UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR: Elisabeth G. Beaubien

TITLE OF THESIS: Phenology of Vascular Plant Flowering in Edmonton and Across Alberta

DEGREE: Master of Science

YEAR THIS DEGREE GRANTED: 1991

Properly recorded and
correctly interpreted, there
is nothing perhaps to equal
the records of the dates of
periodical events in plants
and animals as indices to the
bioclimatic character of a
place or local area, because
such events are in direct
response, not to one or a few,
but to all the complex
elements and factors of the
environment, which no
artificial instrument, or set
of instruments, yet available,
will record.

A.D. Hopkins, 1918, p. 35.

University of Alberta

# Phenology of Vascular Plant Flowering in Edmonton and Across Alberta

by

Elisabeth Gabrielle Beaubien



A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science.

Department of Botany

Edmonton, Alberta

Fall, 1991.

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled " Phenology of Vascular Plant Flowering in Edmonton and Across Alberta" here submitted by Elisabeth Beaubien in partial fulfillment of the requirements for the degree of Master of Science.

Abstract

Phenology, the study of the timing of life cycle events, has a long history in Europe where networks of observers provide data on growth of native and crop plants to agro-meteorological departments. It has much potential for Alberta.

For this thesis, two phenological studies were carried out over the growing seasons of 1987 and 1988. Both concentrated on the phenophases (growth stages) of native perennial plant species.

The intensive study described the flowering phenology of 127 vascular plant species along a 1.5 km transect in Edmonton's Whitemud ravine (aspen parkland). In general, flowering times were earlier in 1987 and 1988 than average, corresponding with higher than average temperatures. Temperatures fluctuated more in the bottom of the ravine, and flowering was generally earlier at the ravine top. Phenodynamic strips illustrate species' development over time and plant wheels show the growing season divided into subseasons marked by the start of indicator species' phenophases.

The extensive study involved volunteers across Alberta to record three flowering phenophases - 10%, 50%, and 90% flowering - for up to 15 species of native "wildflowers". Flowering dates were received from 60 observers in 1987 (1300 dates), and 190 observers in 1988 (approximately 3000 dates). Linear contour mapping using SPANS on a microcomputer illustrated flowering progressions for each species in colour. Trends in flowering were generally from SE Alberta to the NW, continuing on to the foothills, mountains and the north, with a heat island effect causing earlier flowering at cities. Plant species and phenophases were evaluated with respect to their value for phenology. The data from this ongoing survey have large potential benefits for agriculture, forestry, climatology, medicine, tourism and environmental education.

Acknowledgments

I am very grateful to the following for their considerable assistance towards completion of this thesis. Firstly, to my husband Geoff Holroyd and son Michael for their daily encouragement and support throughout. Many thanks to my supervisor, Dr. Walter Moser, for ongoing inspiration and advice. His positive approach, great love of phenology, and talents with dBASE III PLUS were always appreciated. My co-supervisor, Dr. Keith Denford, provided financial support, advice, as well as an office with phone which was essential for the provincial survey. Thanks also to Dr. Greg Henry, Dr. Moser and Dr. Denford for constructive criticism of this thesis.

Congratulations and thanks to Dr. Charles Bird, whose pioneering provincial survey provided a firm base for the extensive survey described in this thesis. His initial advice and ongoing phenology observations are appreciated. Kudos to the many volunteers across Alberta who have contributed substantial amounts of their time in observation and recording of flowering times in the past four years, and whose enthusiastic letters have been a great source of enjoyment.

Contacting potential volunteers around Alberta was greatly assisted by the following: Tim Goos and Bill Hume of the Atmospheric Environment Service, Environment Canada; Bob Young of Fire Detection, Alberta Forest Service; Sherry Maitson of the Curriculum Branch, Alberta Education; and Jim Martin of Environmental Education, Alberta Environment.

Energetic and competent field assistance was provided by Jackie Craig (1987) and Nichole McGarry (1988). Fawziah Gadallah and Kathy Richardson provided data entry assistance.

Essential computer software advice was kindly provided by Ralph Young of this university's Computing Systems (dBASE III PLUS), Sandi Vitt (Canvas 2.0), and the Botany office staff- Brenda Lovas and Cristina Munoz. Dr. Mark Dale provided advice on statistics, and Derek Johnson (Canadian Forestry Service) contributed enthusiastically to discussions of phenology and data analysis.

I am greatly indebted to the following for mapping assistance. Dr. Daniel Johnson of Agriculture Canada in Lethbridge provided very generous assistance in statistical analysis and SPANS mapping, as well as all the colour copies of linear contour maps. Denise Maurice of Crop Protection, and Keith Toogood of Systems Development, Alberta Agriculture, provided considerable time on their mainframe producing large-scale maps. Dr. Ron Eyton of the Geography Department, University of Alberta, provided time and expertise in trend surface analysis.

The friendship and assistance provided by my fellow graduate students, including Sheila MacFie, Elizabeth John, Elaine Gordon, Zoran Ristic, Robert Ellis, Godo Stoyke, and Barb Nicholson, have been a huge bonus. Friends and family assisted with editing over the years as well as with biannual mailings to over 400 addresses - special thanks to Linda and Teslin Seale, Judy Cornish, and Geoff and Michael Holroyd.

Financial assistance was provided through two grants from the Boreal Institute for Northern Studies, by Dr. Denford's NSERC grant, and by the Recreation, Parks, and Wildlife Foundation, which financed two printings of the booklet "Alberta Wildflowers - A Flowering Date Survey".

Table of Contents

Chapter Page

List of Tables

List of Tables, continued:

List of Figures

List of Figures, continued

| Figure | Title | Page |
|---|---|---|

# 1. Introduction

The broad goal for this thesis is to explore the potential of phenology in Alberta, and to test the suitability of some European techniques in this area of short growing season and sparse population. Two phenological studies were done in 1987 and 1988: the first a detailed phenological investigation of flowering in a mixed-wood forest community; the second a survey of flowering times for fifteen plant species across Alberta.

The word phenology comes from the Greek "phaino" meaning "to appear" or "to show". Phenology is thus the science of appearances and has been concisely defined as "the study of the seasonal timing of life cycle events" (Rathcke and Lacey, 1985). The International Biological Program Phenology Committee created this detailed definition:

"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. The unit of study may vary from a single species (or variety, clone, etc.) to a complete ecosystem. The area involved may be small (for intensive studies on all phenophases of entire ecosystems) or very large (for interregional comparison of significant phenophases). The unit of time is usually the solar year with which the events to be studied are in phase. The events themselves may cover variable time spans, often much shorter than the solar year." (Lieth, 1974, p.4)

Phenology has historically focused on autotrophic plants, examining the timing of development of reproductive and vegetative structures (Lieth, 1974). This development is subdivided into "phenophases", distinctive and observable phases in the life cycle of a species. Examples include the timing of first shoots, leafing, flower bud formation, first flowering, full flowering, fruit set, ripe fruit, and leaf colouring. The duration of phases for a species can be graphically illustrated using a "phenodynamic strip" (Figure 1).

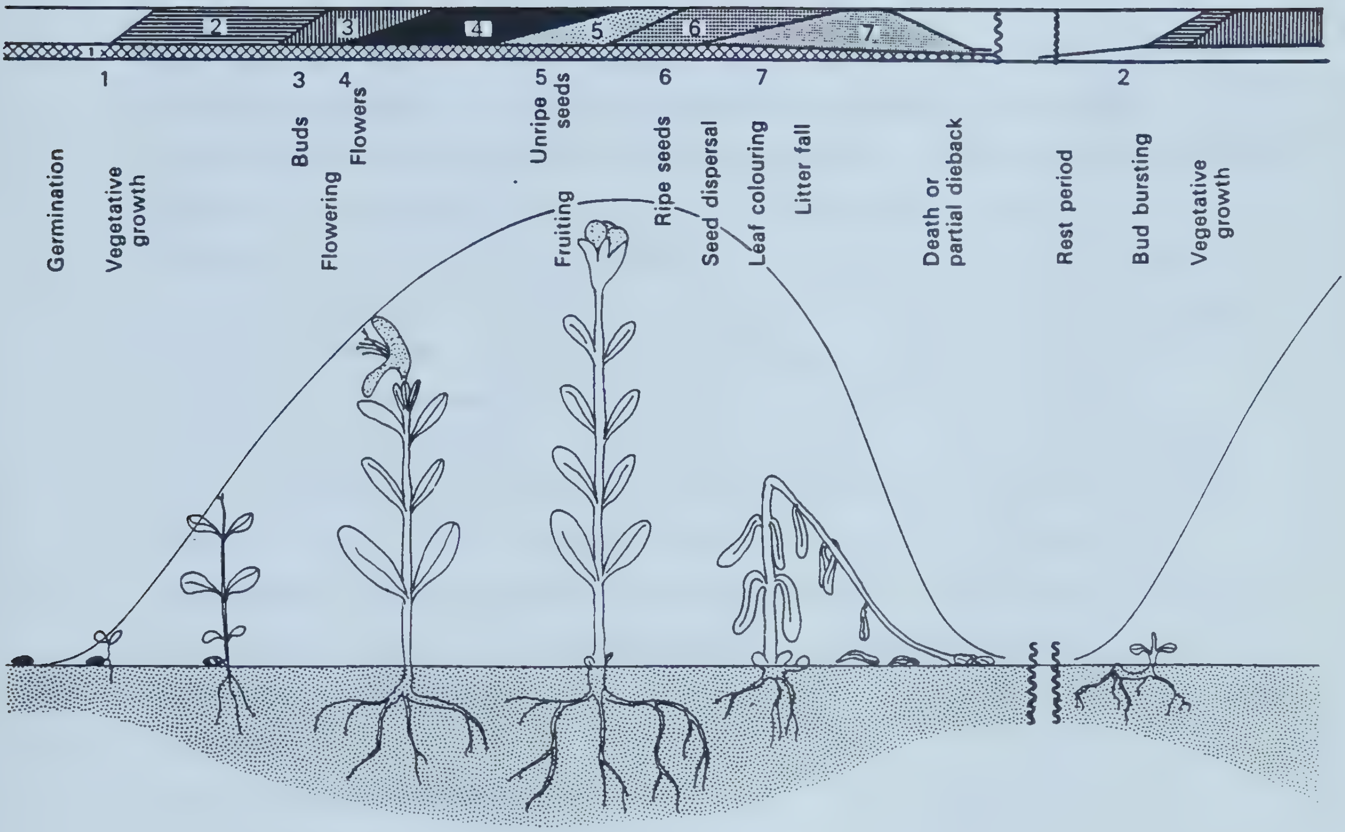



Figure 1: "Phenodynamic Strip" diagram illustrating the stages of a herbaceous plant's development. The patterned strip at the top of the figure illustrates a phenodynamic strip, one technique to present phenological observations. The numbers in the patterns correspond to the numbered phenophases below. The sketch illustrates the life cycle of a perennial herbaceous plant, and the curve above shows the total dry matter built up during its life cycle. Source: Lieth, 1969, Figure 1, p.72.

Phenological research using animals has included the timing of regularly occurring biological phenomena such as the arrival, nesting and migration of birds (Lauscher, 1988) and hibernation of animals.

Phenology attempts to clarify the influence of climatic factors on seasonal phenomena. Plants are sensitive weather instruments, responding to a combination of meteorological conditions (heat, solar radiation, precipitation, wind, etc.), and reflecting this integration in their growth (Caprio, 1966; Hopp, 1974). In this respect plants have advantages over meteorological equipment. They are widespread, and provide an inexpensive way to increase the density of climatological observations. Plants also provide a measure of the conditions close to the ground, whereas the standard weather station is 2 m above the ground where conditions are quite different (Baum, 1949; Geiger, 1965). In addition, mapped phenological data can provide an interpretation of climate conditions that is more readily understood than the various physical measurements (Kreeb, 1977).

## 1.1. History of Phenology

### 1.1.1. Europe and Asia

Phenology has ancient roots. Thousands of years ago, in both China and Rome, agricultural calendars were made using phenophases such as blooming of cherry trees (Hopp, 1974). Twelve centuries of cherry bloom dates are available for Kyoto, Japan (Arakawa, 1955). The father of modern phenology is Carolus Linnaeus, who published in his *Philosophia Botanica* (1751) instructions for recording phenophases and weather observations "so as to show how areas differ". In 1780, over two centuries ago, the first international phenology and meteorology observer network was established in Europe (Hopp, 1974). From 1883 to 1941 Ihne of Germany was the greatest promoter of phenology. He was also the first to use a single species (*Syringa vulgaris*) for mapping (Ihne, 1885), and published his records annually for about 60 years. Schnelle (1955), Caprio (1966),

Rosenkranz (1951) and Hopp (1974) have reviewed the history of phenology.

Networks of volunteer observers have collected phenological data on both native and cultivated plants in most European countries in recent decades (Hopp, 1974). National meteorological departments generally coordinate these networks and use the information gathered to assist agriculture. This linking of a phenology survey to a government agency ensures continuity and uniformity of observations and their analysis. Once the phenology program and its benefits are described to potential observers, recruitment is relatively easy. These volunteers appear to draw much satisfaction from making regular observations and being part of an important national project. The long term data collected in Europe by volunteers has permitted fine-scale mapping of vegetation zones which show how areas differ in potential for agriculture and horticulture (Ellenberg and Ellenberg, 1974 a,b; Schreiber, 1969). (Definition of "vegetation": "the total plant life or cover of an area" (Lincoln et al., 1982, p. 259.)

In Germany, a selected subset of phenology observers who form an instant reporting system mail their reports on the occurrence of important phenophases on the date the phenophase first appears. These results are published in monthly agro-meteorological reports, and are also used immediately by plant protection departments (Hopp, 1974). School children form an important part of this network, whole classes submitting phenology reports as part of their studies in ecology and biology.

Hopp (1974) lists twelve European countries as well as Argentina, Australia, Japan, India, South Africa and the United States as having phenology networks. In Switzerland, the Swiss Meteorological Institute has operated a network of 120 stations at a variety of altitudes since 1951, which record up to 70 phenophases and 36 species (Defila, 1986). In Poland, the phenology survey data have permitted dividing even the mountainous regions of the country into pheno-climatic zones and have supplemented weather records in areas

where they are missing (Obrebska-Starklowa, 1981). The Royal Meteorological Society in England had an observer network which averaged about 200 people annually for the period 1891-1948, and published extensive phenology reports. Long-term averages of this 58-year span are summarized by Jeffree (1960).

In 1959 an International Phenological Garden program was established in Europe by Schnelle and Volkert (1974), which uses clones of tree and shrub species, thus eliminating genetic variability. At a phenology conference in Vienna, Henhappl et al. (1986, p.76) stated that "genetically identical plants can be considered as essentially improved "biological measuring instruments", and that their "measuring accuracy" is a decimal point preciser than through the observations of conventional phenology". In 1987, 62 gardens were reporting observations on vegetative and reproductive phases of these cloned plants, as well as weather records and some observations of perennial wild plants to assist with generalizations to broader areas (Freitag, 1987).

This centuries - old European interest in phenology characterizes a population that is very knowledgeable and interested in native plants, as compared to North American society.

### 1.1.2. United States

As in many other countries, individuals in the United States, of their own motivation, have invested years of personal observation and amassed considerable phenology records for specific sites. Much of this remains unpublished. Huberman (1941), Caprio (1966), and Hopp (1974) review some of the published work. Henry David Thoreau was the American father of phenology, according to Aldo Leopold, who himself contributed an extensive analysis of phenological methods in the publication of a decade of phenological records for two Wisconsin counties (Leopold and Jones, 1947). The regional interest he created later led scientists to form the Wisconsin Phenological Society in 1959. This group still has over 400 members who are annually

encouraged to observe phenophases of native plants and animals (Lettau, 1987).

The first American network of phenological observers began in the 1950's, through regional agriculture departments. The goal was to develop phenology as a climatic tool to characterize seasonal weather patterns and improve predictions of crop yield. Dr. J. M. Caprio at Montana State University started the first survey in 1956. By 1961 his volunteer network of 1000 observers covered eleven western states and used existing lilac (Syringa vulgaris) plants (Caprio, 1966). Later two honeysuckle cultivars were added as indicator plants. By 1972, 2500 observers were submitting annual reports (Hopp, 1974). Similar projects began in the 1960's in the central and eastern states using cloned plants of the Syringa vulgaris cultivar 'Red Rothomagensis' and two honeysuckle cultivars: Lonicera tatarica 'Arnold Red' and Lonicera Korolkowii var. Zabelii. These two projects were combined in 1970, and in 1972 all surveys pooled their expertise in the Phenology Satellite Experiment, using imagery from the first Landsat satellite (Hopp, 1978).

The northeast project also recruited observers in the six eastern Canadian provinces. It was renewed in 1980 as NE 135 and coordinated by Vittum of Cornell until 1985. Unfortunately this project has not been funded to continue. M. Schwartz, who has used the accumulated data to test models of atmosphere-plant interactions (Schwartz and Marotz, 1986, 1988) has taken over this observer network and is currently seeking funding to expand it. The data 1961-1988 for the central and eastern states is available in PC-compatible form (Schwartz, 1989, pers. comm.).

Caprio's network in the western United States is active with almost 500 participants, though more funding is needed to support the project (Caprio, 1990, pers. comm.). These U.S. networks have contributed to agriculture in many ways, including providing both predictions of the timing of insect pest development and early predictions of crop yield (Hopp, 1978; Caprio, 1966).

As part of the International Biological Program, Bliss (1967) issued a call to ecologists to undertake intensive (covering a small area) or extensive (covering a large area) phenological studies. He listed goals for phenology research and also listed organisms (plant and animal) which would be most suitable, having both wide geographic distribution and narrow ranges of genetic diversity. As part of this program, Lieth and his graduate students established phenology networks using developmental phases of dogwood (Cornus florida L.), redbud (Cercis canadensis L.), red maple (Acer rubrum L.) and tulip poplar (Liriodendron tulipifera L.) ( Noggle, 1978; Radford, 1971; Lieth and Radford, 1971). The status of phenological studies in the United States in the late 1960's and early 1970's, including information on biomes, specific locations, species and chosen phenophases, is summarized in the report of the US/IBP Phenology Committee (1972).

### 1.1.3. Canada

There was considerable early Canadian interest in phenology. In 1890 the Royal Society of Canada passed a resolution requesting affiliated natural history and scientific societies to:

> "obtain accurate records in their individual localities of meteorological phenomena, dates of the first appearance of birds, of the leafing and flowering of certain plants, and of any events of scientific interest for collation and publication in the 'Transactions of the Society'"

(Royal Society of Canada, 1893, p. 54).

The following year, 1891, the Botanical Club of Canada was formed, affiliated with the Royal Society. One of its departments was responsible for promoting the nation-wide phenology survey, which included observations on fifty events. At first, most observers were from the Maritimes, but by 1895 prairie observers were contributing records. In that year, 25 reports were received from nine provinces. The secretary of the Botanical Club, Dr. A. H. MacKay,

coordinated the survey up until 1910. The phenology survey was then coordinated by F.F. Payne of the Meteorological Service until 1922. Observations for 1892-1922 were published annually in the Proceedings and Transactions of the Royal Society of Canada.

Dr. MacKay, who was also Superintendent of Education for Nova Scotia, promoted phenology very successfully. In 1898, 800 sets of observations were submitted by school classes (MacKay, 1899). Observations by Nova Scotia schools continued until at least 1923 (MacKay, 1927).

Table 1 lists some Canadian phenology records, compiled in part from Minshall (unpublished annotated bibliography, 1975). A brief review of Canadian phenology research is given by Minshall (1947). In addition, Glendenning (1943) summarizes some methods, history and uses of phenology and recommends certain species as suitable across Canada. Based on his own 34 years of British Columbia observations, he suggests phenological events to observe in each month of the year for the coast. Erskine (1985) lists many phenology references previously published in the Canadian Field Naturalist. Criddle (1927) observed 400 prairie species over 20 years and produced flowering and seed-ripening times valuable for present-day use in reclamation work. Budd and Campbell (1959) compared their flowering sequence to Criddle's using regression and correlation analyses, and found high correlation between the two data sets.

The only large phenology network in Canada was established in Quebec in 1971. Observations were made until 1977 at over 300 stations of which 51 were adjacent to meteorological stations (Dubé and Chevrette, 1978). This survey was affiliated with the United States' NE-69 project, and used the same lilac and honeysuckle cultivars previously described in section 1.1.2. By 1977 observers in the six eastern provinces were involved. Quebec had the largest number of observers by far: with 268 active observation sites in 1977 versus New York State, the next largest, at 84 sites (Vittum and Hopp, 1978). P. Dubé of Laval coordinated the Quebec participants and also computerized results for the whole project.

Table 1: Some Canadian phenology records

| PERIOD | DURATION (YEARS) | ORIGINATOR/ AUTHOR | REGION | COMMENTS |
|---|---|---|---|---|
| 1892-1922 | 30 | Botanical Club of Canada | Canada | Promoted observations on 50 phenological events, using native plants, birds, farm activities and ice thaw and formation. Published annually in the Proceedings and Transactions of the Royal Society of Canada. |
| 1897-1923 | 26 | MacKay, 1899, 1927 | Nova Scotia schools | Observations on 100 phenological events |
| 1904-1924 | 20 | Criddle, 1927 | SE of Brandon Manitoba | First flowering, number of days to ripen seed for 400 native plants |
| 1922-1947 | 25 | Mitchener, 1948 | Manitoba | First flowering of 40 honey-producing plants |
| 1926-1958 | 33 | Moss, 1960 | Edmonton, Alta. | Full flowering of 25 spring-flowering native plants, temperature correlations |
| 1936-1961 | 25 | Russell, 1962 | Winnipeg, Man. Saskatoon, Sask. Edmonton, Alta. | First flowering of 50 native prairie plants, and wheat development. Observations by staff of Canada Agriculture Laboratories of Plant Pathology. Published annually in reports of the Canadian Plant Disease Survey. |
| 1936-1945 | 9 | Minshall, 1947 | Ottawa, Ont. | First flowering of four tree species. |
| 1936-1960 | 24 | Bassett, Holmes, and MacKay, 1961 | Ottawa, Ont. | First flowering of 36 plant species, temperature correlations. |
| 1945-1958 | 13 | Budd and Campbell, 1959 | Swift Current, Saskatchewan | First flowering of 145 native prairie plant species. |
| 1971-1975 | 5 | Erskine, 1985 | Boreal region | First flowering for 64 plant species, spring arrivals of 29 bird species. Each year's observations in a different location, Quebec west to British Columbia. |
| 1973-1983 | 10 | Bird, 1974-1983 | Alberta | Flowering records for native plants, recorded by volunteer network. Published annually in the "Alberta Naturalist". |

More recently, a smaller scale survey of short duration has been carried out in Southern Ontario (Beschel, 1969) using seven phenophases on each of four plant species and one bird species. In British Columbia, a survey launched in 1984 calls for 16 phenophases of up to 50 native species of the observer's choice (B. Merilees, 1988, pers. comm.).

### 1.1.4. Alberta

For native peoples, phenology was a well-honed tool. The Blackfoot Indians in Alberta used the flowering time of *Thermopsis rhombifolia*, Golden Bean (Buffalo Bean), to indicate the brief period when bison bulls were prime for the spring hunt (Johnston, 1987).

The late Dr. Ezra Moss, formerly of the University of Alberta's Botany Department, recorded "height of bloom" dates for 25 spring-blooming shrubs and trees for the years 1926-1958. These flowering data were correlated with degree-days to determine the average amount of warmth the plants were exposed to before flowering (Moss, 1960).

In 1973, Dr. Charles Bird, a botanist at the University of Calgary and an active naturalist, started a ten year phenology survey through the Federation of Alberta Naturalists. For the first few years he requested dates of blooming for 100 species of Alberta wildflowers. This number was reduced over the years to twelve "key phenology species". These plants were all native perennials, easy to recognize, had a reasonably consistent flowering period, and were relatively widespread across the province. These ten years of dates for locations around Alberta were published annually in the spring issues of the "Alberta Naturalist" (Bird, 1974 to 1983). The goal of his phenology survey was to determine the average flowering period of these native plants, and to use the data in the following ways: to identify the relative earliness or lateness of each spring, to provide start-up dates for both natural history and agricultural activities, to compare areas of the province, and to test bioclimatic

theories. In the peak year of participation, 1977, Bird had 180 participants, who reported dates for a total of 71 species (Bird, 1978). In the latter years of the survey, observations requested were "first date", "other dates", and "last date in flower". He calculated first flowering dates for the six best-reported areas of the province and published nine year averages (Bird, 1982).

The "May Species Count", which is a count of wildlife including plants, birds, mammals, etc., has been held in Alberta on the last weekend of May since 1976 (Weseloh, 1976). It has been coordinated by the Federation of Alberta Naturalists and the plant records have been compiled since 1978 by Derek Johnson. All past records are stored at the Provincial Museum of Alberta. Plant species in flower are recorded across the province by naturalists, and the numbers of species flowering from year to year in different areas are compared to see the relative earliness or lateness of each spring. Results are published annually in spring issues of the "Alberta Naturalist".

This Alberta research in phenology by Moss, Bird, and Johnson represents a start toward understanding the phenological behaviour of Alberta's flora. (Definition of "flora": "the plant life of a given region", Lincoln et al., 1982, p. 94.) Considerable research is still needed to describe phenological sequences and to identify the best phenology species for the major ecoregions of the province (parkland, montane, subalpine, alpine, and the different grassland and boreal ecoregions (Strong and Leggatt, 1981).

## 1.2. Applications of Phenology

Phenological observations can be used in a number of fields. Some of the potential applications for Alberta in the sciences and renewable resource-based industries, as well as education and tourism, are covered here.

Once information for an area is available on the average timing of plant development, then one can recognize the arrival of subsequent springs as early, average, or late. By overlaying a phenological

calendar on a civil calendar, seasons can be delimited by groups of phenological events. This provides the best way to compare the timing of a stage of biological development with the same stage in other years.

While phenology serves as a check of season against season, it also provides a comparison of region against region. Caprio (1957) describes plants as "measuring sticks of local environmental differences" (p. 1344). Phenology of individual species, or groups of species, reflects the local microclimate differences, for example hilltops versus valley bottoms, or north-facing versus south-facing slopes (Jackson, 1966). On a larger scale, maps of agricultural areas can be made based on phenological data to indicate early and late growth zones (Ellenberg and Ellenberg, 1974 a, b; Dubé and Chevrette, 1978).

In temperate areas of the world, which have pronounced seasonal changes, the sequence of development of organisms over the course of the year follows a predictable pattern. Pfau (1964, in Lieth, 1974, p.8), calculated correlation coefficients between twenty-one consecutive phenophase events (eg: first flowering of snow drop (Galanthus nivalis) and coltsfoot (Tussilago farfara) from indicator plants used by the German weather service. Averages of thirty years data yielded coefficients ranging from 0.70 to 0.99, with the majority above 0.80.

Lechowicz (1984) found good concordance in leafing sequences between species when examining data for North America and Europe. This predictability applies across trophic levels - a plant's phenological stage can act as a timing indicator for subsequent growth stages in other organisms (Waggoner, 1974; Straub and Huth, 1978).

In ecological research, phenology provides useful information on the timespans of the foliated and reproductive phases in plant species in communities around the world, and the effects of weather on these events (Larcher, 1983). This information can assist us to

manage vegetation resources better, to estimate productivity and to understand the interactions between land and atmosphere (Lieth and Radford, 1971; Justice et al., 1985).

Climate Change:

Climate monitoring is an important application for phenological research, especially with the recent awareness of increasing carbon dioxide concentrations in the atmosphere. Baseline information from phenology studies would allow us to monitor future changes in climate through changing phenological patterns (T. Goos, 1989, pers. comm.) and to track the extremes of weather. In 1980, an examination of 17 years of phenological records from European phenological gardens and observer networks revealed a slight lengthening of the growing season. Leafing was occurring on average 0.36 day/year earlier, and flowering 0.33 day/year earlier. Autumn phenophases were 0.20 day/year later (Lauscher and Roller, 1980). Species-specific information on phenology and physiological tolerances for heat, light and $CO_2$ would help us predict species' movements resulting from future climate warming.

Agriculture:

Phenology can assist agriculture, Alberta's second most important industry, in understanding and adapting to an extreme and variable climate. In the past, for native people on this continent, phenology was essential "common sense" for agriculture. In 1605 Samuel de Champlain was told that the best time to plant corn in Cape Cod was when the leaf of the white oak was the size of a red squirrel's footprint, advice that had spread north from the Aztec's ancient maize fields (Molitor, 1987). With increased size of farms and dependence on technology much of this early wisdom has been lost.

Specific agricultural applications are numerous. The following will be elaborated here: defining bioclimatic zones, maximizing range and crop production, protecting crops from insects and weeds, and timing horticultural activities.

Phenological data can be used to divide agricultural land into bioclimatic zones. In Quebec, using five year observations of three indicator plants species from 300 observation sites, the province's agricultural zones were mapped (Dubé and Chevrette, 1978) and boundaries for taxation refined (Dubé, 1991, pers. comm.).

To maximize production of grasses and forbs on native rangeland, the land should be protected from grazing until approximately early June. Budd and Campbell (1959) determined that first flowering of Rosa woodsii is the best indicator of the optimal "start grazing" time and that this plant generally starts flowering 50 to 55 days after first flowering of Anemone patens. In Montana, Caprio determined that alfalfa is usually ready for its first cutting 30 days after lilac starts to flower (Caprio, 1966).

Many studies have shown the usefulness of phenology in crop protection. One or more indicator plant phenophases are used to predict the emergence of a specific insect "x" days later. Research in this area includes predictions for the European corn borer, Ostrinia nubilalis, (Straub and Huth, 1978); the cabbage maggot, Hylemya brassicae, (Pederson and Eckenrode, 1981); and the elm bark beetle, Scolytus multistriatus. The appearance of the latter can be predicted using the flowering of four plant species (Kapler, 1967). By making an early cut of alfalfa, up to ten days after the common purple lilac starts to flower, farmers can control the alfalfa weevil (Hypera postica Gyll.) by removing eggs before hatching (Caprio, 1966). Phenology of native species as well as lilac and honeysuckle cultivars has been used to predict grasshopper development (Hewitt, 1980). Caprio (1966) describes the phenological indicators for optimal timing of herbicide control of big Sagebrush (Artemisia tridentata) on Montana rangeland.

In Alberta, once the correlations between development of our key plant species and the insect pests are developed, a rapid-reporting volunteer network could feed information to an instant crop yield and

pest prediction system. Experts in international agriculture predict that increasing droughts resulting from climate warming will mean increased problems due to crop pests. For example, the European Corn Borer would spread farther north (Downing and Parry, 1991).

In a given spring, early or late, local phenology can indicate the best time in spring to plant vegetables and flowers to get optimal growth. Bird and Marsh (1979) suggested that rather than using a set date such as May 24 in Alberta, the key phenology species provide the "go ahead" times. Radishes, lettuce and such early seeds should be planted when Viola adunca (Early Blue Violet) flowers, and other seeds such as beans are best delayed until Amelanchier alnifolia or Prunus virginiana begin flowering. Molitor (1987) summarizes horticultural applications.

Other agricultural applications include predictions of the following: timing of seeding and fertilizer application, timing of flowering for apiculturists, crop yields (Blair, 1978), and labour requirements (Taylor, 1969). Further agricultural applications are summarized by Caprio (1966).

Phenology studies of in situ native plant species at reclamation sites can assist in the subsequent timing of seed collection forays and can thus improve the availability of native plant material (Currah et al., 1983).

Remote Sensing:

Phenology has proved effective in ground truthing satellite images. A phenology satellite experiment analysed Earth Resources Technology Satellite imagery to detect the "green wave" of spring growth and the "brown wave" of fall senescence across the United States. To do this, phenological observations from 3200 sites were used in ground truthing (Dethier et al., 1975). Presently remote sensing is being used to identify vegetation cover and communities and indicate their phenological progress (Justice et al., 1985).

Forestry:

Knowledge of tree species' phenology assists in recognition of species on air photographs (Sayn-Wittgenstein, 1961). Also, timber managers and tree breeders need timing details of cambial activity, flowering, and seed production (Ahlgren, 1957). The forest entomologist needs tree development timing to predict insect activity and plan effective insect sampling and control (Morris et al., 1956). Finally, for efficient herbicide application a knowledge of the phenological spectrum of forest communities is necessary (M. Fairbarns, 1988, pers. comm.).

Medicine:

In the field of human health, doctors counselling allergic patients would benefit from local phenology charts. The pharmacological industry also needs to know when to collect pollen types to produce desensitization extracts. (This industry presently uses pollen traps for wind-born pollen, a technique which may be useful for phenology as well.) A knowledge of climates and phenology worldwide would help doctors advise patients (climatherapy).

Tourism and recreation:

Knowledge of both the local flowering sequences and also the timing of peak wildflower bloom in the current year would help parks and communities plan programs for the public. Phenology can also help the tourism industry in planning for: holidays with wildflower photography opportunities, fishing trips without biting flies, and back country trips with minimal bear encounters! Adults, for mental health benefits, need to maintain contact with the natural world, and phenology can provide this opportunity as a lifetime hobby. Phenological events can translate into tourist dollars - a major portion of the economy of the Great Smokies in the eastern states depends upon sight-seeing trips to see dogwood (Cornus florida L.) flowering each spring (Stearns, 1974).

Table 2 outlines some applied and research areas in the sciences. Numerous applications including law and literature are also summarized by Schnelle (1955).

Table 2: Example of applied and research areas using phenological data.

Source: K. Lettau, 1970, Wisconsin Phenological Society, October newsletter.

| Related Sciences | Examples of Practical Applications | Examples of Research Fields |
|---|---|---|
| Physical Sciences | | |
| Climatology | Plants as microclimate indicators | Microclimatic mapping, |
| Limnology | Duration of ice-cover, prediction of algal blooms | Eutrophication trends |
| Soil Science | Plants as soil moisture indicators | Trafficability, evaporivity, climate modification |
| Agricultural Sciences | | |
| Agronomy | Timing of field operations | Remote sensing of crops for growth characteristics |
| Apiculture | Timing of transplantation of hives | Prediction of flowering events |
| Horticulture | Timing of propagation | Development of varieties |
| Plant Genetics | Timing of seed collection and growing season adaptation | Temporal and regional changes in hereditary traits |
| Plant Pathology | Timing of spraying | Pest control through natural enemies |
| Forestry | Timing of Christmas tree shearing, choice of planting sites | Remote sensing of growth development, development of adatped species |
| Life Sciences | | |
| Biology | Ecological relationships | Investigation of adaptation to environments and evolution |
| Entomology | Pest control | Insect development and migration |
| Medicine | Prediction of onset of hayfever and allergies produced by plants | Correlation of events with indicator plants |
| Pharmacology | Timing of collecting plants used in drugs and spices | Correlating of development with indicator plants |

Environmental Education:

Education is one of the most important benefits. Phenology studies are an ideal way to teach ecological concepts through hands-on experiences and are useful at all levels in education to make the interactions between organisms, the observer and the environment relevant. Phenology also raises awareness and appreciation for the plant kingdom and can lead to habitat protection. As the stresses of resource consumption and population growth increase on the prairies, environmental education becomes even more important. The production of a joint phenospectrum for plants and animals would "give the best guarantee for the understanding of our environment" (Lieth, 1969, p.80).

There is an important precedent for phenology in Canadian schools; the largest phenology network in Canada's history was composed of Nova Scotia students. In the 1890's phenology observations were promoted by that province's Superintendent of Education, Dr. A. H. MacKay, who was also secretary of the Botanical Club of Canada. On a voluntary basis, school classes completed schedules of observations on over 100 items including the flowering and leafing of 44 species of native plants, the arrival and departure of 17 species of birds, crop seeding and harvest, and freezing and thawing of water bodies. The goals of this project were to assist the teacher in the nature study part of the curriculum and to gather valuable data on the local area and province. Participation in the survey increased rapidly: in 1897 over 200 schedules were received, and by 1899 almost 800 were submitted. Teachers verified the accuracy of observations, and students who first noted an event for that year were recognized by the whole school. The benefits were obvious:

> "Inspectors report it as being the most valuable stimulus yet given to direct teachers and pupils to the active study of nature - to the elements of the natural sciences underlying the industrial development of the country. It also tends to develop the habit of accurate observation, as necessary to a successful literary or professional career as to the industrial occupations" (MacKay, 1899).

Over 25 years later, almost 300 schedules were still being submitted annually by Nova Scotia schools (MacKay, 1927). Schedules for each year were sent to the Provincial Museum and Science Library in Halifax, and selected averages were published annually in the Transactions of the Nova Scotian Institute of Science. Some of the averaged data is also published in the Proceedings and Transactions of the Royal Society of Canada.

The benefits of phenology for students and society are summarized by Stearns (1974) and Beaubien (1991).

## 2. Phenological Methods

For this thesis, two approaches to phenology were investigated over two growing seasons. The first was an intensive study of a large number of species in a forest community, and the second, an extensive study of 15 plant species across the province. Both concentrated on flowering, since this phenophase facilitated species recognition and observation and provided the best potential for comparison with previous Alberta research (Moss, 1960; Bird, 1982).

### 2.1. Abiotic and Biotic Factors Influencing Phenology

There is a close correlation between phenological events and certain climatic factors. Three major abiotic factors have been identified as initiators of flowering: temperature, photoperiod and moisture (Rathcke and Lacey, 1985).

Temperature:
In the world's temperate zone, the "time of onset of phenophases of the first half year depends primarily on the passing of certain temperature threshholds" (Larcher, 1983, p. 64). This applies to certain types of plants. "Most temperate woody species and some perennial herbs flower in response to temperature, which usually acts through cumulative heat sums above some threshold level" (Rathcke and Lacey, 1985, p. 190). Many researchers have found temperature to be

the most important factor for spring development and flowering (Bassett et al., 1961; Jackson, 1966; Caldwell, 1969; Anderson, 1974). Lindsey and Newman (1956) found that temperature data were highly correlated with flowering data, when they examined a 32 year phenological record from Indiana and compared it with temperature data for that period. They calculated the requisite heat sum for each perennial herb species.

To correlate well with phenology, growing season temperatures should be measured close to the ground (Baum, 1949). Hopp (1974) determined, from a nine year study, that the freeze-free period was thirty days shorter at 7.5 cm above the ground than at 150 cm above. Air temperatures correlate better with flowering than soil temperatures, and microclimate around plants has a major influence on their phenology. Aspect can make a large difference; Jackson (1966) found that flowering dates of nine plant species in a large gorge were six days later on the north-facing slope than on the south-facing slope.

Various heat summation methods have been used in correlation analyses with flowering times. Daily heat sums have been calculated by simply multiplying the average daily temperatures (maximum temperature plus minimum divided by 2) by 24 hours to give degree hours (Anderson, 1974). Degree-days, as currently used, are equal to the average daily temperature less a threshhold temperature. Alberta Agriculture uses 5°C as a threshold (Dzikowski and Heywood, 1990). It is more accurate to estimate the durations of temperatures between the daily maximum and minimum. To do this, Lindsey and Newman (1956) developed a statistical-graphical method for determining the temperature threshhold for physiological flowering activity.

Caprio (1971) used ten years of lilac data to devise "solar thermal units" (STU), combining heatsums above a threshhold of -0.5° C with solar radiation, to calculate the amount that plants needed to flower. Lilacs, no matter whether grown in Norway, Montana or on the west coast of the United States required 380,000 STU to flower.

Moss (1960) and Anderson (1974) summarize some of the literature on heat accumulation models to predict timing of phenophases.

Photoperiod:
In most plants, photoperiod is obviously not the cue responsible for flowering time, since flowering does not occur at the same time every year. Plants which do initiate flowering in response to day length include mainly annuals (Rathcke and Lacey, 1985). Beddows (1968) found that, for grasses, the initiation of flowering was in response to increasing photoperiod. For many perennial species, early development phases are controlled by temperature and later phases by photoperiod (Anderson, 1974).

Moisture:
Rainfall is an important factor influencing the timing and spacing of flowering of tropical plants. In Costa Rica, phenological and meteorological research by Opler *et al*. (1976) showed that aseasonal precipitation in a normally dry period (December to April) was closely linked to the start of flowering. In deserts however, flowering can be induced in annuals by drying of the soil, an environmental cue which signals the end of the growing season (Rathcke and Lacey, 1985).

Biotic Factors:
Besides temperature, light, moisture and other abiotic influences, biotic factors also play a role in inducing flowering.

Within-species variation in flowering time has been observed in some species using uniform garden experiments. In general, populations from higher altitudes flower earlier than do those from lower altitudes, when they are planted together at low altitudes. Clausen *et al*. (1940) demonstrated this ecotypic variation in the flowering time of *Potentilla glandulosa*. McMillan and Pagel (1958) compared phenology of clones of a summer-flowering species, *Symphoricarpos occidentalis*, between field conditions and a common garden. They found that genetic or clonal effects were stronger than environmental

effects in influencing flowering time; clones which flowered unusually early in the field also flowered early in the common garden. Studies of spring-flowering species have yielded different results, however. The spring-flowering Cornus stolonifera showed that its flowering time was environmentally controlled: cuttings from clones in 21 locations (from a latitudinal gradient of 40-65 degrees north) flowered within a 10 day period when grown in a uniform plot in Minnesota (Smithberg and Weiser, 1968). Reader (1975) also found that the flowering time of Cornus florida was environmentally controlled.

The perennial grass species Deschampsia caespitosa was collected from twenty sites from Colorado north to Montana, and placed in three gardens of varying altitude in Colorado (Pearcy and Ward, 1972). Populations from high elevations developed earlier and flowered faster in all gardens than those from low elevations, illustrating genetic control in this species.

In aseasonal tropical forests, biotic pressures from consumers, competitors, dispersers and pollinators may select for phenology patterns. Aide (1988) found that in these forests herbivory influences leaf phenology, and that leafing tends to occur in synchronous peaks.

The ploidy levels of species can influence phenology. Lewis (1976) in studies of Claytonia virginica found that in southern populations polyploids flowered later and longer than diploids.

In summary, biotic influences including ecotypic or genetic variation as well as pressures from herbivores, competitors, and pollinators can all influence plant phenology.

