Proceedings of the Nova Scotian Institute of Science (2011)
Volume 46, Part 2, pp. 149-174

LATE BLOOMING OF PLANTS FROM NORTHERN NOVA SCOTIA: RESPONSES TO A MILD FALL AND WINTER*

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ABSTRACT

Over 1400 flowering records of 135 species were recorded from over 125 visits to more than 20 sites in Antigonish County, Nova Scotia from November 2005 to January 2006, when the growing season is normally over. The species identified were primarily herbaceous dicots; however, there were four species of woody plants (*Cornus sericea, Spiraea latifolia*, *Symphoricarpos albus* and *Salix* sp.) and one monocot (*Allium schoenoprasum*). The number of species flowering declined linearly as fall progressed, as did the amount of flowering for each species. Nevertheless, over 40 species were still in flower in early December, and over 20 species flowered in January. The final flowering date was 21 January, when ten species were found. This work builds on a previous study in 2001, when 93 species were recorded in flower during November-December. In addition to the 30% increase in recorded species in 2005, almost 50% of the species found in 2005 were not recorded in 2001. This study provides an expanded baseline against which changes in flowering phenology can be evaluated with respect to subsequent regional climate change.

Key Words: Antigonish, flowering, Nova Scotia, phenology, climate change

And through this distemperature we see the seasons alter:
hoary-headed frosts fall in the fresh lap of the crimson rose.
– A Midsummer Night's Dream, W. Shakespeare

INTRODUCTION

There is a general consensus that climate warming has occurred on a global scale, and that mean air temperature has increased 0.5-0.6°C during the twentieth century (e.g., Houghton et al. 2001, Menzel et al. 2005, McCarty 2001, Schlelp et al. 2009, Walther et al. 1995a,b,c). In

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many parts of the world the impact or 'fingerprint' of global warming has been recorded in diverse biological systems (IPPC 2007, see Core Writing Team et al. 2007). These biological responses include the timing of bird and insect migrations, amphibian breeding, and various phenomena associated with plant phenology, e.g., changes in timing of leaf bud burst or leaf colour or the timing of flowering (Hughes 2000, Parmesan 2007, Root et al. 2003, Walther 2002, 2004, Walther et al. 2001, 2005a).

Changes in colonization patterns along environmental gradients have been a useful fingerprint of climate change (e.g. Walther et al. 2005b). Changes in the timing of flowering, especially earlier spring flowering, have also been a key indicator (e.g., Abu-Asab et al. 2001, Fitter & Fitter 2002, Gu et al. 2008, Houle 2007, Miller-Rushing & Primack 2008, Thórhallsdóttir 1998). Menzel (2002) argues that aspects of plant phenology are important biological indicators of climate change and form an excellent proxy for temperature.

Published studies take several approaches to examining phenological responses to climate. Most studies are observational and look for correlated changes in plant and animal behaviour with changing environment (e.g., Menzel & Fabian 1999); relatively fewer are experimental and manipulate climate in the field to examine responses of individual species (e.g., Dunne et al. 2003, Post et al. 2008). Some studies use remote sensing of vegetation to quantify phenological changes as a result of climate forcing (Badeck et al. 2005, White et al. 2005).

Although prolongation of the growing season in the fall has been reported, this extension is considered much less significant than early spring growth and flowering (Hovenden et al. 2008, Menzel 2003, Menzel & Fabian 1999, Menzel et al. 2001, Walther 2002, Thakur et al. 2008). The emphasis on the spring arises primarily because climate change is thought to have its greatest impact on winter and spring temperatures, and because fall responses reflect factors in addition to temperature to a greater extent than do spring responses (Sparks & Menzel 2002; Walther 2003). In addition, Schaber & Badeck (2005) and Menzel (2003) report little or no change in the timing of fall leaf colouration, while the growing season was extended by 10 days as a consequence of earlier springs. In Europe and North America, climate warming in the late twentieth century has advanced spring phenology by 1.2-3.8 days/decade, whereas changes in the fall are on the order of 0.3-1.6 days/decade (Menzel 2002, Menzel et al. 2001).

The smaller apparent changes in fall have resulted in much less research emphasis on impacts of changing climate on fall events. For species with indeterminate flowering, such as many ruderal annuals that flower until they are killed by frost, an extension of the flowering season in fall could lead to important increases in reproductive success, if pollinating insects are still active or species are self pollinating. Extensions of the fall growing season may be particularly important in the Canadian Maritime Provinces, where extended warm periods may follow intermittent frosts. Post et al. (2008) argue that changes in the entire life history of species in response to climate change, including reproduction, should be examined in an integrative way. Consequently, there is a need for more empirical data on fall phenomena associated with plant phenology and how this might be affected by climate change.

There is no long-term database of systematically collected observations on fall flowering in Nova Scotia. There is, however, an excellent provincial flora (Roland & Smith 1969, revised by Zinck 1998) with generalized accounts of flowering times for each species, largely based on observations during the 1940s to the1960s. In addition, there are extensive herbarium holdings at Acadia University (ACAD), Nova Scotia Museum (NSPM), Nova Scotia Agricultural College (NSAC) and St. Francis Xavier University (STFX) that reflect both historical and more recent collections. Despite their limitations, regional herbaria provide a useful background against which changes in flowering phenology can be evaluated (e.g., Lavoie & Lachance 2006, Miller-Rushing et al. 2006).

During the course of a particularly warm fall in 2001, robust flowering was apparent in the local flora at the beginning of November. The identity and persistence of plants in flower were recorded at a number of local sites to the end of flowering in mid-December (Taylor & Garbary 2003). These observations provided the latest reported flowering times in Nova Scotia for virtually all the species identified, and extended the limit of flowering by an average of 45 days. The fall of 2005 was another exceptionally warm season, highlighted by the absence of frost during September and October and conspicuously robust flowering of wild plants. A second survey of late-fall flowering times in Antigonish County, from November 2005 to January 2006, was therefore undertaken to compare against the 2001 survey. Specifically, our objectives were (1) to compare late flowering phenology in 2005 with those reported in the flora of Nova Scotia (Roland 1998) and herbarium records in the largest provincial herbarium (ACAD);

(2) to compare late-fall flowering in 2001 and 2005 to determine if the flowering season had lengthened or the flowering species had changed over the four-year period; and (3) to determine whether differences in flowering phenology between 2001 and 2005 were congruent with evidence of local climate change in the fall since the 1950s.

MATERIALS AND METHODS

To assess the prevalence of late fall flowering, 21 sites in Antigonish County, Nova Scotia, were visited two or more times at approximately 10-day intervals beginning 1 November 2005, until flowering ceased

Table 1 Primary collecting sites in Antigonish Town and County and the habitats examined regularly from November 2005 to January 2006. Sites visited in at least two, ten-day periods.

