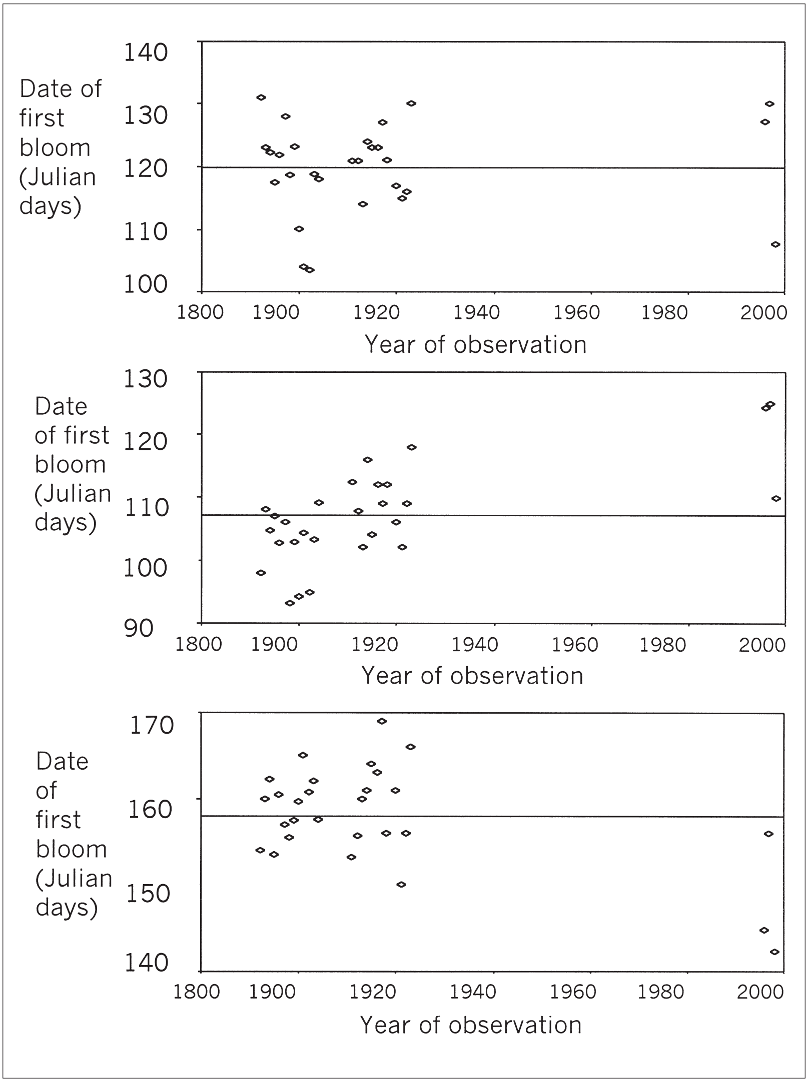


Figure 1. Average dates of first bloom for a) *Populus tremuloides*, b) *Epigaea repens* and c) *Syringa vulgaris*, for all the years of observation. The median horizontal line represents the average of dates of first bloom for the species using the entire data set.

for *E . repens* and *S. vulgaris*, significant variations were observed (Table 1, Fig. 1). *Syringa vulgaris*, most of which are mature bushes of the European cultivar introduced to Nova Scotia last century, flowered significantly earlier (t = 0. 019) in the 1990s than a century ago (Fig. 1a). In contrast, *Epigea repens* was less responsive than the other species and bloomed significantly later (t = .01) in the 1990s than during Mackay's time (Table 1 and Fig. 1b). In 1998, however, all species except *Epigaea repens* flowered on average 12 days earlier. This extraordinary year was marked by an annual temperature increase in Nova Scotia of almost 1°C, with most of this increase occurring in spring and the fall (Environment Canada 1998).