2.2. Study Designs

Phenological studies vary along a continuum of size of area and duration of observations, but basically can be divided into three types:

a) the "snapshot" study, where many observers survey phenology over a large area at one point in time. An example of this "synchrone" study (Kreeb, 1977) is the Alberta May Species Count, held annually on the last weekend of May.

b) The intensive study (Bliss, 1967) where one or a small number of people survey a small area (less than 1000 $km^2$: Kreeb, 1977) over a period of one or more growing seasons.

c) the extensive study - which involves a network of observers, who survey a large area over a period of years.

2.3. Species and Phenophase Selection

To be practical for phenological studies, species should fulfil most of the following requirements (Kreeb, 1977).

a) The species should be abundant where observed, as sufficient individuals are necessary to determine average values of development. An exception would be individual plants with numerous flowers such as Syringa vulgaris (lilac) or Prunus virginiana (Chokecherry).

b) Chosen phenophases should develop in response to temperature, and other factors should have minimal effect. For this reason, spring-flowering perennials should be observed (Rathcke and Lacey, 1985).

c) Plants whose inflorescences do not remain open (eg: dandelions) should be avoided.

d) To gain information about the climate close to the ground, low-growing herbs should be chosen. Trees react to temperatures at the height of their branches (Lechowicz, 1984).

e) If dioecious species are selected, development of male and female plants should be observed.

f) The location of observed plants should be away from buildings or

artificial sources of heat such as buried steam pipes. In choosing a planting site for lilacs to be observed for phenology, the minimum distance recommended from the base of an obstacle should be at least twice the height of the obstacle (Dubé et al., 1984).
Recently flooded areas should be avoided (Leopold and Jones, 1947).
g) Flowering observations should be discontinued on plants where inflorescences are consumed by herbivores.

The number of species observed is determined by how much of the growing season data is required for, available time and manpower, and the number of phenophases recorded for each species. For the purposes of an extensive study, a small number of species facilitates accurate data collection by volunteers. However, limiting a phenological survey to one or two species, as done by the large United States surveys, has disadvantages. Blair (1978) noted that lilac flowered for too short a period to predict crop yields, and he therefore established a phenological garden network in Indiana to provide flowering dates from April to September.

The next consideration is which species to select. Blair et al. (1974) provide a list of characteristics of species chosen for phenological gardens, including ease of establishment over a range of climate and soil conditions and rapid propagation of cuttings or clones from parent plants. Various extensive survey networks have used cultivars (U.S.A.), or a combination of native and crop plants (Europe). Both have certain advantages. Cultivated or crop plants have the benefit of increased genetic consistency, and of course, cloned plants are optimal. Ornamental cultivars can be planted in the vicinity of homes and observed easily. Native species have the advantages of low cost, and wide availability for observers with access to park or natural areas. These plants are already adapted to a region's climate and soils. As well, phenology using native plants provides education opportunities, increasing awareness and future stewardship of native flora and the environment. The problem with using native species is genetic variability, the extent of which could be determined for species using common garden experiments.

Phenophase selection:
For extensive surveys using already-established plants, species selected should be widespread and easily recognized by volunteers. Chosen phenophases should be distinct and occur rapidly, and an easily recognized "first flowering" is important. Phenophases need to be "sharp" so that two independent observers would give the same date (Leopold and Jones, 1947). They should also recur every year, unlike flowering in some species of the Liliaceae or Orchidaceae.

For intensive studies, the points above are still valid. Phenophases should be selected following observations of species' development during the first field season (West and Wein, 1971). Site visit frequency can then be planned to match suitable phenophases. Some challenges in surveying a plant community's phenological characteristics are described by Dierschke (1972): "the chief problem in recording the phenological state lies in the recognition of all species before and after flowering time" (p. 7), and "rare and small growing species are often first visible because of their flowers and can hardly be found again after they cease blooming" (p.10).

## 2.4. Intensive Studies

The results of intensive studies (which cover a small area and use a low number of observers over a restricted time period) have been used in a variety of analyses, of which three are reviewed here. These include investigations of flowering patterns to reveal evolutionary trends, correlations of phenology with abiotic and biotic factors, and descriptions of community phenological characteristics. (Definition of "community": " Any group of organisms belonging to a number of different species that co-occur in the same habitat or area and interact through trophic and spatial relationships" (Lincoln et al., 1982, p. 53.) As well, some past intensive studies in Alberta are reviewed.

A popular current trend in phenological research concerns evolutionary causes and effects of phenological patterns. Rathcke

and Lacey (1985) review literature on selective factors, environmental cues, genetic effects, interspecific and intraspecific synchrony, and ecological and evolutionary constraints affecting the phenological patterns of germination, flowering and fruiting. Primack (1985) examines flowering patterns at levels from the individual plant to the community, and reviews theories relating to possible controlling environmental factors such as competition for pollinators.

Many authors have correlated phenological development with temperature accumulation, as previously reviewed in the section on abiotic factors. As well, Auroi (1975) compared microclimatic factors to phenological development in a Swiss peat bog. Jackson (1966) installed 16 microclimate stations 15 cm above the ground in a heavily dissected gorge area of Indiana, seeking stands of spring wildflowers and maximal topographic and vegetation differences. Plants were marked in 1962 and observed in 1963, when intensive records were kept during the spring. "First shooting, leafing, budding, petal colour first showing, time of first flowering, time of full flowering, petal abscission, fruit set, seed dispersal, and death of aboveground portions were recorded for as many common species as was practicable" (Jackson, 1966, p. 409).

Biotic relationships can also be investigated in intensive studies. The relationships between floral phenology and pollinator behaviour in tropical environments is reviewed by Frankie et al. (1974).

Brundrett and Kendrick (1988) explore relationships between observed patterns of plant phenology and mycorrhizal colonization of vascular plant roots in a hardwood forest.

Lastly, intensive studies permit descriptions of the phenological spectrum of communities: the seasonal characteristics of each species' development and how these interrelate. Average calendar dates can be established for phenological events - a process called "benchmarking" (Lieth, 1969). Examples include work by Leopold and Jones (1947), a comprehensive 10 year record of two Wisconsin sites

with old field, forest and marsh communities. Phenophases observed included stages of plants, vertebrates, and insects, as well as lake ice records. Years were compared with respect to deviations of these events from average dates. Taylor (1969) describes first flowering of 225 vascular plants observed for a 6 year period in Tennessee. Brown et al. (1985) looked at intra- and interspecific variation in two co-existing plant species, Aster acuminatus and Clintonia borealis, and reviewed the literature on forest herbs. Malaisse (1974) compiled phenological information on the Miombo ecosystem of the Zambezian woodland area, including primary and secondary producers, decomposers and aquatic communities. Ellenberg and Strott (1988, fig. 46) describe the phenological development of about 80 species from the tree, shrub, and herb layers of an Oak-Hornbeam forest in Europe.

Dierschke (1972) reviews past workers who have used quantitative symphenological flowering diagrams. These diagrams provide information on species combinations, timing of appearance and disappearance of plants above ground, flowering sequences, floral colour dominances, and relationships between timing of vegetative and generative development, and are important in the evaluation of competitive relationships. Dierschke (1983) describes about 400 species from European summergreen deciduous forests and reviews phenological research on plant communities in Europe.

In Alberta, little intensive phenological research has been done. Prairie studies which may be of value here include Budd and Campbell (1959) for Swift Current, Saskatchewan; Criddle (1927) for southern Manitoba; Stevens (1973) for North Dakota; Dickinson and Dodd (1976) for the shortgrass prairie of NE Colorado; Russell (1962) for Winnipeg, Saskatoon and Edmonton; and Moss (1960) for Edmonton (aspen parkland). Flowering periods of southern Alberta prairie species of potential use in reclamation were studied 1981-1983 (Currah et al., 1983). Boreal studies are few (Erskine, 1985; Flanagan and Moser, 1985).

The alpine zone has received slightly more attention in Alberta. Hegazy (1987) reviews literature on arctic-alpine phenology and notes the lack of phenological studies on alpine cushion plants. Other relevant studies include the phenology of tundra plants of NE Greenland, described in a comprehensive monograph (Soerensen, 1941). Holway and Ward (1965) studied 75 species in the Rockies of Colorado and determined that snow depths were the primary factor affecting their phenology. Ratcliffe and Turkington (1989) explored the effects of aspect and habitat on the phenology of alpine vascular plants in southern British Columbia. A phenological spectrum for each of Alberta's major plant communities is a worthwhile goal for the future.

## 2.5. Extensive Studies

Extensive studies in Europe and the United States have been previously described in the section on history (1.1). The following is a further discussion on plant species used, observer networks, and ways to analyse and visualize data received.

Species selection:

Few researchers have commented on the relative merits of using native species versus cultivars. Literature on the effects of ecotypic variation in the phenology of native species has been previously discussed under biotic factors. In a comparison of phenological data from cloned plants in phenological gardens in Europe versus in situ native plant data from observer networks (for 40 plant species), Lauscher and Roller (1980) found that both were equally valuable for predicting the influence of changing weather conditions on the timing of plant development. The clones provided valuable information for theoretical problems related to those species, but the observer networks were still indispensable for providing information on the characteristics of native plants, which is important in practical applications.

Volunteer network of observers:
Reader _et al_., (1974) provide an example of the composition of their volunteer network. Instructions to observers need to include adequate information on recognition of species and phenophases to permit accurate records. Examples of instructions to observers include: for the German network, Hopp (1974); for the Swiss network, Primault (1971); for the Western U.S. lilac network, Caprio _et al_. (1970); and for the NE-135 (eastern North America) network, Dubé _et al_. (1984).

## 2.6. Data analysis

Correlation with Geographic Variables:
Flowering time varies with geographical location and researchers have attempted to quantify this variation. Huberman (1941) and Caprio (1966) review research on the relationship between periodical phenomena in plants and variability in elevation, latitude and longitude. Hopkins (1918, 1938) developed a bioclimatic law which includes the following:

> "Other conditions being equal, the variation in the time of occurrence of a given periodical event in life activity in temperate North America is at the general average rate of four days to each 1 degree of latitude, 5 degrees of longitude, and 400 feet of altitude, later northward, eastward and upward in the spring and early summer, and the reverse in late summer and autumn" (p. 7, 1918).

Caprio (1966) reviews studies which test this bioclimatic law. Lieth and Radford (1971) compared phenological data from the SE United States to Hopkin's model and found it agreed well for the coastal areas but not for more continental inland areas. Using regression analysis, Reader (1975) found that the variation observed in the temperature summation required for _Cornus florida_ flowering in the eastern states was significantly correlated with altitude and longitude but not with latitude. Dubé and Chevrette (1978) in their five year study of phenology in Quebec's agricultural zones, found

that all the geographic variables were significant in multiple regression analysis, and were increasingly important in this order: altitude, latitude and longitude. Reader et al. (1974) conclude that the effects of the three geographical coordinates on phenology varies with the species studied.

Mapping:

Mapping is the most efficient way to visualize and summarize spatially oriented information from extensive surveys of any size. Phenological data is generally mapped by drawing lines through "isophenes" or "isophanes". These "lines of equal bloom" are made by joining geographic points which enter a particular phenophase at the same time.

A map of a province of Germany (Baden-Württemberg) was produced based only on Ellenberg's phenology observations, recorded 1950-1953 (20 phenological stages of 50 different species including native plants, crops, and horticultural species) (Ellenberg, 1974a). These data are converted to heat or growth zones on the map, indicating the best areas for cultivation of grapes, planting of orchards, grains, root crops, etc.

Caprio (1966) manually mapped lilac survey data, producing different maps for different elevations. Lieth and Radford (1971) review the history of computer phenological mapping in North America. Reader and Lieth (1984) describe the theory behind computer-assisted mapping. The advantages of computer mapping include objectivity in placing isophenes and the ability to handle large amounts of data rapidly. One of the persistent problems in mapping phenological data is the inconsistent density of the observer network. Inevitably, there are areas with little or no data (Caprio et al., 1974). Most programs contain an interpolation routine to estimate values of missing data points between actual points supplied in input. The most popular computer program to map phenological survey data has been SYMAP (Reader and Lieth, 1984; Caprio et al., 1974).

Correlations with Climate:
Caprio (1967) found his isophenal maps of lilac phenology of the western United States were very similar to isothermal maps of the same time period. Schwartz and Marotz (1986) used twenty years of data from the NE 135 survey of NE North America on first leaf emergence of Syringa chinensis (a total of 906 station-years of information), to describe and test a simple model using surface and upper air temperature and radiation data. The model developed is valuable to predict the arrival of the "green wave" of spring.

Western Canada would also benefit from an ongoing extensive survey. With the current rapid developments in geographic information systems and mapping using microcomputers, data analysis is potentially rapid and inexpensive.

## 2.7. Thesis Objectives

Two studies to explore the potential of phenology in Alberta were done for this thesis. An intensive study over two years, and an ongoing extensive study have allowed testing of many phenological techniques.

The goals of the intensive phenology study were the following:

a) to describe the flowering phenology of vascular plants in an Alberta mixed-wood forest community;
b) to test the suitability of phenophases and phenological methods developed in Europe, and to determine the required frequency of observation;
c) to document the effects of location on temperature and phenophase timing, along a 40 m elevation gradient; and
d) to identify species of this plant community well-suited for future phenological studies, and to learn development details for the 15 "key phenology species" used in the extensive study.

The goals of the extensive study were:

a) to establish a continuing provincial phenological survey using a network of volunteer observers to record three flowering phenophases on 15 native "wildflowers";

b) to assess the suitability of species and phenophases;

c) to find appropriate techniques to map the flowering dates and to establish the pattern of phenological development across the province; and

d) to examine applications of phenological research in Alberta.

# 3. Intensive Study: Whitemud Ravine

## 3.1. Materials and Methods

### 3.1.1. The Study Site

The site chosen is a forested ravine about .5 km wide in Southwest Edmonton (Latitude 53° 28′ N, Longitude 113° 33′ W, altitude 666 m at top of ravine) in Alberta, which is easily accessible on foot from the author's home. At the base of the ravine (629 m asl) is Whitemud Creek, a tributary which joins the North Saskatchewan River four km north of the study site. The study site (approximately .6 $km^2$) includes the east side of the creek from approximately 39 Avenue south to Westbrook Drive (Figure 2). The site is within the aspen parkland ecoregion, an ecotonal zone between the prairie to the south and the boreal forests to the north which has been identified on the basis of coexisting aspen/grassland vegetation and Chernozemic soils (Strong and Leggat, 1981). As in other parts of the Whitemud ravine, this site has riverine forest beside the creek and boreal mixedwood components on north facing slopes (Hardy, 1967).

The climate of Edmonton reflects the continental influence which affects the whole province, with cold winters and hot summers. On the longest day of the year, the city receives 17 hours of sunlight, with the midday sun at 60 degrees above the horizon. At the winter solstice however, the solar angle is only 13 degrees at noon. The city has a "heat island" effect on its climate: temperatures are warmer in winter, and humidity and wind are reduced compared to the surrounding countryside (Olson, 1985).

Figure 3 is a climate diagram for Edmonton International Airport (Ecoregions Working Group, 1989). Note that only the five months from May to September have mean monthly temperatures above 0 °C. Most precipitation falls in midsummer, with less than 30 mm per month the rest of the year.

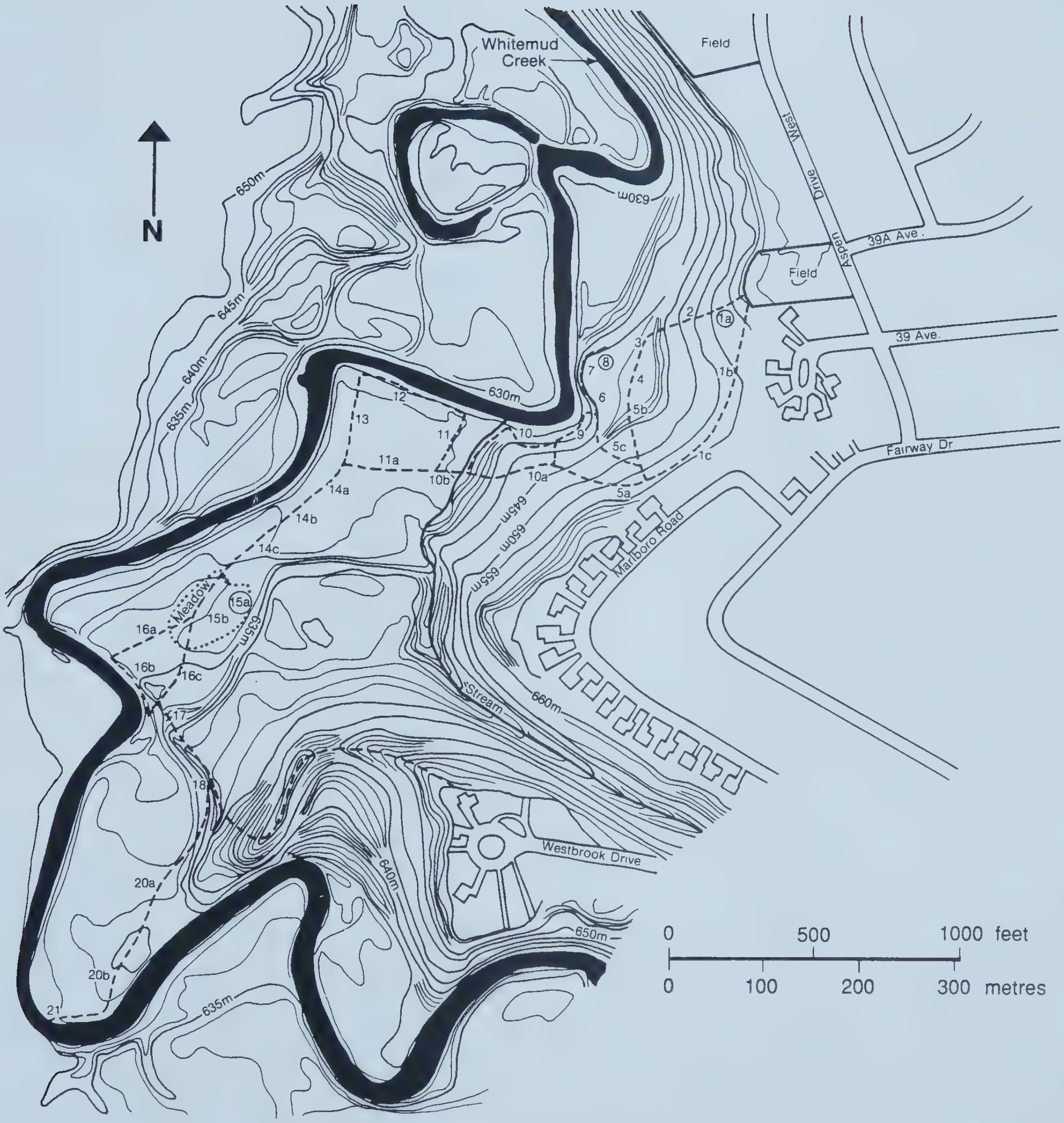
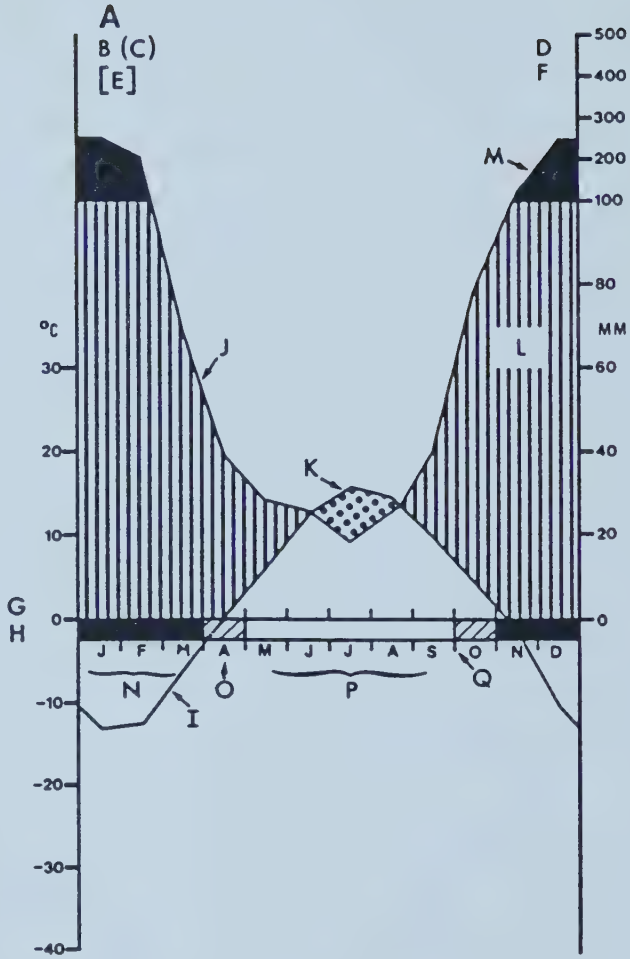



Figure 2: Map of Transect Trail, Whitemud Ravine, in southwest Edmonton. The trail (total length approximately 1.5 km) is divided into numbered sections. Note that thermometer locations at #1a, #8, and #15a are circled. Contour lines are every 1 m, and are discontinuous on the source map this figure was redrawn from. Source: Orthophoto 925 + 32, 2nd ed., November 1984, City of Edmonton Transportation Department.

A - ecoclimatic region;
B - name of climate station;
C - elevation of climate station above sea level (m);
D - mean annual temperature (°C);
E - number of observation years (where two figures are given, the first indicates temperature and the second precipitation);
F - mean annual precipitation (mm);
G - mean daily minimum temperature of coldest month (°C);
H - lowest recorded temperature (°C);
I - curve of mean monthly temperature (°C);
J - curve of mean monthly precipitation (mm);
K - period of relative drought (dotted pattern);
L - period of relatively humid climate (vertical pattern);
M - mean monthly precipitation, scale reduced to 1/10th for values greater than 100 mm per month (shown in solid black);
N - months with mean daily temperature below 0°C (shown in solid black);
O - months with mean daily temperatures above 0°C but mean daily minimum temperatures below 0°C (diagonal pattern);
P - months with mean daily temperatures above 0°C; and
Q - division of the year (January through December, left to right, respectively; monthly temperature and precipitation means are noted at the mid-point of the 'bar' for the respective month).




Key to Climate Diagram in Figure 3

Source: Ecoregions Working Group, 1989, p. 2
Climate diagram concept from Walter and Lieth, 1967

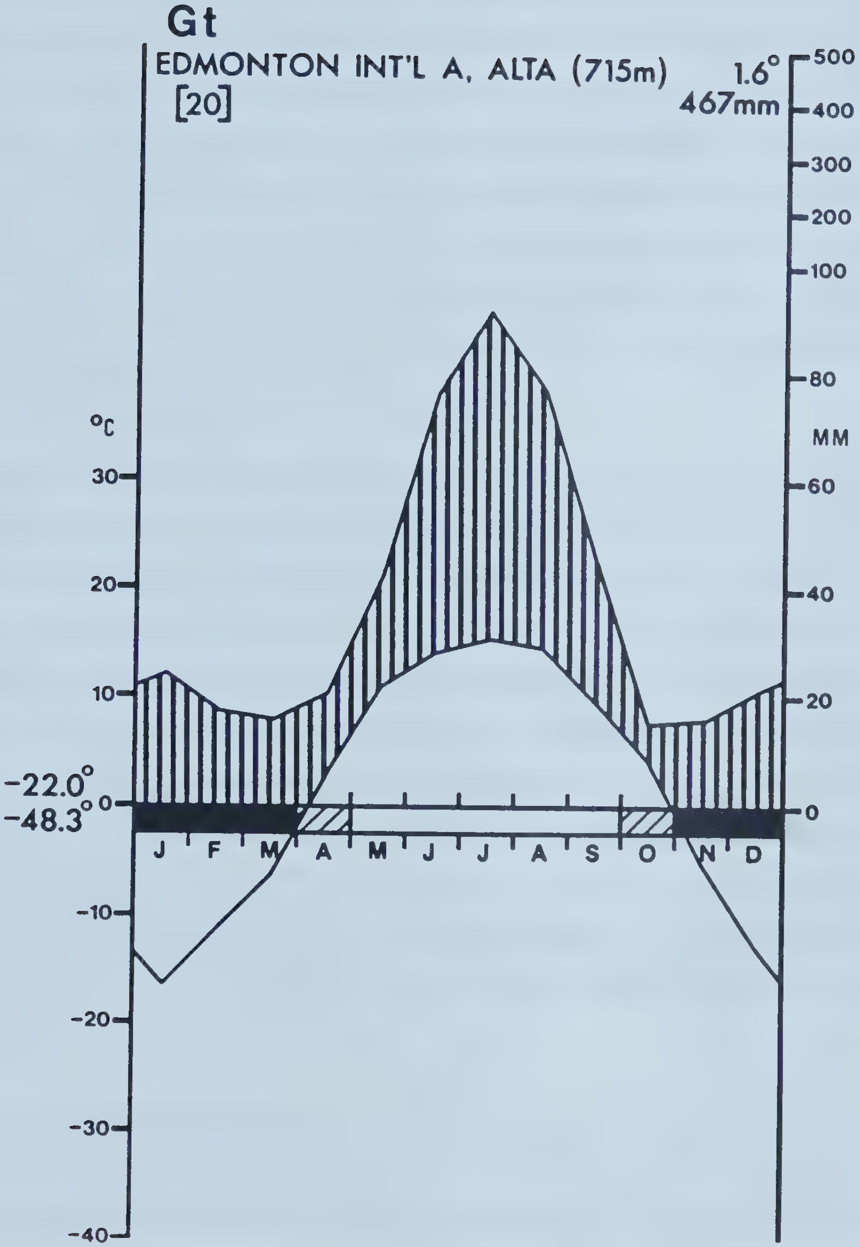



Figure 3: Climate Diagram for Edmonton International Airport
(based on 20 years data)

Source: Ecoregions Working Group, 1989, p. 65.

The area of Whitemud creek is underlain by bedrock of the Edmonton Group (Gibson, 1977), of late Cretaceous age (70 million years). This bedrock is mainly made up of fine-grained bentonitic sandstone and siltstone. Above the bedrock is a layer of glacial till made up of sand, silt and clay with pebbles and boulders. Within this layer, lenses of disturbed bedrock, or outwash gravel or sand are common. The top layer, which underlays the residential areas, is composed of Pleistocene glaciolacustrine deposits (10,000 years). These are bedded silt and clay with minor sand from glacial Lake Edmonton (Kathol and McPherson, 1975).

To date, Whitemud Ravine is the least developed of Edmonton ravines. Settlers arrived in the Edmonton area in the late 1800's, with hunting and later, coal-mining, occurring in the ravine (MacGregor, 1967). The mining tunnels were closed in the mid-1900's. In the section of the ravine surveyed, a history of cattle grazing is indicated by fallen fences within the forest, and a small meadow. The surrounding area was farmed until residential areas began to be developed in the 1950's. An established residential area now skirts the east boundary of the ravine and the west boundary has a rapidly growing housing development (Bulyea Heights). The ravine is used by Edmontonians for recreational walks and exercising pets as well as skiing in winter.

#### 3.1.1.1. The Transect

Phenological observations were made along a 1.5 km trail which descended 37 m from the top of the ravine, in two main stages to the creek level. The transect trail width ranged from narrow footpaths with closed canopies to wide old cart tracks 3 m wide. Slope, aspect, and drainage varied along this transect. Aerial photos (scale 1:5000, flown October 1986) and a contour map of the same scale were used to map the area and the transect. At first, observation sites were noted on copies of this map. Then, in July 1987, a standardized map was developed, with the transect divided into numbered sections. These sections were chosen on the basis of

generally equal size as well as uniform floristics, slope, aspect, and apparent microclimate.

### 3.1.1.2. Vegetation Sampling

Vegetation sampling was done at three elevations along the transect (at 1a, 8, and 19). A 10 by 10 m plot was selected at each elevation, in an area of minimal slope. Plots were oriented N - S, and were at least 2 m away from the transect trail. Tree species and dbh (diameter at breast height) of all woody plants over 2.5 cm in diameter were recorded at 1.35 m above ground level, using calipers or diameter tape. Within this 10 by 10 m plot, a corner nested 2 by 2 m plot was sampled for shrub species and cover. Shrubs with heights of 0.3 m to 5 m above ground, and stem diameters less than 2.5 cm dbh were measured. Slope was measured using a clinometer. Herbaceous and shrub vegetation was sampled in each of the three zones by running a 25 m tape along a N compass bearing through the 10 by 10 m tree plot. Three 1 $m^2$ plots were sampled at 5 m intervals, on alternating sides of the tape. Species composition and % cover for shrubs and herbs were sampled (see Table 3 for cover classes) for two strata: under and over 0.5 m.

### 3.1.1.3. Temperature Measurements

In early June of 1987, four standard mercury "Taylor" maximum-minimum thermometers were placed at four elevations along the transect. Thermometers were hung on nails on the north sides of trees and attached so that the thermometer bases were 10 cm from the ground, to reflect the growing conditions for much of the herbaceous vegetation. Baum (1949) found an appreciable change in the average temperature with height above the ground, especially during the growing season. Readings were taken June 11 to July 21, at each field visit (approximately three times a week). In 1988, the top thermometer from 1987 was moved slightly downhill (25 m distance) to an area (#1a, at 664 m a.s.l.) more representative of the sampled transect. Two thermometers were replaced in the same spots as in

Table 3: Modified Braun-Blanquet cover classes used to describe plant species within each vegetation plot, Whitemud Ravine, 1988. Source: Mueller-Dombois and Ellenberg, 1974.

| Cover Classes | Range of Cover (%) |
| --- | --- |
| 6 | 75-100 |
| 5 | 50--75 |
| 4 | 25--50 |
| 3 | 15--25 |
| 2 | 5--15 |
| 1 | 1-- 5 |
| + | less than 1 |

1987, at #8 (639 m) and #15a (633 m) on the transect (see circled locations on Figure 2). The fourth thermometer used in 1987 was omitted as it was not functioning well and its relief above the creek was roughly the same as location 15a. Temperatures were recorded May 4 to October 4 (five months), at each field visit. Thermometers were not installed earlier as the vegetation had few leaves to hide these instruments from public view.
The max-min thermometers were standardized using an electronic thermometer in a growth chamber and field readings adjusted accordingly.

3.1.2. Phenological Observations

3.1.2.1. Selection of Species

Phenological data were recorded for all species of trees, shrubs, and herbs that were easily observed along the trail (127 species listed in Table 4). Grasses, sedges, mosses and lichens were omitted. Some plant specimens were collected and four species of Salix and six of Ribes were tagged to assist in identification. Plant identifications follow the Flora of Alberta (Packer, 1983). Once a week, an extra loop of transect was followed to observe riparian species by Whitemud creek (#'s 11 to 13 on Figure 2). Herbivory by mammals and insects was noted.

Particular attention was paid to the fifteen species of the extensive survey (see chapter 4) to determine their development characteristics. Occasional trips to areas near Edmonton provided habitat and phenology information on some prairie species eg. Anemone patens, and Thermopsis rhombifolia.

In 1988, individuals of 21 plant species found along the transect were tagged with numbered plastic markers and their development recorded at each field visit. These species included 11 of the 15 key phenology species used in the provincial survey. The three key species not occurring at this site were Anemone patens, Thermopsis

Table 4: Plant species for which phenological observations were made, Whitemud ravine, 1987 and 1988. Information listed includes: the plant family; an abbreviation which is formed from the first two letters from each of the genus and species names; the latin name with authorities; and one or more common names.

| | | |
|---|---|---|
| PINACEAE | | |
| PIGL | *Picea glauca* (Moench) Voss | White Spruce |
| ALISMATACEAE | | |
| SACU | *Sagittaria cuneata* Sheld. | Arrowhead |
| LILIACEAE | | |
| DITR | *Disporum trachycarpum* (S. Wats.) B.& H. | Fairy Bells |
| LIPH | *Lilium philadelphicum* L. | Western Wood Lily |
| MACA | *Maianthemum canadense* Desf. | Wild Lily-of-the-Valley |
| SMST | *Smilacina stellata* (L.) Desf. | Star-flowered Solomon's-seal |
| IRIDACEAE | | |
| SIMO | *Sisyrinchium montanum* Greene | Common Blue-eyed Grass |
| SALICACEAE | | |
| POBA | *Populus balsamifera* L. | Balsam Poplar |
| POTR | *Populus tremuloides* Michx. | Trembling Aspen |
| SABE | *Salix bebbiana* Sarg. | Beaked Willow |
| SADI | *Salix discolor* Muhl. | Pussy Willow |
| SAEX | *Salix exigua* Nutt. | Sandbar Willow |
| SAPL | *Salix planifolia* Pursh | Flat-leaved Willow |
| BETULACEAE | | |
| ALTE | *Alnus tenuifolia* Nutt. | River alder |
| BEPA | *Betula papyrifera* Marsh. | White Birch |
| COCO | *Corylus cornuta* Marsh. | Beaked Hazelnut |
| URTICACEAE | | |
| URDI | *Urtica dioica* L. | Common Nettle |
| POLYGONACEAE | | |
| POLA | *Polygonum lapathifolium* L. | Pale smartweed |
| CARYOPHYLLACEAE | | |
| MOLA | *Moehringia lateriflora* (L.) Fenzl. | Blunt-leaved Sandwort |
| STLO | *Stellaria longipes* Goldie | Long-stalked Chickweed |
| RANUNCULACEAE | | |
| ACRU | *Actaea rubra* (Alt.) Willd. | Red Baneberry |
| ANCA | *Anemone canadensis* L. | Canada anemone |
| ANRI | *Anemone riparia* Fern. | Tall anemone |
| AQBR | *Aquilegia brevistyla* Hook. | Blue Columbine |
| CLOC | *Clematis occidentalis* (Hornem.) DC. | Purple Clematis |
| RAMA | *Ranunculus macounii* Britt. | Macoun's Buttercup |
| THDA | *Thalictrum dasycarpum* Fisch. & Ave-Lall. | Tall Meadow Rue |
| THVE | *Thalictrum venulosum* Trel. | Veiny Meadow Rue |
| FUMARIACEAE | | |
| COAU | *Corydalis aurea* Willd. | Golden Corydalis |
| CRUCIFERAE | | |
| DESO | *Descurainia sophia* (L.) Webb | Flixweed; Tansy Mustard |
| ERCH | *Erysimum cheiranthoides* L. | Wormseed Mustard |
| THAR | *Thlaspi arvense* L. | Stinkweed; Pennycress |

Table 4, continued:

| | | |
|---|---|---|
| SAXIFRAGACEAE | | |
| HERI | *Heuchera richardsonii* R. Br. | Alum-root |
| MINU | *Mitella nuda* L. | Bishop's-cap |
| GROSSULARIACEAE | | |
| RIAM | *Ribes americanum* Mill. | Wild Black Currant |
| RIGL | *Ribes glandulosum* Grauer | Skunk Currant |
| RIHU | *Ribes hudsonianum* Richards. | Wild Black Currant |
| RILA | *Ribes lacustre* (Pers.) Poir. | Bristly Black Currant |
| RIOX | *Ribes oxyacanthoides* L. | Wild Gooseberry |
| RITR | *Ribes triste* Pall. | Wild Red Currant |
| ROSACEAE | | |
| AGST | *Agrimonia striata* Michx. | Agrimony |
| AMAL | *Amelanchier alnifolia* Nutt. | Saskatoon |
| CRRO | *Crataegus rotundifolia* Moench | Round-leaved Hawthorn |
| FRVE | *Fragaria vesca* L. | Woodland Strawberry |
| FRVI | *Fragaria virginiana* Duschesne | Wild Strawberry |
| GEAL | *Geum aleppicum* Jacq. | Yellow Avens |
| GEMA | *Geum macrophyllum* Willd. | Yellow Avens |
| GESP | (*Geum* species) | |
| POAN | *Potentilla anserina* L. | Silverweed |
| POAR | *Potentilla arguta* Pursh | White Cinquefoil |
| PRPE | *Prunus pensylvanica* L.f. | Pin Cherry |
| PRVI | *Prunus virginiana* L. | Choke Cherry |
| ROAC | *Rosa acicularis* Lindl. | Prickly Rose |
| ROWO | *Rosa woodsii* Lindl. | Wood's rose |
| ROSP | (*Rosa* species) | |
| RUID | *Rubus idaeus* L. | Wild Red Raspberry |
| RUPU | *Rubus pubescens* Raf. | Dewberry |
| LEGUMINOSAE | | |
| ASDA | *Astragalus dasyglottis* Fisch. ex DC. | Purple Milk Vetch |
| GLLE | *Glycyrrhiza lepidota* (Nutt.) Pursh | Wild Licorice |
| LAOC | *Lathyrus ochroleucus* Hook. | Cream-colored Vetchling |
| LAVE | *Lathyrus venosus* Muhl. | Purple Peavine |
| MEAL | *Melilotus alba* Desr. | White Sweet Clover |
| MEOF | *Melilotus officinalis* (L.) Lam. | Yellow Sweet Clover |
| TRPR | *Trifolium pratense* L. | Red Clover |
| TRRE | *Trifolium repens* L. | White Clover |
| VIAM | *Vicia americana* Muhl. | Wild Vetch |
| VICR | *Vicia cracca* L. | Tufted Vetch |
| GERANIACEAE | | |
| GERI | *Geranium richardsonii* Fisch. & Trautv. | Wild White Geranium |
| ACERACEAE | | |
| ACNE | *Acer negundo* L. | Manitoba maple |
| BALSAMINACEAE | | |
| IMNO | *Impatiens noli-tangere* L. | Touch-me-not |

Table 4, continued:

| | | |
|---|---|---|
| VIOLACEAE | | |
| VIAD | *Viola adunca* J.E. Smith | Early Blue Violet |
| VICA | *Viola canadensis* L. | Western Canada Violet |
| VIRE | *Viola renifolia* A. Gray | Kidney-leaved Violet |
| ELAEAGNACEAE | | |
| ELCO | *Elaeagnus commutata* Bernh. ex Rydb. | Silverberry; Wolf Willow |
| SHCA | *Shepherdia canadensis* (L.) Nutt. | Canadian Buffalo-berry |
| ONAGRACEAE | | |
| EPAN | *Epilobium angustifolium* L. | Fireweed |
| OEBI | *Oenothera biennis* L. | Yellow Evening-primrose |
| ARALIACEAE | | |
| ARNU | *Aralia nudicaulis* L. | Wild Sarsaparilla |
| UMBELLIFERAE | | |
| HELA | *Heracleum lanatum* Michx. | Cow Parsnip |
| SAMA | *Sanicula marilandica* L. | Snake-root |
| CORNACEAE | | |
| COCA | *Cornus canadensis* L. | Bunchberry |
| COST | *Cornus stolonifera* Michx. | Red Osier; Dogwood |
| PYROLACEAE | | |
| ORSE | *Orthilia secunda* (L.) House | One-sided Wintergreen |
| PYAS | *Pyrola asarifolia* Michx. | Common Pink Wintergreen |
| PYEL | *Pyrola elliptica* Nutt. | White Wintergreen |
| MONOTROPACEAE | | |
| MOUN | *Monotropa uniflora* L. | Indian Pipe |
| PRIMULACEAE | | |
| LYCI | *Lysimachia ciliata* L. | Fringed Loosestrife |
| LYTH | *Lysimachia thyrsiflora* L. | Tufted Loosestrife |
| CONVOLVULACEAE | | |
| COSE | *Convolvulus sepium* | Wild Morning-glory |
| BORAGINACEAE | | |
| MEPA | *Mertensia paniculata* (Alt.) G. Don. | Blue-bells, Tall Lungwort |
| | *Lappula occidentalis* (S. Wats.) Greene | Blue-bur |
| LABIATAE | | |
| AGFO | *Agastache foeniculum* (Pursh) Ktze. | Giant Hyssop |
| GATE | *Galeopsis tetrahit* L. | Hemp Nettle |
| PHPA | *Physostegia parviflora* Nutt. | False Dragonhead |
| STPA | *Stachys palustris* L. | Marsh Hedge-nettle |
| SCROPHULARIACEAE | | |
| LIVU | *Linaria vulgaris* Hill | Butter and Eggs |
| LENTIBULARIACEAE | | |
| UTVU | *Utricularia vulgaris* L. | Common Bladderwort |
| PLANTAGINACEAE | | |
| PLMA | *Plantago major* L. | Common Plantain |
| RUBIACEAE | | |
| GABO | *Galium boreale* L. | Northern Bedstraw |
| GATR | *Galium triflorum* Michx. | Sweet-scented Bedstraw |

Table 4, continued:

| | | |
|---|---|---|
| CAPRIFOLIACEAE | | |
| LIBO | *Linnaea borealis* L. | Twin-flower |
| LODI | *Lonicera dioica* L. | Twining Honeysuckle |
| LOIN | *Lonicera involucrata* (Richards.) Banks | Bracted Honeysuckle |
| SYAL | *Symphoricarpos albus* (L.) Blake | Snowberry |
| SYOC | *Symphoricarpos occidentalis* Hook. | Buckbrush |
| SYSP | (*Symphoricarpos* species) | |
| VIED | *Viburnum edule* (Michx.) Raf. | Low-bush Cranberry; Mooseberry |
| VIOP | *Viburnum opulus* L. | High-bush Cranberry; Pembina |
| ADOXACEAE | | |
| ADMO | *Adoxa moschatellina* L. | Moschatel |
| CAMPANULACEAE | | |
| CARO | *Campanula rotundifolia* L. | Harebell |
| COMPOSITAE | | |
| ACMI | *Achillea millefolium* L. | Common Yarrow |
| ACSI | *Achillea sibirica* Ledeb. | Many-flowered Yarrow |
| ASCI | *Aster ciliolatus* Lindl. | Lindley's Aster |
| ASCO | *Aster conspicuus* Lindl. | Showy Aster |
| ASHE | *Aster hesperius* A. Gray | Western Willow Aster |
| ASLA | *Aster laevis* L. | Smooth Aster |
| ASUM | *Aster umbellatus* Mill. | Flat-topped White Aster |
| BICE | *Bidens cernua* L. | Nodding Beggar-ticks |
| CHLE | *Chrysanthemum leucanthemum* L. | Ox-eye Daisy |
| CIAR | *Cirsium arvense* (L.) Scop. | Canada Thistle |
| ERPH | *Erigeron philadelphicus* L. | Philadelphia Fleabane |
| GAAR | *Gaillardia aristata* Pursh | Brown-eyed Susan; Gaillardia |
| MAPE | *Matricaria perforata* Merat | Scentless Chamomile |
| PEPA | *Petasites palmatus* (Alt.) A. Gray | Palmate-leaved Coltsfoot |
| PESA | *Petasites sagittatus* (Pursh) A. Gray | Arrow-leaved Coltsfoot |
| SOCA | *Solidago canadensis* L. | Canada Goldenrod |
| SOUL | *Sonchus uliginosus* Bieb. | Perennial Sow Thistle |
| TAOF | *Taraxacum officinale* Weber | Common Dandelion |

rhombifolia, and Gaillardia aristata. Viola adunca was not found on the transect, though it does occur in the area.