Site name and coordinates	**Habitats**
Hawthorne Street (45°37.5’N, 62°00.0’W)	backyards, old field, lawns, garden plots; ~0.5 km walk
St. Andrews Street (45°37.0’N, 61°58.5’W)	waste ground and soil banks surrounding building lot with unfinished house foundation; 100 m walk
Williams Point (45°37.2’N, 61°57.5’W)	waste ground and streamside; ditches and garden plots along 3 km drive
Lower West River Road (45°36.1’N, 62°00.2’W)	ditches, roadside banks and fields along 5 km road
South Side Harbour Road (45°37.7’N, 61°53.8’W)	ditches and roadside fields and garden plots along 10 km drive
Pomquet Harbour (45°38.8’N, 61°50.1’W)	fields, ditches, roadside, salt marsh; 5 km drive with several stops
Arisaig Provincial Park (45°45.3’N, 62°10.0’W)	roadside, ditches and regenerating boreal forest; 0.25 km walk
‘Liquor Lane’ and StFX Campus (45°37.0’N, 61°59.5’W)	flower beds, grassy banks, waste ground, margins of conifer stand; ~1 km walk
Kells Construction, Antigonish Municipal Facility (45°37.6’N, 61°59.5’W)	waste ground, river bank, construction waste piles, soil mounds; ~1 km walk
Antigonish Landing (45°38.0’N, 61°57.7’W)	waste ground, soil banks, margins of marshy areas, field; ~ 0.5 km walk
Tera Tory Drive (45°39.6’N, 61°54.7’W)	roadside, ditches, lawns, garden plots; 2 km drive

Table 1 *Continued*

Site name and coordinates	Habitats
Seabright Road (45°40.2'N, 61°57.6)	roadside and ditches, corn field, waste ground around barn construction site, margins of boreal forest; 2 km drive
Beech Hill Road (45°36.9'N, 61°58.3'W)	waste ground, muddy banks, gravel surfaces; 5 km drive
Whidden's Camp Ground (45°37.3'N, 61°59.9'W)	grass field and stream banks; waste ground at margin of parking lots; 0.5 km walk
Mount Cameron (45°37.8'N, 61°58.5'W)	grassy banks, old field, gravel surfaces, garden plots, soil mounds and around housing construction sites; 0.5 km walk
Main Street, opposite Hospital (45°37.7'N, 61°58.8'W)	large building lot consisting of waste ground and fine gravel with numerous soil mounds and bare banks; 0.25 km walk
Archibalds Point Road (45°40.8'N, 61°54.6'W)	roadside and ditches, garden plots, margin of boreal forest, disturbed ground at building site; 1 km drive
Antigonish Mall (45°37.1'N, 61°58.9'W)	waste ground and soil heaps beside parking lot, farmer's field, 0.5 km walk
Adam Street (45°37.5'N, 61°58.7'W)	waste ground around commercial buildings and industrial sites, small garden plot; 0.5 km walk

in late January (Table 1). The 31st of December and January were assigned to the final period in each month (i.e., they were 11 days long). A number of additional sites were visited once, for a total of over 125 site-time combinations. All sites were located within 30 km of the Town of Antigonish. Except for occasional forays inland to St. Andrews (45°32.8'N, 61°53.5'W) and Glen Alpine (45°28.8'N, 62°00.6'W), all sites were within 5 km of salt water. Latitude and longitude for each site were determined with a hand-held global positioning unit (Garmin GPS 12, Garmin Corp., Olathe, Kansas) or calculated from the Nova Scotia Atlas (Anonymous 2001) with values rounded to the nearest 0.1'. All sites were at low elevation, mostly < 20 m and all < 75 m above sea level. Although some sites were revisited within the same 10-day period, only new-found species for that collection period were counted as additions to the list, regardless of the number of visits. Some sites were visited only once or a few times during the study because of logistic constraints or the occurrence of only a few species in flower. At each site, a complete list of species in bloom was made during a 15-120 min excursion with one or two observers.

At least one specimen of each species was collected and preserved. Vouchers were deposited in STFX. Nomenclature and species authorities follow Roland (1998) and are given in Appendix 1.

The number of days that flowering was lengthened was calculated with reference to the latest flowering period cited by Roland (1998), with the last day of the cited month being scored as within the flowering period. Furthermore, herbarium records at ACAD, NSAC and NSPM were examined, and the latest flowering time among these specimens was used as the reference point for counting flowering extension when this was later than that from Roland (see Appendix 1). Records in the three herbaria were examined for the Taylor & Garbary (2003) study; only records in ACAD (the largest regional herbarium, Holmgren and Holmgren 1998) were re-evaluated for the current study. Plants were considered in blossom if a single flower was present in which the petals retained their natural colour and the pistils or stamens remained intact. Typically, multiple plants, each with multiple flowers, were present at a given site. Inconspicuous flowers (e.g. *Chenopodium album*) were dissected under a stereomicroscope to ensure that appropriate organs were present before including the species in the list of actively flowering species. When flowering apparently ended in 2005 for a given species earlier than in 2001, this was recorded as a number of negative days in the calculation of the overall average for the study (see Appendix 1). This mitigated potential exaggeration of flowering extension times in 2005 relative to 2001.

To determine if late flowering was consistent with evidence of climate change, climate data from two weather stations in Antigonish County, at Collegeville (45°28'N, 62°1'W, 1950-2005) and South Side Harbour (45°37'N, 61°54'W, 1997-2005) were obtained by downloading data from the National Climate Data and Information Archive of Environment Canada (http://climate.weatheroffice.ec.gc.ca). South Side Harbour is close to Antigonish Harbour and 7 km from the Town of Antigonish; Collegeville is 25 km inland. Only the Collegeville station has sufficient data to have established 30-year climate normals (1971-2000). Antigonish County falls into plant hardiness zone 5B of Agriculture Canada (http://sis.agr.gc.ca/cansis/nsdb/climate/ hardiness/intro.html), in which harsh winters kill non-hardy species (see Davis & Browne 1997 for regional climate summary).

The relationship between numbers of species in flower during each ten-day period and weather variables during the fall and early winter of 2005-2006 was explored using linear correlations. Mean maximum, minimum and overall mean temperatures were computed for each 10-day period from Environment Canada data at Collegeville. In addition, heat units (with units of degree-days) were calculated as the sum of the daily, above-zero maxima for each period; cold units were calculated similarly as the sum of all daily minima below zero. Linear regression was also used to model the decline in number of species flowering over time, as this facilitated comparisons with the 2001 study.

RESULTS

Weather in fall 2005.

Temperatures in fall are typically warmer at South Side Harbour, along the coast, than at Collegeville, which lies inland. Frosts arrive later and are less severe near the coast as well (Table 2). Temperatures throughout the fall and early winter of 2005 were conspicuously warmer than usual. At Collegeville, mean temperatures remained 1-3ºC warmer than the 30-year normal from September to December (Table 2). The bigger difference, however, is in the much lower frequency and severity of frost in 2005. In 2005 there were only 3 days of frost at Collegeville in October 2005, and 14 in November, compared with 14 and 23 in the 30-year Normals (Table 2). Frosts were less frequent nearer the coast, where most flowering observations were made. The temperature difference between 2005 and previous years is less obvious in December, but even in this month the daytime high was above zero on 15 days at Collegeville. A 16-cm snowfall on 10 December would have insulated low-lying plants from the most severe cold. Even in January, the coldest month of the year, the mean maximum temperature was above zero in 2006.

There is no consistent difference among most temperature statistics between 2001 and 2005; the earlier year was warmer in some months and by some measures, the later year by other measures or in other months. The number of frost days, however, was consistently less in 2005 than in 2001 at both South Side Harbour and Collegeville weather stations (Table 2).

Fall climate warming in northern Nova Scotia.