Flowering dates varied greatly between the different parts of Nova Scotia because of the east-west and north-south ranges in climatic conditions. For all the species, flowering occurred earlier in Yarmouth (southwestern county) than in Cape Breton (northeastern area), where temperatures were usually lower in the spring. For example, according to MacKay's data, while *Epigea repens* (mayflower) flowered by April 2 (Julian date = 92) in the southwestern part of the province, it did not

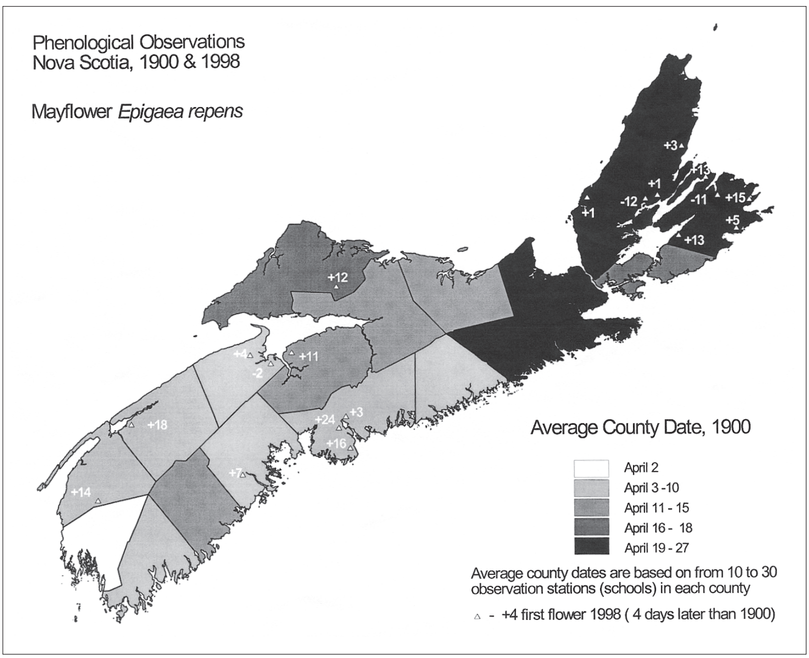


Figure 2. Average dates of flowering of *Epigaea repens* between 1898-1900 according to MacKay's data for the province of Nova Scotia. Similar shade of grey relates to similar dates of flowering. The additional numbers of the map show the difference in flowering dates between 1898/1900 and 1998 for the same regions.

start flowering before April 24 (Julian date = 114) in the northeast (Fig. 2). In 1998, spatial variation appeared to be more pronounced for some species. Phenology of *Acer rubrum* (red maple) showed not only southwestern to northeast variation but in 1998 there were also notable differences in phenology between the coast and the interior part of the province (Fig. 3). For example, on the south shore of mainland Nova Scotia, in 1998, red maple flowered at the same time or later than in 1898 on the south coast, while in the interior part of the province and northwest Nova Scotia, flowers tend to bloom earlier (Wilcoxon test = 6.87, P = 0.032, Fig. 3).

## DISCUSSION

Due to the short time span and limited spatial coverage of the new Nova Scotia Plantwatch program, the 1996-1998 results allow only a preliminary analysis of possible long-term changes. Several more years will be necessary to obtain more definite conclusions about the climatic trends in Nova Scotia, yet there seem to be some initial results that are

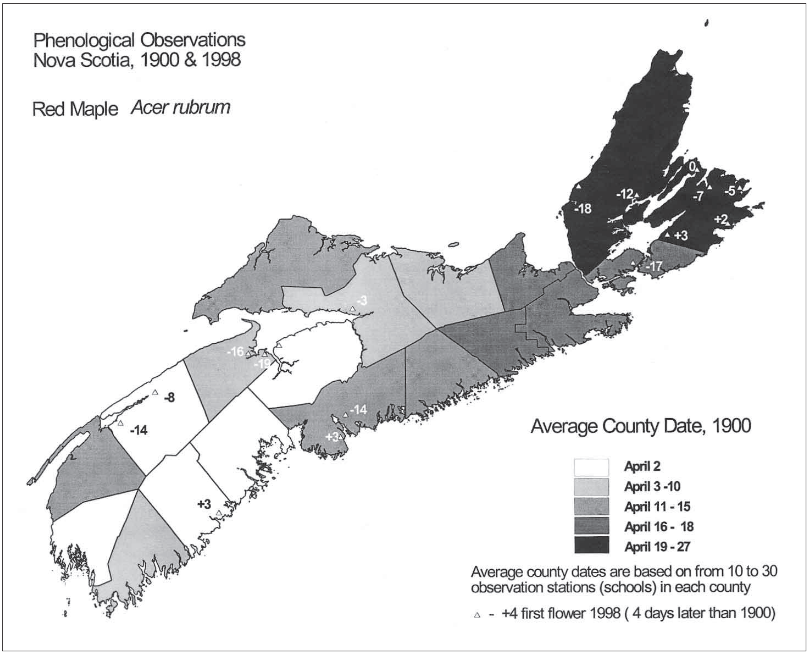


Figure 3. Average dates of flowering of *Acer rubrum* between 1898-1900 according to MacKay's data for the province of Nova Scotia. Similar shade of grey relates to similar dates of flowering. The additional numbers of the map show the difference in flowering dates between 1898/1900 and 1998 for the same regions.