3.1.2.2. Timing of Observations

Phenological observations were carried out over two growing seasons. The first season (1987) permitted familiarization with the species present, their pattern of flowering, and distribution along the ravine transect. In 1987, the ravine transect was visited weekly from April 12-26 and July 19- Sept. 6, and two to three times weekly from April 27 to July 18.

In 1988, data were collected approximately weekly from Feb. 28 to April 17, twice weekly to July 17, then once every two weeks until Sept. 11, 1988, with a final visit on Oct. 4. Field visit dates are listed in Table 5.

3.1.2.3. Phenophase Selection

Reproductive and vegetative phenophases of the plants were noted along the transect, with particular attention to flowering. In 1987, observations regarding plant development were recorded, and reference photos were taken of some species and phenophases. In 1988, data sheets were developed (see Appendix 1), to record observations on about 110 plant species and 34 locations (numbered sections) along the transect.

To simplify phenophase recording an alphabetic code was used (Table 6), based on Ellenberg's system (Dierschke, 1972), and reduced to a smaller number of phenophases to simplify observing many species at each field visit. The 15 phenophase codes selected are listed under "Field Codes 1988" in Tables 7a,7b.

Table 5: Frequency of Field Visits, Whitemud Ravine, 1987 and 1988
Calendar dates on which phenological observation were made, in Whitemud Ravine, in 1987 and 1988.

| | 1987 |
|---|---|
| April | 15, 21, 27, 30 |
| May | 4, 6, 8, 11, 13, 15, 18, 21, 25, 27, 29, 31 |
| June | 1, 3, 5, 8, 11, 16, 18, 22, 24, 26, 29 |
| July | 1, 3, 7, 10, 14, 17, 21, 28 |
| Aug. | 4, 13, 19 |
| Sept. | 1, 15, 26 |

| | 1988 |
|---|---|
| March | 5, 12, 21, 24, 26 |
| April | 2, 9, 20, 23, 26, 29 |
| May | 2, 4, 6, 9, 12, 17, 20, 24, 27, 30 |
| June | 2, 6, 9, 13, 16, 20, 23, 27, 30 |
| July | 4, 7, 11, 13, 15, 25 |
| Aug. | 9, 25, 28 |
| Sept. | 9 |
| Oct. | 4 |

Table 6: Phenophases for deciduous trees, herbs and grasses
Source: Dierschke, 1972, p.9, after Ellenberg, 1954.

| | VEGETATIVE | | GENERATIVE |
|---|---|---|---|
| | **A) DECIDUOUS TREES** | | |
| 0 | Closed bud | 0 | Without blossom buds |
| 1 | Buds with green tips | 1 | Blossom buds recognizable |
| 2 | Green leaf out but folded | 2 | Blossom buds strongly swollen |
| 3 | Leaf unfolding up to 25% | 3 | Shortly before flowering |
| 4 | Leaf unfolding up to 50% | 4 | Beginning flowering |
| 5 | Leaf unfolding up to 75% | 5 | In bloom up to 25% |
| 6 | Full leaf unfolding | 6 | In bloom up to 50% |
| 7 | First leaves turned yellow | 7 | Full bloom |
| 8 | Leaf yellowing up to 50% | 8 | Fading |
| 9 | Leaf yellowing over 50% | 9 | Completely fading |
| 10 | Bare | 10 | Bearing fruit |
| | **B) HERBS** | | |
| 0 | Without shoots above ground | 0 | Without blossom buds |
| 1 | Shoots with folded leaves | 1 | Blossom buds recognizable |
| 2 | First leaf unfolds | 2 | Blossom buds strongly swollen |
| 3 | 2-3 leaves unfolded | 3 | Shortly before flowering |
| 4 | Several leaves unfolded | 4 | Beginning bloom |
| 5 | Almost all leaves unfolded | 5 | Up to 25% in blossom |
| 6 | Plant fully developed | 6 | Up to 50% in blossom |
| 7 | Stem and/or first leaves fading | 7 | Full bloom |
| 8 | Yellowing up to 50% | 8 | Fading |
| 9 | Yellowing over 50% | 9 | Completely faded |
| 10 | Dead | 10 | Yielding fruit |
| | **C) GRASSES** | | |
| 0 | Without shoots aboveground | 0 | Without recognizable inflorescence |
| 1 | Shoots with folded leaves | 1 | Inflorescence recognizable, closed |
| 2 | First leaf unfolded | 2 | Inflorescence partly visible |
| 3 | 2-3 leaves unfolded | 3 | Inflorescence fully visible, folded |
| 4 | Beginning development of blades of grass | 4 | Inflorescence unfolded |
| 5 | Blades partly formed | 5 | First blooms pollenizing |
| 6 | Plants fully developed | 6 | Up to 50% pollenized |
| 7 | Blades and/or first leaves turning yellow | 7 | Full bloom |
| 8 | Yellowing up to 50% | 8 | Fading |
| 9 | Yellowing over 50% | 9 | Fully faded |
| 10 | Dead | 10 | Bearing fruit |

K Embryo
J Young plants that do not reach full development in the scope of the observation
W Wintergreen leaves of the previous year.

Table 7a: Phenophase codes for reproductive phases (R) used in field work (1988, Whitemud ravine) and in data entry.

| FIELD CODES 1988 symbol | meaning | DATA ENTRY CODES symbol | meaning |
|---|---|---|---|
| | | R0 | no flowering |
| E | flower buds (if stage noted:) | R1 | flower buds |
| | | R2 | flower buds recognizable |
| | | R3 | buds strongly swollen, catkins lengthening on amentiferous trees |
| F | flowering, % noted | R4 | general flowering |
| | | R5 | up to 10% flowering |
| | | R6 | 10 to 25% flowering |
| | | R7 | 25 to 50% flowering |
| | | R8 | 50 to 75% flowering |
| | | R9 | 75 to 100% flowering |
| G | past full bloom, noted % of petals remaining | R10 | general: past full bloom (catkins: pollen shed finished) |
| | | R11 | 50% to 100% petals remain |
| | | R12 | 0% to 50% petals remain |
| H | fruit setting | R13 | fruit setting |
| I | fruit ripe, % noted | R14 | 0% to 50% of fruit ripe |
| | | R15 | 50 to 100% of fruit ripe |
| J | seeds shedding | R16 | fruit or seed dispersal |
| | | R17 | dispersal finished |
| | | R20 | fruit never developed (insect or weather causes) |

Table 7b: Phenophase codes for vegetative phases (V) used in field work (1988, Whitemud ravine) and in data entry.

| FIELD CODES 1988 | | DATA ENTRY CODES (modified Ellenberg,1954) | | | |
|---|---|---|---|---|---|
| | | Woody species | | Herbaceous species | |
| symbol | meaning | symbol | meaning | symbol | meaning |
| Nbb | no bud break | V0 | no bud break | V0 | no shoots |
| A | bud break | V1 | green tip on bud | | |
| B | shoots | | | V1 | shoots with furled leaves, regreening of wintergreen spp. |
| C | new furled leaves | V2 | leaves out, furled | | |
| D | unfurled leaves (if amount specified:) | V3<br>V4<br>V5<br>V6 | unfurling,<br>to 25% unfurled<br>to 50% unfurled<br>all unfurled | V3<br>V4<br>V5<br>V6 | unfurling, general<br>2-3 leaves unfurled<br>half leaves unfurled<br>all unfurled |
| L | foliage colour change (colour, % noted) | V7<br><br>V8<br>V9<br>V10 | first leaves coloured<br>up to 50% coloured<br>over 50% coloured<br>bare branches | V7<br><br>V8<br>V9<br>V10 | up to 5% faded<br><br>colouring up to 50%<br>over 50% coloured<br>dead |
| K | herbivore effects (% consumption noted) | i-w<br>i-g<br>i-m<br>i-%<br>d | weevils<br>galls<br>mildew, fungus<br>% noted<br>deer | | (same) |
| | weather effects (snow or frost damage) | <br>f-1<br>f-2<br>f-3<br>f-4 | new growth killed:<br>up to 25%<br>up to 50%<br>all new growth<br>flowers or fruit lost | | (same) |

3.1.2.4. Data Collection (Estimation of phenophases)

For both years, a field assistant was available from May to July. Due to the large number of species at each field visit, flowering observations received the most attention. The average flowering stage for individuals of a species within the numbered section of the transect was recorded. For each, the flowering estimate took into consideration three levels: individual development, progress of individuals in a group, and relative progress of other groups. If only one or two plants of a species were seen, this was generally noted.

In most species, flowering % was estimated by comparing proportions of buds, flowers, and fading flowers. This worked best for species with multiple inflorescences such as Cornus stolonifera, Viburnum edule and Prunus virginiana. In plants where flowering progressed acropetally, ie. from the base of the inflorescence towards the tip of the stem (eg: Agrimonia striata, Agastache foeniculum, Mertensia paniculata, Mitella nuda), full flowering or 90% was interpreted as meaning that 2/3 of the flowers on the stem had opened. One special case of a flowering raceme was Epilobium angustifolium, for which more precise definitions had been established for the provincial survey (see "Alberta Wildflowers", p. 18, Appendix 2). For flowers with petal-like bracts, such as Cornus canadensis, and Viburnum opulus, flowering was considered to have begun only when the small central flowers opened. For plants with single flowers (eg: Lilium philadelphicum, Anemone canadensis), a patch of plants of one species was sought so that development could be averaged.

For dioecious species, the sex was noted (eg: Thalictrum, Shepherdia, Aralia). As male flowering or pollen shed is easier to observe than female stigma receptivity, male flowering was emphasized. In catkin-bearing plants (Populus, Betula, Salix, Corylus, Alnus), the approximate % of male catkins shedding pollen was recorded. "Pollen will show on an object if the catkins are hit lightly by snapping one's fingers against them or by hitting them with a piece of wood over black paper" (Dierschke, 1972, p. 21).

"Fruit setting" meant that flowers were faded or gone and fruit was developing. "Fruit ripe" meant some fruit was full colour or that fruits or seeds were easily removed from the plant.

### 3.1.3. Data Analyses

Phenophase symbols and location numbers for 1987 and 1988 were synchronized and converted to Ellenberg's codes to facilitate database entry and analysis (see Tables 7a and 7b). dBASE III PLUS (Ashton-Tate, 1986) was the program chosen and data entry included date, species, sex of plant (if applicable), location, and stage of reproductive or vegetative development (Appendix 3). Information on herbivory and weather effects such as frost or snowstorms on the plants, was also entered. Specific details on interpretations of reproductive development for different species were noted separately. The 1987 database has 1170 observations, and the 1988 database, 4077 observations. These files were sorted by species, date, and location and then each species was charted out to show development at each ravine transect location over the growing season.

#### 3.1.3.1. Flowering Sequence for Whitemud Ravine

The 1988 data set was selected on the basis of optimal detail, and species were graphed using phenodynamic strips (Figure 1), showing the durations of green leaves, flower buds, flowering, and fruiting, and arranged in the order of 1988 first flowering.

#### 3.1.3.2. Flowering Times: 1987 and 1988

Species charts were examined to determine first flowering dates in the ravine in each year. Unusually early dates, far in advance of general first flowering for a species, were omitted. Generally, observations of 1 to 10% flowering at one or more locations signified "first flowering". If only 30-50% flowering had been noted, the date of first flowering was estimated.

For each species, the timespan of full bloom (r9 = 75% to 100% flowering) was determined, including all ravine locations where the species occurred. The midpoint of each timespan was selected as the "full bloom date" for that species.

Species were listed for both years, in order of their first flowering in the ravine in 1988. First flowering was chosen to order species, as it seemed to provide more precise dates than full flowering, which was often difficult to estimate. The 1988 data were used to rank species, as these were recorded after a year of familiarization with species' development.

### 3.1.3.3. Relationship between Temperature, Location, and Flowering

Temperature extremes were compared for the three ravine elevations (top, middle and bottom). The species charts for 1988 were examined to determine which species were found at a number of locations of varying altitude along the transect. First flowering dates at different locations were compared for thirty-six widespread species, and differences of more than three days in time of first flowering were sought. Of these species, four which showed a trend of earlier development at the top of the ravine were graphed to demonstrate the difference in flowering times from the top to the bottom of the ravine.

### 3.1.3.4. Indicators of the Seasons - Plant Wheels

One way to chart seasonal progress which has great visual effectiveness is through phenological circle diagrams (Winkler and Menneweger, 1977), or "plant wheels". The growing season can be divided into spring, summer and fall subseasons using plant phenophases to indicate when they begin. Figure 4 shows data for Innsbruck, Austria. Using plant wheels, comparisons between years and locations can quickly be made.

Key to Figure 4:

Months: 1 = January
2 = February
3 = March
etc.

Inner circle describes monthly temperatures: average, maximum, and minimum.

Species:

| Common name | Latin name |
|---|---|
| snowdrop | Galanthus nivalis |
| elderberry | Sambucus nigra |
| horse-chestnut | Aesculus hippocastanum |
| cherry | "Kirsche"-no latin name given |
| apple | "Apfel" -no latin name given |

Length of Seasons:

Pre-spring: 54 days

Early Spring: 7 days

Full Spring: 49 days

Early Summer: 13 days

High Summer: 69 days

Early Fall: 12 days

Mid Fall: 30 days to Late Fall

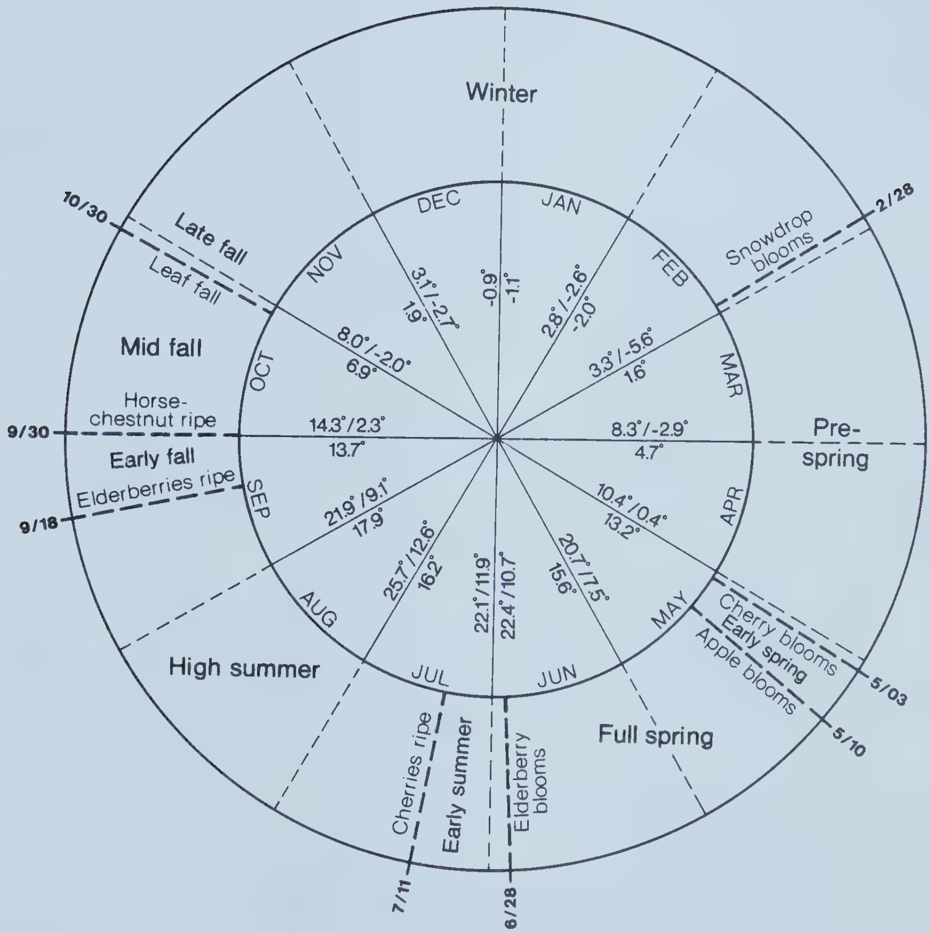



Figure 4: Phenology diagram (Plant wheel) for Innsbruck (Botanical Garden), Austria, 1973

Source: Winkler et al (1977), p. 212.

A plant wheel was produced for 1988, describing three spring subseasons, four summer subseasons, and four fall subseasons. The species selected as "indicators of the seasons" were those which were appropriately spaced in time, widespread, and easy to recognize, and the chosen phenophases had relatively sharp onsets.

## 3.2. Results

### 3.2.1. Plant Communities

At the top of the ravine (location #1a, Figure 2, 664 m above sea level) there is a relatively dense regrowth of Populus tremuloides. Table 8a shows species composition and cover estimates. (See Table 4 for full species names and Table 3 for cover class definitions.) The 10 by 10 m tree plot had a slope of 8°, with a SW aspect. Taller shrubs within the corner nested plot included Amelanchier alnifolia, and Prunus pensylvanica, with lower shrubs: Rosa species, and Rubus idaeus. The three vegetation plots were dominated by Prunus virginiana in the layer above 0.5 m, and by Aralia nudicaulis in the layer below 0.5 m. There were 17 other herbaceous species.

The middle location #8 (elevation 639 m) is a level area of more open forest than # 1a, with scattered spruce (Picea glauca) and Populus balsamifera (see Table 8b). Dominant species in the plot were as follows: tree - Populus tremuloides, large shrub - Amelanchier alnifolia, and lower shrub - Viburnum edule. In the vegetation plots, Viburnum edule dominated above 0.5 m, with the herbaceous layer consisting mainly of Rubus idaeus and V. edule.

The lowest area sampled, location # 19 (631 m), is fairly level and lies about 2 m above the creek floodplain. This area has occasional large trees (Populus balsamifera, scattered Picea glauca, and again mainly Populus tremuloides (Table 8c). Tall shrubs in the plot consisted mainly of P. tremuloides, and C. stolonifera. In the vegetation plots the upper layer was dominated by C. stolonifera, while the lower level had as its most abundant species: Cornus canadensis, Equisetum spp., and Petasites palmatus.

Table 8 - a: Results of Vegetation Sampling, area #1a, the top plot in Whitemud ravine (elevation 664 m).
See Table 4 for full species names.

$10\ m^2$ Plot (field work: July 29, 1988)

| Trees | species | # of stems | average dbh (cm) | range of dbh (cm) |
|---|---|---|---|---|
| (over | POTR | 22 | 16.0 | 4.6 -23.9 |
| 2.5cm | AMAL | 6 | 2.8 | 2.5 - 3.0 |
| dbh) | PRPE | 2 | 2.8 | 2.5 - 3.0 |

$2\ m^2$ Plot (shrubs)

| species: | ROSP | RUID | POTR | PRPE | AMAL |
|---|---|---|---|---|---|
| cover: | 4 | 3 | 2 | 2 | 2 |

$1\ m^2$ Plots (field work, Aug. 8, 1988)

| | species | Plot 1 | Plot 2 | Plot 3 | Sum of Cover | Constancy |
|---|---|---|---|---|---|---|
| over | PRVI | 4 | 4 | 5 | 13 | 3 |
| .5 m | ROSP | 2 | 3 | - | 5 | 2 |
| | COCO | - | 2 | 3 | 5 | 2 |
| | COST | 5 | - | - | 5 | 1 |
| | PRPE | - | 4 | - | 4 | 1 |
| | POTR | - | 4 | - | 4 | 1 |
| | AMAL | - | - | 4 | 4 | 1 |
| under | ARNU | 4 | 6 | 4 | 14 | 3 |
| .5 m | FRVI | 1 | 3 | 1 | 5 | 3 |
| | (graminoids) | 2 | 2 | - | 4 | 2 |
| | ROSP | - | 1 | 2 | 3 | 2 |
| | SYAL | 2 | - | 1 | 3 | 2 |
| | ASCI | 1 | - | 2 | 3 | 2 |
| | COCO | - | - | 3 | 3 | 1 |
| | VICA | 1 | - | 1 | 2 | 2 |
| | MACA | 1 | 1 | - | 2 | 2 |
| | GABO | 1 | 1 | - | 2 | 2 |
| | SMST | 1 | - | 1 | 2 | 2 |
| | GATR | - | 1 | 1 | 2 | 2 |
| | (bryophytes) | - | - | 2 | 2 | 1 |
| | THVE | + | 1 | - | 1 | 2 |
| | COSP | 1 | - | - | 1 | 1 |
| | SAMA | 1 | - | - | 1 | 1 |
| | SOCA | 1 | - | - | 1 | 1 |
| | GERI | - | 1 | - | 1 | 1 |
| | SOSP | - | - | 1 | 1 | 1 |
| | MOLA | - | - | + | + | 1 |

(COSP = Cotoneaster spp., SOSP = Sorbus spp.)

Table 8 - b: Results of Vegetation Sampling, area #8, the middle plot in Whitemud ravine (elevation 639 m).
See Table 4 for full species names.

10 m² Plot (field work: July 29, 1988)

| | species | # of stems | average dbh (cm) | range of dbh (cm) |
|---|---|---|---|---|
| Trees: | POTR | 9 | 11.8 | 7.6 -19.3 |
| | POBA | 2 | 25.1 | 23.9 -26.2 |
| | AMAL (large shrub) | 3 | 3.5 | 2.5 -4.6 |

---

2 m² Plot

| species: | VIED | POTR | VIOP | LOIN | PRVI | SYAL |
|---|---|---|---|---|---|---|
| cover | 4 | 2 | 2 | 2 | 2 | 1 |

---

1 m² Plots field work: Sept. 3, 1988

| | species | Plot1 | Plot 2 | Plot 3 | Sum of cover | constancy |
|---|---|---|---|---|---|---|
| over .5 m | VIED | 4 | 3 | 3 | 10 | 3 |
| | COST | 2 | 5 | - | 7 | 2 |
| | POTR | 2 | - | - | 2 | 1 |
| | ROSP | - | - | 2 | 2 | 1 |
| | RUID | 1 | - | - | 1 | 1 |
| Under .5 m | RUID | 4 | 1 | 1 | 6 | 3 |
| | VIED | - | 3 | 4 | 7 | 2 |
| | (graminoids) | 2 | 1 | 1 | 4 | 3 |
| | COST | - | 3 | 1 | 4 | 2 |
| | LODI | 1 | 2 | - | 3 | 2 |
| | ROSP | - | 2 | 1 | 3 | 2 |
| | MACA | - | 1 | 2 | 3 | 2 |
| | ASCI | 1 | - | 1 | 2 | 2 |
| | RUPU | 2 | - | + | 2 | 2+ |
| | COCA | 1 | - | 1 | 2 | 2 |
| | LOIN | - | - | 2 | 1 | 2 |
| | SMST | 2 | - | - | 2 | 1 |
| | RITR | 1 | - | - | 1 | 1 |
| | VICA | 1 | - | - | 1 | 1 |
| | GATR | 1 | - | - | 1 | 1 |
| | THVE | 1 | - | - | 1 | 1 |
| | GABO | 1 | - | - | 1 | 1 |
| | PRVI | 1 | - | - | 1 | 1 |
| | PYAS | - | - | 1 | 1 | 1 |
| | ARNU | - | - | 1 | 1 | 1 |
| | LAOC | - | - | + | + | 1 |

Table 8 - c: Results of Vegetation Sampling, area #19, the lowest plot in Whitemud ravine (elevation 631 m).
See Table 4 for full species names.

$10\ m^2$ Plot (field work: July 29, 1988)

| | species | # of stems | average dbh (cm) | range of dbh (cm) |
|---|---|---|---|---|
| Trees: | POTR | 7 | 19.6 | 15.0-26.7 |
| | POBA | 1 | 54.5 | |
| | PIGL | 1 | 13.7 | |

---

$2\ m^2$ Plot

| species: | POTR | COST | COCO | ROSP | SYAL |
|---|---|---|---|---|---|
| cover: | 4 | 4 | 2 | 2 | 2 |

---

$1\ m^2$ Plots (field work: Sept. 3 and 9, 1988)

| | Species | Plot 1 | Plot 2 | Plot 3 | Sum of cover | Constancy |
|---|---|---|---|---|---|---|
| Over .5 m | COST | 5 | 1 | 6 | 12 | 3 |
| | ROSP | 1 | 3 | - | 4 | 2 |
| | POTR | + | - | 2 | 2 | 2 |
| Under .5 m | COCA | 2 | 4 | 3 | 9 | 3 |
| | (equisetum) | 3 | 2 | 2 | 7 | 3 |
| | PEPA | 1 | 3 | 2 | 6 | 3 |
| | ROSP | 2 | 1 | 2 | 5 | 3 |
| | COST | 1 | 1 | 3 | 5 | 3 |
| | RUPU | 1 | 1 | 2 | 4 | 3 |
| | FRVI | 1 | 2 | 1 | 4 | 3 |
| | MACA | 1 | 3 | - | 4 | 2 |
| | ARNU | + | 2 | 1 | 3 | 3 |
| | RIOX | 1 | - | 2 | 3 | 2 |
| | POTR | 1 | 2 | - | 3 | 2 |
| | (graminoids) | + | 1 | 1 | 2 | 3 |
| | GATR | 1 | - | 1 | 2 | 2 |
| | THVE | 1 | 1 | - | 2 | 2 |
| | HELA | 1 | - | 1 | 2 | 2 |
| | PYAS | - | 1 | 1 | 2 | 2 |
| | ASCI | 1 | - | + | 1 | 2 |
| | SYAL | + | + | - | + | 2 |
| | GABO | - | 1 | - | 1 | 1 |
| | (bryophytes) | 1 | - | - | 1 | 1 |
| | SMST | + | - | + | + | 2 |
| | LAOC | - | + | + | + | 2 |

In summary, the plots sampled consisted mainly of Populus tremuloides, with a small component of P. balsamifera and Picea glauca. The plot at the top of the ravine had a much greater density of trees than the lower plots. The understory flora includes about 21 species in each location sampled, with the lowest location, #19, as least well-drained, shown by the presence of species such as Petasites palmatus and Equisetum which are restricted to wet-mesic soils (Corns and Annas, 1986).

3.2.2. Weather and Insect Factors

On May 19, 1987, a heavy snowstorm lasted most of the day, followed by a frost that night of -2.5°C (H. Turchansky, Atmospheric Environment Service, 1990, pers. comm.). As a result, many trees and branches broke under the weight of snow. Shrubs were bent, growing tips killed (eg: Picea glauca, Rosa species), and flowers frozen. This led to greatly-reduced fruit crops on Amelanchier alnifolia, Acer negundo, and Sorbus species (Mountain Ash) in the Edmonton area.

On July 31, 1987, tornado winds struck Edmonton, killing many people, destroying houses and felling countless trees. The combined effect in 1987 of the snowstorm and the tornado opened the forest canopy in many ravine locations (personal observation).

Forest tent caterpillars (Malacosoma disstria Hübner) were present in 1987, but were not as numerous as in 1988, when much of the transect canopy ( e.g. sections #'s: 1a, 8, 14, 15, 17 on Figure 4) was completely defoliated for the period May 30 - June 15.

In only one area of regular Populus observations were the trees not defoliated, this being the edge of the mowed urban park at the ravine top. The city parks department sprayed the trees with insecticide to kill the tent caterpillars, and as a result these poplars kept their leaves all summer.

### 3.2.3. Phenology

#### 3.2.3.1. Flowering Sequence for Whitemud Ravine: 1988

The developmental sequence for 77 plant species is shown with phenodynamic strips (Figure 5), in order of first flowering in 1988. The development for each species illustrated reflects the average for the ravine. Developmental stages illustrated include: flower buds, flowers, full bloom, flowers continuing past full bloom, fruit setting and ripe fruit, and when the data are available, green leaves. For diagramatic purposes I have assumed that fruit set begins shortly after full bloom.

Note that the time scale has been adjusted to provide maximum detail during the rapid spring development period, and also to reflect the level of accuracy available from varying frequencies of field visits. Therefore, the period of May 10 to June 30 is expressed in 3 day intervals and the period before and after, by 6 day intervals.

Some species were quite uncommon along the transect (e.g. Viola adunca, Corydalis aurea, Aquilegia brevistyla, Erigeron philadelphicus) and/or were almost impossible to locate once bright flowers had dropped (Viola renifolia, Stellaria longipes, Sisyrinchium montanum) and thus of the reproductive phenophases only flowering was recorded. Because the main focus of the study was on flowering phenology, vegetative development was not recorded for many species and these species lack a vegetative line on the diagrams.

Figure 5: Phenodynamic strips showing phenological development of 77 plant species in Whitemud Ravine, 1988. The species are arranged in order of first flowering. Note that the timescale varies from 3-day intervals to 6-day intervals to reflect the accuracy available with respect to the frequencies of field visits (see Table 5).

See Table 7b for the vegetative codes used on the line beneath the reproductive strip. Vegetative lines with arrows indicate incomplete vegetative observations.

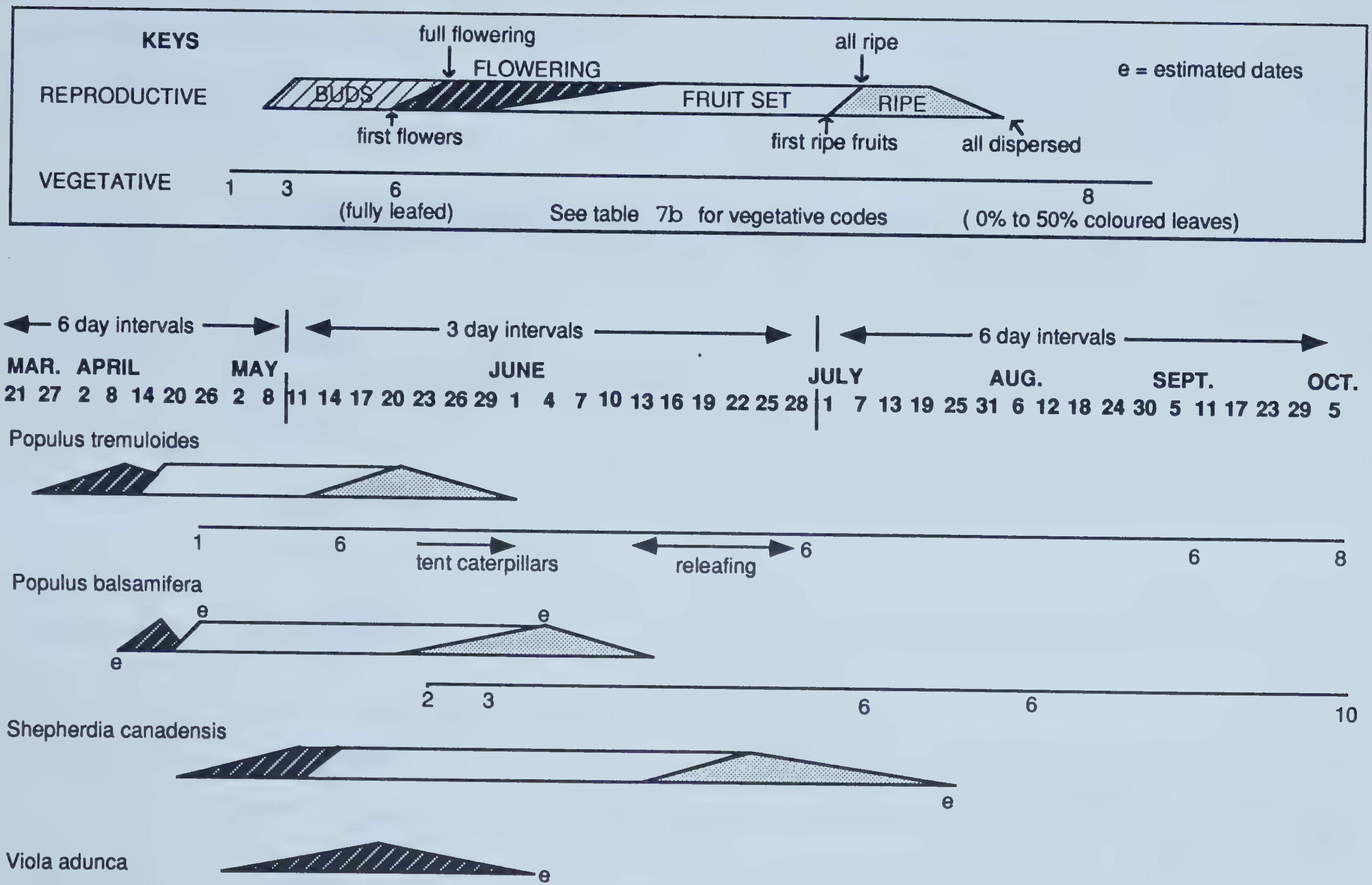



Figure 5: Phenodynamic Strips showing phenological development of 77 plant species in Whitemud Ravine, 1988.

Figure 5, continued:

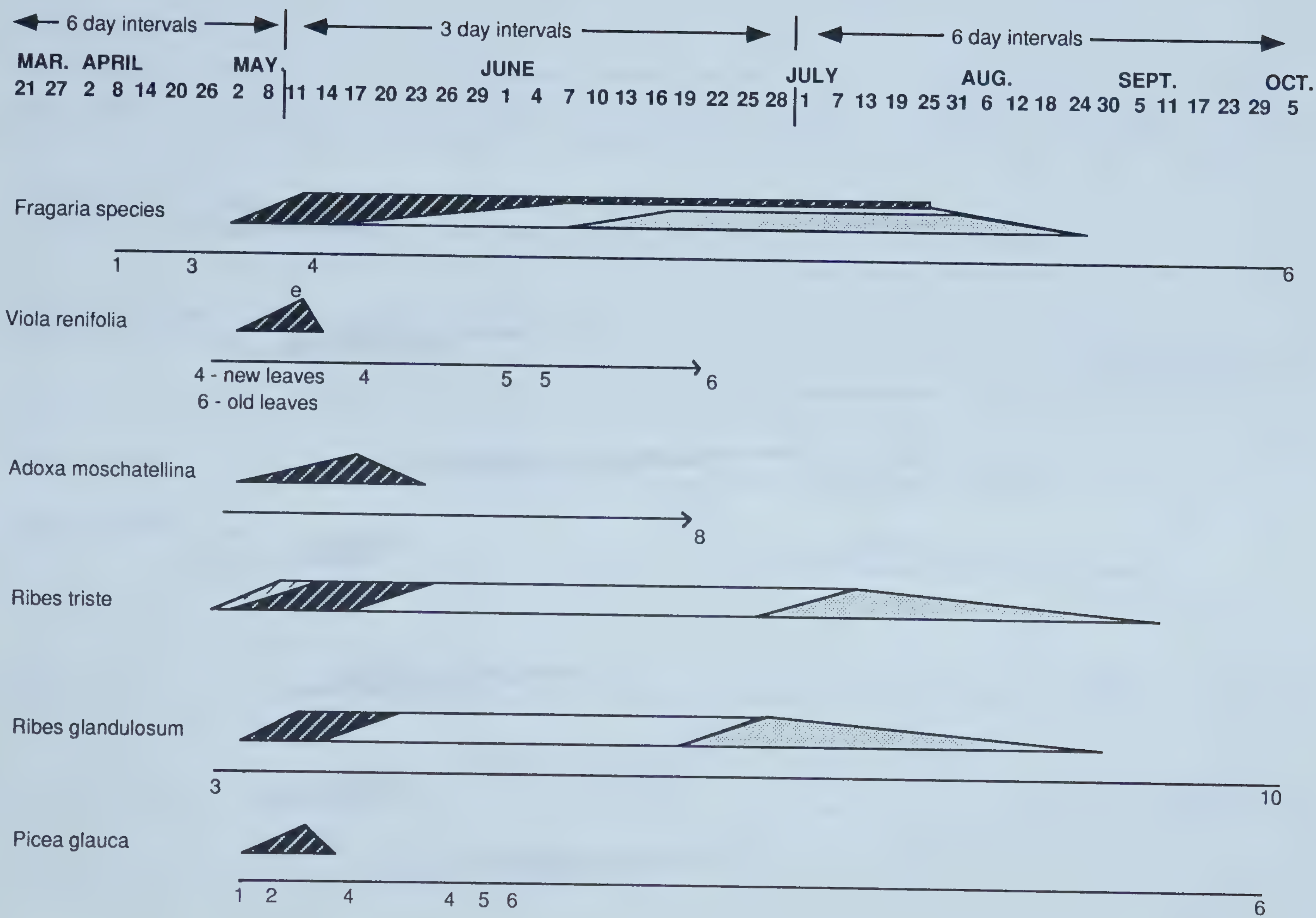


Figure 5, continued:

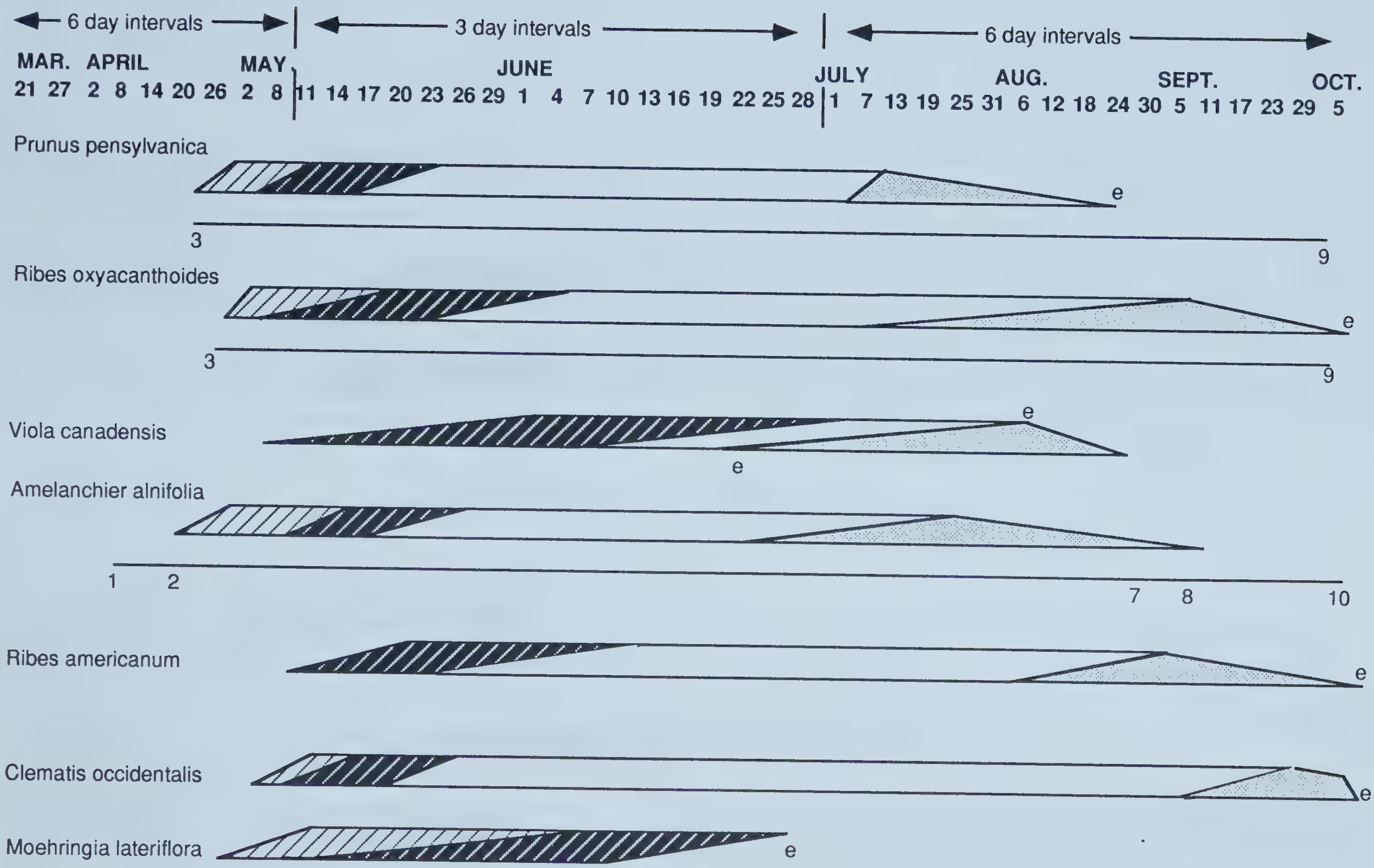


Figure 5, continued:

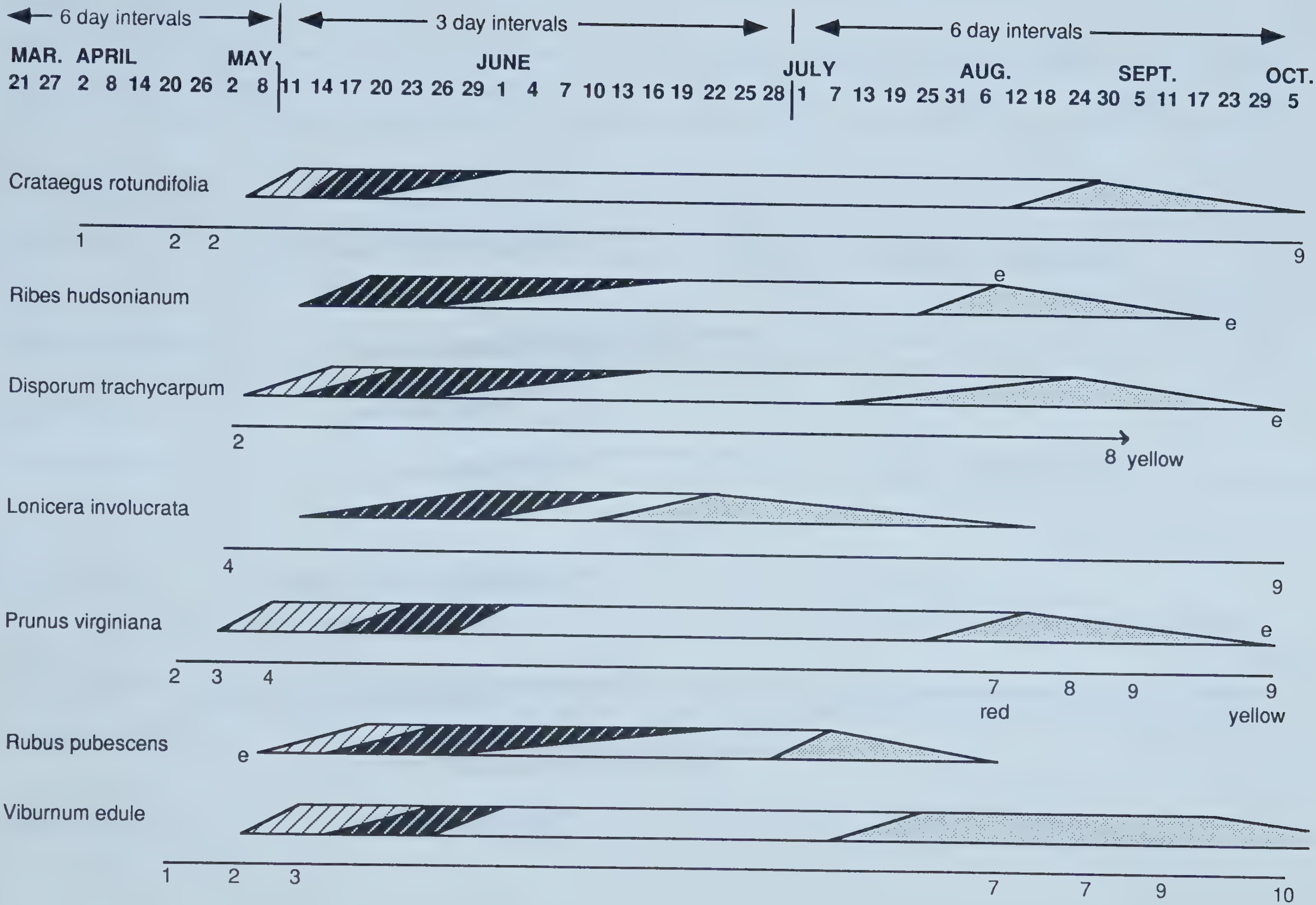


Figure 5, continued:

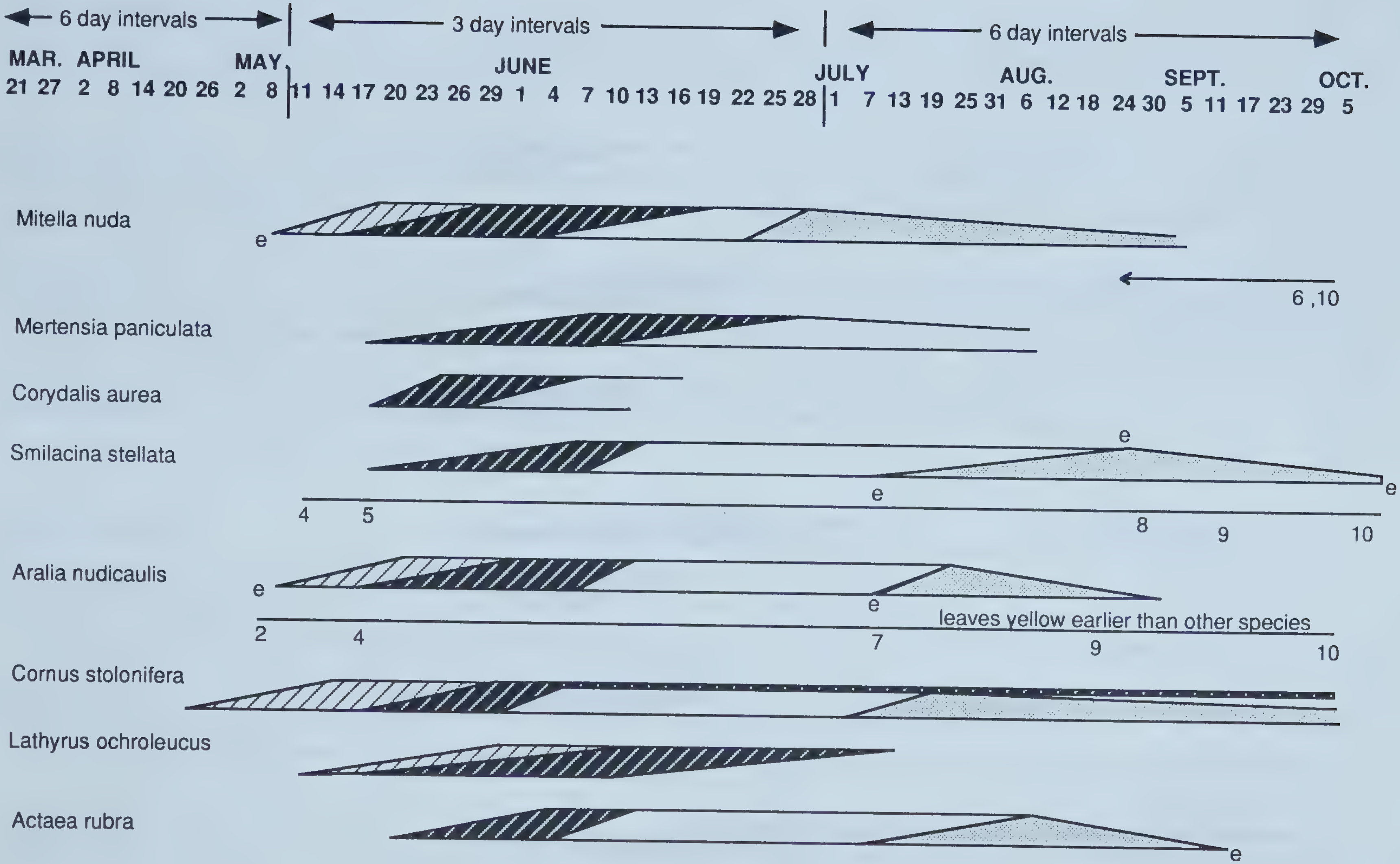


Figure 5, continued:

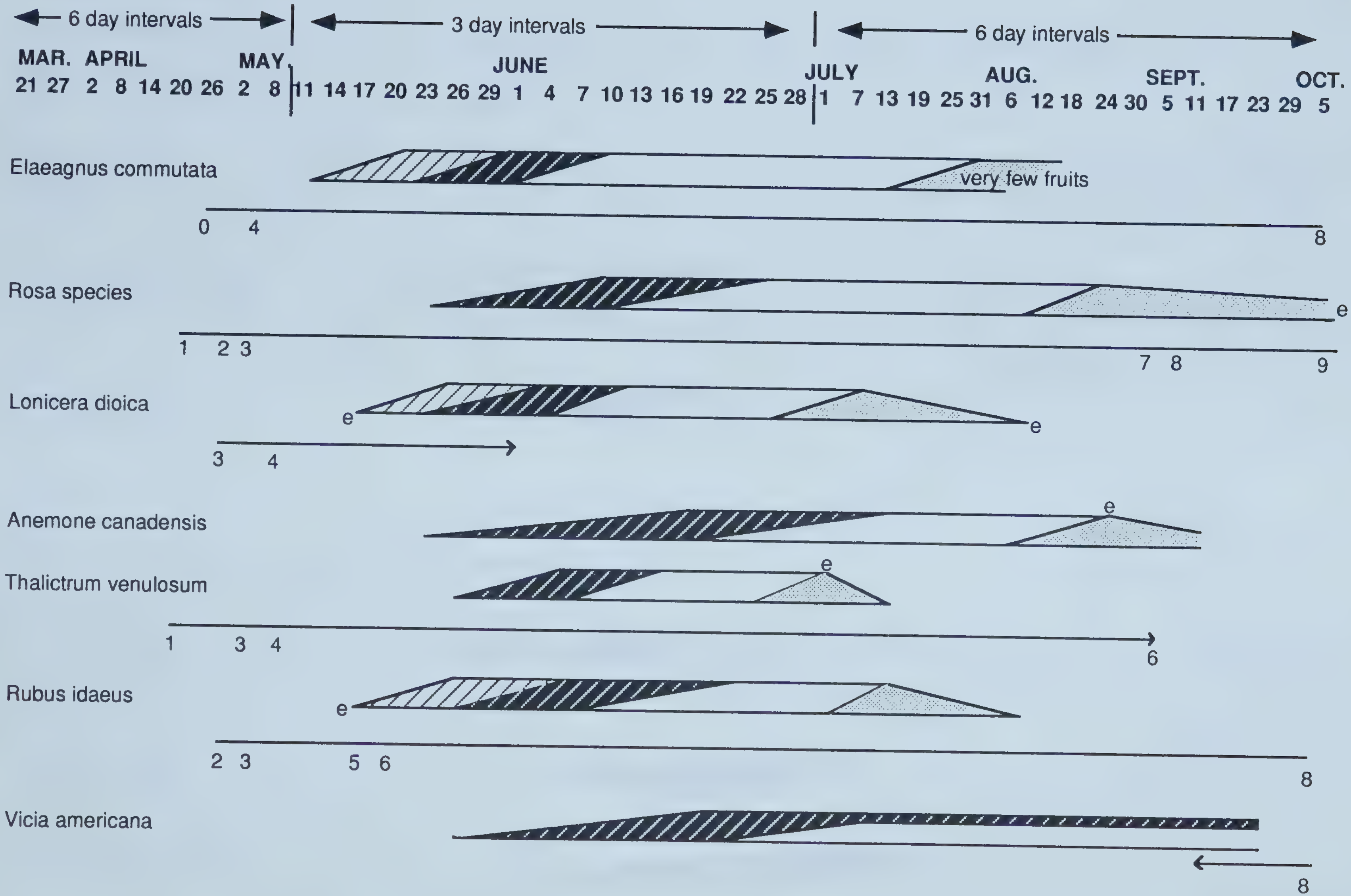


Figure 5, continued:

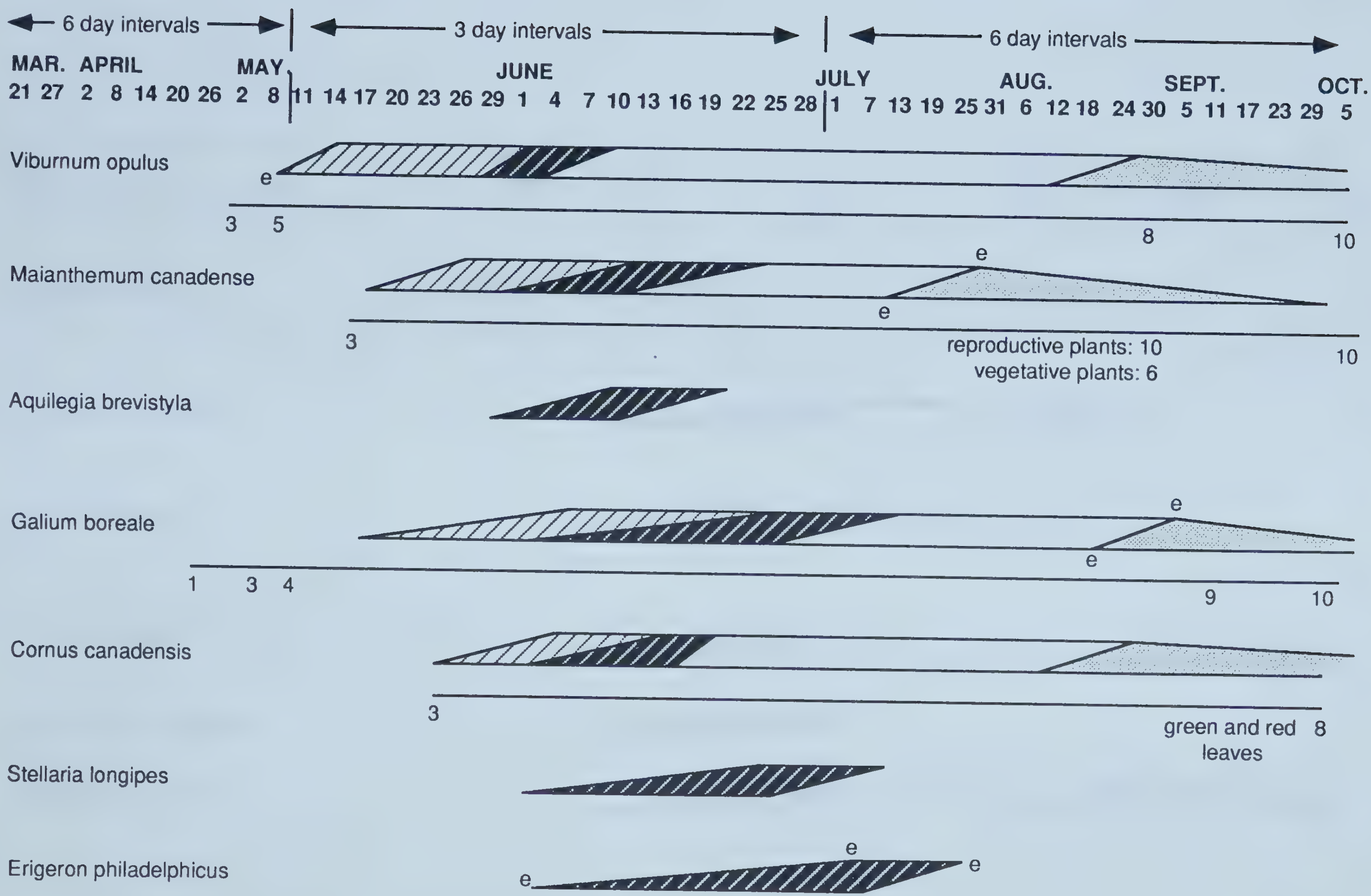


Figure 5, continued:

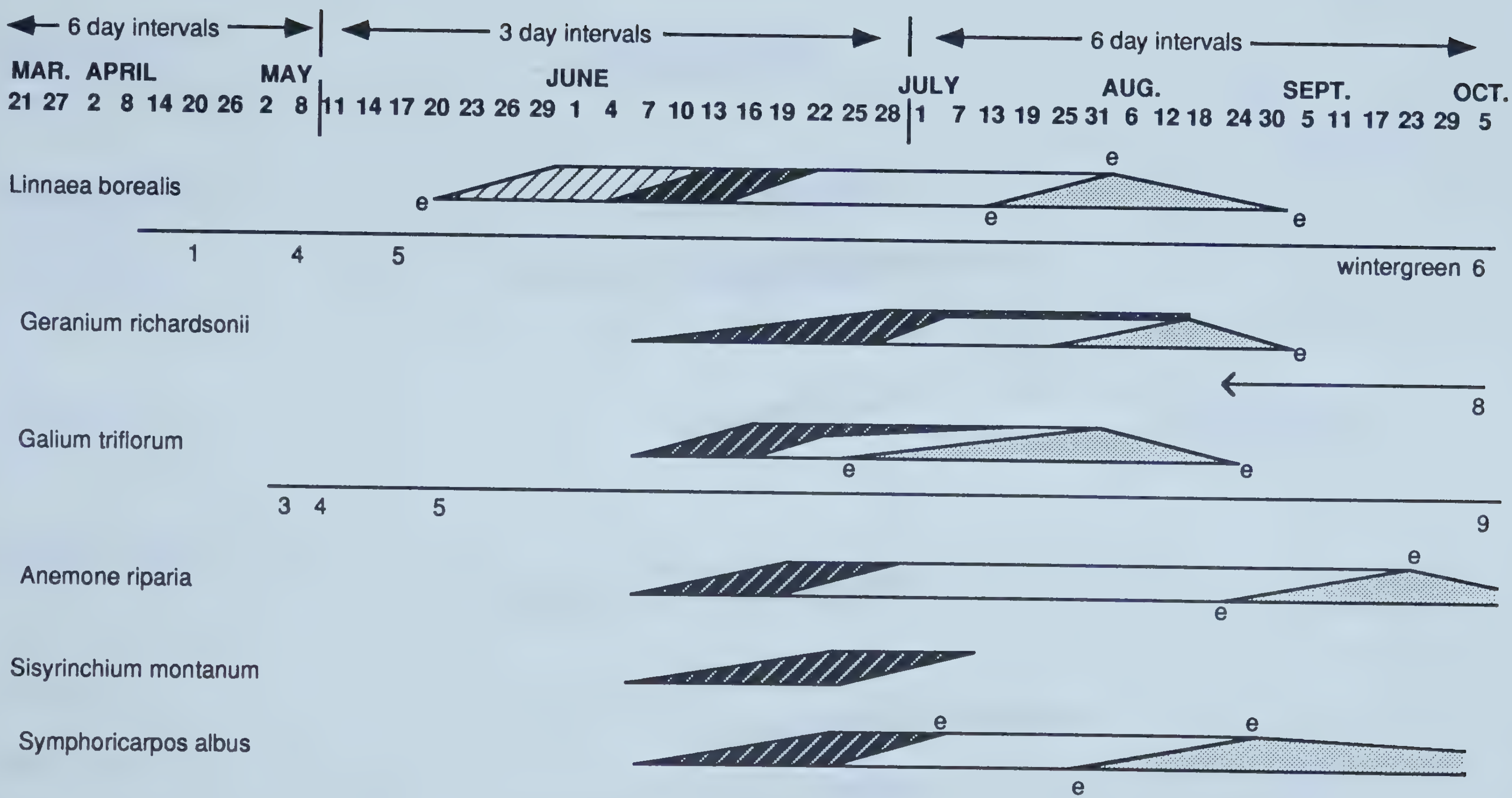


Figure 5, continued:

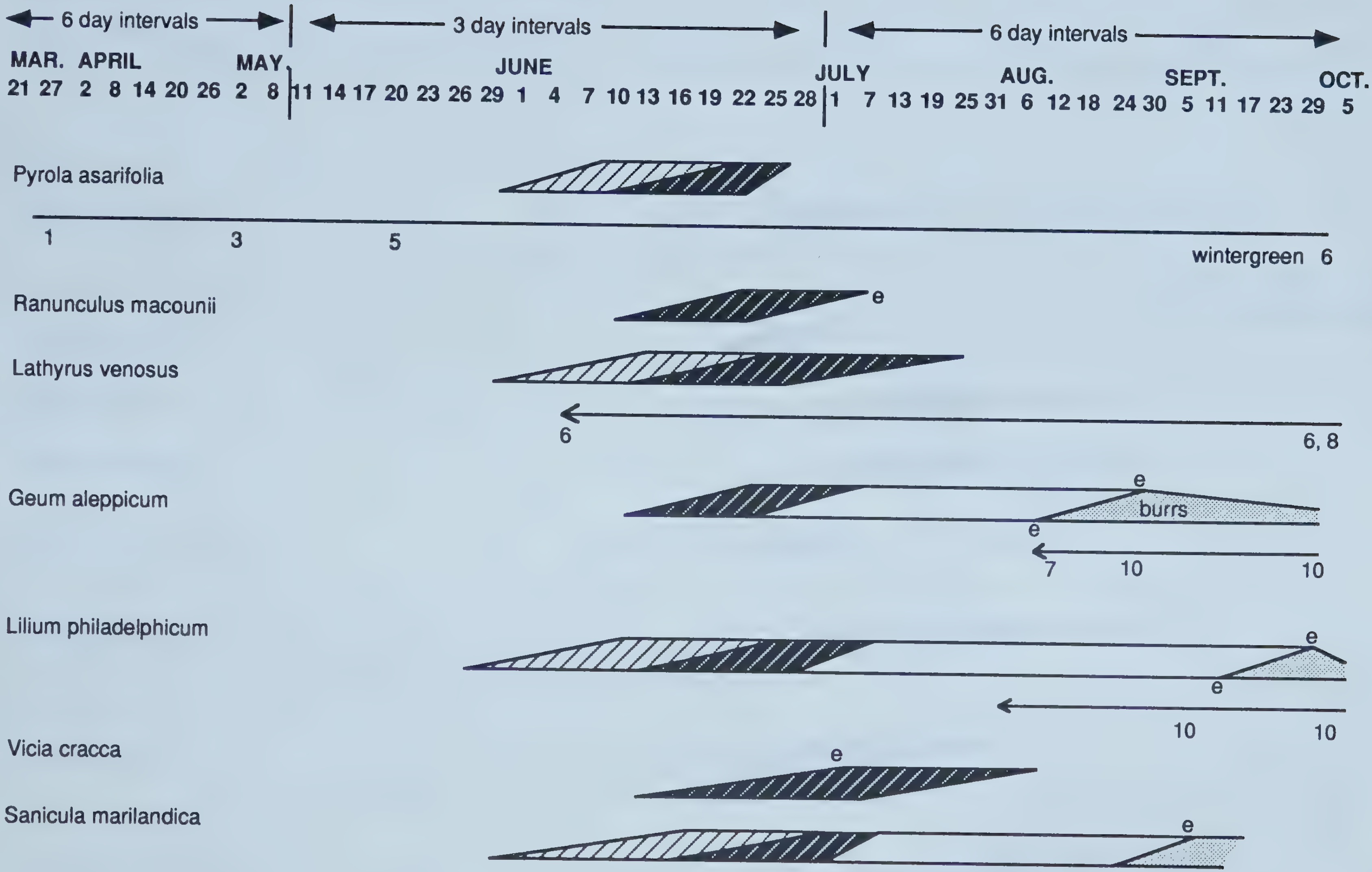


Figure 5, continued:

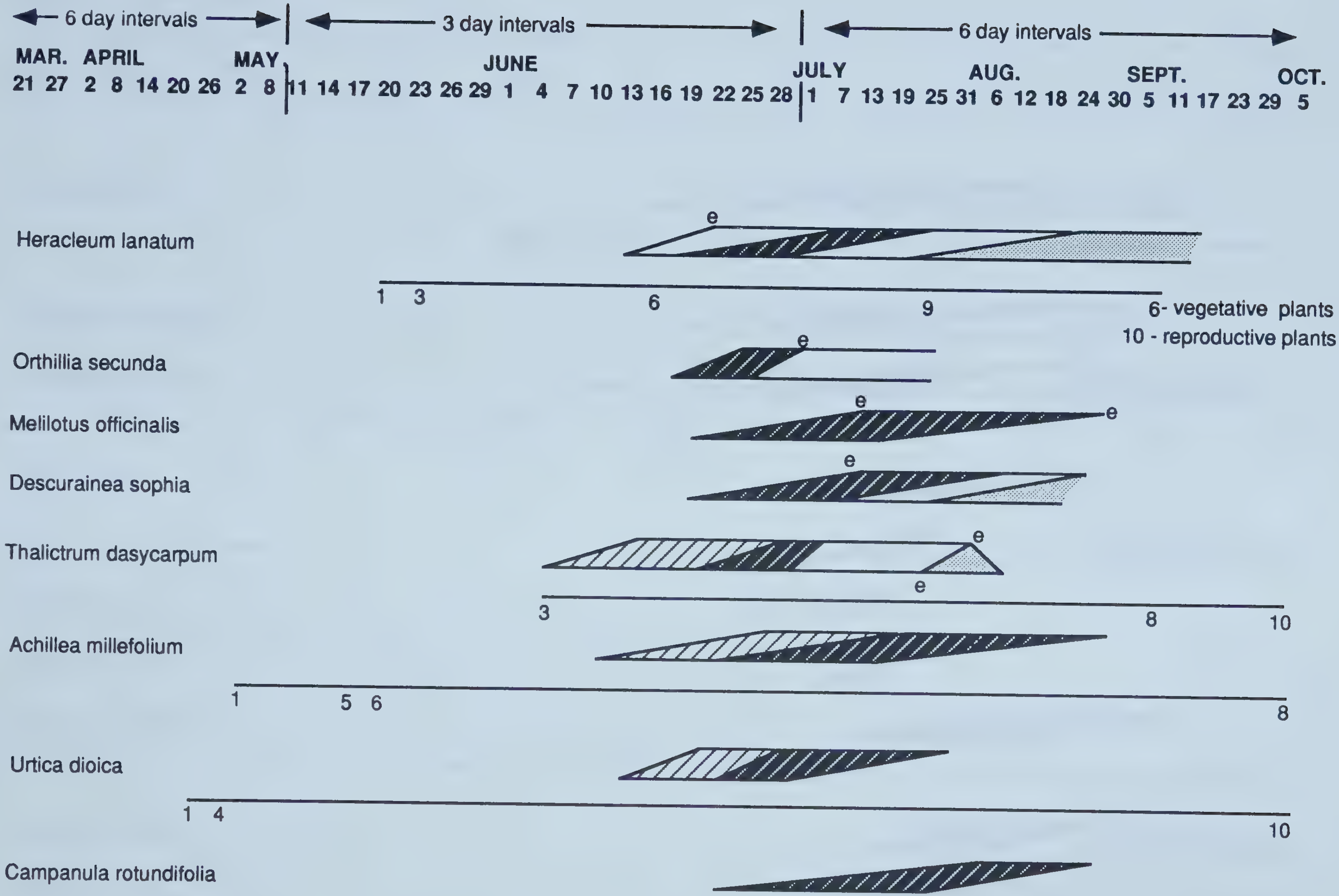
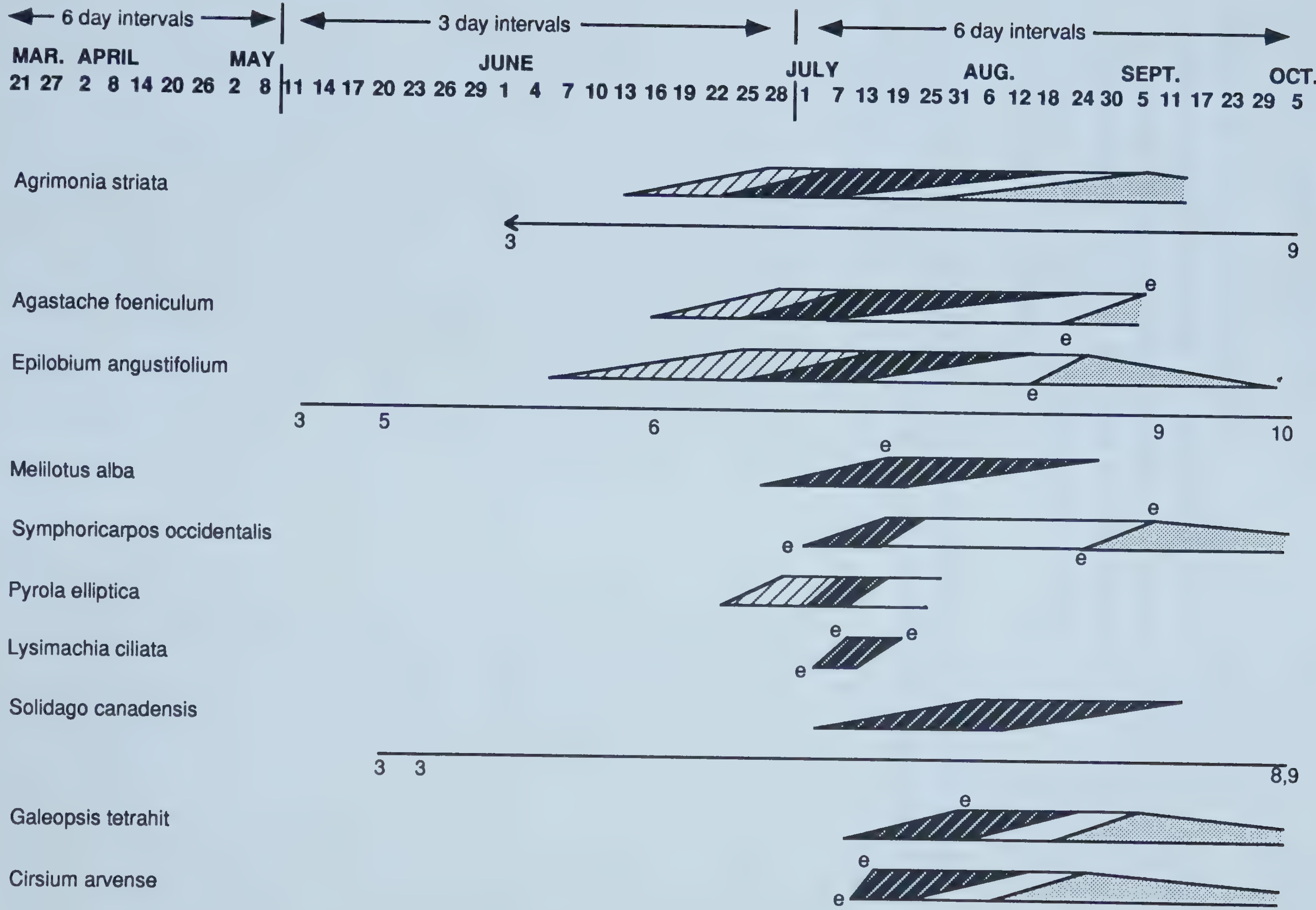


Figure 5, continued:



### 3.2.3.2. Flowering Times: 1987 and 1988

First and full flowering dates are presented for 87 species representing 65 genera and 32 families (Table 9). Species are listed in order of their 1988 first flowering. Calendar dates and Julian dates are given for 1987 and 1988 for standardization, as 1988 was a leap year. (In the Julian calendar, Jan.1 = day 1, Feb. 1 = day 32 and so on up to 365 days.)

Of 72 species for which first bloom comparisons could be made, 78% flowered earlier in 1988. Full bloom dates for 68 species show 66% being earlier in 1988.

Table 9: First and full flowering dates for vascular plant species in Whitemud ravine, 1987 and 1988, and comparisons between years. Differences between flowering times (1987-1988) are given for the two years, for both first and full flowering. If flowering for a species was earlier in 1987 than 1988, the difference has a (-) sign.

J = Julian date; D = difference in days, 1987-1988; -- = no observation; (date) = estimated date

| | FIRST FLOWERING | | | | | FULL FLOWERING | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | 1988 | J | 1987 | J | D | 1988 | J | 1987 | J | D |
| Populus tremuloides | Mar. 24 | 84 | Apr. 10 | 100 | 16 | Apr. 9 | 100 | Apr. 17 | 107 | 7 |
| Populus balsamifera | Apr. 14 | 105 | Apr. 22 | 112 | 7 | Apr. 17 | 108 | Apr. 28 | 118 | 10 |
| Shepherdia canadensis | " 20 | 111 | Apr. 24 | 114 | 3 | May 11 | 132 | May 3 | 123 | -9 |
| Viola adunca | " 30 | 121 | May 5 | 125 | 4 | " 16 | 137 | 18 | 138 | 1 |
| Fragaria species | May 1 | 122 | May 11 | 131 | 9 | " 12 | 133 | 22 | 142 | 9 |
| Taraxacum officinale | " 1 | 122 | May 8 | 128 | 6 | -- | - | (May 13) | 133 | |
| Viola renifolia | " 4 | 125 | (May 11) | 131 | 6 | May 5 | 126 | (May 11) | 131 | 5 |
| Adoxa moschatellina | " 4 | 125 | (May 15) | 135 | 10 | " 18 | 139 | (May 15) | 135 | -4 |
| Ribes triste | " 4 | 125 | May 4 | 124 | -1 | " 15 | 136 | May 15 | 135 | -1 |
| Ribes glandulosum | " 4 | 125 | Apr. 30 | 120 | -5 | " 12 | 133 | (May 8) | 128 | -5 |
| Picea glauca | " 4 | 125 | May 11 | 131 | 6 | " 13 | 134 | 13 | 133 | -1 |
| Prunus pensylvanica | May 6 | 127 | May 6 | 126 | -1 | May 12 | 133 | May 10 | 130 | -3 |
| Ribes occidentalis | " " | " | May 8 | 128 | 1 | May 20 | 141 | May 16 | 136 | -5 |
| Viola canadensis | " " | " | May 16 | 136 | 9 | (Jun.3) | 155 | (Jun.10) | 161 | 6 |
| Amelanchier alnifolia | May 9 | 130 | May 5 | 125 | -5 | May 16 | 137 | May 13 | 133 | -4 |
| Ribes americanum | " " | " | -- | | | May 21 | 142 | May 21 | 141 | -1 |
| Clematis occidentalis | " " | " | -- | | | May 17 | 138 | - | | -- |
| Moehringia lateriflora | (May 10) | 131 | May 11 | 131 | 0 | June 8 | 160 | May 23 | 143 | -17 |

Table 9, continued:

| Species | FIRST FLOWERING 1988 | J | 1987 | J | D | FULL FLOWERING 1988 | J | 1987 | J | D |
|---|---|---|---|---|---|---|---|---|---|---|
| *Crataegus rotundifolia* | May 12 | 133 | May 12 | 132 | -1 | May 15 | 136 | May 22 | 142 | 6 |
| *Ribes hudsonianum* | " " | " | — - | - | | May 19 | 140 | - - | - | |
| *Disporum trachycarpum* | May 12 | 133 | May 27 | 148 | 15 | May 22 | 143 | June 1 | 152 | 9 |
| *Lonicera involucrata* | " " | " | May 13 | 133 | 0 | June 2 | 154 | May 26 | 146 | -8 |
| *Prunus virginiana* | May 15 | 136 | May 18 | 138 | 2 | May 23 | 144 | May 29 | 149 | 5 |
| *Rubus pubescens* | " | " | May 15 | 135 | -1 | May 26 | 147 | May 31 | 151 | 4 |
| *Viburnum edule* | May 15 | 136 | May 15 | 135 | -1 | May 25 | 146 | May 26 | 146 | 0 |
| *Mertensia paniculata* | " | " | (June 3) | 154 | 18 | June 7 | 159 | June 10 | 161 | 2 |
| *Mitella nuda* | " | " | May 18 | 138 | 2 | May 29 | 150 | June 2 | 153 | 3 |
| *Corydalis aurea* | " | " | — | | | May 24 | 145 | — | | |
| *Smilacina stellata* | May 17 | 138 | May 25 | 145 | 7 | June 6 | 158 | June 12 | 163 | 5 |
| *Aralia nudicaulis* | " | " | May 25 | 145 | 7 | June 1 | 153 | June 4 | 155 | 2 |
| *Cornus stolonifera* | " | " | May 26 | 146 | 8 | May 30 | 151 | June 5 | 156 | 5 |
| *Lathyrus ochroleucus* | " | " | (June 5) | 156 | 18 | June 9 | 161 | (Jun.28) | 179 | 18 |
| *Actaea rubra* | May 20 | 141 | June 1 | 152 | 11 | June 4 | 156 | June 12 | 163 | 7 |
| *Elaeagnus commutata* | May 22 | 143 | May 25 | 145 | 2 | May 31 | 152 | June 6 | 157 | 5 |
| *Rosa* species | May 24 | 145 | May 27 | 147 | 2 | June 9 | 161 | June 14 | 165 | 4 |
| *Lonicera dioica* | " | " | June 3 | 154 | 9 | June 5 | 157 | June 10 | 161 | 4 |
| *Anemone canadensis* | " | " | June 3 | 154 | 9 | June 18 | 170 | (Jly. 2) | 183 | 13 |
| *Rubus idaeus* | May 27 | 148 | June 11 | 162 | 14 | June 7 | 159 | June 13 | 164 | 5 |
| *Thalictrum venulosum* | " | " | May 21 | 141 | -7 | June 6 | 158 | June 3 | 154 | -4 |
| *Vicia americana* | May 28 | 149 | June 5 | 156 | 7 | June 20 | 172 | (July 2) | 183 | 11 |
| *Viburnum opulus* | " | " | June 7 | 158 | 9 | June 1 | 153 | June 9 | 160 | 7 |

Table 9, continued:

| Species | FIRST FLOWERING 1988 | J | 1987 | J | D | FULL FLOWERING 1988 | J | 1987 | J | D |
|---|---|---|---|---|---|---|---|---|---|---|
| Maianthemum canadense | May 30 | 151 | June 4 | 155 | 4 | June 9 | 161 | June 15 | 166 | 5 |
| Aquilegia brevistyla | " | " | June 11 | 162 | 11 | (Jun. 9) | 161 | (Jun.25) | 176 | 15 |
| Galium boreale | June 2 | 154 | June 13 | 164 | 10 | June 25 | 177 | July 1 | 213 | 36 |
| Cornus canadensis | June 2 | 154 | June 5 | 156 | 2 | June 15 | 167 | June 11 | 162 | -5 |
| Stellaria longipes | June 2 | 154 | -- | | | (Jun.24) | 176 | -- | | |
| Erigeron philadelphicus | June 2 | 154 | -- | | | July 4 | 186 | -- | | |
| Linnaea borealis | June 4 | 156 | June 11 | 162 | 6 | June 13 | 165 | June 18 | 169 | 4 |
| Anemone riparia | June 6 | 158 | (Jun.20) | 171 | 13 | June 19 | 171 | June 28 | 179 | 8 |
| Galium triflorum | " | " | June 15 | 166 | 8 | June 16 | 168 | July 2 | 183 | 15 |
| Geranium richardsonii | " | " | June 13 | 164 | 6 | June 27 | 179 | July 9 | 190 | 11 |
| Symphoricarpos albus | June 6 | 158 | (Jly. 1) | 182 | 24 | (Jun.23) | 175 | (Jly.10) | 191 | 16 |
| Sisyrinchium montanum | " | " | (Jun.18) | 169 | 11 | (Jun.23) | 175 | (Jun.18) | 169 | -6 |
| Pyrola asarifolia | June 9 | 161 | June 11 | 162 | 1 | June 21 | 173 | June 25 | 176 | 3 |
| Ranunculus macounii | June 10 | 162 | June 24 | 175 | 13 | (Jun.22) | 174 | (Jly. 4) | 185 | 11 |
| Geum aleppicum | June 11 | 163 | June 20 | 171 | 8 | June 24 | 176 | June 23 | 174 | -2 |
| Lathyrus venosus | " | " | June 8 | 159 | -6 | June 26 | 178 | (Jly.14) | 195 | 17 |
| Lilium philadelphicum | June 13 | 165 | (Jun.25) | 176 | 11 | June 27 | 179 | July 4 | 185 | 6 |
| Lysimachia thyrsiflora | " | " | -- | | | -- | | -- | | |
| Sanicula marilandica | June 16 | 168 | June 22 | 173 | 5 | July 2 | 184 | (Jun.26) | 177 | -7 |
| Vicia cracca | " | " | June 22 | 173 | 5 | (Jly. 5) | 187 | July 3 | 184 | -3 |
| Heracleum lanatum | June 18 | 170 | June 24 | 175 | 5 | July 9 | 191 | July 15 | 196 | 5 |
| Orthilia secunda | " | " | -- | | | June 25 | 177 | -- | | |
| Descurainia sophia | June 20 | 172 | -- | | | July 12 | 194 | -- | | |

Table 9, continued:

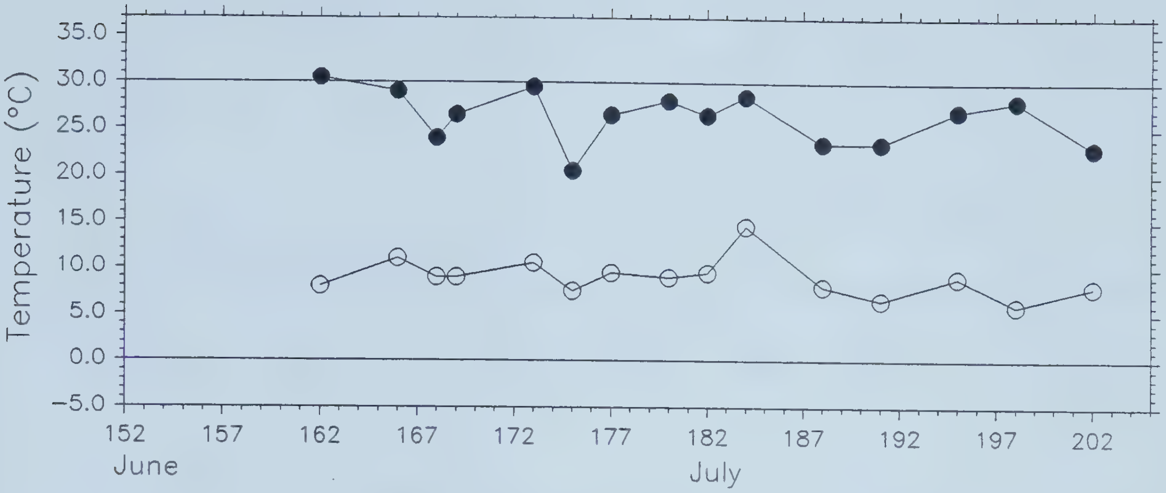
| Species | FIRST FLOWERING | | | | | FULL FLOWERING | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | J | 1987 | J | D | 1988 | J | 1987 | J | D |
| <u>Melilotus officinalis</u> | 20 | 172 | (Jly. 4) | 185 | 13 | July 13 | 195 | -- | | |
| <u>Thalictrum dasycarpum</u> | (Jun.21) | 173 | (Jun.22) | 173 | 0 | June 30 | 182 | (Jun.23) | 174 | -8 |
| <u>Achillea millifolium</u> | June 23 | 175 | June 22 | 173 | -2 | July 16 | 198 | July 20 | 201 | 3 |
| <u>Agrimonia striata</u> | June 23 | " | July 3 | 184 | 9 | July 7 | 189 | July 18 | 199 | 10 |
| <u>Campanula rotundifolia</u> | " | " | June 29 | 180 | 5 | Aug. 6 | 219 | July 8 | 189 | -30 |
| <u>Matricaria perforata</u> | " | " | June 25 | 176 | 1 | July 9 | 191 | -- | | |
| <u>Urtica dioica</u> | " | " | June 24 | 175 | 0 | June 29 | 181 | July 3 | 184 | 3 |
| <u>Utricularia vulgaris</u> | " | " | (Jun.29) | 180 | 5 | (Jun.28) | 180 | (Jun.29) | 180 | 0 |
| <u>Agastache foeniculum</u> | June 25 | 177 | June 29 | 180 | 3 | July 11 | 193 | July 15 | 196 | 3 |
| <u>Epilobium angustifolium</u> | " | " | July 5 | 186 | 9 | July 16 | 198 | July 28 | 209 | 11 |
| <u>Melilotus alba</u> | June 27 | 179 | July 4 | 185 | 6 | July 18 | 200 | (Jly.15) | 196 | -4 |
| <u>Symphoricarpos occidentalis</u> | July 1 | 183 | Jly 14 | 195 | 12 | July 17 | 199 | (Jly.22) | 203 | 4 |
| <u>Pyrola elliptica</u> | July 2 | 184 | June 29 | 180 | -4 | July 8 | 190 | July 12 | 193 | 3 |
| <u>Lysimachia ciliata</u> | (Jly. 4) | 186 | July 14 | 195 | 9 | (Jly. 9) | 191 | July 21 | 202 | 11 |
| <u>Glycyrrhiza lepidota</u> | July 4 | 186 | July 10 | 191 | 5 | -- | | -- | | |
| <u>Solidago canadensis</u> | July 4 | 186 | July 15 | 196 | 10 | Aug. 5 | 218 | Aug. 9 | 221 | 3 |
| <u>Heuchera richardsonii</u> | July 10 | 192 | -- | | | -- | | -- | | |
| <u>Galeopsis tetrahit</u> | July 11 | 193 | -- | | | (Aug. 2) | 215 | (Jly.30) | 211 | -4 |
| <u>Cirsium arvense</u> | July 12 | 194 | July 10 | 191 | -3 | -- | | -- | | |
| <u>Linaria vulgaris</u> | (Jly.18) | 200 | -- | | | -- | | -- | | |
| <u>Oenothera biennis</u> | (Jly.18) | 200 | -- | | | -- | | -- | | |
| <u>Convolvulus sepium</u> | (Jly.25) | 207 | -- | | | -- | | -- | | |
| <u>Achillea sibirica</u> | July 28 | 210 | -- | | | -- | | -- | | |

3.2.3.3. Temperature, Location and Flowering

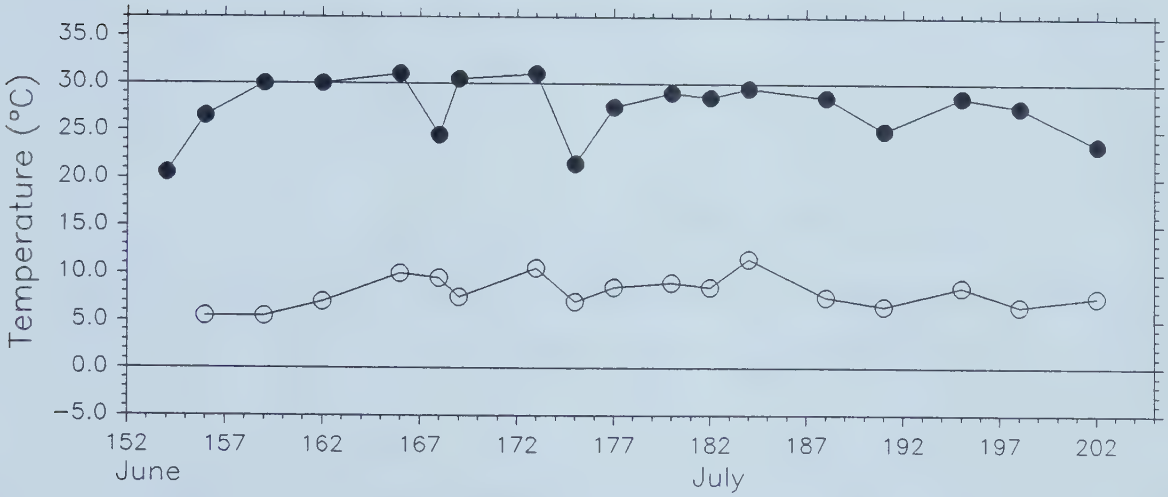
In general, there was a minor trend from the top to the bottom of the ravine (from #1a to #8 to #15a, Figure 2) towards more extreme temperatures. At the bottom site, #15a, maximum temperatures were higher with more peaks above 30 °C, and minimums were lower with more peaks below 5 °C. These trends were consistent for 1987 and 1988 (Figures 6a and 6b). However, the thermometer at #15a was noted May 12, 1988, to be receiving some direct sunshine at noon, so maximum readings may be artificially high. Comparisons of sites for the timespan of Julian day 133 to 143 on Figure 6b (1988) shows clear differences between sites. The lower the site, the lower the minimum temperatures. Table 10 shows the number of temperature extremes for the three locations.