In addition to the specific temperature indicators in Table 2, we also examined changes in numbers of frost days between 1950 and 2005 using the Collegeville data set (Figure 1). While these data show major fluctuations on a year to year basis, there is no apparent trend in the five-year running average until the mid 1990s, after which there is a strong decline. This decline is more apparent in the data from 1997-2005 from South Side Harbour (Figure 2) where there is an almost continuous decline in number of frost days from 8 days to 1 day, and a major increase in days to first frost after 1 September from 33 to 61 days. The reduction in early fall frosts may be a key factor in the persistence of flowering after 1 November.

Table 2 Climate data for an inland site (Collegeville) and a coastal site (South Side Harbour) in Antigonish County during 2001 and 2005, and 30-year climate normals for Collegeville, 1971-2000. Climate normals not yet established for South Side Harbour. Some data missing for South Side Harbour in 2005-2006; bracketed numbers allow possibility that these were frost days.

Month	Temperature (°C) and Frost Days	South Side Harbour		Collegeville		Collegeville Climate Normals
		2005-2006	2001-2022	2001-2002	2005-2006	1971-2000
Sept	Mean maximum	21.5	22.8	22.8	21.0	18.8
	Mean	16.1	16.7	15.6	15.8	13.5
	Mean minimum	10.7	10.5	9.1	10.6	7.8
	Extreme minimum	3.4	0.5	-2.0	2.0	-
	Frost days	0	0	2	0	4.9
Oct	Mean maximum	14.7	17.2	16.1	14.5	13.0
	Mean	10.5	11.1	10.1	9.9	8.0
	Mean minimum	6.4	5.0	3.9	5.2	3.3
	Extreme minimum	-1.4	-1.8	-4.0	-3.0	-
	Frost days	1	4	5	3	13.8
Nov	Mean maximum	10.0	8.7	8.8	10.0	6.9
	Mean	5.6	4.6	4.3	5.4	2.9
	Mean minimum	1.3	0.4	0.3	0.7	-0.9
	Extreme minimum	-6.7	-6.5	-9.0	-7	-
	Frost days	12	17	15	12	22.6
Dec	Mean maximum	1.8	3.6	-0.5	2.2	1.0
	Mean	-2	0.6	-0.5	-1.2	-3.1
	Mean minimum	-5.9	-2.6	-3.5	-4.7	-7.5
	Extreme minimum	-15.1	-9.25	-10.0	-17.5	-
	Frost days	23 (25)	25	27	25	29.6
Jan	Mean maximum	3.5	-1.1	-2.2	2.4	-1.5
	Mean	-0.2	-4.8	-7.1	-0.7	-6.6
	Mean minimum	-3.9	-8.6	-12.0	-3.8	-11.6
	Extreme minimum	-10.6	-17.2	-22.0	-10.0	-
	Frost days	17 (20)	30	31	23	28.8

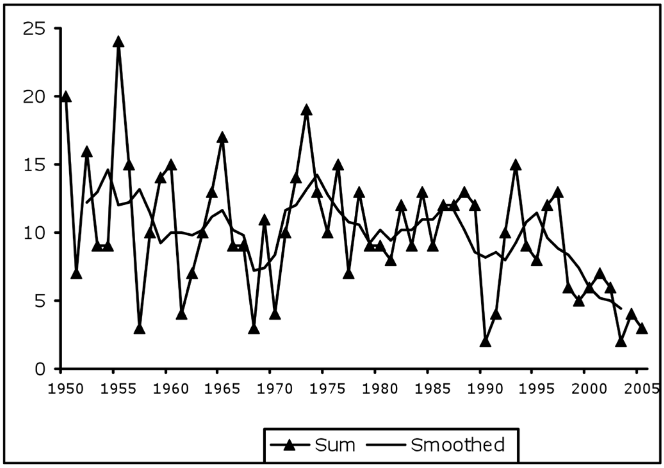

Fig 1 Days of frost, September and October combined, with five year smoothed line based on data from Collegeville.

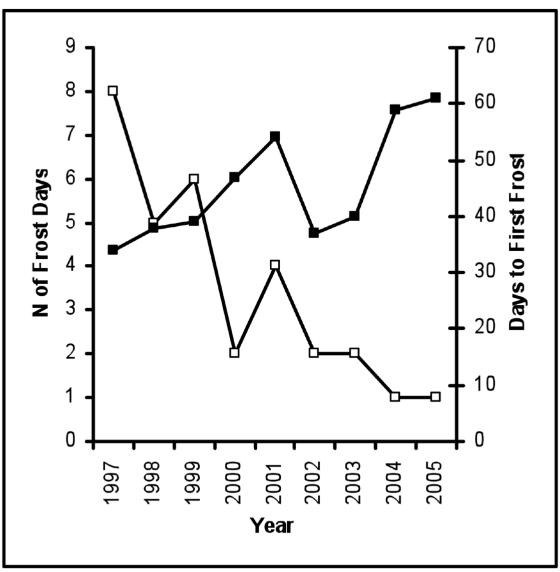

Fig 2 Number of frost days September and October combined (open squares) and days to first frost after 1 September (filled squares) based on data from South Side Harbour.

Plants in flower.

Over 1400 site-time observations of flowering were made during the 113 days of this research (Appendix 2). The field observations produced a tally of 136 species from the 21 sites that were regularly visited and 20 or more additional sites that were visited once or a few times (Appendix 2). Limited destructive sampling of plants for identification and preparation of vouchers necessitated continual exploration of new sites. Most of the sites represented similar habitats: waste ground, roadside ditches, lawns, garden plots and agricultural fields (Table 1). Most sites were highly disturbed, many with less than 50% cover of vegetation, used for agriculture or industry (e.g., building sites, soil dump sites, parking lots, ditches), and were characterized by pioneer successional communities in which the bulk of the plants in flower were herbaceous, weedy species. Although various wetlands and forest communities were explored, these were typically devoid of plants in flower. Exceptions were open spaces in mixed conifer forest at Arisaig with *Solidago bicolor*, a streamside *Alnus* thicket near Monastery with *Solidago flexicaulis*, and a salt marsh at Monks Head (Pomquet Harbour) with *Solidago sempervirens* and *Sueda maritima*.

Unlike the survey in 2001, the list of flowering species in 2005 includes woody plants for the first time. Three of the four species observed are shrubs that normally bloom in summer: *Spiraea latifolia, Cornus sericea* and *Symphoricarpos albus*. The fourth species, *Salix* sp. (probably pussy willow, *S. discolor* or *S. pellita*) ordinarily blooms in April or May. All of these species were found at either more than one site or during more than one ten-day period (Appendix 2), suggesting that this late fall flowering was more than a rare and isolated event.

In early and mid-November, 20-30 species were found in flower at most sites, with a maximum of 34. By the end of November, flowering was conspicuously reduced, with an average of 13 species per site and a maximum of 23 species. In early December there was a slight further reduction to an average of 12 species per site and a maximum of 19. Middle and late December showed a mean of 4 species per site with a maximum of 6 species. Snow cover and low temperatures produced a limited window for collecting in mid-December and precluded visiting large numbers of sites. About half of the sites visited in late December had no species flowering and several still had extensive snow cover.