worthy of further discussion. The present study showed that in Nova Scotia, most of the spring flowering plants did not bloom earlier in 1996 and 1997 than at the turn of the century, although global mean temperatures of the past years were higher than earlier in the century. This trend is consistent with the slight cooling reported for the Atlantic region (Nova Scotia to Newfoundland) as a whole and it may indicate major inter-regional differences between eastern and western Canada, where spring flowering is now 10 days earlier than it was 45 years ago (Beaubien et al. 1996).

The semi-insular setting of Nova Scotia probably has an important effect on flowering phenology. Most species, such as red maple, exhibited more spatial variation in phenological dates within in the Nova Scotia study area than between the two periods of survey. These differences were most noticeable between coastal and interior sites. On the coast, cold nearshore currents and prolonged spring fog may have buffered effects of air warming; in the interior, conditions are more subject to rapid changes in response to warm, dry, continental air masses.

There were also important differences in phenological responses between the two surveys that seemed to reflect species characteristics. Notable in our study, while lilac bloomed significantly earlier over time, *Epigea repens* did not seem as sensitive to change. Past phenology studies (Price and Wasser 1998, Sparks and Carey 1995) have shown that it is normal for the response to climate change to vary according to species. With regard to mayflower, this may reflect a lack of plastic response or the buffering conditions associated with its prostrate morphology. The sheltered conditions in which mayflower grows might have buffered its ability to respond to climatic changes. Eco-physiological studies on this species are needed to better understand its response mechanisms.

Spatial variation in flowering dates of several species suggested that large variations in micro- and mesoscale physical and climatic conditions should be integrated into the analysis. For future surveys, it is important that volunteers carefully note habitat, direction of slope, and degree of shading in order to evaluate the importance of microclimatic differences (Beaubien et al. 1996, Jackson 1966). At the mesoscale, there is a need for more uniform coverage of some subregions of the province, particularly in the warmer southwest section and on the Northumberland Strait coast, where delay in sea ice break-up may slow the time of flowering.

For the Atlantic region as a whole, studies have suggested that recent winter cooling trends may be related to either high levels of atmospheric aerosols over Atlantic Canada, or to changes in ocean and sea ice patterns (e.g., Morgan et al. 1993). The semi-insular topography of Nova Scotia may further increase the impact of lowered coastal water temperature, which warms more slowly than continental areas. Under the scenario of future climate change in the Atlantic regions, if global temperatures rise by more than 1ºC over the next 50 years (Jones et al. 1999), the 1998 survey response may indicate that most species will flower earlier by about 4 days to two weeks. However, other factors such as the season of warming may also influence the level of response (Fitter et al. 1995). Warming in winters and early spring may advance flowering dates (Price and Wasser 1998) but subsequent frosts may lead to the death of the plants. Therefore, earlier flowering dates may have drastic impacts on species populations and distribution. In order to predict how species can survive in some regions affected by climate change, it is also important to understand their means of adaptation to environmental variation. Studies such as Nova Scotia Plantwatch can help determine how species can respond in terms of flowering capacity. Since this trait is directly link to fitness and to the survival of the populations, such information will contribute in predicting their possible distribution and survival in the future.

The first three years of our new survey showed that it is possible to monitor phenology with the help of volunteers. But, as pointed out by Klaveness and Wielgolaski (1996), analysis and interpretation of the data require a critical sense of data quality and sound judgement. The large variation observed in the 1996 phenological data suggested that, in addition to the province-wide variability in spring temperatures, there was a need for more detailed information on flowering morphology and the definition of the flowering stages. In MacKay's survey, training of the teachers was done on a regular basis to maintain a certain quality of the data. For the Plantwatch studies, the description of the species was modified to help the volunteers in recording the dates of first flowering and colour posters have been distributed to further help with species and flower identification. It was also explained to the volunteers that in some species such as coltsfoot (*Tussilago farfara*), flowers may close at night or in cloudy weather.

The historical value of the MacKay data set and the enthusiastic response of the public to the current survey clearly show that phenology programs are useful for public education purposes. Because of its simplicity, such a program can improve awareness about global environmental and ecological issues.

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