A summary of 1987 and 1988 weather records for the Edmonton International Airport, 18 km south of the Whitemud study site, is shown in Table 11. In 1987, growing degree days in April were double the average; they were also above normal for May and June. Conditions were somewhat dryer than average in April, much wetter than usual in May, and then dry again in June. July and August were wetter than usual and had average temperatures. In 1988, temperatures were again unseasonally high in April, and growing degree days were above average for the whole of the growing season. Precipitation was considerably below average in March and May, and then above average for the rest of the summer.

Location #1a (664 m asl)




Location #8 (639 m asl)




Location #15a (633 m asl)

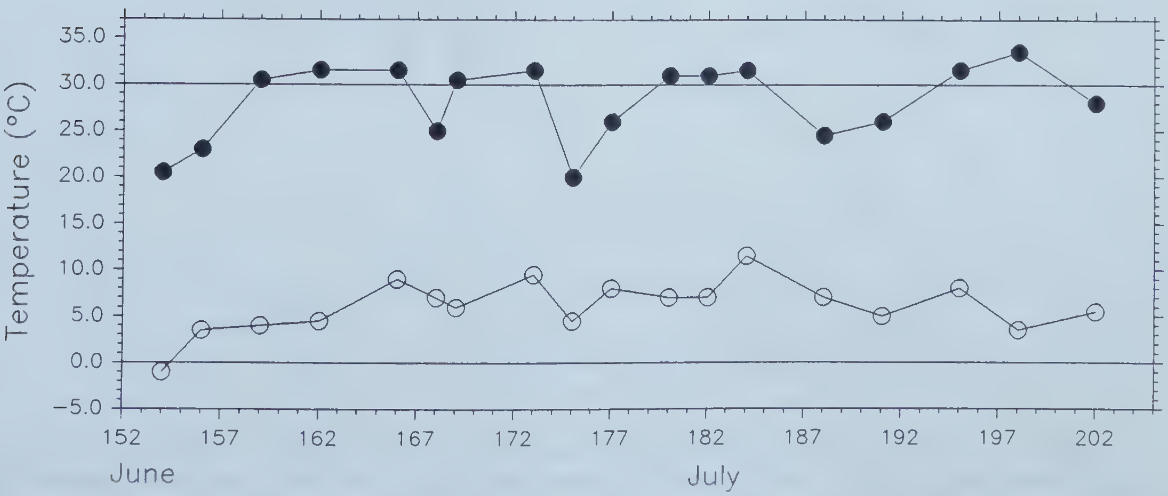



Figure 6a: 1987: Maximum and minimum temperatures at three locations in Whitemud Ravine, for June 3 to July 21 (in Julian dates). Closed circles represent maximum temperatures; open circles - minimum temperatures.

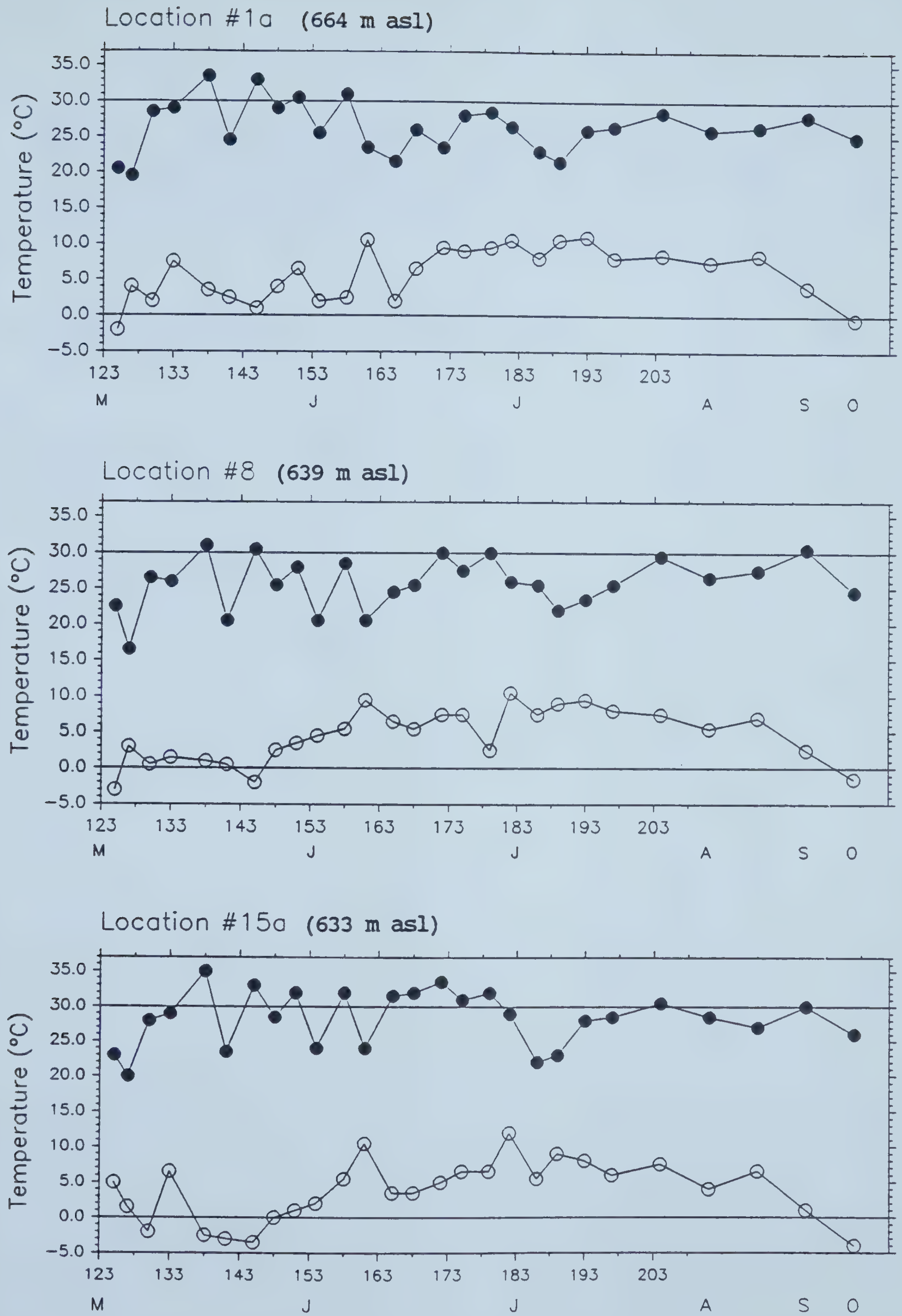



Figure 6b: 1988: Maximum and minimum temperatures at three locations in Whitemud Ravine, for May 4 to October 4. Note that the Julian date scale is compressed for August to October. Closed circles represent maximum temperatures; open circles - minimum temperatures.

Table 10: Number of temperature readings above 30°C and below 5°C for three ravine locations, (top is #1a, middle is #8, bottom is #15a), for 1987 and 1988.

| | | Location: 1a | 8 | 15a |
|---|---|---|---|---|
| Number of readings at or above 30°: | | | | |
| (June-July) | 1987: | 1 | 5 | 10 |
| (May-October) | 1988: | 4 | 5 | 11 |
| Number of readings at or below 5°C: | | | | |
| | 1987 | 0 | 0 | 7 |
| | 1988 | 12 | 13 | 15 |

Table 11: Weather summary for Edmonton International Airport, which is 18 km south of the Whitemud Ravine study site. Brackets () indicate months which were drier or cooler than average. The remaining differences show months which were wetter or warmer than average. Source: Alberta Agriculture (1987, 1988)

**1987**

| | March | April | May | June | July | Aug | Year: |
|---|---|---|---|---|---|---|---|
| (in mm:) | | | | | | | |
| Precipitation | 23.4 | 11.0 | 79.7 | 67.7 | 124.4 | 95.7 | 479.6 |
| 30 year normal | 16.0 | 20.2 | 42.2 | 76.7 | 91.6 | 78.2 | 466.6 |
| difference | 7.4 | (9.2) | 37.5 | (9.0) | 32.8 | 17.5 | 13.0 |
| (in °C:) | | | | | | | |
| Mean monthly temp. | -5.1 | 7.2 | 11.5 | 15.8 | 15.8 | 13.0 | 5.2 |
| 30 year normal | -6.7 | 3.2 | 10.1 | 14.1 | 15.8 | 14.8 | 1.6 |
| difference | 1.6 | 4.0 | 1.4 | 1.7 | 0 | (1.8) | 3.6 |
| Total degree days (above 5 °C:) | | 75 | 201 | 316 | 335 | 249 | |
| 30 year normal | | 38 | 164 | 272 | 336 | 304 | |
| difference | | 37 | 37 | 44 | (1) | (55) | |

**1988**

| | March | April | May | June | July | Aug | Year |
|---|---|---|---|---|---|---|---|
| (in mm:) | | | | | | | |
| Precipitation | 7.0 | 22.2 | 16.2 | 120.8 | 119.9 | 102.3 | 500.4 |
| 30 year normal | 16.0 | 20.2 | 42.2 | 76.7 | 91.6 | 78.2 | 466.6 |
| difference | (11.0) | 2.0 | (26.0) | 44.1 | 28.3 | 24.1 | 33.8 |
| (in °C:) | | | | | | | |
| Mean monthly temp. | 2.0 | 6.4 | 12.9 | 16.0 | 16.0 | 15.5 | 4.7 |
| 30 year normal | -6.7 | 3.2 | 10.1 | 14.0 | 15.8 | 14.8 | 1.6 |
| difference | 4.7 | 3.2 | 2.8 | 2.0 | .2 | .7 | 3.1 |
| Total degree days (above 5 °C:) | | 68 | 246 | 330 | 340 | 326 | |
| 30 year normal | | 38 | 164 | 272 | 336 | 304 | |
| difference | | 30 | 82 | 58 | 4 | 22 | |

Flowering was slightly earlier at the top of the ravine than at the bottom. Twenty-two of the 35 species, or 63%, showed this trend. Four of these are illustrated (Figure 7). No species showed a progression to later flowering at the top of the ravine.

Full bloom (1988) was earlier at location #1a than location #15a by the following number of days: A. alnifolia: 7 days, P. virginiana: 4 days, and Smilacina stellata: 14 days. For Galium boreale, full flowering at #1a was about 10 days earlier than at #16b.

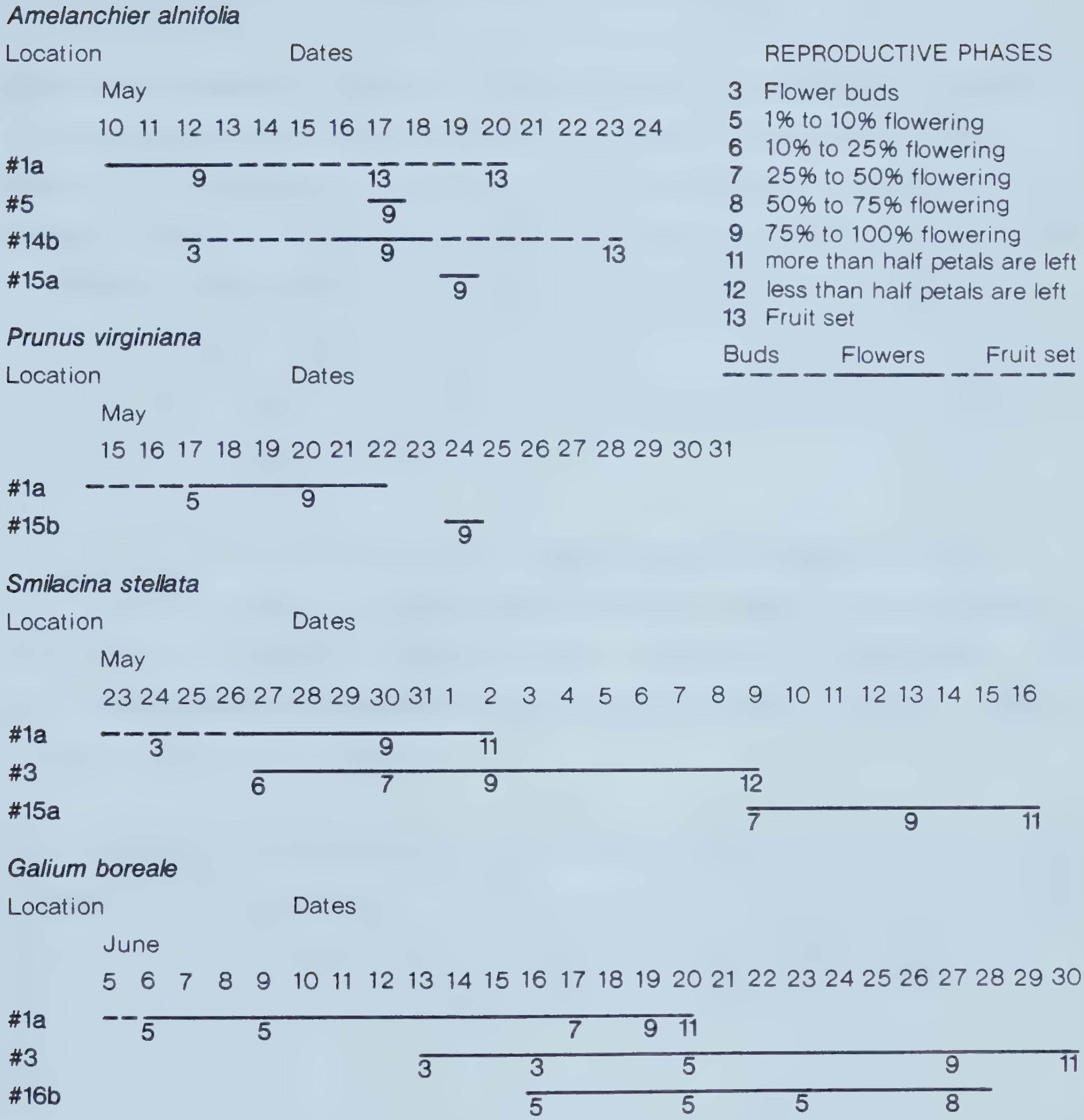



Figure 7: Comparison of 1988 flowering times at locations from the top (#1a) to the bottom (#15a, #15b, or #16b) of Whitemud ravine, for four plant species. See Figure 2 for a map of transect locations.

3.2.3.4. Indicators of the Seasons: Plant Wheels

Figure 8 illustrates the 1988 "Plant Wheel", where certain Whitemud ravine species have been selected as natural indicators of the seasons. It gives the durations of ten phenological subseasons in Whitemud Ravine in 1988, and spans 166 days from April 9 (full bloom of Populus tremuloides) to the height of leaf colour in the same species. The chosen flowering phenophase is first bloom for all species except P. tremuloides. Moss (1960) found, through his poplar studies, that "the fully elongated staminate catkin" was the best "criterion of anthesis".

The first spring indicator is P. tremuloides flowering. First flowering of Prunus virginiana indicates the onset of early summer, and flowering of Aster laevis indicates the start of early fall. For 1988, durations of seasons were as follows: spring, 34 days; summer, 73 days, and fall, 59 days.

The subseason indicators following Solidago canadensis (July 11) are based on rough estimates of timing, as field readings were taken only every two weeks after July 17. These indicators should be refined after a number of years of summer and fall phenological data collecting.

Key to Figure 8: This figure shows the growing season divided into subseasons. The start and end of each subseason is marked by the occurrence of a phenophase. Phenophases and species were selected from the available Whitemud data. Plant wheels are useful to compare phenology between years or locations.

| Common Name | Species name |
|---|---|
| Poplar | Populus tremuloides |
| Violet | Viola adunca |
| Saskatoon | Amelanchier alnifolia |
| Chokecherry | Prunus virginiana |
| Bedstraw | Galium boreale |
| Wood Lily | Lilium philadelphicum |
| Buffaloberry | Shepherdia canadensis |
| Goldenrod | Solidago canadensis |
| Smooth Aster | Aster laevis |
| Bunchberry | Cornus canadensis |
| Fairy Bells | Disporum trachycarpum |

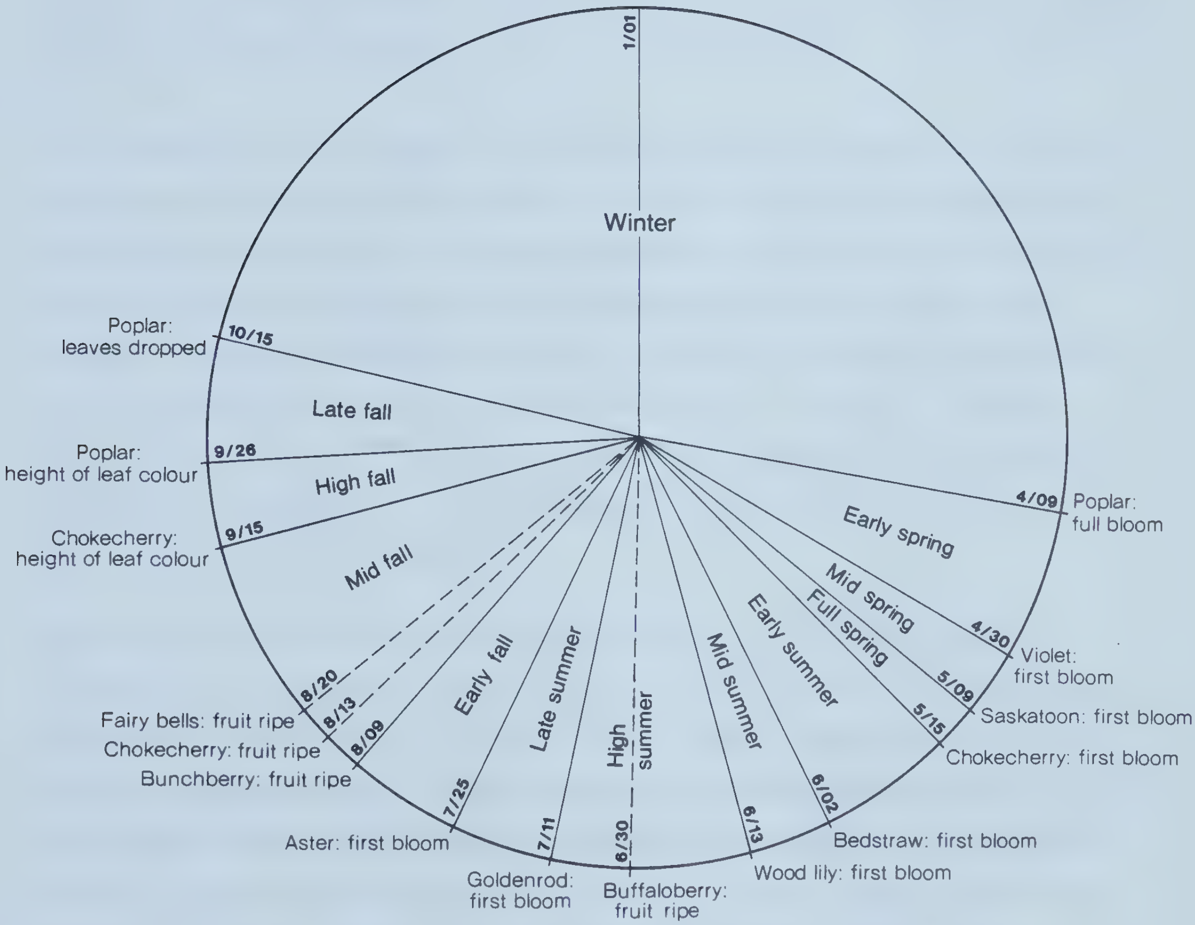



Figure 8: Plant wheel for 1988, Whitemud Ravine, a circular phenological diagram showing the subseasons of the year marked by selected plant phenophases.

### 3.3. Discussion

#### 3.3.1. Flowering Sequence for Whitemud Ravine

The flowering sequence illustrated by the phenostrips in Figure 5 establishes an initial estimate of the phenological pattern in this aspen parkland community. Ultimately, a sequence should be based on at least 10 year averages.

This phenological sequence for Whitemud Ravine provides an overview of timing for many species, but has not focussed on the specific timing of both sexes in dioecious species. Phenological information on some dioecious species is available in the literature, for example, Aralia nudicaulis is one of the few species where females flower earlier than males (Flanagan and Moser, 1985). Similar research on other dioecious species such as Populus tremuloides, Shepherdia canadensis, or Acer negundo would greatly assist future phenological investigations.

Species with short flowering times (Populus tremuloides, P. balsamifera, Shepherdia canadensis, Ribes spp., etc.) are the most useful for phenological studies. Less useful species seen here include: Fragaria spp., Viola canadensis, Mitella nuda, and Vicia americana, where full flowering is hard to estimate. Note that in general, later-flowering species tended to have longer flowering periods. "Best" species for phenology studies in the aspen parkland/mixed-wood boreal ecoregions of Alberta are listed in Appendix 4.

In Whitemud ravine there was no flowering peak of spring ephemerals as one sees in the eastern deciduous forests, where spring is a time of abundant resources; light, moisture and soil nutrients are higher on the forest floor than during the summer (Muller, 1978). In these deciduous forests, two major flowering peaks occur, before and after leaf expansion in the canopy. Canopy species include maples, oaks,

and other hardwoods which leaf out over a six week period in southwestern Quebec (Lechowicz, 1984). In Alberta, restricted deciduous tree diversity (Hosie, 1973) is most likely caused by lack of moisture and extreme winter temperatures. Populus tremuloides leafs out very early (May 1-12 in 1988), and light levels on the dry forest floor are thus reduced early in the spring. In the Edmonton area, almost all species flowering before the middle of May are woody (Moss, 1960). Shrubs such as Ribes and Shepherdia flower early while frosts are still occurring.

Recommended frequency of observations:
In Alberta, the growing season is compressed into a short period. Edmonton's frost-free period is 148 days long (Olsen, 1985). The vegetation grows rapidly, with flowering of poplar (Populus) and hazelnut (Corylus cornuta) occurring in April. For information on the whole growing season, phenology observations should be done at least every 3-4 days during the height of the growing season (mid-May to mid-August), and once a week before and after this period. Daily visits are necessary as Populus is starting to flower. Frequent visits are especially important during the first season of observation when individual development patterns for different species are being learned. Even with this frequency, first flowering will be missed for some species, and this can be overcome by using % flowering phenophases or with a bit of experience by noting "first bloom plus 2 days, or full bloom less one day".

Time permitted only a limited number of analyses for this Whitemud data. However, many other comparisons are possible. Mahall and Bormann (1978) divide nine common herbs of the hardwood forest of New Hampshire in four phenological groups : vernal photosynthetic, summer-green, late summer, and semi-evergreen. Future analysis of phenological data for Whitemud Ravine could also identify similar groups. Dierschke (1983) described symphenological groups and classified plants of the central European deciduous forest using a) Raunkiaer's (1934) classification based on position of overwintering perennating parts (geophyte, phanerophyte, etc.) and

b) whether flowers appear at the same time, earlier or later than leaves. Once similar analyses were made here of the ravine species, questions such as "do all low evergreen species such as Linnaea borealis leaf out relatively early yet flower late?" could be answered.

3.3.2. Flowering Times: 1987 and 1988

In general, flowering was earlier in 1988 than in 1987 (Table 9). In April, full bloom of Populus tremuloides and P. balsamifera was about a week earlier in 1988. In early May, however, flowering times were about the same, or 1987 was slightly earlier than 1988 (e.g. first flowering for Ribes triste, Ribes glandulosum, Prunus pensylvanica, Amelanchier alnifolia). This corresponds well with weather data from Table 11: in 1988, March was 4.7°C warmer than the 30-year average, whereas in 1987, March was only 1.6°C warmer. The month of April was roughly similar in the two years (1987 slightly warmer) but in 1988, May was 2.8°C or 82 degree-days warmer than average, as compared to May of 1987 which was 1.4°C or 37 degree-days warmer than average.

The snow and frost of May 19, 1987 seems to have delayed flowering, so that 1987 continued to be consistently later than 1988 for the rest of these flowering records (ends mid-July), by about a week. Herbaceous and shrubby species were compared to see if herbaceous species were more affected by this 1987 cold snap (i.e. had later flowering times) than shrubby species. No appreciable difference could be found between these two growth forms, for species flowering within two weeks after the storm.

Tent caterpillars defoliated Populus tremuloides in the second half of May, 1988 (Figure 5). Leaves grew back in June, but meanwhile it can be assumed that transect areas were exposed to more light and heat than usual. Therefore, flowering times for forest floor perennial species after defoliation would be expected to be somewhat earlier (Rathcke and Lacey, 1985) than the long-term averages. This

herbivory also meant a steady rain of caterpillar frass (excrement) which may also have enhanced growth by providing nutrients for the herbaceous plants below.

As a basis for comparing phenology between years, first flowering appears to be the best parameter. Full flowering is harder to estimate in the field for many species (Moss, 1960), especially in indeterminate inflorescences such as Epilobium angustifolium, Agrimonia striata, or Mertensia paniculata, in which the inflorescence keeps growing at the tip and developing new buds.

In the first field season (1987), familiarization with the locations and identity of species was occurring. Flowering of some species (especially inconspicuous ones such as Adoxa moschatellina) was most likely not recorded until their first flowering was past. Because of this, intensive phenology studies on large numbers of species require a minimum of two field seasons.

In studies of similar ecosystems, this data set will provide guidelines for the most efficient timing of field studies. The flowering sequences can help botanists locate rare species in the following way: if rare species "a" flowers 5 days after common species "b", then "a" can be sought effectively at the correct time. A future extension of this study could also examine insects with respect to pollination: which of the plants have concurrent or overlapping flowering periods, and how does this affect competition for resources such as pollinators? Which plant species develop and flower concurrently, thus competing for nutrients (Primack, 1985)?

### 3.3.3. Temperature, Location and Flowering

The relationship between location and flowering is consistent for most species, with earlier flowering occurring near the top of the ravine (Figure 7). Some exceptions to this trend include: Anemone canadensis, Epilobium angustifolium, Geum aleppicum, and Vicia americana.

The greater number of low minimum temperatures at #15a corresponds with later flowering as shown by the illustrated flowering sequences. The thermometer at #15a was on a poplar tree at the edge of a small meadow of Rosa and Symphoricarpos shrubs. This area often showed the latest flowering for species on the whole transect, possibly due to cold air drainage from a coniferous ravine nearby. This location also had the highest maximum temperatures, and there are possible explanations for this. This meadow was open to sunshine and heated up more than the shadier forest locations of #1a and #8. Air circulation was perhaps reduced in this bowl-like low meadow. While all thermometers were shaded by surrounding trees, they lacked any protective covers.

A more extensive measurement of microclimate conditions in a wider range of conditions (e.g. north versus south-facing slopes) would likely show more sharply-defined differences between sites in both temperature and flowering times. Jackson (1966) found that though the flowering phenology of each species varied considerably in diverse microclimates, the temperature sums required for flowering for that species in each location varied little.

3.3.4. Indicators of the Seasons: Plant Wheels

In a comparison with Figure 8 (the 1988 plant wheel), Figure 9 illustrates some of the same subseasons using long term average data from Edmonton (Russell, 1962; and Moss, 1960). The first bloom date for Viola adunca was estimated by subtracting 10 days from Moss' (1960) full bloom date. This number of days was based on average blooming periods as seen in the provincial data (see chapter 4).

Most 1988 subseasons (Figure 8) have a longer duration than the corresponding periods in Figure 9, with the period of full spring being the single exception. The period from early spring to early fall in 1988 lasted 107 days, compared to 96 days on long term average. As well, every species began flowering earlier in 1988 than expected from average dates. This earlier development corresponds as

Key to Figure 9:

Source: Moss (1960), Russell (1962).

| Indicator Plants | Latin name | calendar date | Julian date | Source |
|---|---|---|---|---|
| Poplar | _Populus tremuloides_ | April 25 | 115 | Moss (1960) |
| Violet | _Viola adunca_ | May 13 | 133 | Moss (1960) -his full bloom date minus 10 days was used as an estimate. |
| Saskatoon | _Amelanchier alnifolia_ | May 17 | 137 | Russell (1962) |
| Chokecherry | _Prunus virginiana_ | May 28 | 148 | Russell (1962) |
| Bedstraw | _Galium boreale_ | June 21 | 172 | " |
| Goldenrod | _Solidago canadensis_ | July 21 | 202 | " |
| Aster | _Aster laevis_ | July 30 | 211 | " |

Months of the Year:

1= January, 2= February, 3= March, 4= April, etc.

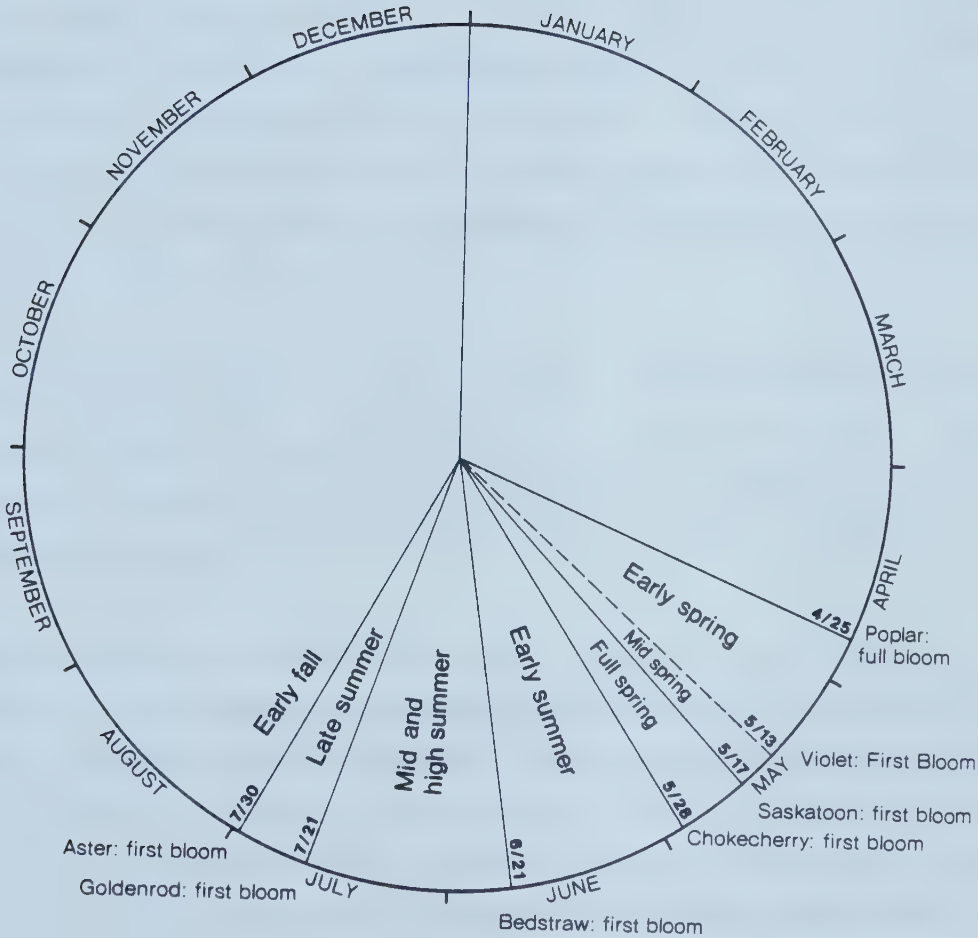



Figure 9: Plant wheel for Edmonton, using flowering dates averaged from long-term phenology studies for many of the same plant species as in Figure 8, for comparison.

one would expect with Edmonton airport climatic data which show increased temperatures in 1988.

Comparing Figure 8 to Figure 4 (the plant wheel using Innsbruck data of Winkler and Menneweger, 1977), the timespan from first spring flowering to the end of fall phenophase is much shorter for Edmonton (166 days) than for Innsbruck (244 days from bloom of Galanthus nivalis to leaf fall). The growing season is obviously much more compressed in Edmonton than in Innsbruck. In fact, the "only other region of the world that has a climate similar to Edmonton's is on the West Siberian Plain in the Union of Soviet Socialist Republics"! (Olson, 1985, p.42.)

Climatologists define a season as that "distinct portion of the year with uniform climate characteristics" (Olson, 1985, p.4). In Edmonton there are two consistent periods or seasons, winter and summer, and two, spring and fall, which are very variable in temperature (Table 12).

Phenologists could similarly define a season as "that distinct portion of the year with uniform plant development characteristics". Using indicator plants provides a much more reliable measurement of the seasonal progress of the biota than using the calendar date, as the timing of this seasonal progress can vary considerably from year to year. Over the decades of his Edmonton study, Moss (1960) found a spread of four to five weeks between the earliest and latest dates of full bloom for many of the spring-flowering species.

Summer-flowering species seem to show less year to year variation (Criddle, 1927). Both Moss and Criddle agreed that the "seasons vary enormously and the influences of an early or late spring are frequently felt throughout the entire flowering period of the year" (Criddle, 1927). Certainly the earliness of development in the spring of 1988 continued for the rest of the season.

Table 12: Climatological definitions of the four seasons of the year, as defined for Edmonton. "Starts" below refers to the average starting date when the mean daily temperature reaches the matching temperature definition (eg: drops below 0°C). Source: Olson, 1985, p. 5-7.

| season | starts | duration | temp. definition |
|---|---|---|---|
| winter | Nov.16 | 121 days | drops below 0°C |
| spring | Mar.17 | 63 days | rises to 0°C |
| summer | May 19 | 111 days | rises to 18°C |
| fall | Sept.6 | 70 days | drops below 18°C |

### 3.3.5. Comparisons With Other Data

First Flowering:

Russell (1962) summarized phenological records collected by Canada Agriculture at Edmonton for the 25 year period 1936-1961. A summary of these first flowering dates (earliest records and average dates) and the 1987 and 1988 dates from Whitemud ravine are shown in Table 13. First flowering dates for both 1987 and 1988 are consistently earlier than the long term average dates, as seen in the row of differences in this table.

This trend of early flowering in the two years recorded in Whitemud Ravine corresponds with the greater than usual number of growing degree days as shown in Table 11.

Bird (1982) averaged first flowering data for 12 key phenology species in Edmonton, from 1973-1982. Of the six species in common between Bird's and the Whitemud study, the four which flowered before mid-June were earlier in 1987 and 1988. In 1988, these species showed earlier flowering dates than Bird's averages by the following number of days: Populus tremuloides: 21, Amelanchier alnifolia: 4, Smilacina stellata: 8, and Prunus virginiana: 5.

Note that Bird's averages, which are from a more recent decade, are all (except Smilacina stellata) earlier than Russell's averages. There are other factors to consider which may influence this trend towards earlier flowering over time. Firstly, Russell's long-term averages are affected by the variability between years. A few isolated cold springs and subsequent delayed flowering may have greatly affected the average. As well, the expansion of the city of Edmonton over the years has most likely increased the "heat island effect", such that local plants now enjoy greater growing degree-days. There are many possible factors besides the "greenhouse effect" that must be considered.

Table 13: Comparison of first flowering dates, 1987 and 1988, for 14 plant species in Whitemud ravine, with long-term Edmonton average first flowering data. Underlined dates are earlier than Russell's earliest-recorded dates. "Differences" shows the number of days by which 1988 or 1987 dates were earlier than the Russell average date.
Source: Russell (1962), averaged from 1936-1961;
Bird (1982), averaged from 1973-1981;

| Species: | Populus tremuloides | Shepherdia canadensis | Amelanchier alnifolia | Prunus pensylvanica | Smilacina stellata | Prunus virginiana | Cornus stolonifera | Elaeagnus commutata |
|---|---|---|---|---|---|---|---|---|
| 1988 date Whitemud | month/day<br>3/24 | 4/20 | 5/09 | 5/06 | 5/17 | 5/15 | 5/17 | 5/22 |
| 1987 date Whitemud | 4/10 | 4/24 | 5/05 | 5/06 | 5/25 | 5/18 | 5/26 | 5/25 |
| Bird (1982): | | | | | | | | |
| average date: | 4/15 | | 5/14 | | 5/26 | 5/21 | | |
| # of years observed: | 6 | | 9 | | 9 | 9 | | |
| Russell (1962): | | | | | | | | |
| average date: | 4/27 | 5/03 | 5/17 | 5/18 | 5/25 | 5/28 | 6/01 | 6/05 |
| earliest date: | 4/13 | 4/13 | 5/05 | 5/06 | 5/10 | 5/18 | 5/20 | 5/26 |
| # of years observed: | 26 | 9 | 26 | 26 | 23 | 23 | 23 | 24 |
| Differences: | | | | | | | | |
| 1988-Russell average: (in Julian days) | -33 | -12 | -7 | -11 | -7 | -12 | -14 | -14 |
| 1987-Russell average: (in Julian days) | -17 | -9 | -12 | -12 | 0 | -10 | -6 | -11 |

Table 13, continued:

| Species: | *Maianthemum canadense* | *Viburnum opulus* | *Galium boreale* | *Anemone canadensis* | *Achillea millefolium* | *Solidago canadensis* |
|---|---|---|---|---|---|---|
| 1988 date Whitemud | 05/30 | 05/28 | 06/02 | 05/24 | 06/23 | 07/04 |
| 1987 date Whitemud | 06/04 | 06/07 | 06/13 | 06/03 | 06/22 | 07/15 |
| Bird (1982): | | | | | | |
| average date: | | | 06/10 | | 06/18 | |
| # of years observed: | | | 9 | | 9 | |
| Russell (1962) | | | | | | |
| average date: | 06/06 | 06/08 | 06/21 | 06/23 | 06/27 | 07/21 |
| earliest date: | 05/28 | 05/30 | 06/06 | 06/08 | 06/18 | 07/11 |
| # of years observed: | 10 | 8 | 12 | 20 | 18 | 22 |
| Differences: | | | | | | |
| 1988-Russell average (in Julian days) | -6 | -10 | -18 | -29 | -3 | -16 |
| 1987-Russell average (in Julian days) | -2 | -1 | -8 | -20 | -5 | -6 |

Full Flowering:

Moss (1960) recorded full flowering data on spring-flowering woody species for 32 years (1926-1958) (Table 14) . Most of his observations were made near the University of Alberta in Edmonton, in or near the North Saskatchewan River valley. He recorded the phenophase full bloom because he found this worked best as a measure of flowering in his earlier studies of poplar species (Moss, 1960). However, he noted that "though satisfactory for most amentiferous species, full bloom as a criterion is not so readily used for many other plants" (Moss, 1960, p. 113). First flowering seems to yield more consistent results in many species, therefore this phenophase has been used in most of the analyses of the Whitemud data.