A total of 22 species remained in bloom in the last third of December (Figure 3); indeed 15 observations were made of 12 species from four sites on December 30, when air temperature reached 14°C. These records varied from the occurrence of a single blossom on a population of dozens of individuals (*Ranunculus repens*), to abundant blossoms on many highly frost-compromised (i.e. wilted) plants (*Raphanus raphanistrum*), to healthy plants with large numbers of buds and blossoms (e.g., *Polygonum arenastrum* and *Stellaria media*). *Taraxacum officinale* was present at three of the four sites visited, albeit with only one or two flowering individuals per site. All of these species, except *Salix* sp. and *Ranunculus repens* had been in bloom in every ten-day period since the beginning of November.

There was little change in the flowering species between the end of December and records from January. Most species flowered in two of the three time intervals. No species was lost, and there was a single record of *Epigea repens* added in mid-January. Even the final collection day for the study (21 January) yielded twelve records of eight species of herbaceous plants from seven sites, with two further records of *Salix*.

Our observations in 2001 and 2005 (Appendix 1) extend the known flowering periods of plants in Nova Scotia by 70 days. The observations in 2001 for some species are later than those collected here, but usually within the same ten-day period. The late January collections (see Garbary & Taylor 2007 for details of these collections) provide the latest flowering records in the province.

The change in number of species in flower over consecutive 10-day periods from 1 November clearly follows a two-phase pattern (Figure 3). Over the first five periods, from 1 November to 20 December, the number of species in flower declines regularly, to a minimum of 12 during the 11-20 December period. Over the last five periods, from 11 Dec to 21 January, the number of species in flower remains low (< 25) and more or less constant. The fifth period is a transition from the first phase to the second. The decline in species flowering over the first five periods can be well described by a simple linear regression:

$$\text{Number of species} = 140.9 - 25.3 * (\text{Time Period})$$
$$(R^2 = 0.99, n = 5, p = 0.0017)$$

In contrast, the change in species flowering over the last 5 periods has no significant correlation with time, and in fact $r = 0$. Hence, rather than the flowering period ending abruptly at the first deep frost, successive bouts of cold weather removed progressively more species from the

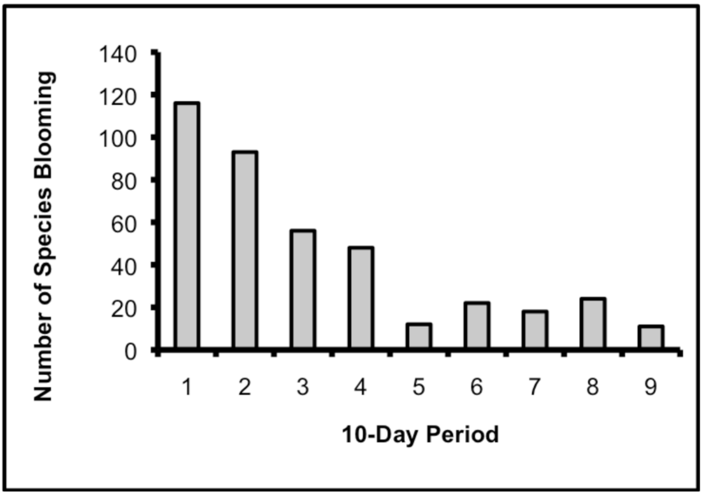

Fig 3 Number of species of plants recorded in bloom in Antigonish County, Nova Scotia during 10-day periods from 1 November 2005 to 21 January 2006. Periods 1-3 cover November, 3-6 cover December and 7-9 cover January.

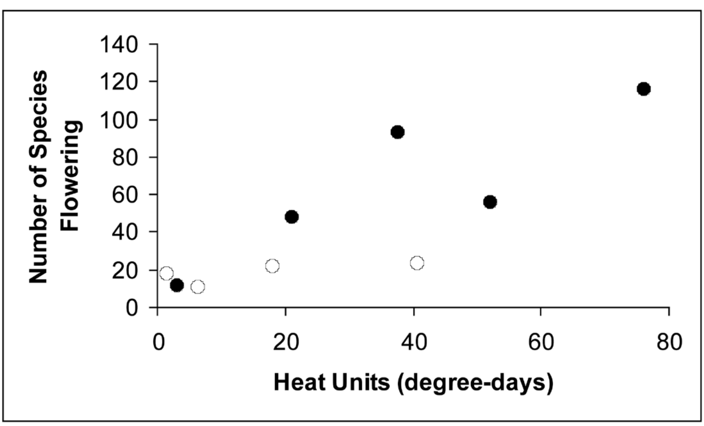

Fig 4 Relationship between number of species of plants in flower from 1 November 2005 to 21 January 2006 and cumulative heat units in each 10-day period. Dark circles represent data from 1 November to 20 December, when the number of species declined linearly. Open circles are data from 21 December to 21 January, when the number of species in flower was approximately constant.

flowering pool. The final group of species, those that persisted until mid-January, were evidently able to prolong their growing season even further because of the continued mild weather and their ability to suffer frosts that were fatal to less resistant species.

Over the entire nine periods, the number of species in flower is more or less equally correlated with mean maximum, mean minimum and daily mean temperatures and cumulative heat units in each period ($r = 0.82$ to 0.84, $n = 9$). Only cold units are a relatively poor predictor of number of species ($r = 0.73$). Nevertheless, the response in number of species flowering to temperature during the last four 10-day periods appears to be weaker than that during the first five periods (Figure 4). This is probably so because after 20 December there were only a few species available to reflower when the weather turned warmer again at the end of the month, the others having entered dormancy or succumbed to frost. Therefore above-zero temperatures were less effective in encouraging flowering late in the season than earlier.

In the 2001 study, flowering ended in the fifth 10-day period, between 11 and 20 December. Over those five periods however, the rate of decline in 2005 appears remarkably similar to that in 2001. A direct comparison between the two equations is not possible, however, because of the greater number of species collected in 2005. To correct for this disparity, the 2001 and 2005 regressions were both recomputed in terms of percentages of the total number of species found in bloom that year. The slope of the line in 2005 (-18.7 ± 1.7 % period^{-1}) is not significantly different ($t = 1.59$, $p > 0.10$) from the slope of the line in 2001 (-17.4 ± 1.0% period^{-1}). Hence, the identical ecological process of sequential removal of progressively more frost-resistant species appears to have been active in both years.

DISCUSSION

This study and the previous one (Taylor & Garbary 2003) were initiated because of the high diversity of plants in flower and the robustness of flowering in early November of 2005 (and 2001). This pattern was highly unusual for northern Nova Scotia, where frosts in September and October typically terminate flowering of all but the most robust species. While some of our records are based on a single plant with a single inflorescence (e.g., *Hieracium aurantiacum* on 15 November), many of our records, even those in January, are based on multiple specimens, from multiple times and multiple sites (Appendix 2 and Garbary & Taylor 2007).

This study of late flowering phenology in a local area of Nova Scotia provides an empirical approach to documenting biological responses to changes in weather patterns, if not the impact of climate change. Our use of herbarium records to establish baseline flowering phenologies is consistent with previous work in northeastern North America by Miller-Rushing et al. (2006) and Primack et al. (2004), although these studies used estimates of peak flowering times rather than latest flowering times. Our use of herbarium specimens and the regional flora (Roland 1998) as starting points against which to gauge our observations assumes that prior observations and collections were made throughout the flowering period. We have mitigated this potential source of error by assuming that the last day of the month cited by Roland (1998), or the latest herbarium specimen in ACAD or NSAC, was the end of the flowering period; this minimizes our estimate of the flowering period extension. Furthermore, our primary reference herbarium, ACAD, is in a warmer plant hardiness zone than Antigonish (5B rather than 5A), and plants from the Annapolis Valley might be assumed to have a later flowering period than those from Antigonish County do. Many of the collections of roadside flowers and ruderals in ACAD, NSAC and STFX are student collections made as part of course assignments, and therefore many specimens would likely have been collected later in the autumn, toward the end of flowering periods when some collectors were attempting to meet course requirements. This background, combined with over 20 years experience on the local flora by DJG and BRT, gives us confidence in our conclusion that 2001 and 2005 represent major anomalies in flowering phenology for the Antigonish area, and these events were associated with an apparent fall warming trend in the area (Table 2).

Our results complement and extend the previous study by Taylor & Garbary (2003) that showed a 45 day average extension of known flowering durations for Nova Scotia during 2001. The current study suggested a further 25 day extension in mean flowering duration for the 135 documented species. We conclude that persistent flowering beyond the normal growing season is a reliable integrator of weather phenomena associated with a warming climate (i.e., higher mean temperatures, later frost, less frequent and less severe cold periods), and therefore fall-flowering surveys can be a useful instrument to document and detect climate change. Table 2 shows that 2001 and 2005 were consistently warmer than climate normals based on a variety of metrics. Furthermore, we documented an apparent change in temperature since the mid 1990s as shown by a reduction of frost occurrences in northern Nova Scotia (Figures 1-2). Whether these are part of an ongoing trend remains to be established, but they are consistent with predictions of global climate change (e.g., Walther et al. 2005).

While our systematic observations were carried out only in 2001 and 2005, casual observations in all other years since 2001 did not show the diversity of species in flower or robustness of flowering after 1 Nov that we observed during the study years. In 2009 and 2010 for example, typical frosts occurred in October and casual observation of several sites by one of us (DJG) revealed fewer than ten species in flower at any site in Antigonish County during November. Our analysis of climate data for the region (Table 2) shows that the fall and early winter seasons of 2001 and 2005 were particularly mild, and supports our conclusion that late flowering is a response to milder temperatures.

It is remarkable that the rate of disappearance of flowering species, expressed as a percentage of the total, through the first five 10-day periods should follow the same linear trajectory in 2005 as in 2001, especially given that the 2005 survey includes many new species. This pattern has been interpreted previously as successive cold snaps acting as environmental sieves, separating groups of species according to increasing frost tolerance (Taylor & Garbary 2003). The reappearance of the same pattern in 2005 as in 2001 suggests that most ruderal species are differentiated along this niche axis. As well, the apparent generality of the pattern suggests that deviations from the expected sequence may be used as an indicator of climate change. Such a deviation was observed in the current study, when the final, most persistent group of species, rather than succumbing to deep cold as winter approached, instead persisted well into January along with the unseasonable warmth.

The majority of studies on changes in phenology in relation to climate warming refer to the advancement of flowering or other phenomena in the spring, and much smaller effects during the fall (e.g., Cleland et al. 2007, Fitter & Fitter 2002, Gu et al. 2008, Menzel et al. 2006, and references therein). Hence the apparent 45-day prolongation of flowering reported by Taylor & Garbary (2003), and the further 25-day apparent prolongation reported here (Appendix 1) would seem counter to generalized responses in the literature. It may be that later flowering is more difficult to document as it requires multiple visits to many sites as was done here and in Taylor & Garbary (2003).

The 135 species recorded in this study represent about 10% of the total vascular flora of Nova Scotia. However, the dicotyledenous flora of Nova Scotia consists of about 970 species. Based on distributions reported in Roland (1998) and additions in Garbary & Deveau (2007) and Taylor et al. (2008), only about 75% of this diversity may be represented in Antigonish County, a small area with low habitat and climatic diversity (Davis & Browne 1997). Hence, the species we observed flowering during November-January comprise ~20% of the local diversity of dicots. This total qualifies the late flowering assemblage as a significant component of the angiosperm flora, and highlights the phenological changes that can arise from even slight changes in temperature. The capacity of so many species to extend or recommence flowering in warm fall weather raises the prospect of even greater blooming for longer periods with climate change that includes further warming during the late autumn and early winter. It remains to be determined if viable seeds can be produced by these late fall flowering species, especially those that require insect pollination.

Acknowledgements We thank Anne Louise MacDonald, Randy Lauff and Ian Bryson for contributing several collections to this study, and Ruth Newell of ACAD for access to collections. This work was supported by a research grant from the Natural Sciences and Engineering Research Council of Canada to DJG.

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Appendix 1 Combined list of species from 2001 and 2005 that were observed flowering in Antigonish County after November 1st. The date given under latest herbarium record indicates the latest flowering specimens found in one of the following herbaria - ACAD, NSAC or NSPM. Flowering extension (days) indicates the number of additional flowering days in Antigonish County compared with the latest times given in Roland (1998) or a previous herbarium collection. Symbols are as follows: Question marks indicate missing data; #-Species found in 2001 study but not in the fall of 2005; *-earliest flowering times for two pussy willow species; ^-interpreted as late second flowering rather than early flowering – see text.

Species	Flowering in Roland (1998)	Latest herbarium record	Latest flowering 2001	Latest flowering 2005	Flowering extension (days)
Achillea millefolium L.	Sep	2 Dec '05	14 Dec	12 Jan	29
Allium schoenoprasum L.	July	1 Aug '57	-	2 Dec	124
Ambrosia artemisiifolia L.	Sep	16 Nov '06	-	23 Nov	7
Anaphalis margaritaceae (L.) Benth. & Hook.	Sep	18 Oct '81	5 Dec	6 Nov	-29
Anthemis tinctoria L.	Sep	3 Aug '51	-	2 Dec	122
Arctium minus (Hill.) Bernh.	Sep	15 Nov '94	-	13 Nov	0
Aster ciliolatus Lindl.	Sep	14 Aug '68	12 Dec	2 Dec	-10
A. cordifolius L.	Oct	18 Oct '79	12 Dec	22 Nov	-20
A. lateriflorus (L.) Britton	Sep	28 Oct '87	10 Dec	3 Dec	-7
A. novae-angliae L.	Oct	16 Nov '05	-	1 Nov	-
A. novi-belgii L.	Sep	2 Dec '05	10 Dec	3 Dec	-7
A. puniceus L.	Sep	7 Oct '30	11 Nov	3 Dec	22
A. umbellatus P. Mill.	Sep	9 Sep '54	-	6 Nov	36
#*Bellis perennis* L.	Sep	6 July '50	16 Nov	-	47
Berteroa incana (L.) DC	Sep	1 Oct '41	-	1 Nov	31
Bidens connata Muhl.	Sep	6 Sep '52	-	7 Nov	38
#*Bidens frondosa* L.	Sep	29 Sep '41	7 Nov	-	37
Brassica nigra (L.) W.J.D. Koch	Oct	11 Nov '69	10 Nov	2 Nov	-8
#*B. rapa* L.	Oct	27 Sep '91	12 Dec	-	-
Campanula rapunculoides L.	Aug	20 Sep '79	7 Nov	3 Nov	-4
Capsella bursa-pastoris (L.) Medik.	Nov	2 Dec '05	14 Dec	14 Jan	31
Cardamine pensylvanica Muhl. ex Willd.	Aug	11 Sep '49	15 Dec	21 Jan	37
Centaurea nigra L.	Sep	20 Nov '94	17 Nov	15 Nov	-2
Cerastium vulgatum L.	?	12 Dec '06	15 Nov	21 Jan	44
Chenopodium album L.	?	14 Oct '79	17 Nov	1 Dec	14
C. glaucum L.	Oct	-	-	22 Nov	22
Chaenorrhinum minus (L.) Lange	Aug	4 Sep '48	15 Nov	15 Nov	0
Chrysanthemum leucanthemum L.	July	18 Sep '83	26 Nov	22 Nov	-4
Cichorium intybus L.	Aug	15 Oct '90	-	12 Nov	28
Cirsium arvense (L.) Scop.	Aug	9 Oct '30	-	18 Nov	39
C. palustre (L.) Scop.	July	9 Aug '45	-	6 Nov	90
C. vulgare (Savi) Tenore	Sept	1 Oct '32	-	7 Nov	36
#*Conioselinum chinense* (L.) Britton, Sterns & Poggenb.	Sep	17 Sep '55	11 Nov	-	-