Comparing Moss's average full bloom dates (Table 14) to 1987 and 1988 full bloom dates, it is evident that years 1987 and 1988 show earlier flowering. However, this earliness is within the range of variability noted by Moss, as seen by comparing the 1987 and 1988 ravine records with the earliest dates that Moss noted for full flowering over his decades of observations. Only three species were earlier than his records: Populus tremuloides , Populus balsamifera, and Viburnum opulus, and these by less than five days.

One potentially important but unknown factor is the exact location of Moss's observations, described as "in or near the river valley and close to the University of Alberta, Edmonton". This can refer to two very different microclimates. The first is the steep North Saskatchewan River valley near the University, which is coniferous, northeast facing, and cool. The second is very warm: the forest edge at the top of this river valley runs along the north side of campus (Saskatchewan Drive) and faces southwest. Most of the woody species he observed can be found there and this forest edge is one of the earliest flowering locations in the city (personal observation).

Table 14: Comparison of full flowering dates, 1987 and 1988, for 16 plant species in Whitemud ravine, with long-term Edmonton average data. Species are in order of Moss's full flowering dates. Underlined 1988 dates were earlier than Moss's earliest-recorded dates. A minus value in the "Differences" column indicates a 1988 or 1987 date that was earlier than than Moss's average date. Source: Moss (1960), averaged for 1926-1958

| Species: | Populus tremuloides | Populus balsamifera | Shepherdia canadensis | Ribes triste | Ribes oxyacanthoides * | Adoxa moschatellina | Prunus pensylvanica | Amelanchier alnifolia |
|---|---|---|---|---|---|---|---|---|
| | month/day | | | | | | | |
| 1988 date | 4/09 | 4/17 | 5/11 | 5/15 | 5/20 | 5/18 | 5/12 | 5/16 |
| 1987 date | 4/17 | 4/28 | 5/03 | 5/15 | 5/16 | 5/15 | 5/10 | 5/13 |
| Moss (1960): | | | | | | | | |
| average date: | 4/25 | 5/04 | 5/06 | 5/10 | 5/14 | 5/16 | 5/18 | 5/20 |
| earliest date: | 4/12 | 4/21 | - | 5/01 | 5/03 | - | 5/03 | 5/03 |
| latest date: | 5/15 | 5/19 | - | 5/21 | 5/22 | - | 6/10 | 6/07 |
| # of years observed: | 32 | 24 | 9 | 11 | 11 | 6 | 6 | 25 |
| Differences: | | | | | | | | |
| 1988-Moss's average: (in Julian days) | -15 | -16 | 6 | 6 | 7 | 3 | -5 | -3 |
| 1987-Moss's average (in Julian days) | -8 | -6 | -3 | 5 | 2 | -1 | -8 | -7 |

* (Moss uses the name Ribes setosum)

Table 14, continued

| Species: | *Viola adunca* | *Prunus virginiana* | *Viola canadensis* * | *Actaea rubra* | *Aralia nudicaulis* | *Viburnum opulus* | *Rosa acicularis* | *Lilium philadelphicum* |
|---|---|---|---|---|---|---|---|---|
| | month/day | | | | | | | |
| 1988 date | 5/16 | 5/23 | 6/03 | 6/04 | 6/01 | 6/01 | 6/09 | 6/27 |
| 1987 date | 5/18 | 5/29 | 6/10 | 6/12 | 6/04 | 6/09 | 6/14 | 7/04 |
| Moss (1960): | | | | | | | | |
| average date: | 5/23 | 6/03 | 6/04 | 6/06 | 6/09 | 6/15 | 6/20 | 6/22 |
| earliest date: | - | 5/16 | - | - | - | 6/02 | - | - |
| latest date: | - | 6/22 | - | - | - | 6/30 | - | - |
| # of years observed | 4 | 17 | 5 | 7 | 6 | 12 | 7 | 4 |
| Differences | | | | | | | | |
| 1988-Moss's average: (in Julian days) | -6 | -10 | 0 | -1 | -7 | -13 | -10 | 6 |
| 1987-Moss's average: (in Julian days) | -5 | -5 | 6 | 6 | -5 | -6 | -6 | 12 |

* (Moss uses the name: Viola rugulosa)

If Moss's observations were made mainly in this second, warmer location, then these dates should be early compared to the cooler Whitemud ravine location. This is shown by the following data. Full flowering of Amelanchier alnifolia in 1987 and 1988 was five days earlier at the top of the valley along Saskatchewan Drive than it was at the earliest Whitemud Ravine location. Similarly, full flowering of Populus tremuloides in 1988 was about 6 to 8 days earlier along Saskatchewan Drive than in Whitemud Ravine. So, if Moss's observations were at the top of the valley, and five days are subtracted from the Whitemud flowering records to better match them to the University area, the earlier nature of these 1987 and 1988 Populus records becomes even more apparent. The other species still fall into the range of variability found in Moss's long-term study.

While the 1987 and 1988 data show consistently earlier first flowering dates than either Bird's or Russell's longer-term averages, they do not show consistently earlier full bloom dates. Long-term phenology records do provide a useful climatic tool, and as more years of flowering data become available in the future, comparisons with previous long-term averages may provide meaningful evidence of the climate warming caused by the human-enhanced greenhouse effect.

## 4. Extensive Study: the Phenology Survey of Alberta

### General Physical Environment of Alberta:

Much of Alberta was extensively glaciated in the last ice age. This ice receded by 8000-9000 years ago, leaving behind surficial till and moraine, and deposits of clay, sand, and silt from ancient lakes. The province's natural regions are illustrated in Figure 10, and maps of the major vegetation types and the soils of Alberta are illustrated in Packer (1983).

Alberta's climate is largely continental, influenced by air masses from the north which bring intense periods of winter cold. But warm weather systems from the Pacific moderate the climate, thus Alberta is warmer than provinces farther east at the same latitude. The most important controlling factors of Alberta's climate are the altitude and width of the Canadian Rockies which act as a barrier, and the direction of the prevailing winds (generally west, southwest, and northwest (Longley, 1967). Warm Pacific winds (chinooks) often displace cold Arctic air, causing rapid winter temperature increases especially in southern Alberta.

Temperature changes in spring and fall are rapid. On average, the temperatures on the prairies rise .3° C per day between mid-March and mid-May. Summers can be hot, with maximum temperatures over 30° C to be expected annually. The solar angle is low even in summer, but long days and the relative lack of moisture and dust in the air means that Alberta absorbs much heat from sunlight.

Two thirds or more of annual precipitation falls in the summer. In southeast Alberta, lack of precipitation has produced an area of steppe or semi-desert, and none of the agricultural areas of the province receive more than 480 mm of precipitation annually (Longley, 1980).

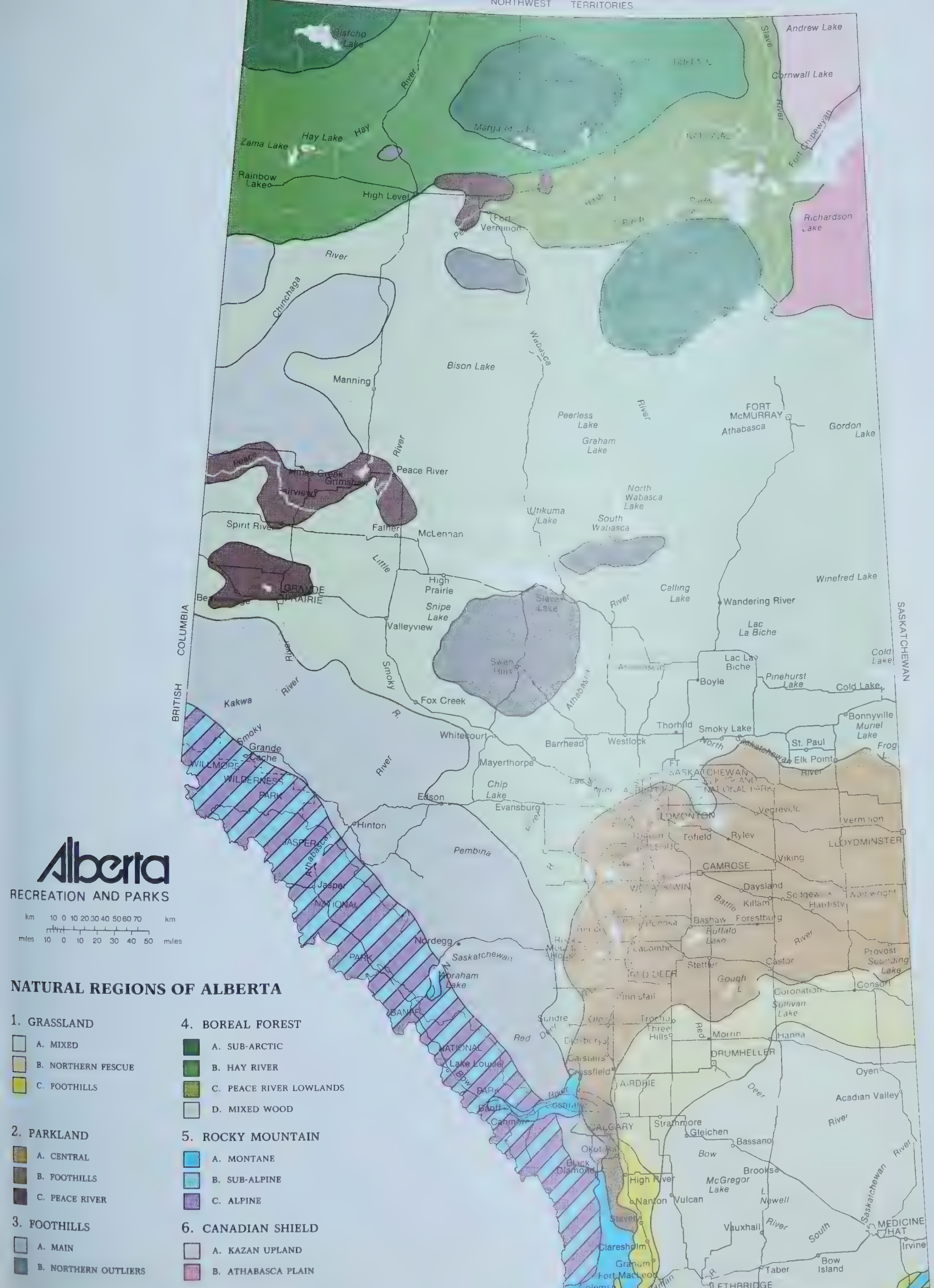



Figure 10: Map of the natural regions of Alberta
Source: Alberta Recreation and Parks

## 4.1. Materials and Methods

### 4.1.1. Survey Establishment

This survey asked volunteers around the province to observe and record three flowering dates (10%, 50%, and 90% flowering) for up to 15 native plant species (Table 15). A previous provincial survey had collected information on general flowering times of 12 "key" phenology species for the period 1973-1983 (Bird, 1983). The present survey used these same species and added three more species which had the four important qualities necessary for a public phenology survey. These qualities are: ease of recognition, wide distribution, a relatively short and consistent flowering period, and lack of subspecies. The three additional species, *Elaeagnus commutata*, *Linnaea borealis*, and *Epilobium angustifolium*, have a distribution which includes northern Alberta. They were selected to enhance the phenological knowledge of this area.

Three flowering phenophases were selected for this survey: first flowering, defined here as 10% of flower buds open; mid flowering, or 50% of buds open; and full flowering, 90% of buds open (Kreeb, 1977). This sequence of development dates was requested to ensure that the plants would be observed over a period of time, thus increasing the accuracy of phenophase estimation.

Table 15: The 15 "key" phenology species used in the provincial survey

| Latin name | Common name |
|---|---|
| Anemone patens L. var. wolfgangiana (Bess) Koch | Prairie Crocus |
| Populus tremuloides Michx. | Aspen Poplar |
| Viola adunca J.E. Smith | Early Blue Violet |
| Thermopsis rhombifolia (Nutt.) Richards. | Golden Bean |
| Amelanchier alnifolia Nutt. | Saskatoon |
| Smilacina stellata (L.) Desf. | Star-flowered Solomon's-seal |
| Prunus virginiana L. var. melanocarpa (A.Nels.) Sarg. | Choke Cherry |
| Elaeagnus commutata Bernh. ex Rydb. | Wolf Willow |
| Lathyrus ochroleucus Hook. | Yellow Pea Vine |
| Galium boreale L. | Northern Bedstraw |
| Linnaea borealis L. | Twinflower |
| Achillea millefolium L. | Common Yarrow |
| Lilium philadelphicum L. var. andinum (Nutt.) Ker. | Western Wood Lily |
| Gaillardia aristata Pursh | Brown-Eyed Susan |
| Epilobium angustifolium L. | Fireweed |

4.1.2. Promotion in 1987 and 1988

In 1987, material sent to potential observers included: a) a one page description of the survey, b) a three-page "Wildflower Guide" which provided black and white sketches and descriptions to help observers identify the plants; c) a data sheet which included space for dates and remarks, and which provided information on recognition of flowering and site selection.

Address lists were obtained from Dr. Bird for his previous volunteer network, and from the Federation of Alberta Naturalists' membership list. Material was sent to about 200 potential volunteers.

Early in 1988, a 22-page four-colour booklet entitled "Alberta Wildflowers - A Flowering Date Survey" was produced and a total of 3500 copies were printed, of which 3000 were distributed by July of that year. The booklet (Appendix 2) provides information on how to recognize plants (colour photos and text), how to observe flowering, and how to select areas and plants for observation. As well, notes on the species' habitats, ecology, ethnobotany and importance to wildlife are included.

Overall, promotion of this survey required a large time commitment. From 1987 to the spring of 1990, the following were done. Articles varying in length from a few paragraphs to several pages have appeared in the newsletters or special publications of 12 organizations (societies, foundations, government departments), and in at least eleven newspaper articles. Two radio interviews, two papers presented at conferences (Regina, Toronto), four poster sessions and 13 public talks have also promoted awareness of the survey (Appendix 5). As well, answering correspondence and enquiries about the survey (especially in spring), about plant taxonomy, and about issues related to native plants was a continuous process.

#### 4.1.3. Data analysis

Information submitted by observers for 1987 (1285 flowering dates) and 1988 (2970 flowering dates) was processed with dBASE III PLUS. This database program was selected because it offered the capability of handling several data files at the same time.

#### 4.1.4. Mapping

##### 4.1.4.1. Plotting

One avenue in the search for a suitable mapping technique led to the Crop Protection Branch of Alberta Agriculture, noted for its computer mapping capability. Plotting of data was done using their Geographic Data Processing and Plotting system, and different techniques were explored to find trends in the progression of flowering across Alberta. Files were checked before mapping and a total of 89 inconsistent records with unusually early or late dates were eliminated. Large 1:2,000,000 scale maps were produced showing the distributions of 1987 and 1988 observers. As well, observation locations for a few species with relatively large data sets, Achillea millefolium, Anemone patens, Prunus virginiana and Epilobium angustifolium were plotted. To show the pattern of development, maps of one flowering phase of a species were done plotting different colour and symbol combinations for each successive 4 day interval. This was done for three species: Prunus virginiana (10% flowering), and Epilobium angustifolium and Amelanchier alnifolium (10 and 90% flowering). At this point it was realized that trends in flowering were difficult to see using this method and plotting was therefore abandoned.

Alberta Agriculture also assisted later by adding the latitude and longitude coordinates to the existing legal descriptions (section, township, range, meridian) in the 1988 data file, which permitted further mapping at other institutions.

4.1.4.2. Area Averaging and Mapping by Hand:

The plotting revealed a lot of variability in the data. A possible solution (in the search for trends in flowering across the province), was to average the data by area. Because the 1987 data represented much fewer observers than the 1988 set, as well as having very little representation from northern Alberta, the 1988 data set was used for further analysis.

Previous Alberta phenology data for these species, collected 1973-1981 had been averaged for the six most-reported areas of the province (Bird, 1982). To delimit areas for averaging the 1988 data set, the province was divided into 29 rectangular areas defined by township and range. These were selected by enclosing observation locations, by approximating the areas previously described (Bird, 1981), and by restricting areas to one ecoregion where possible (Strong and Leggat, 1981). The designated areas were selected from the database, and then the 1988 records were sorted in order of species, phenophase, and dates. The data were seen to be quite variable even for the same species, phase and location. Often a one month range in dates was found within one area or city (e.g. Calgary), in the estimates of 10% flowering for a species. Dates which appeared very unusually early or late with respect to other dates from a certain location or observer, were eliminated.

A dBASE program was developed to convert data to Julian dates and average them (Appendix 6). Since data had to be checked and some inconsistent data removed, it was as quick to average it by hand for each area, species and phase. Averages for areas were then transferred to maps, to portray by patterned intervals the progression of flowering for 10% and 90% flowering for each species.

### 4.1.4.3. Computer Mapping

One very useful way to map flowering trends is through computer contouring programs. For phenological data, the contours are isophanes, or lines which join points of equal blooming time. The maps then show which areas are at the same stage of development at a given time and show the progression of flowering. While "SYMAP" has been the favoured mapping program of many phenologists (Reader and Lieth, 1984), the Alberta mapping experts that were consulted felt that it was less useful than some more modern programs. Two avenues were explored: two surfacing methods with the University of Alberta's Geography Department, and a contouring package with Agriculture Canada in Lethbridge.

At our University's Geography Department, the Amelanchier alnifolia first bloom data set (selected for large size and consistency) was mapped using two surfacing techniques: exact fitting, and trend surface analysis. The latter is a polynomial program capable of fitting global trends from 1 to 7 degrees of freedom for up to 1000 observations (Dr. Eyton, 1989, personal communication).

Another mapping technique tried was a microcomputer-based geographic information system (GIS) called SPANS (TYDAC Technologies, 1989), equipped for colour map production, at Agriculture Canada, Lethbridge.

An initial series of linear and non-linear contour maps were made using SPANS of all 15 species and flowering phases, to illustrate the progression of flowering across the province. The contour maps connect points of equal blooming with isolines and shade the areas enclosed with a specified colour. Data sets selected for further refinements in mapping included species and phases with a greater number of observations, and more consistency in observer estimates as determined during the area averaging. These included: Amelanchier alnifolia 10, 50, and 90%; Smilacina stellata 10%; Prunus virginiana

10 and 90%; Elaeagnus commutata 10%, Galium boreale 90%; and Epilobium angustifolium 10% and 90%.

Many series of maps were done with improvements including changes to the colour palette to clearly show the flowering sequence, and the reduction of interpolation by SPANS to earlier dates at the east and west observation boundaries.

4.1.5. Synchronization of Species

It is useful to have a set of flowering predictions for areas of the province, such as "species A = species B + 4 days". These can act as a gauge of the season's progress, and show up accelerated or retarded plant development.

The dates averaged by location for 29 areas of the province were used to examine time intervals between flowering phases of species sequential in their order of flowering. These intervals were averaged for 10 areas. The number of days difference between phenophases for three intervals was calculated: for full bloom of a species (A) to first bloom of the next species (B), for first bloom of A to first bloom of B, and for full bloom of A to full bloom of B.

4.1.6. Statistics

The revised 1988 data set (89 records removed as previously described under "Plotting") was analysed using SAS (1985) while on the VAX mainframe computer of Agriculture Canada. The following descriptive statistics were produced.

a) Frequency bar charts of the numbers of observations versus midpoint Julian date (5 day intervals) were created for each of the three flowering phases of the 15 species.

b) The total number of observations, mean Julian date, range of dates, and standard deviation for the 45 data sets were determined.

c) Moran's I statistic: This spatial autocorrelation coefficient was recommended (Dr. Johnson, 1990, pers. comm.) as potentially valuable for analyzing the degree of dependence of flowering dates. It expresses the ratio of the spatial covariance to the observation variance (Sokal and Oden, 1978), and varies from -1 to +1. If values are close to 1, points are highly correlated, that is flowering dates are dependent on the values at neighbouring sites, but if close to 0, poorly correlated.

To test this statistic for future use with annual phenology data, one species was selected. The Moran's I coefficient was calculated for pairs of observation points 0-10, 10-20, etc. up to 90-100 km apart, using the data set for Amelanchier alnifolia, since it had both relatively large size and small standard deviations.

d) Regression: Linear and/or quadratic regressions of Julian date as a function of latitude were made for the less mountainous part of Alberta (110 to 116 degrees longitude and 51 to 60 degrees latitude), to see if there was a clear relationship between latitude and flowering time. The data sets for Amelanchier alnifolia, Prunus virginiana, and Epilobium alnifolium were chosen on the basis of large size and wide geographic distribution.

## 4.2. Results

Data received:

In 1987, 60 observers sent in 1285 flowering dates for a total of 76 observation locations. In 1988, 209 data sheets and 2970 flowering dates were received. This represented 190 observers and 231 different locations. Thirty-three of the 226 volunteer weather observers initially contacted in 1988 returned flowering dates (15%), as did 22 of the 143 fire towers contacted (15%). This corresponds with the Wisconsin Phenological Society, which receives a maximum of 15% response from its membership (Lettau, 1987). Reminders to send in flowering dates were sent out to observers in the fall of 1988. This does increase the amount of data received, and should be done annually.

Observer distribution in 1988 showed the greatest density in south central Alberta which is the most populated part of the province (Figure 11). The areas with few observations included the southeast corner (Lethbridge - Medicine Hat and south), the foothills NW of Calgary to Grande Prairie, and north of a line drawn from the Peace Country to Fort McMurray.

### 4.2.1. Statistics

#### 4.2.1.1. Summary

Frequency distributions of flowering dates show that the distributions are all approximately normal (Appendix 7).

In the summary of descriptive statistics (Table 16), species are listed in the order of their mean 10% flowering date.

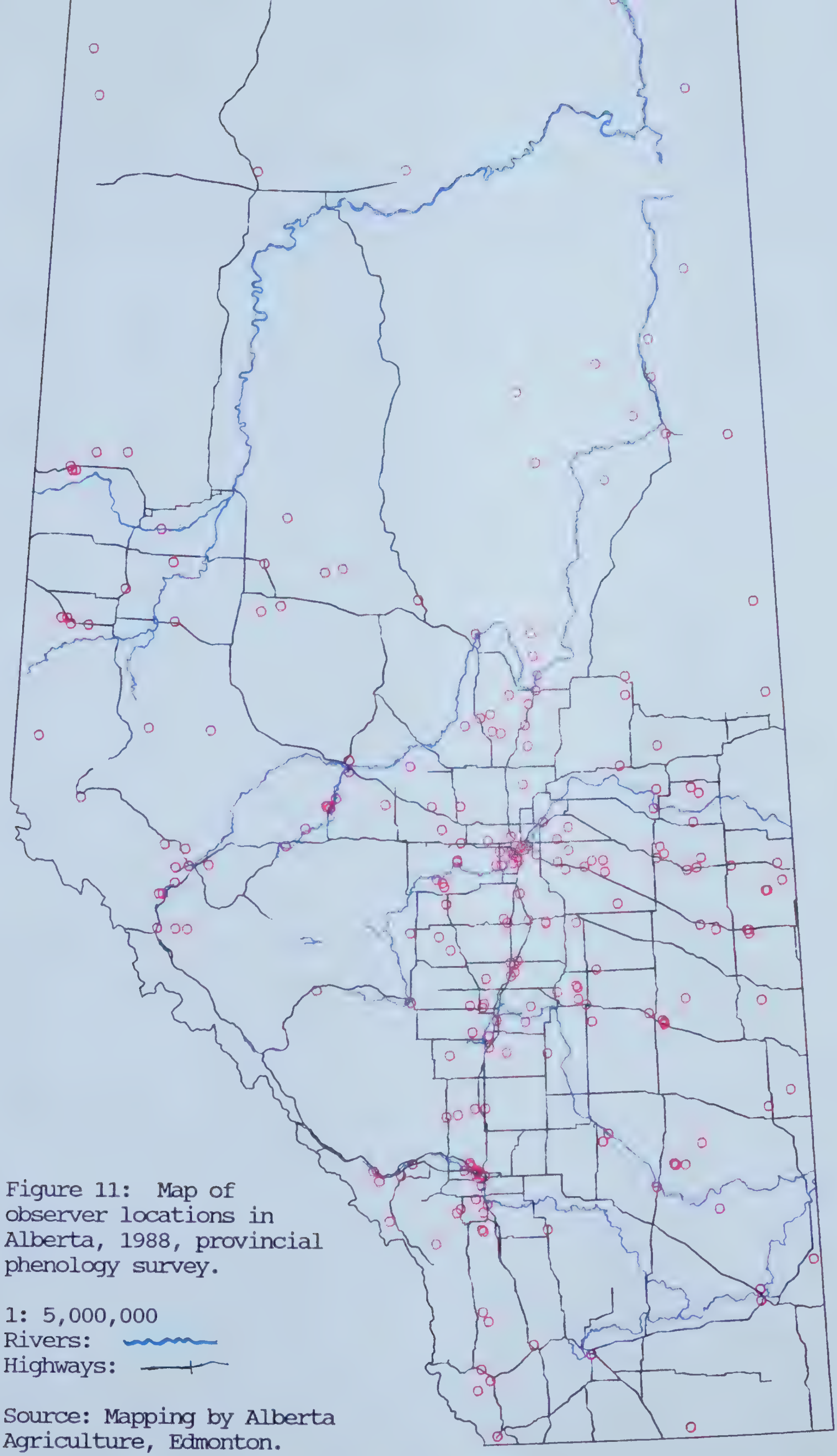


Figure 11: Map of observer locations in Alberta, 1988, provincial phenology survey.

1: 5,000,000
Rivers:
Highways:

Source: Mapping by Alberta Agriculture, Edmonton.

Table 16: Summary of descriptive statistics for the 1988 Provincial Survey results

KEY: N = number of observations (* indicates values greater than 70);
min. value = minimum Julian date for this flowering phase of this species;
* under standard deviations indicates values smaller than 8;
Rate in days is the rate of flowering, = 90% mean date - 10% mean date.

| Species | Flowering phase | N | Mean Julian date | Mean calendar date | Min. day | Max. day | Range in days | Standard deviation | Rate in days |
|---|---|---|---|---|---|---|---|---|---|
| Anemone patens | 10% | 72* | 98.3 | April 7 | 80 | 139 | 59 | 8.62 | |
| | 50% | 59 | 104.2 | April 13 | 92 | 144 | 52 | 8.34 | 13 |
| | 90% | 73* | 110.7 | April 20 | 93 | 147 | 54 | 10.42 | |
| Populus tremuloides | 10% | 61 | 101.8 | April 11 | 74 | 136 | 62 | 14.35 | |
| | 50% | 58 | 106.9 | April 16 | 84 | 137 | 53 | 12.53 | 7 |
| | 90% | 66 | 109.1 | April 18 | 90 | 153 | 63 | 14.22 | |
| Viola adunca | 10% | 75* | 123.6 | May 3 | 96 | 143 | 47 | 8.56 | |
| | 50% | 72* | 130.0 | May 9 | 106 | 150 | 44 | 7.42* | 13 |
| | 90% | 92* | 136.5 | May 16 | 119 | 168 | 49 | 9.60 | |
| Thermopsis rhombifolia | 10% | 55 | 123.6 | May 3 | 107 | 136 | 29 | 6.21* | |
| | 50% | 53 | 128.8 | May 8 | 113 | 140 | 27 | 6.17* | 10 |
| | 90% | 53 | 133.7 | May 13 | 108 | 147 | 39 | 7.21* | |
| Amelanchier alnifolia | 10% | 90* | 130.8 | May 10 | 108 | 148 | 40 | 5.58* | |
| | 50% | 85* | 134.1 | May 13 | 116 | 153 | 37 | 5.68* | 7 |
| | 90% | 112* | 138.0 | May 17 | 127 | 162 | 35 | 5.94* | |
| Prunus virginiana | 10% | 62 | 139.2 | May 18 | 122 | 162 | 40 | 7.62* | |
| | 50% | 49 | 142.5 | May 21 | 127 | 166 | 39 | 6.49* | 7 |
| | 90% | 67 | 145.6 | May 25 | 132 | 168 | 36 | 6.84* | |
| Smilacina stellata | 10% | 61 | 140.7 | May 20 | 121 | 170 | 49 | 9.01 | |
| | 50% | 56 | 145.4 | May 24 | 128 | 178 | 50 | 10.42 | 11 |
| | 90% | 63 | 151.5 | May 30 | 133 | 177 | 44 | 10.72 | |

Table 16, continued:

| Species | Flowering phase | N | Mean Julian date | Mean calendar date | Min. day | Max. day | Range in days | Standard deviation | Rate in days |
|---|---|---|---|---|---|---|---|---|---|
| Elaeagnus commutata | 10% | 45 | 145.6 | May 25 | 127 | 167 | 40 | 9.11 | |
| | 50% | 33 | 148.7 | May 28 | 131 | 170 | 39 | 9.71 | 7 |
| | 90% | 46 | 152.7 | June 1 | 138 | 183 | 50 | 9.55 | |
| Lathyrus ochroleucus | 10% | 72* | 148.6 | May 28 | 135 | 173 | 38 | 8.93 | |
| | 50% | 46 | 153.9 | June 2 | 140 | 177 | 37 | 10.63 | 13 |
| | 90% | 74* | 161.5 | June 9 | 140 | 192 | 52 | 11.73 | |
| Galium boreale | 10% | 80* | 163.0 | June 11 | 142 | 193 | 51 | 10.11 | |
| | 50% | 69 | 169.8 | June 18 | 149 | 202 | 53 | 11.34 | 10 |
| | 90% | 81* | 172.9 | June 21 | 152 | 207 | 55 | 11.44 | |
| Linnaea borealis | 10% | 33 | 164.5 | June 12 | 138 | 187 | 49 | 12.21 | |
| | 50% | 31 | 171.6 | June 20 | 141 | 201 | 60 | 13.85 | 11 |
| | 90% | 37 | 175.8 | June 24 | 146 | 206 | 60 | 12.46 | |
| Lilium philadelphicum | 10% | 56 | 165.2 | June 13 | 142 | 180 | 38 | 7.29* | |
| | 50% | 50 | 170.8 | June 19 | 149 | 185 | 36 | 7.37* | 11 |
| | 90% | 58 | 175.8 | June 24 | 159 | 200 | 41 | 7.50* | |
| Gaillardia aristata | 10% | 40 | 165.7 | June 14 | 142 | 184 | 42 | 9.29 | |
| | 50% | 39 | 174.7 | June 23 | 149 | 215 | 66 | 12.64 | 15 |
| | 90% | 40 | 181.0 | June 29 | 157 | 223 | 66 | 14.50 | |
| Achillea millefolium | 10% | 88* | 169.2 | June 17 | 134 | 193 | 59 | 11.56 | |
| | 50% | 58 | 175.5 | June 23 | 146 | 199 | 70 | 11.58 | 14 |
| | 90% | 78* | 183.3 | July 1 | 147 | 215 | 68 | 15.08 | |
| Epilobium angustifolium | 10% | 90* | 177.5 | June 25 | 151 | 211 | 60 | 10.19 | |
| | 50% | 82* | 185.6 | July 4 | 162 | 223 | 61 | 11.37 | 17 |
| | 90% | 76* | 194.6 | July 13 | 157 | 229 | 72 | 14.77 | |

The most reported species (over 85 observations) include Viola adunca- 90%, Amelanchier alnifolia- all phases, Achillea millefolium- 10%, and Epilobium angustifolium - 10%. Least-reported species (under 50 observations per phase for all phases) include Elaeagnus commutata, Linnaea borealis, and Gaillardia aristata.

Rate of flowering across Alberta is calculated by subtracting the 10% mean date from the 90% date. This gives a figure in days with which to compare species. The fastest pulse of flowering is shown by Populus tremuloides, Amelanchier alnifolia, Prunus virginiana, and Elaeagnus commutata.

Standard deviations range from a low of 5.58 (Amelanchier alnifolium 10%) to a high of 14.77 (Epilobium angustifolium 90%).

4.2.1.2. Moran's I coefficient

The spatial autocorrelation (Table 17) is very low, indicating that the variation is considerable even over a short distance. There is no obvious geographic pattern for the scale under examination. One would expect the correlation to be highest for the closest points (0-10 km, 10-20 km), and decrease as space between sites increased. This is shown only by the 10% Amelanchier alnifolia data, but even here the correlation figures are not significant. As the flowering progresses from first to full or 90% bloom, there is some increase in autocorrelation, perhaps reflecting the slightly larger size of the 90% data set (112 observations) versus the 10% set (90 observations) or the 50% set (85 observations). Ease of recognition of the full bloom phase by volunteers may be a factor in the increased correlation.

Table 17: Moran's I statistic, used to test spatial autocorrelation for 1988 dates of three flowering phases of <u>Amelanchier</u> <u>alnifolia</u>. Data from Alberta observers.

Note: Range refers to the distance between two points; # of pairs the number of data pairs this distance apart. The standard error is shown in brackets after the Moran's I statistic. NS means "not significant", * means significant at a=0.05, and ** means significant at a=0.01.

10% or First Flowering:

| Range (km) | # of pairs | Moran's I | | |
|---|---|---|---|---|
| 0 - 10 | 12 | 0.289 | (0.278) | NS |
| 10 - 20 | 30 | 0.186 | (0.177) | NS |
| 20 - 30 | 35 | 0.296 | (0.162) | NS |
| 30 - 40 | 43 | -0.024 | (0.146) | NS |
| 40 - 50 | 51 | 0.021 | (0.134) | NS |
| 50 - 60 | 63 | -0.036 | (0.121) | NS |
| 60 - 70 | 50 | 0.040 | (0.135) | NS |
| 70 - 80 | 58 | -0.198 | (0.126) | NS |
| 80 - 90 | 60 | 0.024 | (0.123) | NS |
| 90 -100 | 61 | -0.040 | (0.123) | NS |

50% or Mid-Flowering:

| Range (km) | # of pairs | Moran's I | | |
|---|---|---|---|---|
| 0 - 10 | 6 | -0.006 | (0.398) | NS |
| 10 - 20 | 29 | -0.034 | (0.180) | NS |
| 20 - 30 | 34 | 0.048 | (0.164) | NS |
| 30 - 40 | 42 | -0.022 | (0.148) | NS |
| 40 - 50 | 37 | 0.042 | (0.158) | NS |
| 50 - 60 | 60 | 0.084 | (0.124) | NS |
| 60 - 70 | 45 | 0.021 | (0.143) | NS |
| 70 - 80 | 41 | -0.328 | (0.151) | * |
| 80 - 90 | 47 | -0.064 | (0.141) | NS |
| 90 -100 | 50 | 0.027 | (0.136) | NS |

90% or Full Flowering:

| Range (km) | # of pairs | Moran's I | | |
|---|---|---|---|---|
| 0 - 10 | 28 | -0.094 | (0.182) | NS |
| 10 - 20 | 59 | 0.210 | (0.125) | NS |
| 20 - 30 | 44 | 0.435 | (0.146) | ** |
| 30 - 40 | 73 | 0.139 | (0.112) | NS |
| 40 - 50 | 66 | 0.215 | (0.119) | NS |
| 50 - 60 | 115 | 0.168 | (0.089) | * |
| 60 - 70 | 85 | 0.085 | (0.104) | NS |
| 70 - 80 | 95 | 0.293 | (0.099) | ** |
| 80 - 90 | 95 | 0.152 | (0.098) | NS |
| 90 -100 | 105 | 0.143 | (0.094) | NS |

4.2.1.3. Regression

Regressions shown in Figures 12: a-l were calculated using data from the less mountainous area of Alberta, and show flowering dates as a function of latitude. A subset of species was selected on the basis of large sample size and wide distribution of observations. Linear regressions (y=a+bx) of all phases of Amelanchier alnifolia and Prunus virginiana (Figures 12:a-f), and quadratic regressions ($y=a+bx+cx^2$) of all phases of Prunus virginiana and Epilobium angustifolium (Figure 12:g-l) are shown. The linear regressions appear to fit the data as well as the quadratic regressions, but the p values show that while the slopes (b) of all the linear regressions are significant at .01, many of the quadratic regressions are not. In particular, the slope of the regression of Prunus virginiana 10% is not significant once the quadratic term is added.

The $r^2$ value is the proportion of the variance of the flowering date which is accounted for by the latitude. It is relatively large in some cases (e.g. linear regressions: Amelanchier 10%, $r^2$ =42%, and Prunus 90%, $r^2$= 36%), considering that many other factors such as altitude, longitude, proximity to cities, aspect, etc. should also be considered. While in general the flowering date increases with increasing latitude, it is not a direct relationship.

Figure 12: Linear (a-f) and quadratic (g-l) regressions of flowering dat
and latitude for the non-mountainous parts of Alberta,
(ie: 110 to 116 degrees W longitude, and 51 to 60 degrees N latitude),
for selected plant species from the provincial survey.