Appendix 1 *Continued*

Species	Flowering in Roland (1998)	Latest herbarium record	Latest flowering 2001	Latest flowering 2005	Flowering extension (days)
Cornus sericea L.	June	4 Sep '25	-	22 Nov	80
Coronilla varia L.	July	13 Sep '90	-	12 Nov	50
#Dianthus armeria L.	July	1 Oct '67	19 Nov	-	-
Daucus carota L.	Sep	2 Dec '05	20 Nov	2 Dec	0
Echinocystis lobata (Michx.) T. & G.	Oct	30 Sep '90	-	12 Nov	12
Echium vulgare L.	Sep	18 Aug '55	-	2 Nov	33
Epigaea repens L.	May	7 Nov '98	-	14 Jan	68
Erigeron annuus (L.) Pers.	Sep	1 Oct '45	16 Nov	24 Nov	8
E. philadelphicus L.	Aug	14 June '51	-	2 Nov	64
E. strigosus Muhl. Ex Willd.	Sep	16 Nov '06	8 Dec	6 Nov	-32
Erucastrum gallicum (Willd.) O.E. Schulz	Oct	18 Sep '54	12 Dec	3 Dec	-9
Erysimum cheiranthoides L.	Sep	16 Nov '06	15 Dec	14 Jan	30
Euphorbia helioscopia L.	Sep	7 Jan '02	14 Dec	21 Jan	17
Euphrasia officinalis L.	Sep	10 Oct '30	10 Nov	24 Nov	14
Euthamnia graminifolia (L.) Nutt.	Sep	17 Oct '17	22 Nov	1 Nov	-21
Fragaria vesca L.	June	27 July '46	-	1 Nov	63
F. virginiana Duchesne	May	5 Sep '86	27 Nov	15 Nov	-12
Fumaria officinalis L.	Aug	6 Sep '54	-	14 Jan	131
Galeopsis tetrahit L.	Sep	10 Oct '69	14 Dec	3 Dec	-11
Galium mollugo L.	Aug	23 Aug '52	-	1 Dec	93
Glechoma hederacea L.	Summer	1 Aug '62	-	2 Nov	64
Hesperis matronalis L.	July	25 Sep '63	17 Nov	22 Nov	5
Hieracium aurantiacum L.	Aug	18 Oct '79	-	15 Nov	27
H. floribundum Wimm. & Grab	July	3 Dec-06	24 Nov	-	-
H. lachenalii C. Gmelin.	Aug	16 Nov '05	-	3 Dec	17
H. paniculatum L.	Sept	17 Sep '45	-	15 Nov	46
H. piloselloides Vill.	July	29 Aug '62	-	6 Nov	69
Hypericum perforatum L.	Aug	12 Nov '79	5 Nov	7 Nov	-5
#Lamium amplexicaule L.	Nov	18 Sep '79	8 Dec	-	-
Lathyrus pratensis L.	July	15 Aug ' 66	-	2 Nov	79
Leontodon autumnalis L.	Oct	3 Dec '05	16-Dec	30 Dec	14
Lepidium campestre (L.) R. Br.	Sep	3 Sep '69	6-Dec	18 Dec	12
L. virginicum L.	Sep	2 Dec '06	5-Dec	15 Nov	-20
Linaria vulgaris Mill.	Aug	18 Nov 1869	5-Dec	28 Nov	-7
Lupinus polyphyllus Lindl.	July	20 Sep '79	-	11 Nov	53
Malva moschata L.	July	3 Dec '05	-	1 Dec	-2
M. neglecta Wallr.	Oct	2 Dec '05	14-Dec	14 Nov	-30
#M. rotundifolia L.	?	18 Oct '92	10-Nov	-	-
Matricaria maritima L.	Aug	2 Dec '05	15-Dec	13 Jan	29
M. matricarioides (Less.) Porter	Nov	16 Nov '06	14-Dec	14 Jan	31
Medicago lupulina L.	Sep	7 Oct '87	12-Dec	9 Nov	-33
M. sativa L.	Aug	16 Nov '05	-	1 Nov	-15

Appendix 1 *Continued*

Species	Flowering in Roland (1998)	Latest herbarium record	Latest flowering 2001	Latest flowering 2005	Flowering extension (days)
Melilotus alba Desr.	Aug	9 Nov '79	20-Nov	2 Dec	12
M. officinalis (L.) Lam.	Aug	19 Sep '71	11-Nov	14 Nov	3
Myosotis laxa Lehm.	July	10 Oct '30	-	12 Nov	33
M. scorpioides L.	July	13 Oct '30	-	6 Nov	24
Oenothera biennis L.	Oct	16 Oct '15	24-Nov	24 Nov	0
O. perennis L.	Sep	6 Sep '38	10-Nov	-	-
Oxalis dillenii Jacq.	?	6 Sep '29		4 Nov	60
Pastinaca sativa L.	July	5 Sep '62	5-Dec	2 Dec	-3
Physalis heterophylla Nees	Aug	25 Oct '49	-	12 Nov	18
Plantago lanceolata L.	Oct	11 Nov '79	11-Nov	13 Nov	2
Polygonum arenastrum Jord. ex Boreau	?	24 Oct '23	12-Dec	30 Dec	18
P. aviculare L.	Nov	-	-	19 Nov	-11
P. convolvulus L.	Nov	16 Oct '44	24-Nov	15 Nov	-9
P. cuspidatum Sieb. & Zucc.	Sep	6 Oct '78	-	1 Nov	26
P. hydropiper L.	?	11 Nov '05	-	12 Nov	1
P. lapathifolium L.	?	31 Aug '55	-	5 Nov	67
P. pensylvanicum L.	?	17 Sep '13	-	9 Nov	54
P. persicaria L.	Oct	10 Dec '25	25 Nov	15 Nov	-10
P. sagittatum L.	Oct	10 Oct '17	10 Nov	9 Nov	-1
Potentilla argentea L.	Aug	20 Nov '37	5 Dec	18 Nov	-17
P. canadensis L.	June	27 July '55	24 Nov	-	-
#*P. intermedia* L.	July	21 July '62	18 Nov	-	-
P. norvegica L.	July	4 Sep '53	-	2 Dec	90
P. simplex Michx.	July	19 Sep '83	-	13 Nov	56
Potentilla recta L.	July	28 Oct '51	16 Nov	-	-
Prunella vulgaris L.	Summer	10 Oct '83	-	15 Nov	36
Ranunculus acris L.	Aug	1 Oct '78	-	6 Nov	36
R. repens L.	Sep	4 Dec '05	25 Nov	30 Dec	26
Raphanus raphanistrum L.	Oct	2 Dec '05	20 Nov	30 Dec	28
Rubus ideaus L.	July	6 Nov '94	-	6 Nov	0
Rudbeckia laciniata L.	Aug	20 July '87	-	23 Nov	85
Rumex longifolius Alph. de Candolle	Oct	20 Oct '30	16 Nov	15 Nov	-1
#*R. obtusifolius* L.	Sep	20 Oct '30	10 Nov	-	-
Salix discolor Muhl.	*Feb-May	-	-	24 Nov	68
S. pellita Andersson	*May-June	-	-	24 Nov	157
Senecio jacobaea L.	Sep	7 Oct '73	9 Dec	24 Nov	-15
S. vulgaris L.	Nov	1 Nov '12	15 Dec	30 Dec	15
Silene latifolia Poir.	Sep	16 Nov '05	7 Nov	18 Nov	11
Sinapis alba L.	Aug	30 July '71	14 Dec	3 Dec	-9
S. arvensis L.	Oct	-	-	15 Nov	15
Sisymbrium officinale (L.) . Scop	Oct	2 Dec '05	-	15 Nov	-17
#*Solanum dulcamara* L.	Sep	23 Sep '90	17 Nov	-	-
Solidago bicolor L.	Sep	16 Nov '06	-	2 Dec	16

Appendix 1 *Continued*

Species	Flowering in Roland (1998)	Latest herbarium record	Latest flowering 2001	Latest flowering 2005	Flowering extension (days)
S. canadensis L.	Aug	2 Dec '05	5 Dec	3 Dec	-2
S. flexicaulis L.	Sep	25 Sep '63	-	12 Nov	43
S. puberula Nutt.	Sep	15 Nov '94	10 Nov	-	-
S. rugosa P. Mill.	Sep	16 Nov '05	29 Nov	1 Nov	-28
S. sempervirens L.	Sep	2 Dec '05	18 Nov	13 Nov	-5
Sonchus arvensis L.	Sep	22 Oct '70	22 Nov	3 Dec	11
S. asper L.	Oct	18 Oct '79	9 Nov	3 Dec	25
S. oleraceus L.	Oct	3 Dec '05	15 Nov	6 Nov	-9
Spergula arvensis L.	Oct	28 Oct '87	12 Dec	14 Jan	33
Spergularia marina (L.) Griseb.	Sep	5 Oct '28	12 Dec	30 Dec	18
Spiraea latifolia (Ait.) Borkh.	Aug	5 Oct '01	-	15 Nov	41
Stellaria graminea L.	Oct	16 Sep '60	-	24 Nov	24
S. media (L.) Cirillo	Nov	11 Sep '52	12 Dec	21 Jan	40
Sueda maritima (L.) Dumort.)	Sep	3 Oct '80	-	3 Nov	31
Symphoricarpos albus (L.) Blake	?	15 July '55	-	22 Nov	131
Tanacetum vulgare L.	Aug	5 Nov '12	12 Dec	3 Dec	-9
Taraxacum officinale (L.) Weber	June	23 Sep '95	15 Dec	21 Jan	37
Thlaspi arvense L.	Sep	29 Aug '36	12 Dec	21 Jan	40
#*Thymus serpyllum* L.	Aug	4 Sep '64	15 Nov	-	-
Tragopogon pratensis L.	Aug	2 Dec '05	7 Dec	1 Dec	-6
#*Trifolium hybridum* L.	?	10 Sep '25	5 Nov	-	93
Trifolium pratense L.	Sep	16 Nov '05	12 Dec	3 Dec	-9
T. repens L.	?	20 Oct '30	18 Nov	18 Nov	0
Verbascum thapsus L.	Sep	16 Nov '05	-	3 Dec	17
Veronica agrestis L.	Sep	14 July '48	-	29 Nov	60
V. longifolia L.	Aug	2 Sep '48	-	23 Nov	83
V. officinalis L.	Aug	20 Nov '94	-	3 Dec	13
V. persica Poir.	Sep	7 Sep '51	28 Nov	21 Jan	54
Vicia cracca L	Aug	16 Nov '05	27 Nov	3 Dec	6
V. sepium L.	July	26 June '00	-	1 Nov	94
V. villosa L.	Sep	12 Oct '27	-	3 Nov	22
#*Viola cucullata* Aiton	July	14 Sep '51	10 Nov	-	-
V. tricolor L.	Nov	13 Oct '44	5 Dec	21 Jan	47

Appendix 2 List of species and numbers occurring at collection sites from November 2005 to January 2006 in Antigonish County. Values indicate the number of different sites where each species was found in flower during that ten-day period. No species were found in flower following January 21st.

Species	**Nov 1-10**	**Nov 11-20**	**Nov 21-30**	**Dec 1-10**	**Dec 11-20**	**Dec 21-31**	**Jan 1-10**	**Jan 11-20**	**Jan 21**
Achillea millefolium	16	15	12	7	1	2	2	1	-
Allium schoenoprasum	1	1	-	1	-	-	-	-	-
Ambrosia artemisiifolia	-	3	1	-	-	-	-	-	-
Anaphalis margaritacea	2	-	-	-	-	-	-	-	-
Anthemis tinctoria	-	1	1	1	-	-	-	-	-
Arctium minus	1	1	-	-	-	-	-	-	-
Aster ciliolatus	2	3	3	2	-	-	-	-	-
A. cordifolius	6	2	1	-	-	-	-	-	-
A. lateriflorus	2	2	2	2	-	-	-	-	-
A. novae-angliae	3	-	-	-	-	-	-	-	-
A. novi-belgii	10	14	10	6	-	-	-	-	-
A. puniceus	5	1	-	-	-	-	-	-	-
A. umbellatus	1	-	-	-	-	-	-	-	-
Berteroa incana	1	-	-	-	-	-	-	-	-
Bidens connata	1	-	-	-	-	-	-	-	-
Brassica nigra	1	-	-	-	-	-	-	-	-
Campanula rapunculoides	3	-	-	-	-	-	-	-	-
Capsella bursa-pastoris	5	9	12	8	2	6	4	8	1
Cardamine pensylvanica	1	1	1	1	1	1	1	1	1
Centaurea nigra	5	3	-	-	-	-	-	-	-
Cerastium vulgatum	2	12	7	7	-	2	2	3	1
Chenopodium album	4	6	2	1	-	-	-	-	-
C. glaucum	1	1	1	-	-	-	-	-	-
Chenorrhinum minus	-	1	-	-	-	-	-	-	-
Chrysanthemum leucanthemum	4	4	1	-	-	-	-	-	-
Cichorium intybus	-	1	-	-	-	-	-	-	-
Cirsium arvense	3	3	-	-	-	-	-	-	-
C. palustre	2	-	-	-	-	-	-	-	-
C. vulgare	1	-	-	-	-	-	-	-	-
Cornus sericea	2	1	1	-	-	-	-	-	-
Coronilla varia	1	1	-	-	-	-	-	-	-
Daucus carota	21	18	10	2	-	-	-	-	-
Echinocystis lobata	3	1	-	-	-	-	-	-	-
Echium vulgare	2	-	-	-	-	-	-	-	-
Epigaea repens	-	-	-	-	-	-	-	1	-
Erigeron annuus	15	12	6	-	-	-	-	-	-
E. philadelphicus	2	-	-	-	-	-	-	-	-
E. strigosus	1	-	-	-	-	-	-	-	-
Erucastrum gallicum	1	1	1	1	-	-	-	-	-
Erysimum cheiranthoides	5	9	10	6	-	4	-	2	-
Euphorbia helioscopia	2	3	4	4	1	1	1	1	1
Euphrasia officinalis	3	3	2	-	-	-	-	-	-
Euthamnia graminifolia	1	-	-	-	-	-	-	-	-