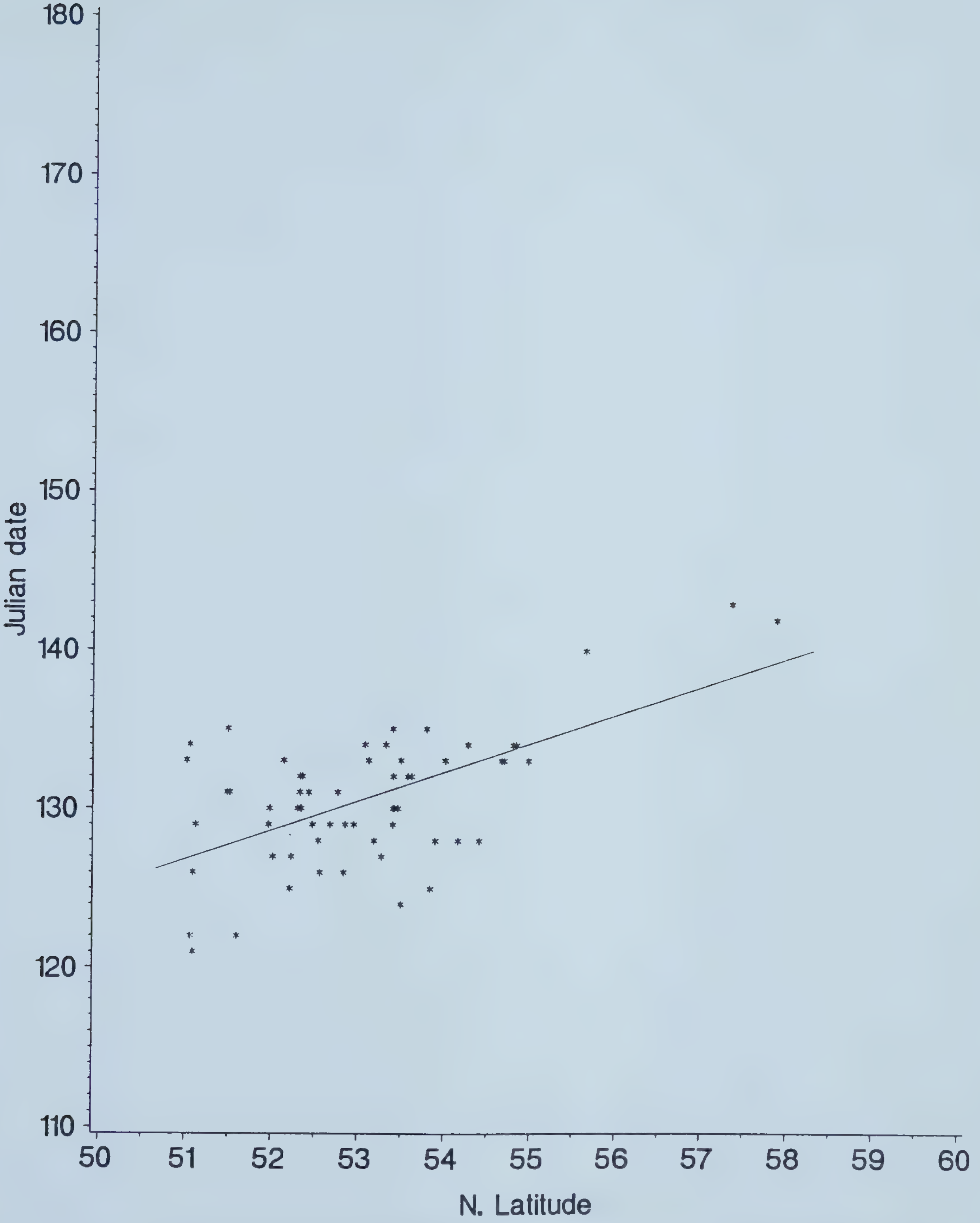



Figure 12-a: Linear regression for Amelanchier alnifolia, 10% flowering for flowering date and degrees N latitude.
$r^2$=.36; y=a+bx where a=34.31 (p=.0390) and b=1.81 (p=.0001)

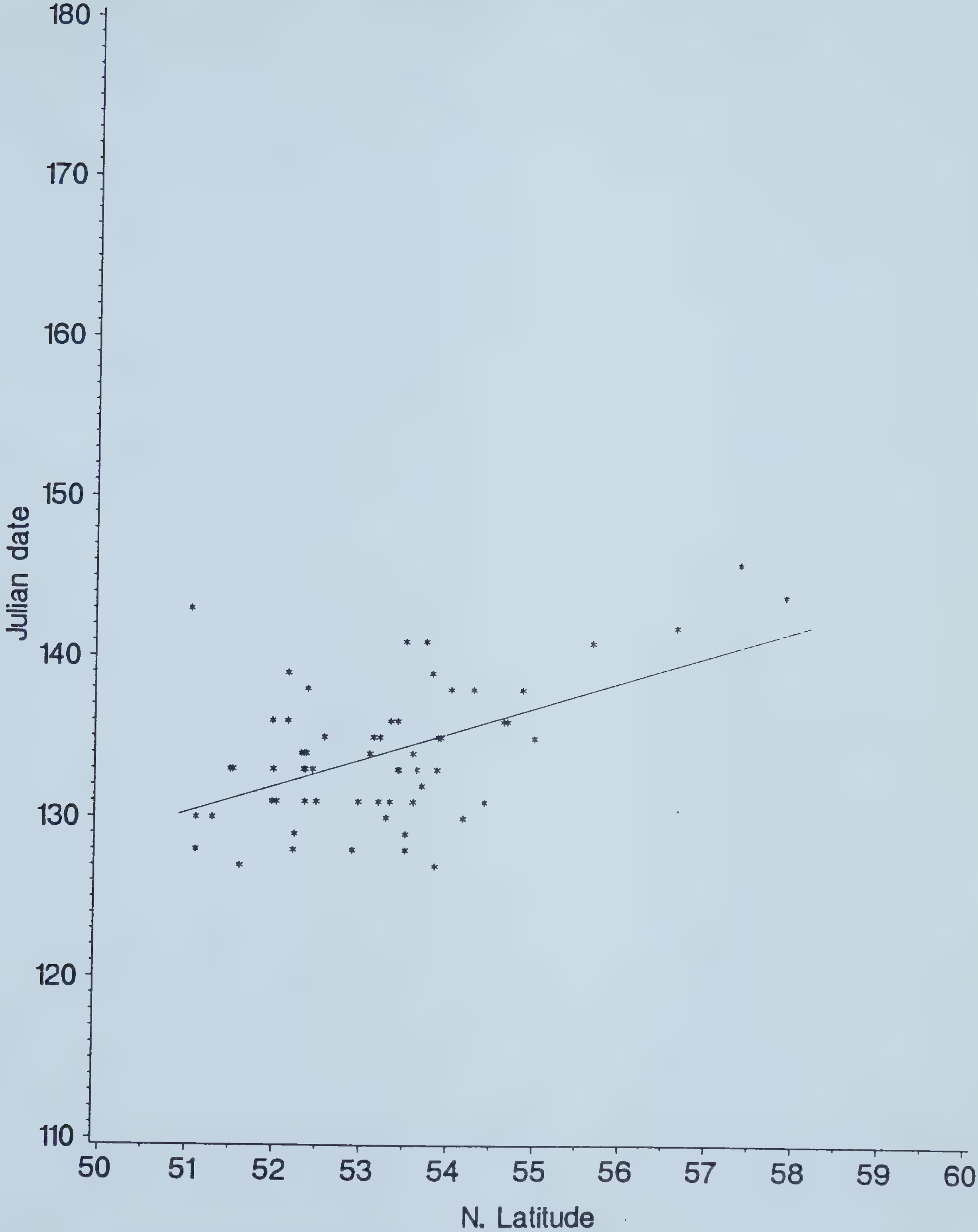



Figure 12-b: Linear regression for Amelanchier alnifolia, 50% flowering for flowering date and degrees N latitude.
$r^2$=.28; y = a+bx where a=46.78 (p=.0107) and b=1.64 (p=.0001)

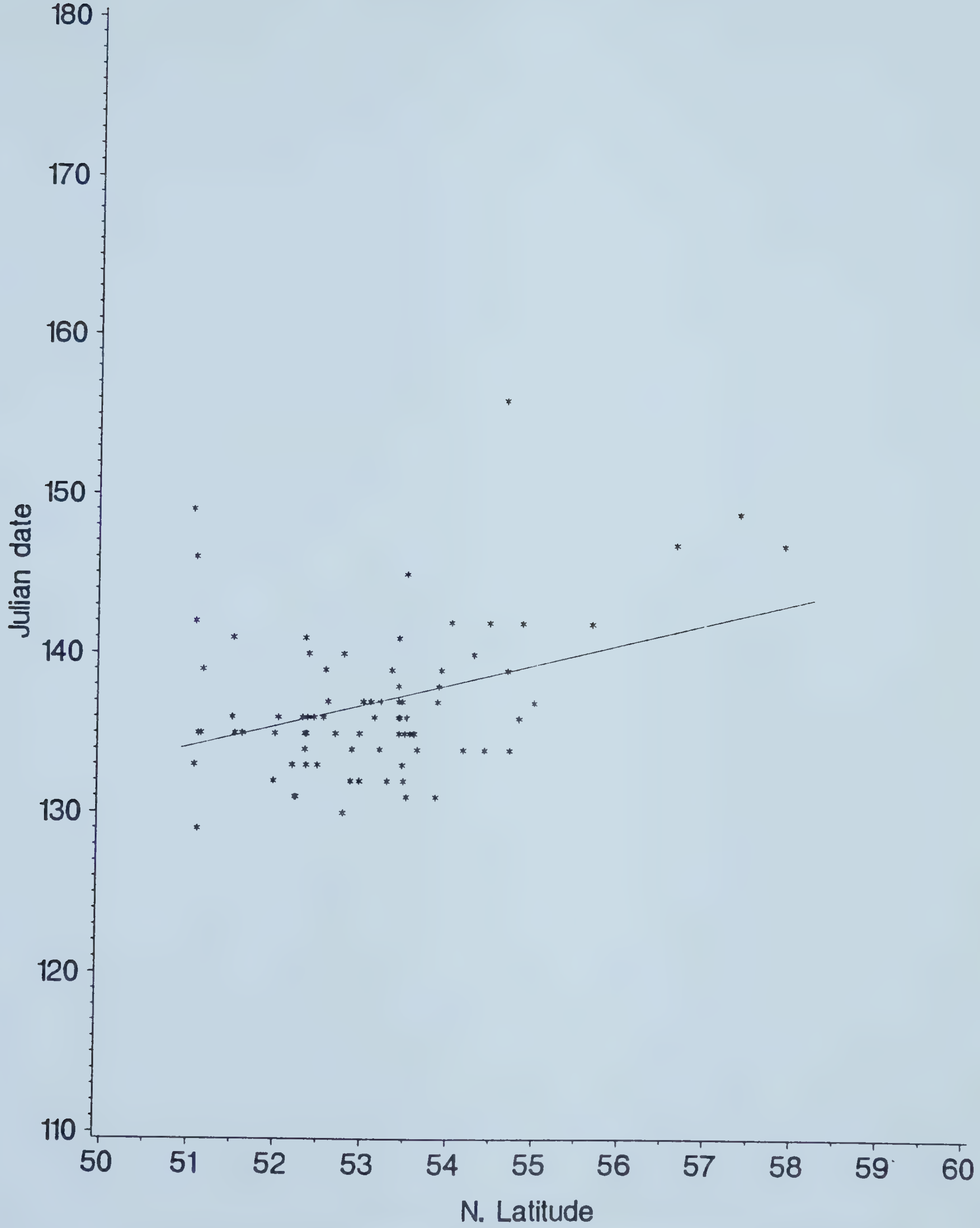



Figure 12-c: Linear regression for Amelanchier alnifolia, 90% flowering for flowering date and degrees N latitude.
$r^2$=.14; y = a+bx where a=67.37 (p=.0006) and b=1.31 (p=.0004)

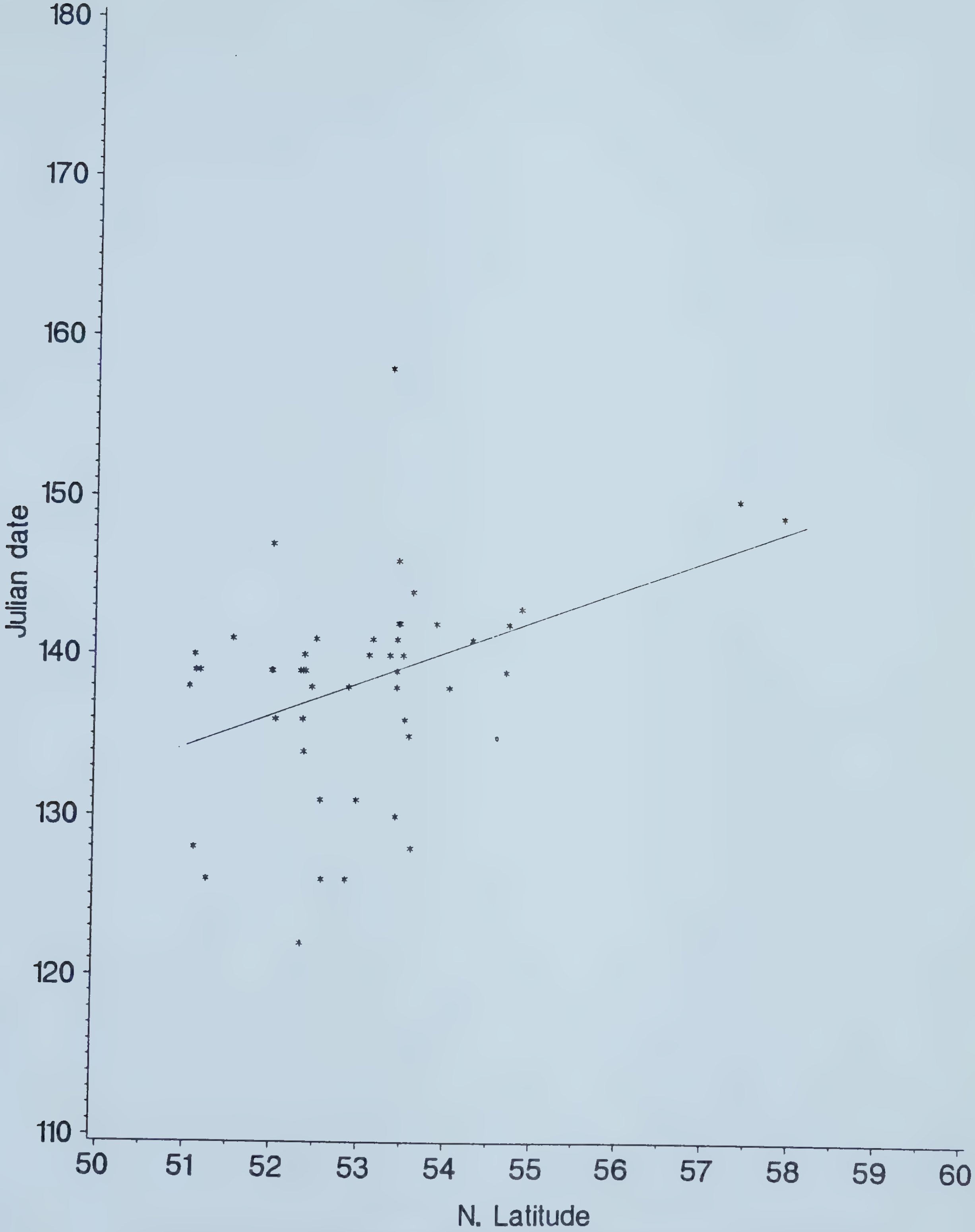


Figure 12-d: Linear regression for Prunus virginiana, 10% flowering for flowering date and degrees N latitude.
$r^2$=.17; y = a+bx where a=33.36 (p=.3297) and b=1.98 (p=.0033)

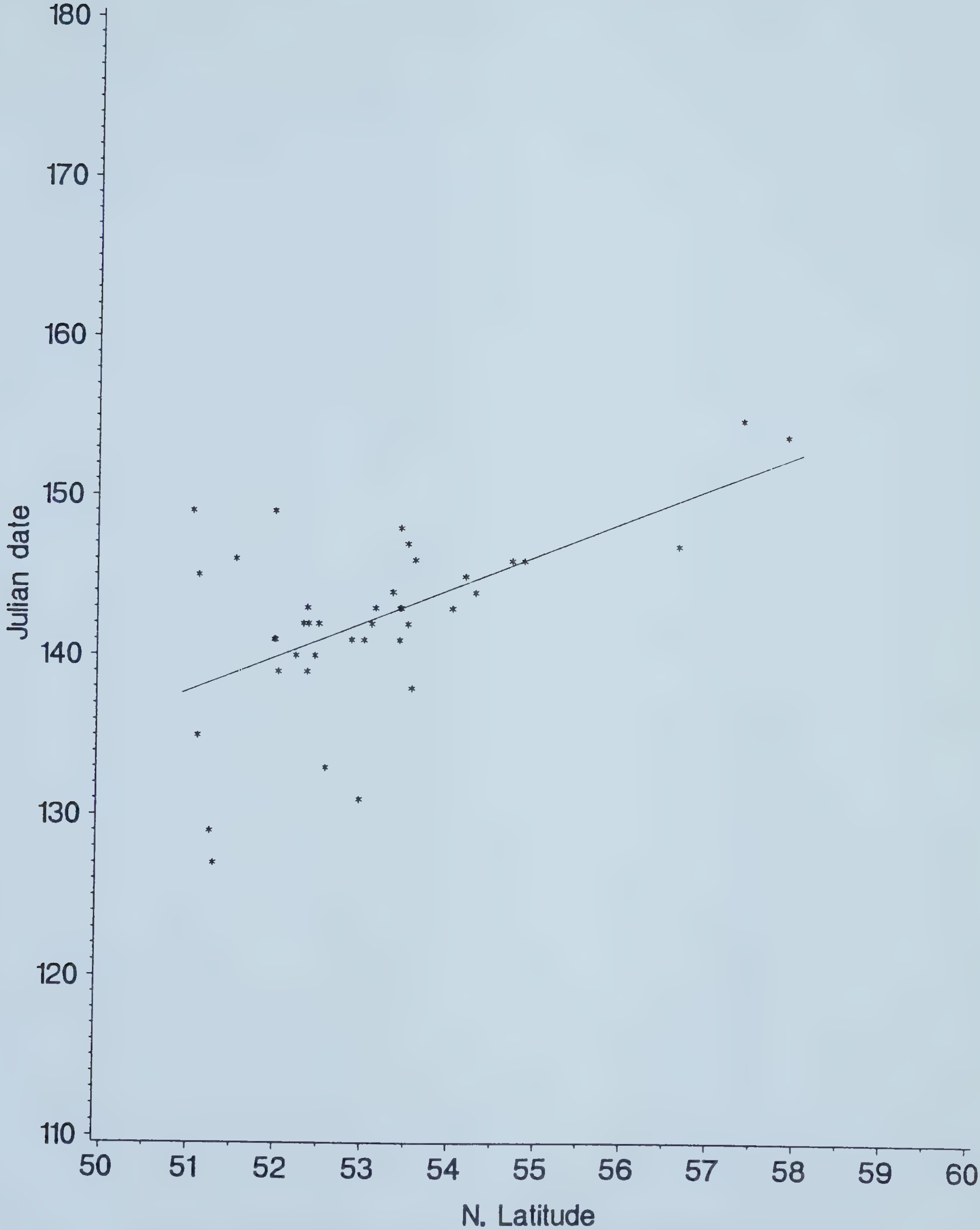



Figure 12-e: Linear regression for Prunus virginiana, 50% flowering for flowering date and degrees N latitude.
$r^2$=.34; y = a+bx where a=28.88 (p=.2685) and b=2.14 (p=.0001)

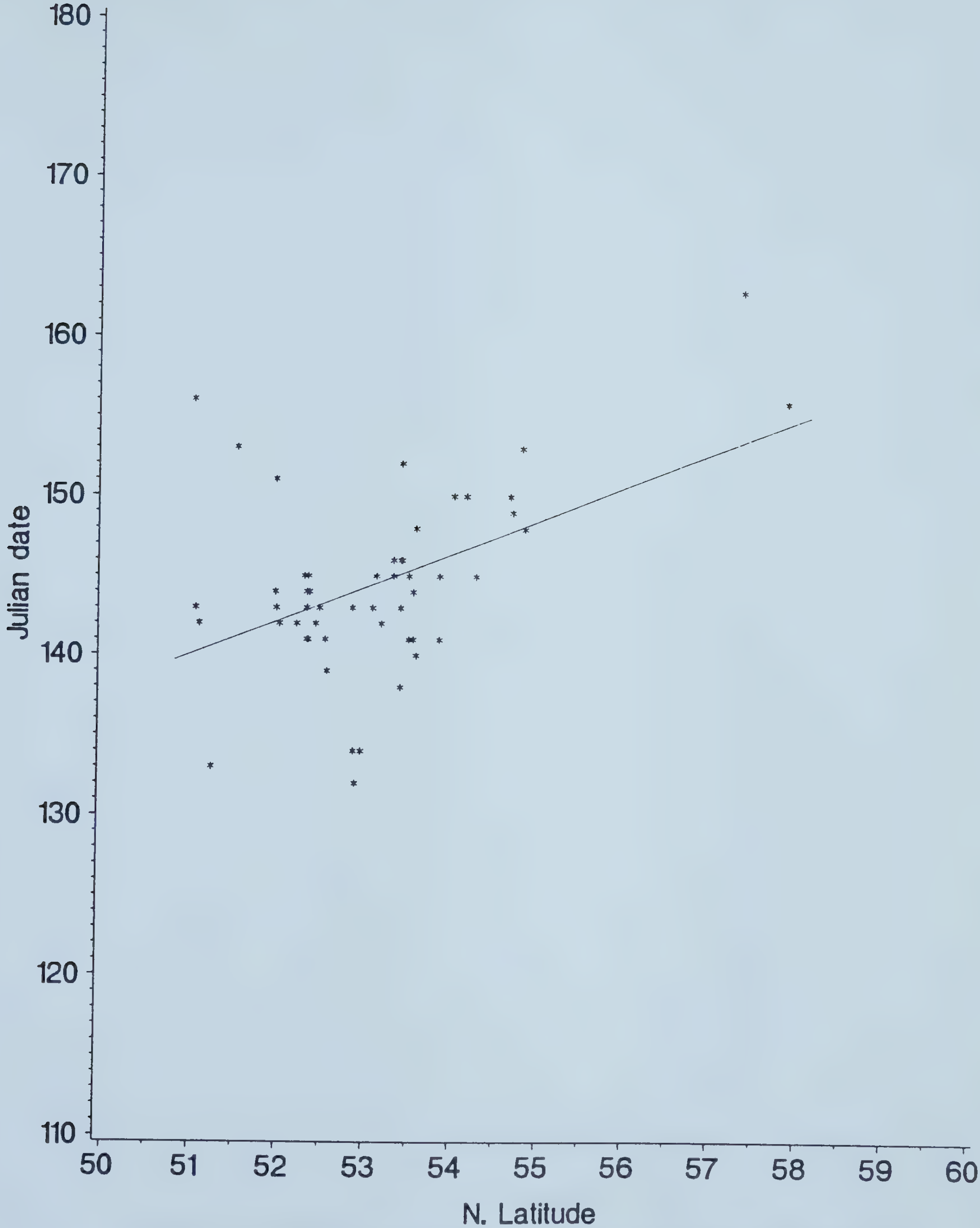



Figure 12-f: Linear regression for Prunus virginiana, 90% flowering for flowering date and degrees N latitude.
$r^2$=.24; y = a+bx where a=32.56 (p=.2496) and b=2.11 (p=.0002)

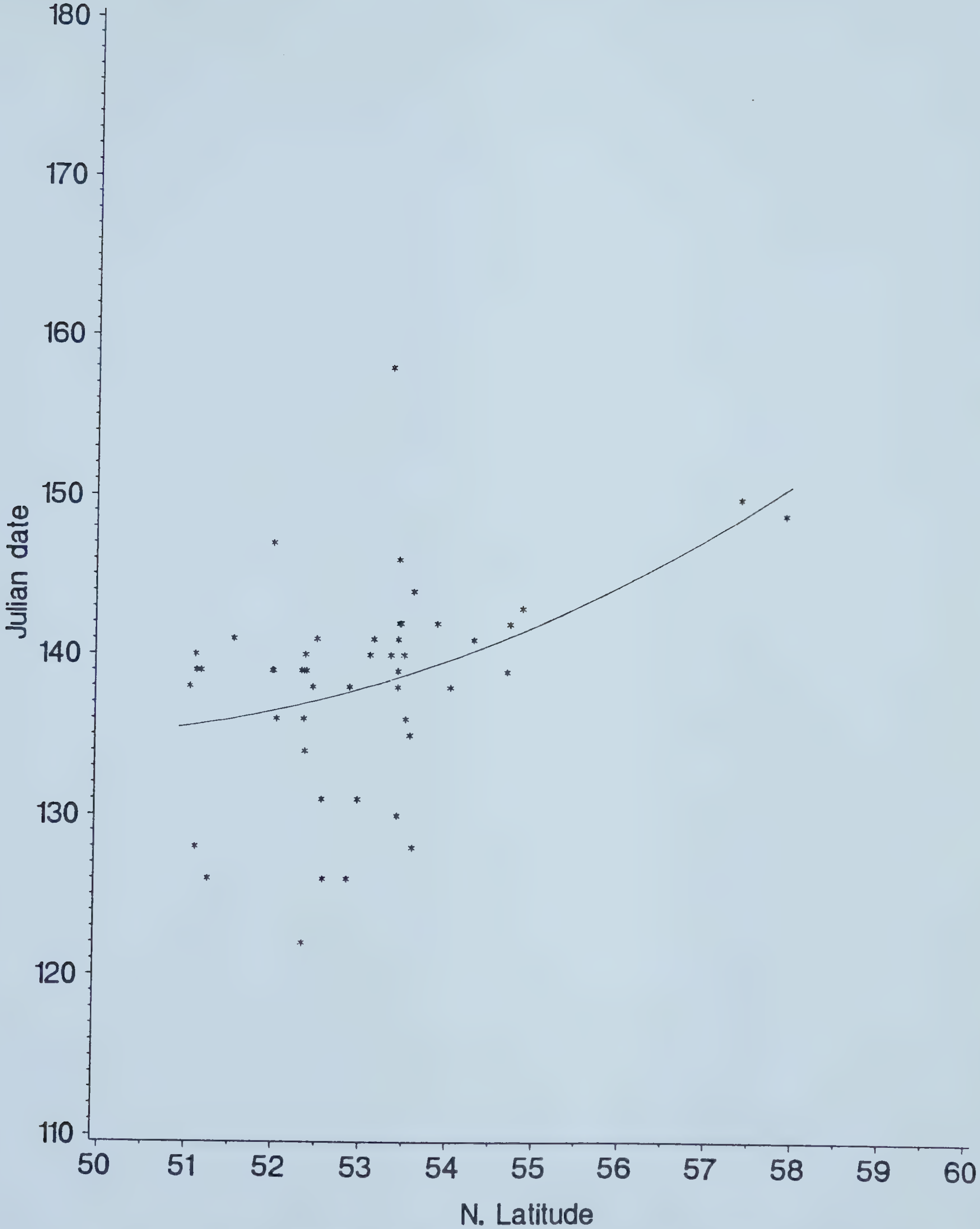



Figure 12-g: Quadratic regression for Prunus virginiana, 10% flowering for flowering date and degrees N latitude.
$r^2$=.18; $y = a+bx+cx^2$ where a=624.68 (p=.4045) and b=-19.96 (p=.4721) and c=0.20 (p=.4294).

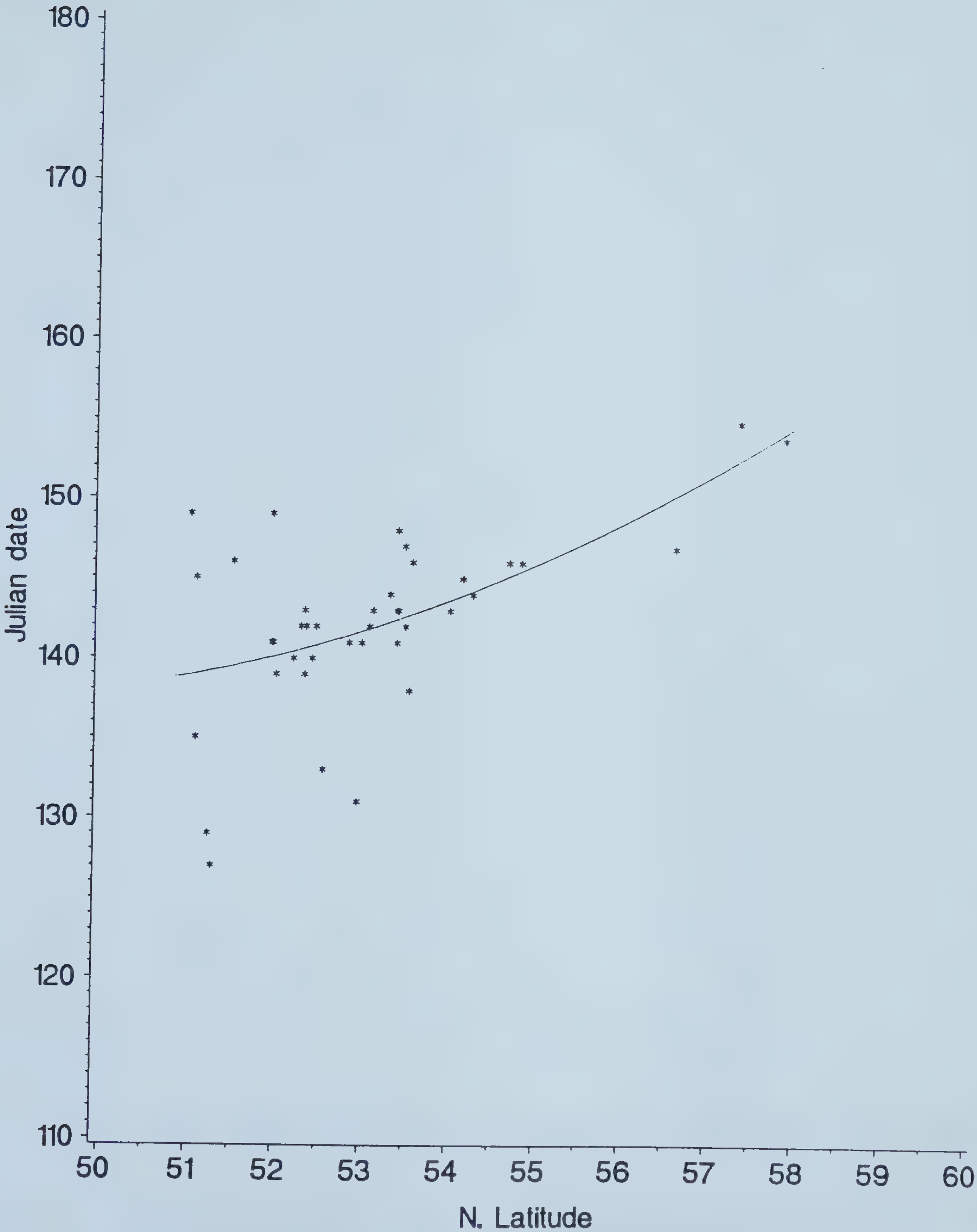



Figure 12-h: Quadratic regression for Prunus virginiana, 50% flowering for flowering date and degrees N latitude.
$r^2$=.35; $y = a+bx+cx^2$ where a=537.39 (p=.3909) and b=-16.68 (p=.4708) and c=0.17 (p=.4163).

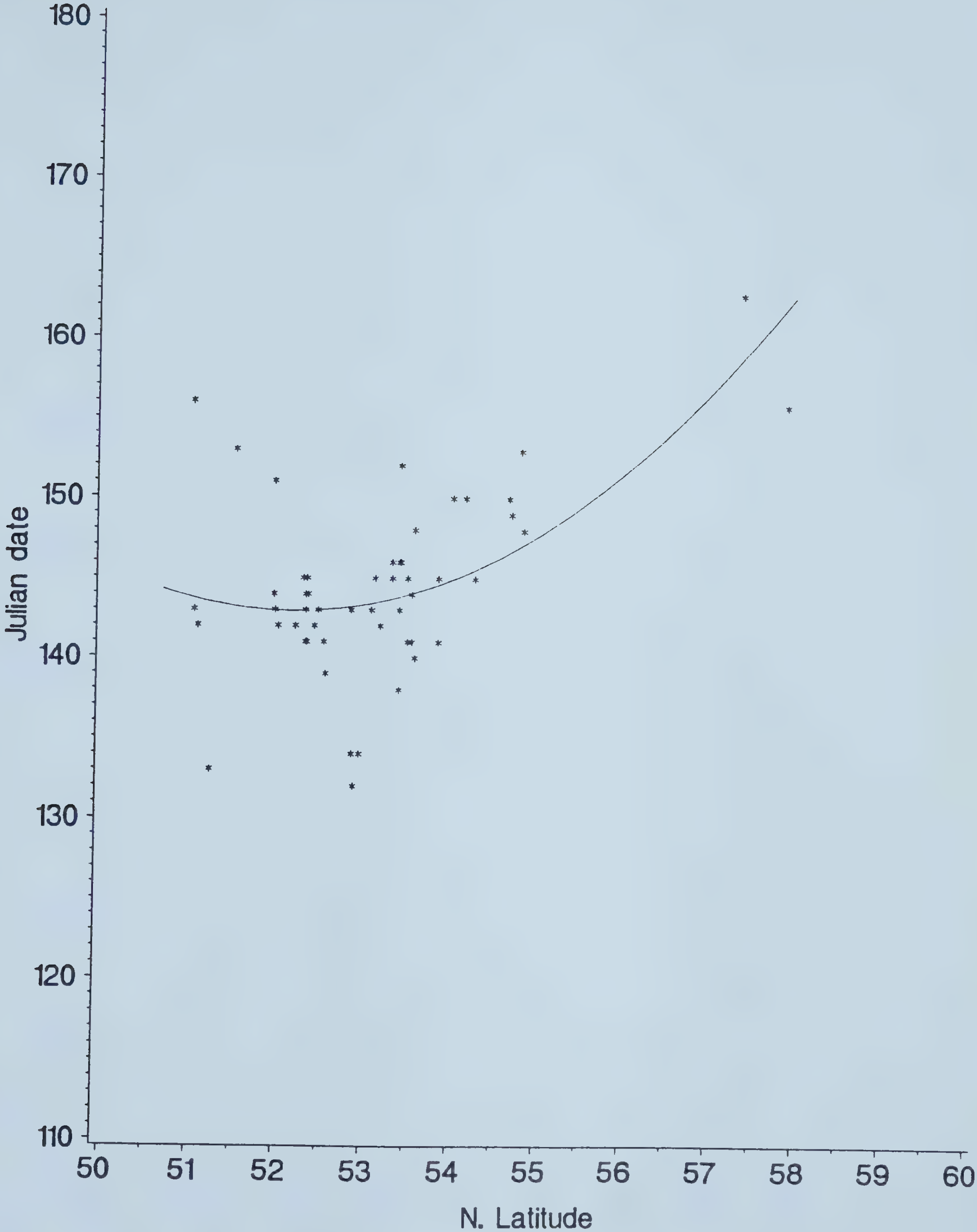



Figure 12-i: Quadratic regression for <u>Prunus</u> <u>virginiana</u>, 90% flowering for flowering date (y) and degrees N latitude (x).
$r^2$=.36; $y = a+bx+cx^2$ where a=1762.58 (p=.0036) and b=-62.08 (p=.0055) and c=0.59 (p=.0042).

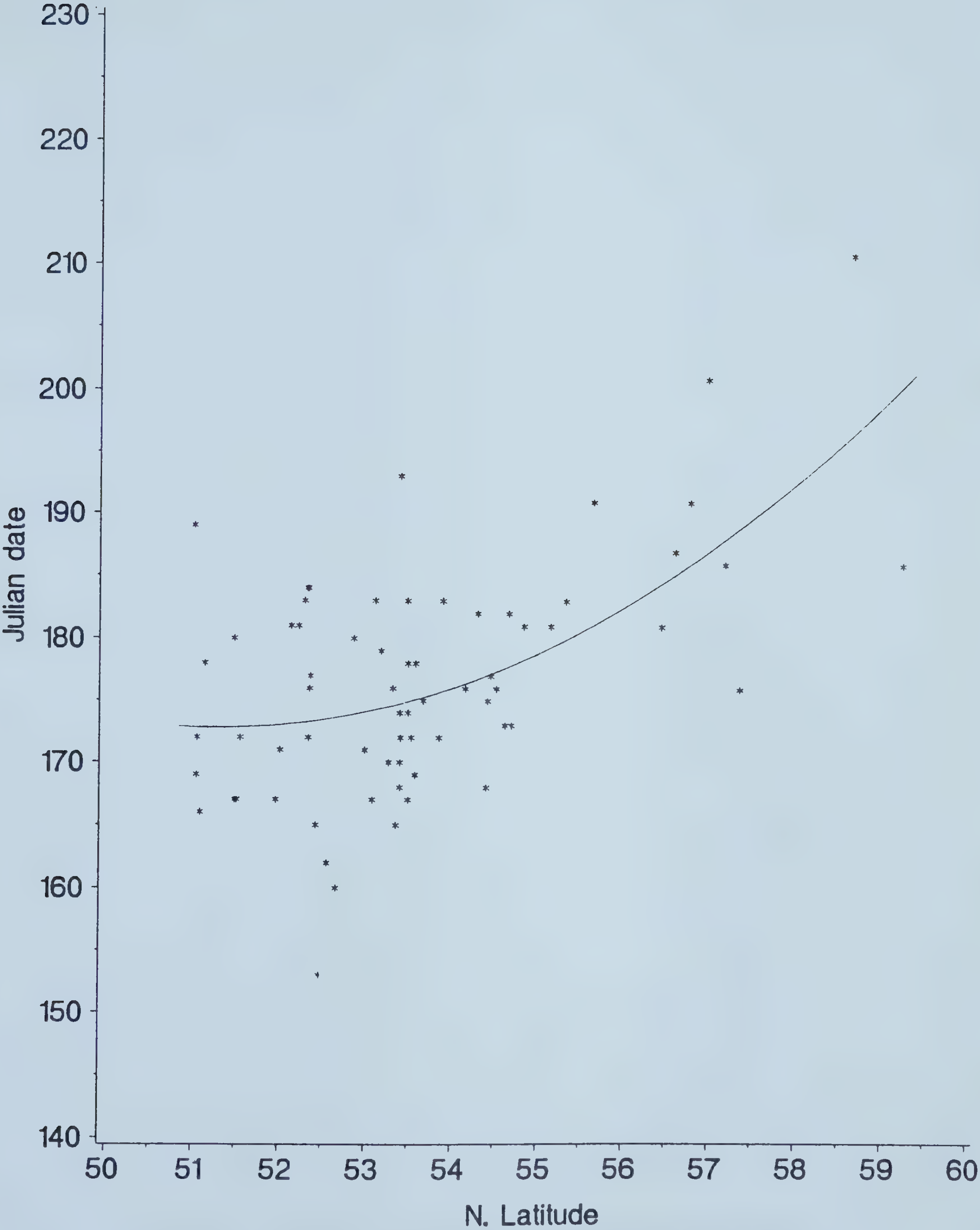



Figure 12-j: Quadratic regression for Epilobium angustifolium, 10% flowering, for flowering date (y) and degrees N latitude (x). $r^2$=.34; $y = a+bx+cx^2$ where a=1316.82 (p=.0385) and b=-44.62 (p=.0555) and c=0.43 (p=.0420).

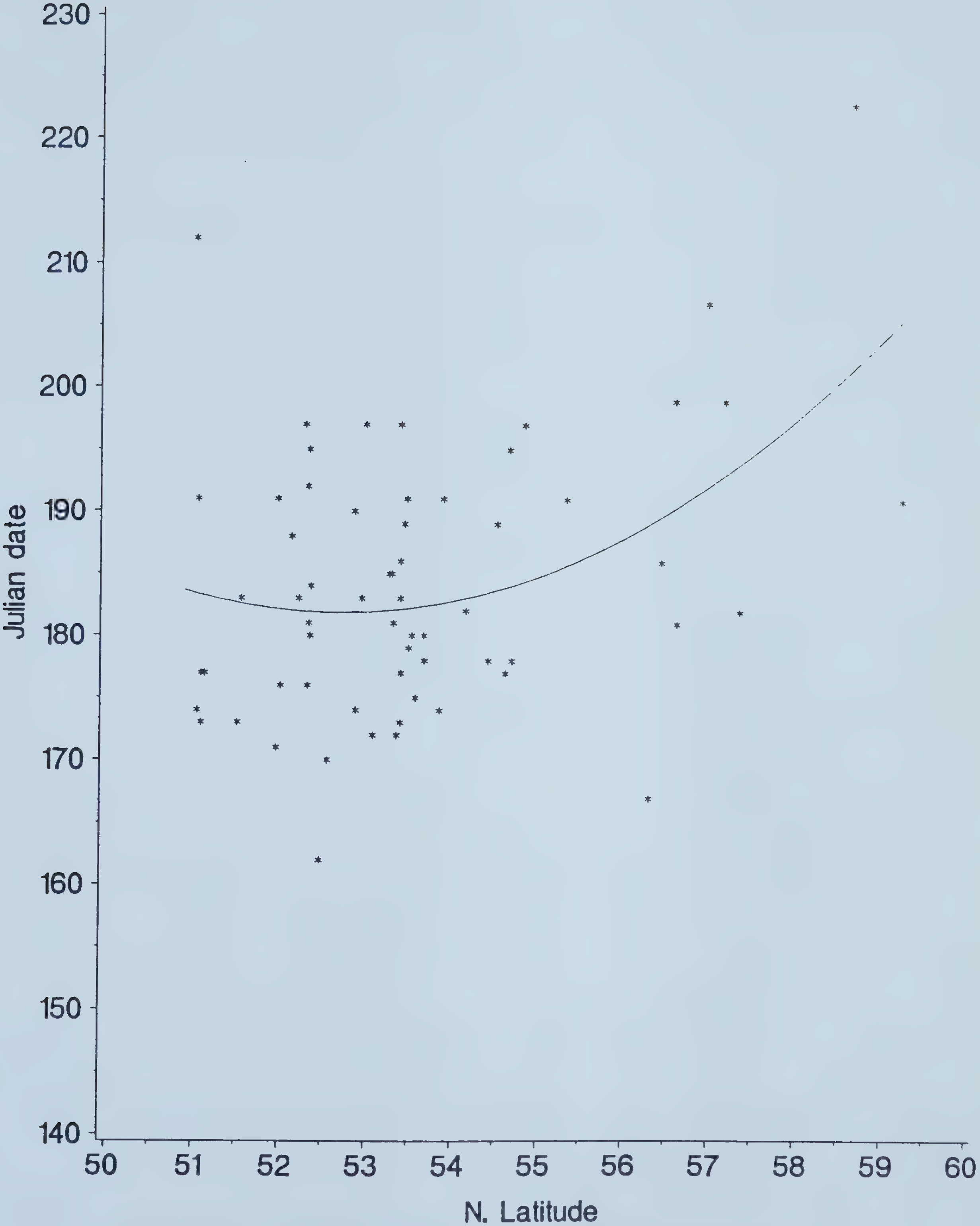



Figure 12-k: Quadratic regression for Epilobium angustifolium, 50% flowering, for flowering date (y) and degrees N latitude (x). $r^2$=.18; $y = a+bx+cx^2$ where a=1721.60 (p=.0457) and b=-58.43 (p=.0639) and c=0.55 (p=.0552).

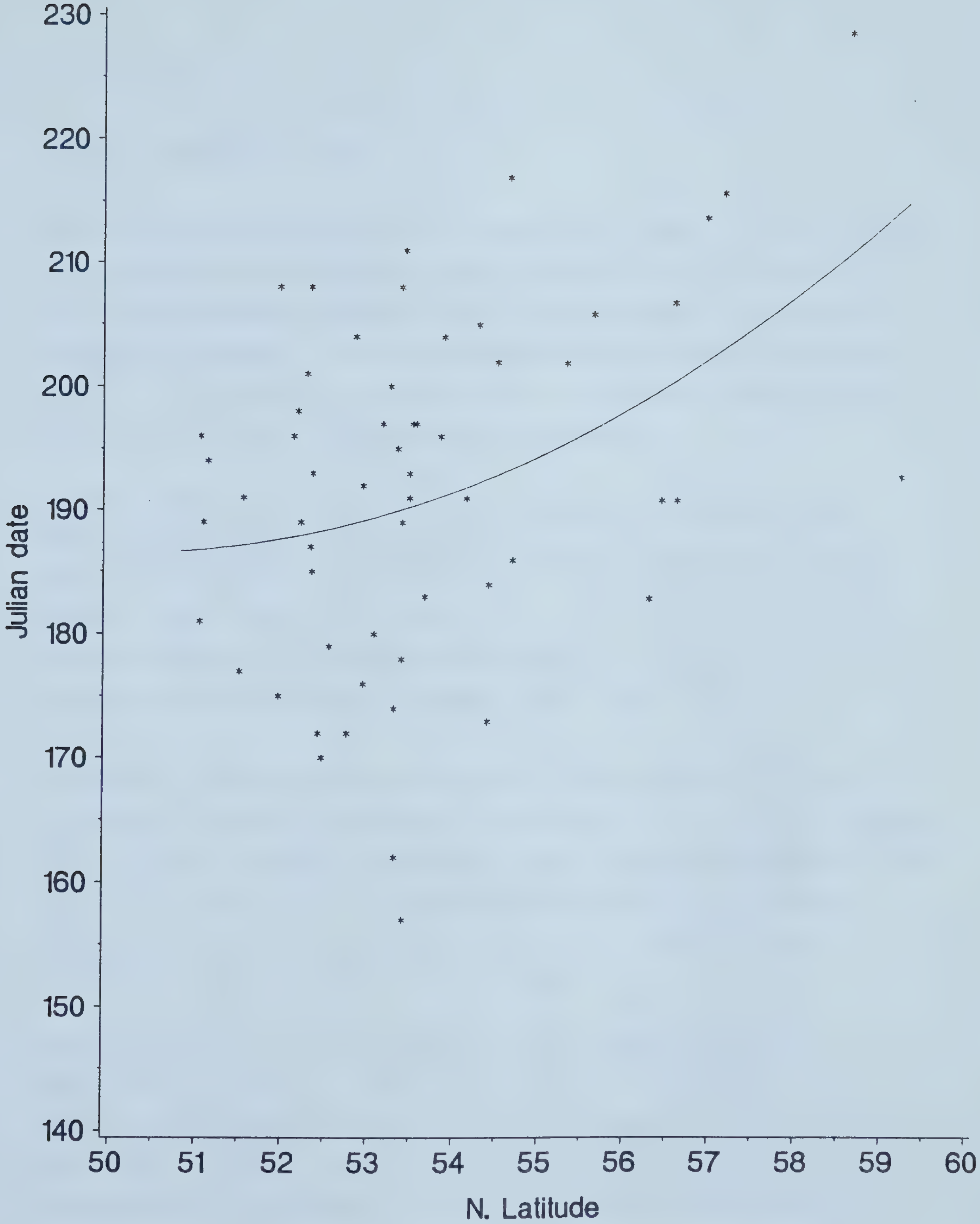



Figure 12-1: Quadratic regression for <u>Epilobium angustifolium</u>, 90% flowering, for flowering date (y) and degrees N latitude (x). $r^2$=.16; $y = a+bx+cx^2$ where a=1042.27 (p=.3837) and b=-34.12 (p=.4359) and c=0.34 (p=.3962).