Appendix 2 *Continued*

Species	Nov 1-10	Nov 11-20	Nov 21-30	Dec 1-10	Dec 11-20	Dec 21-31	Jan 1-10	Jan 11-20	Jan 21
Fragaria vesca	1	-	-	-	-	-	-	-	-
F. virginiana	3	1	-	-	-	-	-	-	-
Fumaria officinalis	2	2	3	3	-	1	1	1	-
Galeopsis tetrahit	3	3	3	4	-	-	-	-	-
Galium mollugo	1	3	2	-	-	-	-	-	-
Glechoma hederacea	1	-	-	-	-	-	-	-	-
Hesperis matronalis	1	1	1	-	-	-	-	-	-
Hieracium aurantiacum	-	1	-	-	-	-	-	-	-
H. lachenalii	3	1	-	1	-	-	-	-	-
H. paniculatum	1	1	-	-	-	-	-	-	-
H. piloselloides	1	-	-	-	-	-	-	-	-
Hypericum perforatum	3	-	-	-	-	-	-	-	-
Lathyrus pratensis	1	-	-	-	-	-	-	-	-
Leontodon autumnalis	12	20	18	13	-	5	2	-	-
Lepidium campestre	2	2	4	3	1	-	-	1	-
L. virginicum	1	2	-	-	-	-	-	-	-
Linaria vulgaris	14	16	1	-	-	-	-	-	-
Lupinus polyphyllus	2	1	-	-	-	-	-	-	-
Malva moschata	1	1	2	1	-	-	-	-	-
M. neglecta	-	1	-	-	-	-	-	-	-
Matricaria maritima	10	7	8	4	1	1	1	2	-
M. matricarioides	2	6	4	4	1	2	2	2	-
Medicago lupulina	9	2	-	-	-	-	-	-	-
M. sativa	1	-	-	-	-	-	-	-	-
Melilotus alba	14	9	3	1	-	-	-	-	-
M. officinalis	3	1	-	-	-	-	-	-	-
Myosotis laxa	3	1	-	-	-	-	-	-	-
M. scorpioides	1	-	-	-	-	-	-	-	-
Oenothera biennis	15	13	4	-	-	-	-	-	-
Oxalis dillenii	1	-	-	-	-	-	-	-	-
Pastinaca sativa	3	8	5	2	-	-	-	-	-
Physalis heterophylla	-	1	-	-	-	-	-	-	-
Plantago lanceolata	3	1	-	-	-	-	-	-	-
Polygonum arenastrum	3	3	1	4	-	1	-	1	-
P. aviculare	-	1	-	-	-	-	-	-	-
P. convolvulus	3	2	-	-	-	-	-	-	-
P. cuspidatum	1	-	-	-	-	-	-	-	-
P. hydropiper	1	1	-	-	-	-	-	-	-
P. lapathifolium	2	-	-	-	-	-	-	-	-
P. pensylvanicum	1	-	-	-	-	-	-	-	-
P. persicaria	7	7	-	-	-	-	-	-	-
P. sagittatum	3	-	-	-	-	-	-	-	-
Potentilla argentea	2	2	-	-	-	-	-	-	-
P. norvegica	-	-	-	1	-	-	-	-	-
P. simplex	1	2	-	-	-	-	-	-	-
Prunella vulgaris	6	3	-	-	-	-	-	-	-
Ranunculus acris	5	-	-	-	-	-	-	-	-
R. repens	2	7	-	1	-	1	-	-	-
Raphanus raphanistrum	5	9	10	5	-	3	2	1	-

Appendix 2 *Continued*

Species	**Nov 1-10**	**Nov 11-20**	**Nov 21-30**	**Dec 1-10**	**Dec 11-20**	**Dec 21-31**	**Jan 1-10**	**Jan 11-20**	**Jan 21**
Rubus ideaus	1	-	-	-	-	-	-	-	-
Rudbeckia laciniata	1	1	2	-	-	-	-	-	-
Rumex longifolius	2	2	-	-	-	-	-	-	-
Salix discolor	-	-	1	1	-	1	1	1	1
S. pellita	-	-	1	1	-	1	-	1	1
Senecio jacobaea	9	10	2	-	-	-	-	-	
S. vulgaris	9	7	11	8	1	3	1	1	-
Silene latifolia	-	1	-	-	-	-	-	-	-
S. vulgaris	1	-	-	-	-	-	-	-	-
Sinapis alba	1	1	-	1	-	-	-	-	-
S. arvensis	1	3	2	4	-	-	-	-	-
Sisymbrium officinale	-	1	-	-	-	-	-	-	-
Solidago bicolor	2	1	-	-	-	-	-	-	-
S. canadensis	20	14	12	8	-	-	-	-	-
S. flexicaulis	-	1	-	-	-	-	-	-	-
S. puberula	1	-	-	-	-	-	-	-	-
S. rugosa	3	-	-	-	-	-	-	-	-
S. sempervirens	1	1	-	-	-	-	-	-	-
Sonchus arvensis	13	21	6	2	-	-	-	-	-
S. asper	1	-	-	-	-	-	-	-	-
S. oleraceus	3	-	-	-	-	-	-	-	-
Spergula arvensis	3	2	2	3	-	1	1	1	-
Spergularia marina	1	-	-	1	-	2	-	1	-
Spiraea latifolia	2	2	-	-	-	-	-	-	-
Stellaria graminea	1	3	1	1	-	-	-	-	-
S. media	5	1	4	5	1	2	3	4	2
Suaeda maritima	1	-	-	-	-	-	-	-	-
Symphoricarpos albus	1	2	1	-	-	-	-	-	-
Tanacetum vulgare	3	2	2	3	-	-	-	-	-
Taraxacum officinale	13	16	14	11	1	5	5	7	1
Thlaspi arvense	-	3	2	2	1	1	3	2	1
Tragopogon pratensis	21	5	3	1	-	-	-	-	-
Trifolium pratense	10	14	8	3	-	-	-	-	-
T. repens	13	7	-	-	-	-	-	-	-
Verbascum thapsus	2	1	-	1	-	-	-	-	-
Veronica agrestis	-	1	1	-	-	-	-	-	-
V. longifolia	-	1	1	-	-	-	-	-	-
V. officinalis	4	-	-	2	-	-	-	-	-
V. persica	-	-	-	-	-	-	-	1	1
Vicia cracca	3	6	2	1	-	-	-	-	-
V. sepium	1	-	-	-	-	-	-	-	-
V. villosa	1	-	-	-	-	-	-	-	-
Viola tricolor	2	2	3	4	2	2	2	2	1
Number of records	458	408	236	161	14	48	34	46	11
Number of sites	21	21	18	14	3	16	10	18	7