### 4.2.2. Maps

#### 4.2.2.1. Mapping by Hand

Data were averaged for each of 29 rectangular areas, for the 3 phases and 15 species. The clearest trend in this "flowering wave" was shown by Amelanchier alnifolia- 10% and 90%, Prunus virginiana- 90%, Elaeagnus commutata- 90%, and Epilobium angustifolium- 10% (Figures 13:a-e). Every species and phase shows a different pattern, with greatest similarity between phases of a species.

For the first plants in the flowering sequence (Anemone patens, Populus tremuloides, Viola adunca, Elaeagnus commutata), flowering began in the major cities: Calgary, Red Deer and Edmonton. After mid-June, this heat island effect is no longer noticeable, in fact for 1988 Lilium philadelphicum and Gaillardia aristata were later in Red Deer and Edmonton than in some nearby areas.

In general, southern areas were earlier than areas north of them. For example, Calgary was earlier than Edmonton in 15 out of 22 cases (68%), despite the fact that Calgary lies at a higher altitude (1049 m) than Edmonton (668 m). Frequent chinook winds warm Calgary in winter. The Lethbridge - Medicine Hat area was earlier than the Drumheller - Oyen area in 6 out of 8 cases (75%).

Some adjacent blocks at the same latitude showed a consistent difference in earliness. The Grande Prairie - Fairview area was earlier than the High Prairie - Slave Lake area in 10 out of 11 cases (91%). The Athabasca block was earlier than the Cold Lake - Lac LaBiche area (adjacent block to the east) in 11 out of 15 cases (73%).

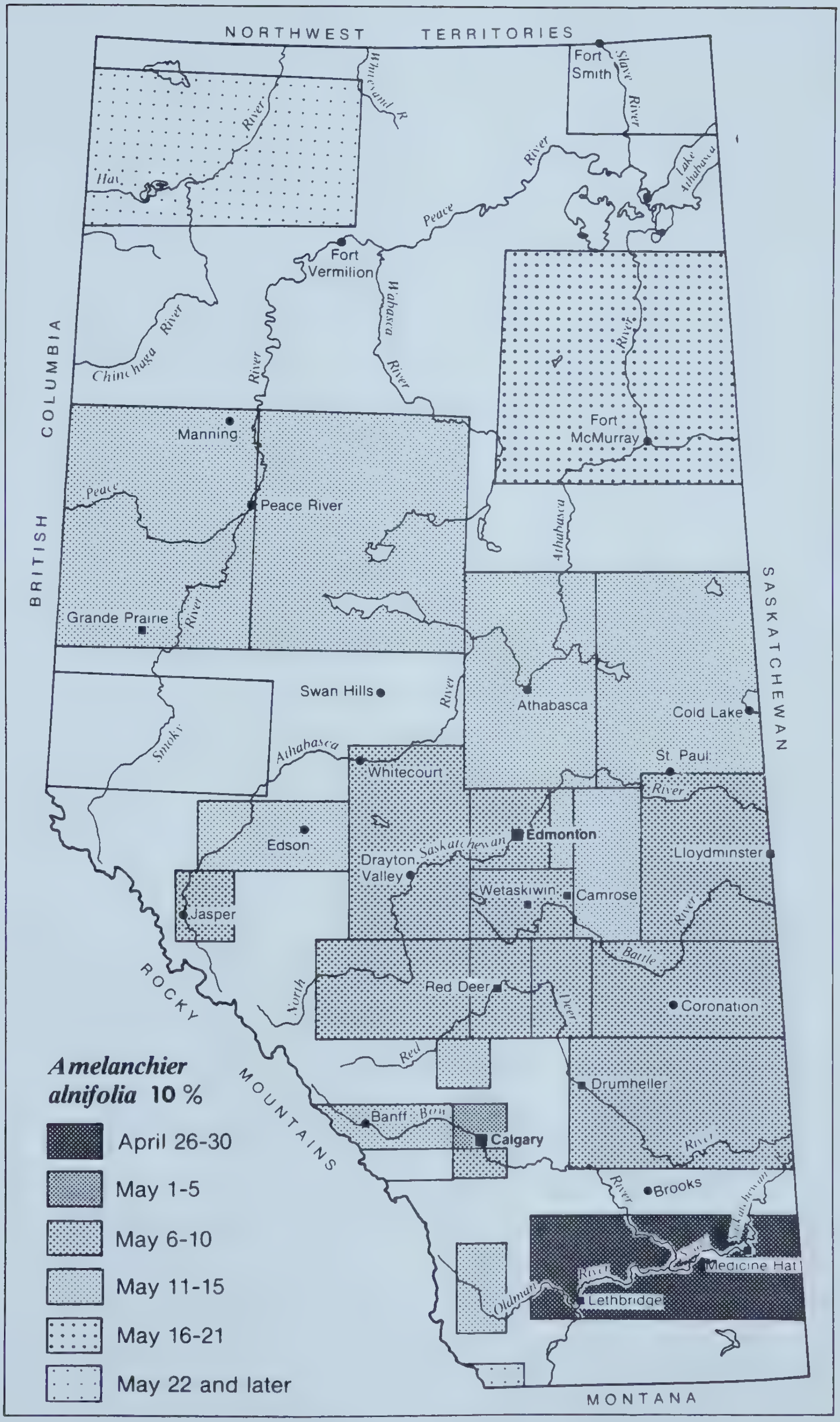



Figure 13-a: Map of Amelanchier alnifolia, 10% or first flowering dates averaged within blocks, 1988, Alberta.

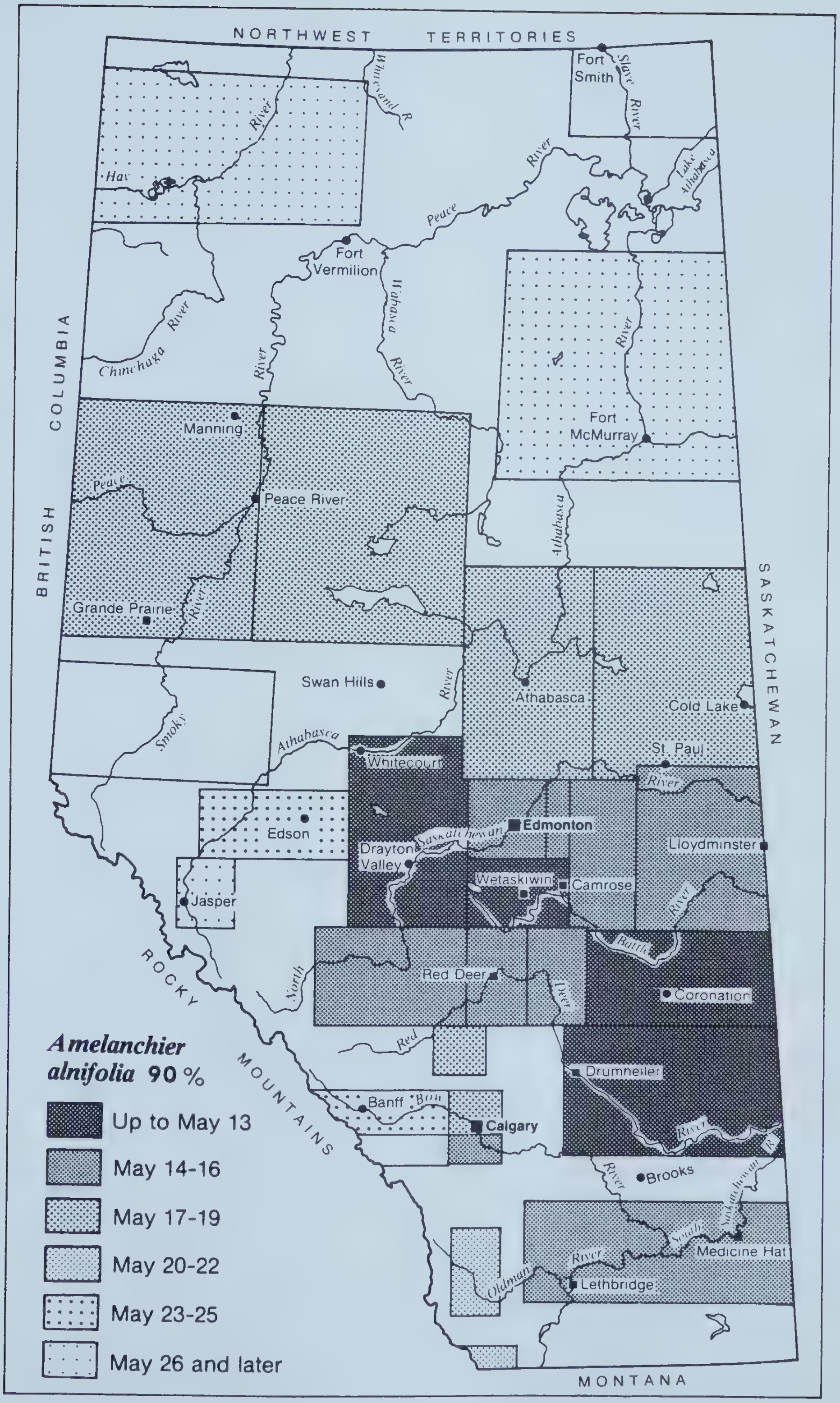



Figure 13-b: Map of Amelanchier alnifolia, 90% or full flowering dates averaged within blocks, 1988, Alberta.

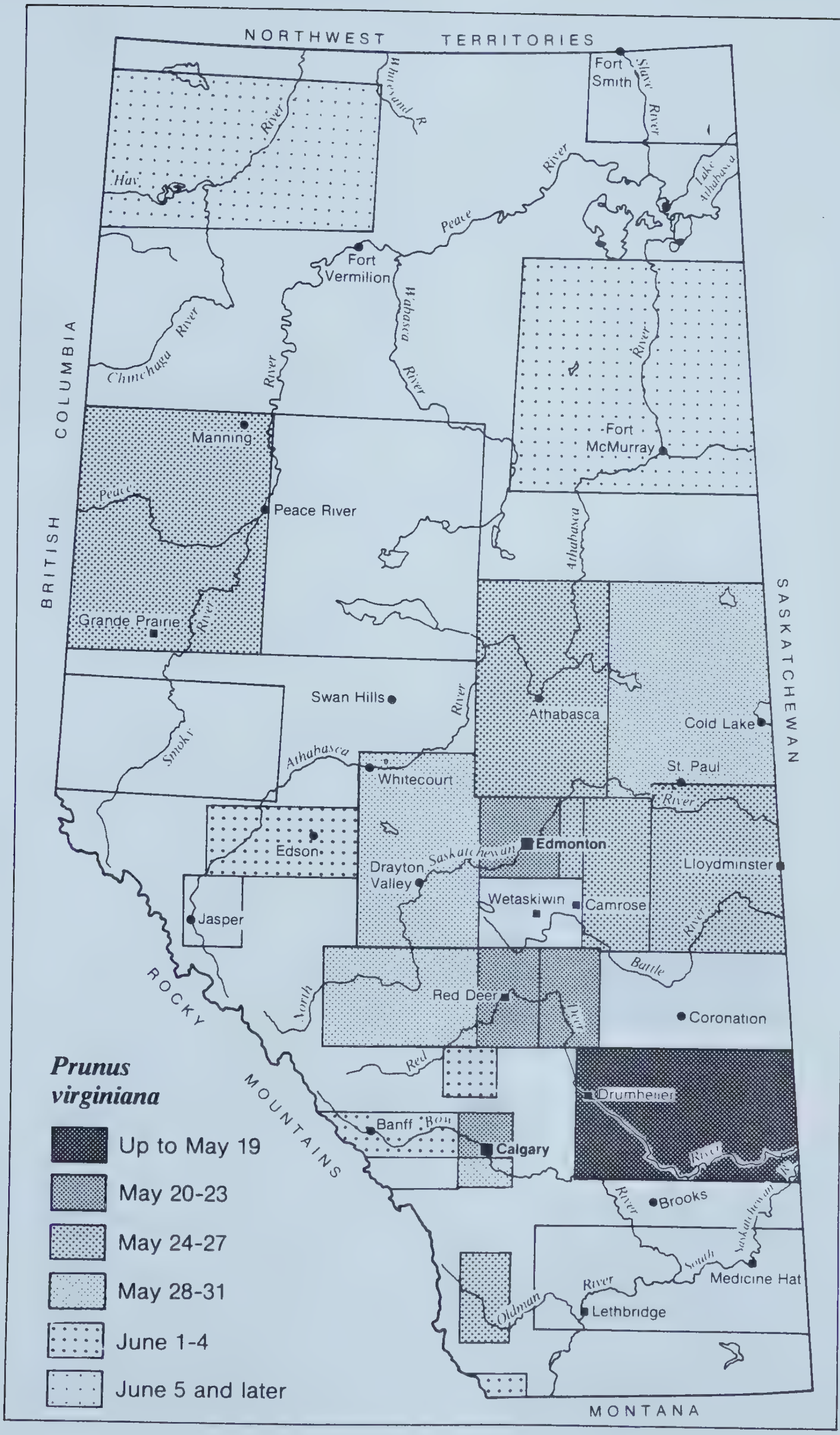



Figure 13-c: Map of Prunus virginiana, 90% or full flowering dates averaged within blocks, 1988, Alberta.

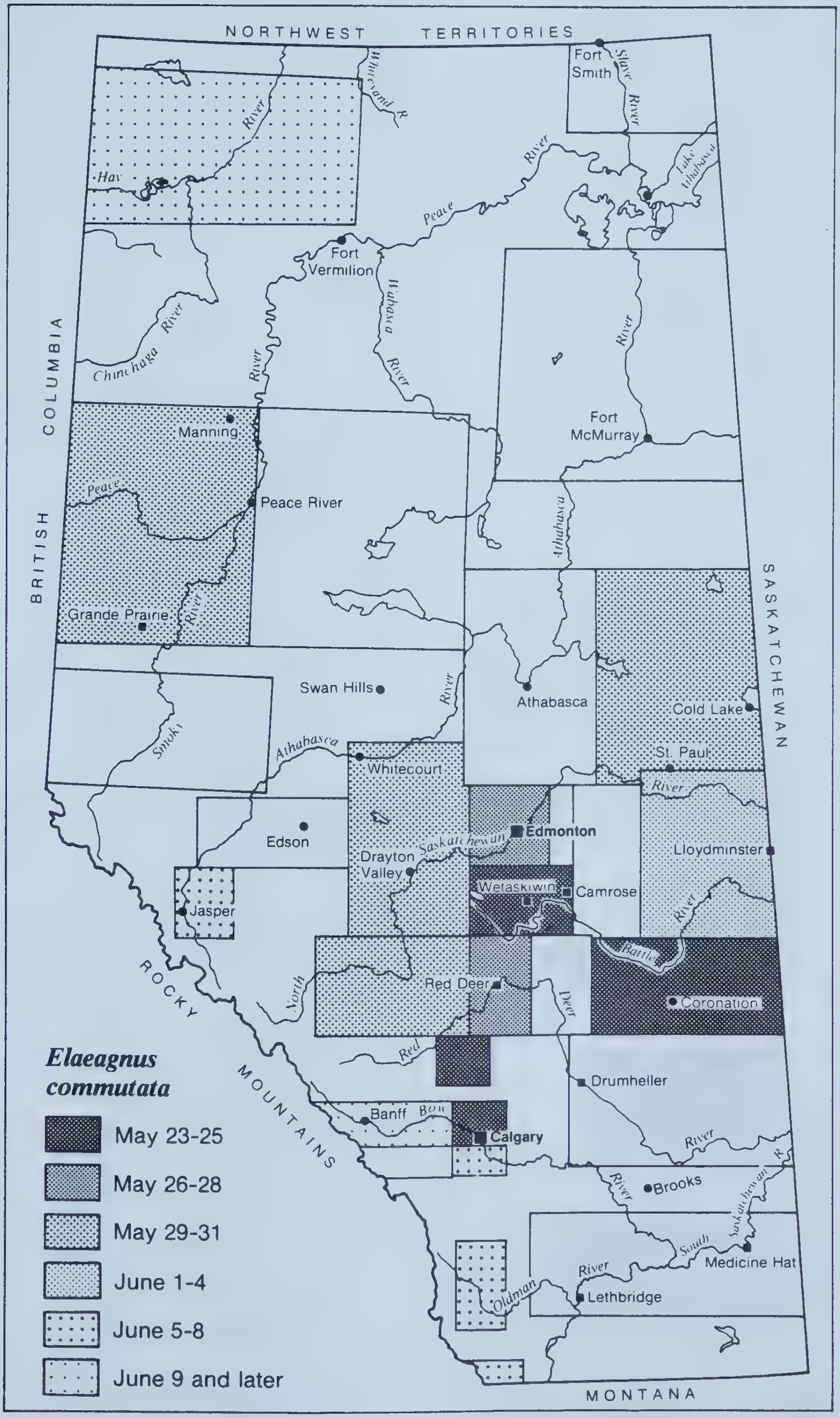



Figure 13-d: Map of Elaeagnus commutata, 90% or full flowering dates averaged within blocks, 1988, Alberta.

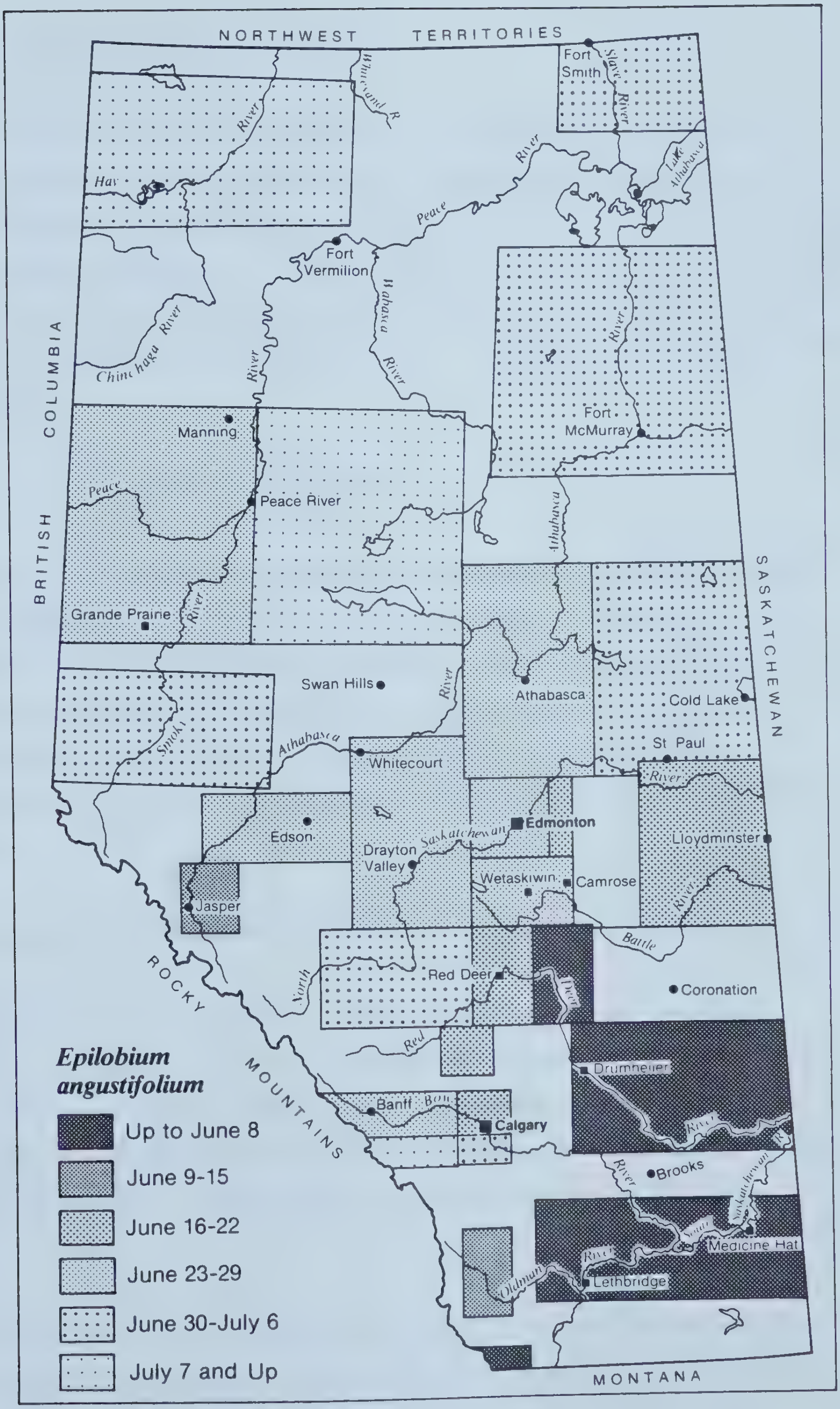



Figure 13-e: Map of Epilobium angustifolium, 10% or first flowering dates averaged within blocks, 1988, Alberta.

4.2.2.2. Trend Surface Analysis

The data set used at the department of Geography, University of Alberta, was 1988 - 10% flowering of Amelanchier alnifolia. No pattern could be seen using two surfacing methods (exact fitting and trend surface analysis). One problem seemed to be the heat island effect of the cities which produced unusually early flowering and confused the flowering pattern across the province (R. Eyton, 1989, pers. comm.).

4.2.2.3. Linear Contour Maps- G.I.S.

At Agriculture Canada in Lethbridge, computer-generated contour maps of selected species were produced (Figure 14:a-m). (See Appendix 8 for a 1988 Julian calendar.) The linear contour maps appeared to smooth the variability in the data more accurately than the non-linear maps which showed some unwarranted extrapolations of data. Non-linear contouring was not pursued further.

The maps are discussed as follows.

Amelanchier 10, 50, and 90% (Figure 14: a-c): the earliest locations are in a band from SE Alberta (Drumheller) to the NW (Grande Prairie area). The latest locations are in the mountains and in the north. Jasper shows unusually early dates for the 10 and 50% stages, and then late dates for the 90% stage.

For each data set a larger-scale window was also mapped of the area enclosing Athabasca, Drayton Valley, Red Deer, and east to the Alberta border (Figure 14:d-f). On the 90% window map (Figure 14-f), the dark blue colour in the NE corner is due to a late date at Cold Lake (day 156 = June 4).

Figure 14: a-m : Computer-generated (SPANS) linear contour maps, full colour, showing the flowering progression of selected species and phenophases from the Alberta 1988 provincial phenology survey

The following linear contour maps follow:

a: Amelanchier alnifolia 10% flowering
b: Amelanchier alnifolia 50% flowering
c: Amelanchier alnifolia 90% flowering
d: Amelanchier alnifolia 10% flowering, larger scale window
e: Amelanchier alnifolia 50% flowering, larger scale window
f: Amelanchier alnifolia 90% flowering, larger scale window
g: Prunus virginiana, 10% flowering
h: Prunus virginiana, 90% flowering
i: Smilacina stellata, 10% flowering
j: Smilacina stellata, 10% flowering, larger scale window
k: Elaeagnus commutata, 10% flowering
l: Galium boreale, 90% flowering
m: Epilobium angustifolium, 10% flowering

Note on the maps that black dots indicate location of one or more observers. This program does not extrapolate beyond the outermost observations (thus the colour ends and grey begins).

To translate from Julian dates to calendar dates, see Appendix 9.

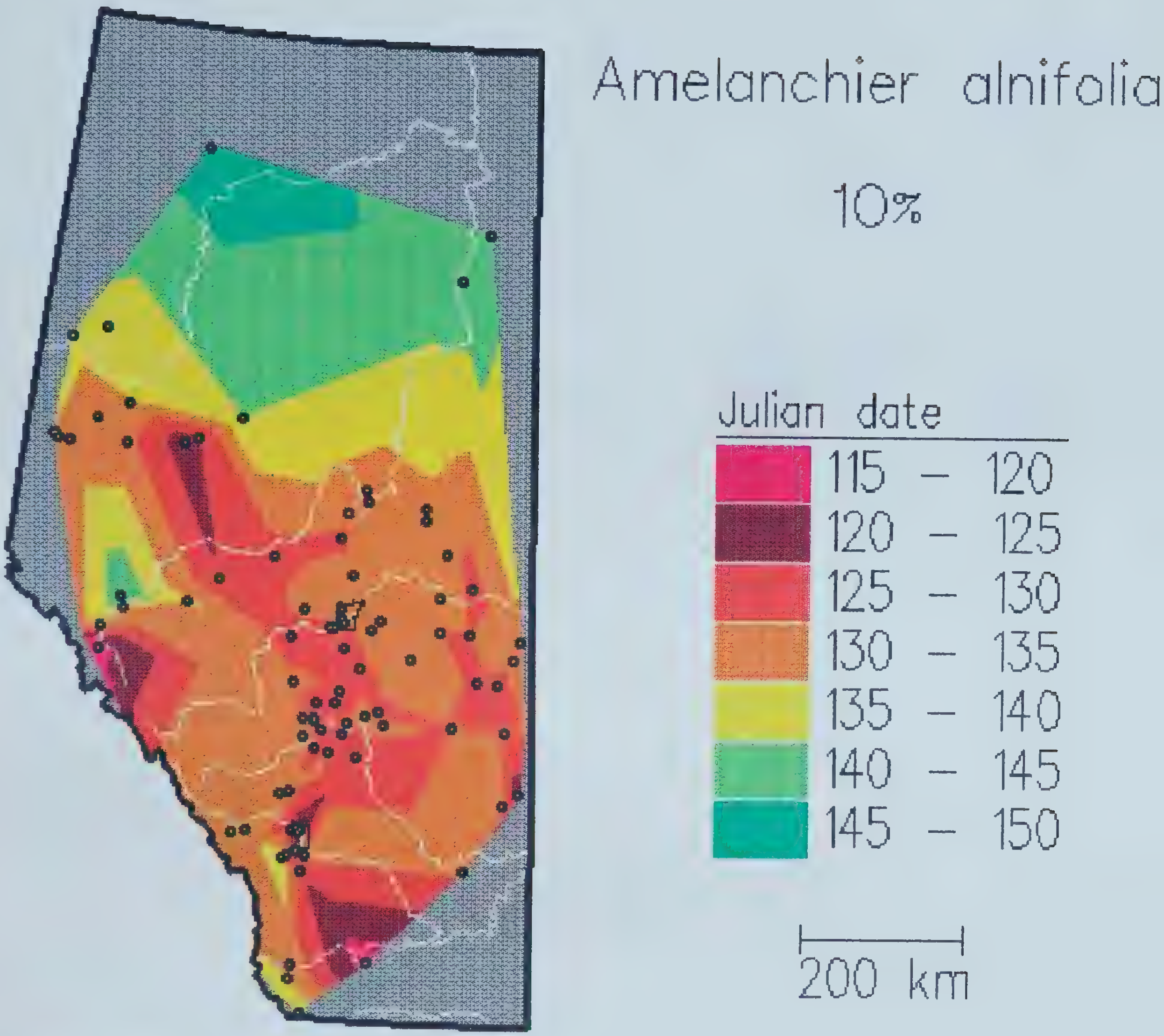
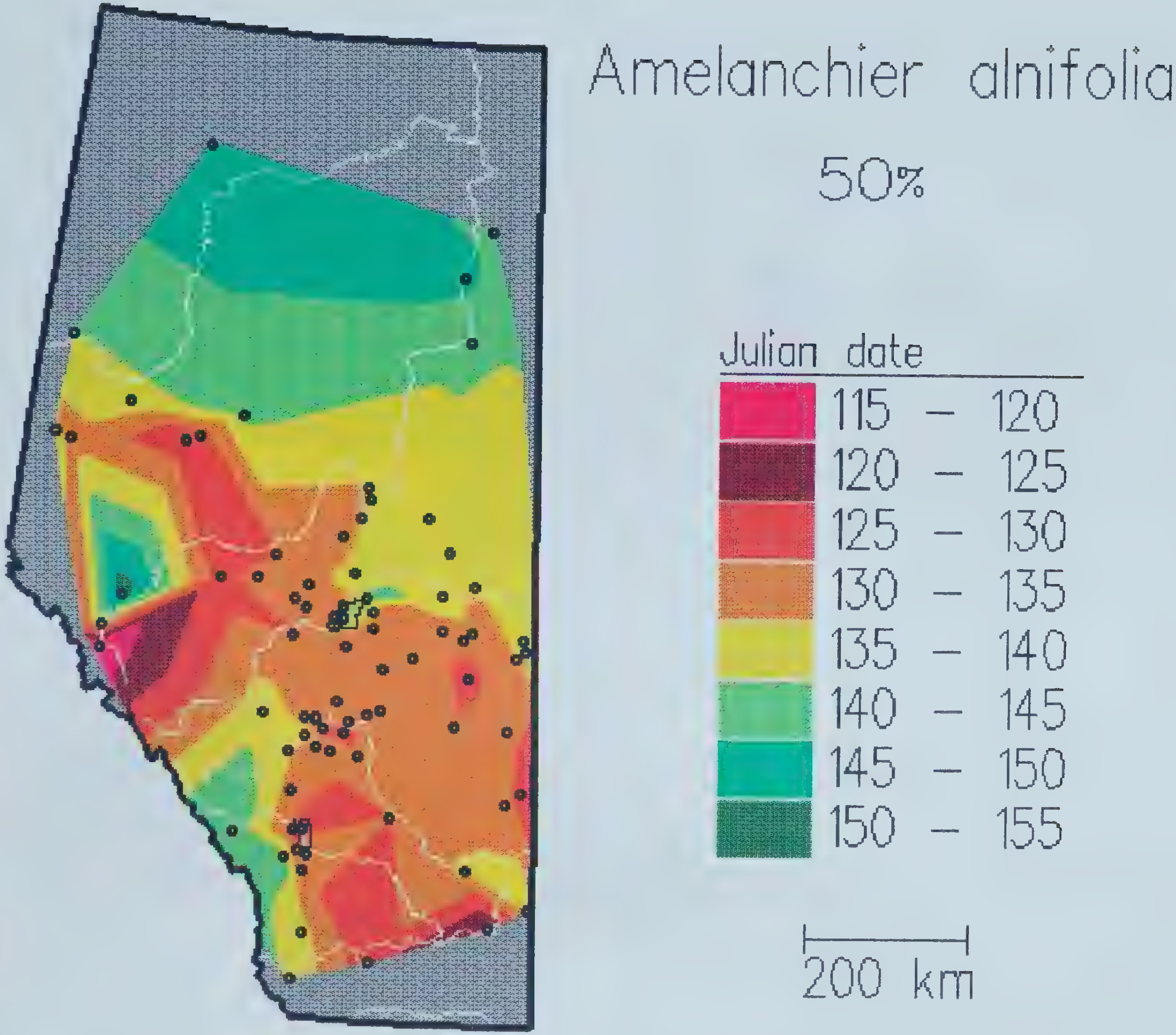
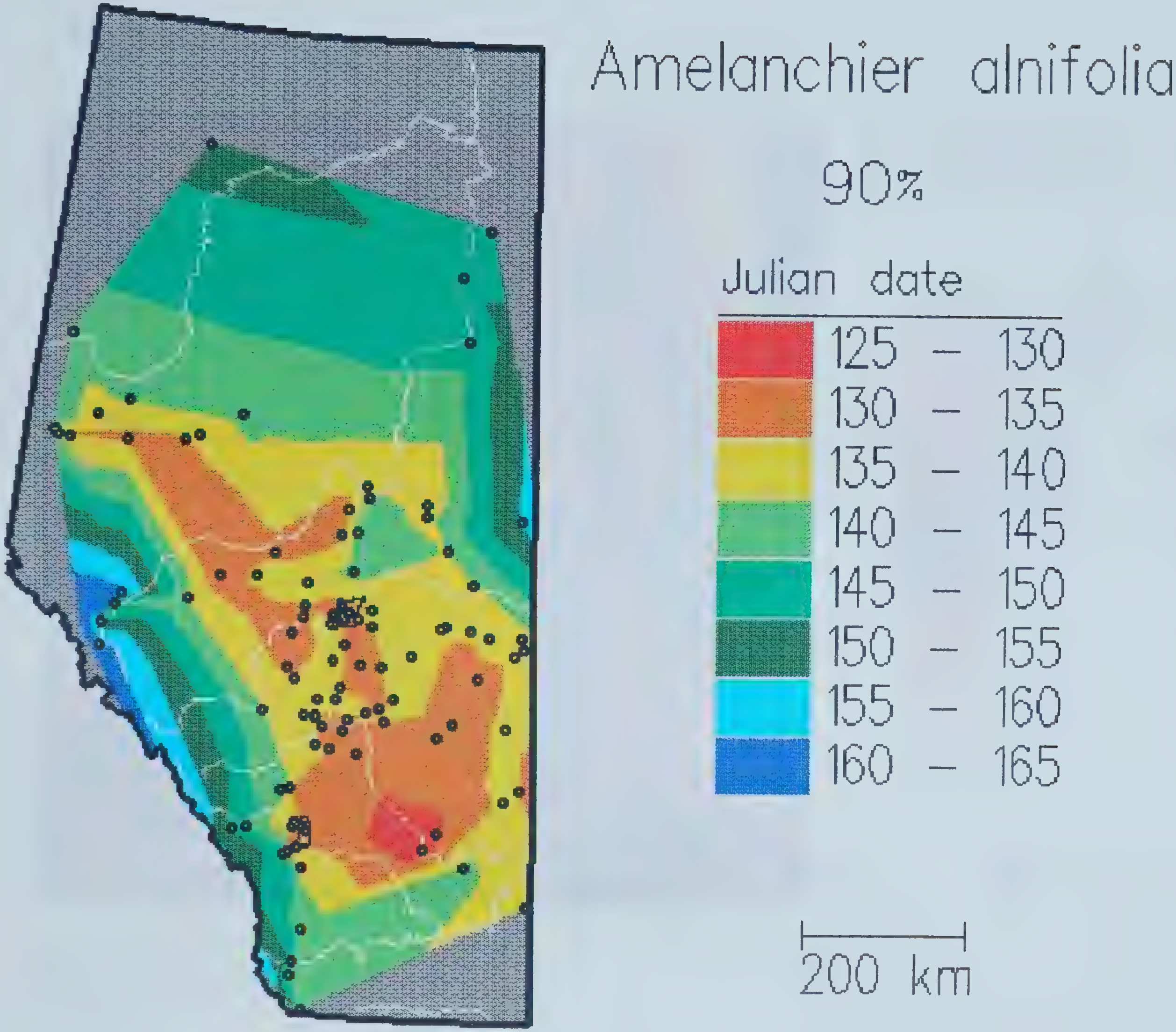

Amelanchier alnifolia
10%
Julian date
115 – 120
120 – 125
125 – 130
130 – 135
135 – 140
140 – 145
145 – 150
200 km

Figure 14-a:



Amelanchier alnifolia
50%
Julian date
115 – 120
120 – 125
125 – 130
130 – 135
135 – 140
140 – 145
145 – 150
150 – 155
200 km


Figure 14-b:



Amelanchier alnifolia
90%
Julian date
125 – 130
130 – 135
135 – 140
140 – 145
145 – 150
150 – 155
155 – 160
160 – 165
200 km


Figure 14-c:

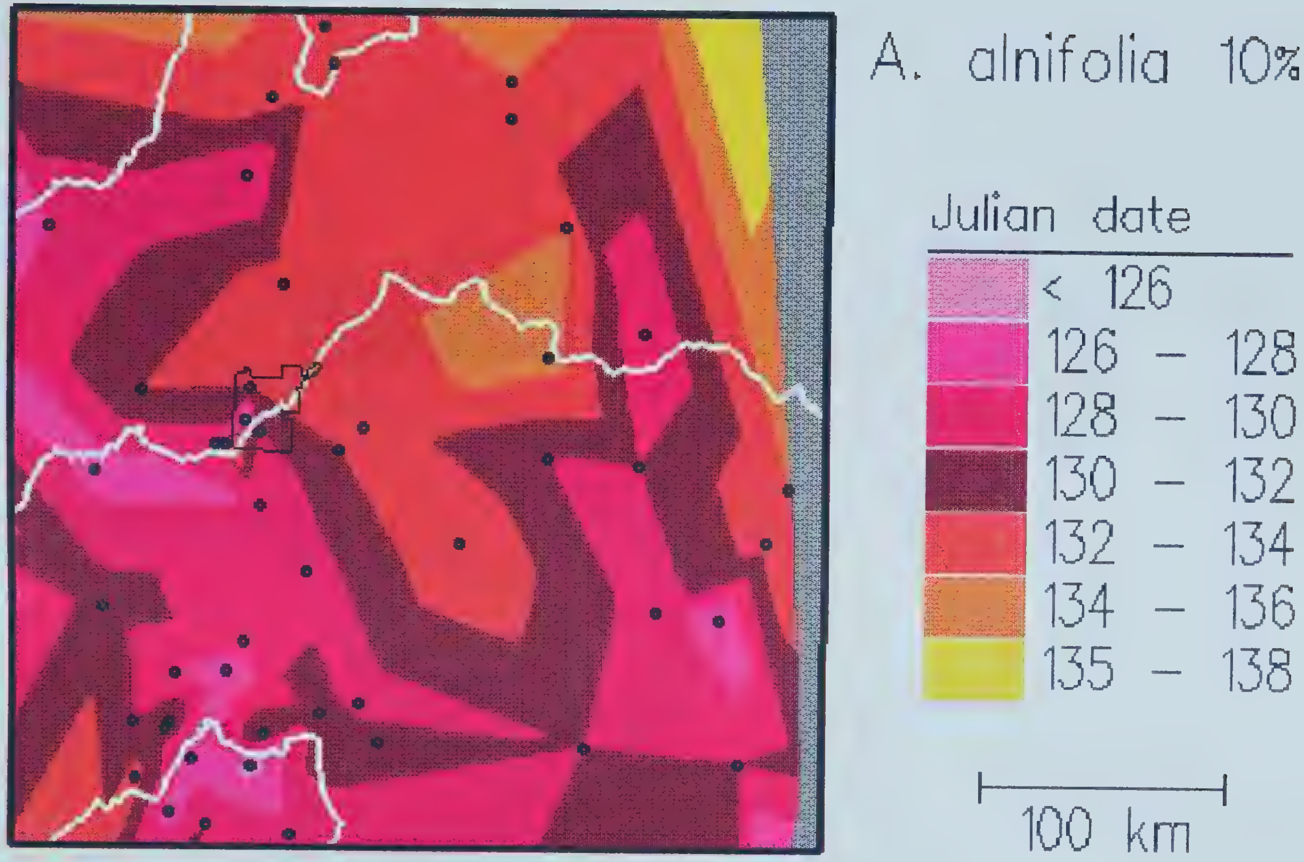

A. alnifolia 10%
Julian date
< 126
126 – 128
128 – 130
130 – 132
132 – 134
134 – 136
135 – 138
100 km

Figure 14-d:

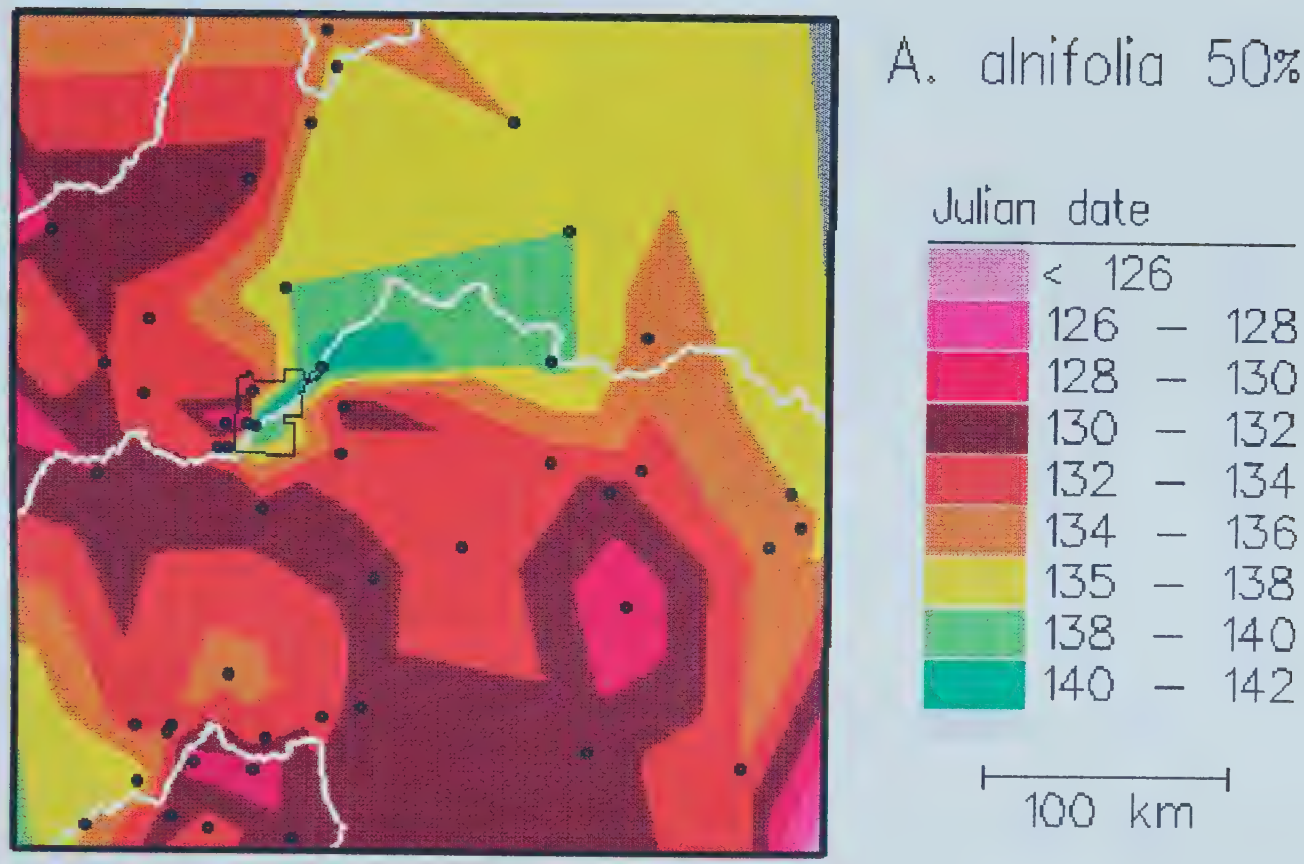

A. alnifolia 50%
Julian date
< 126
126 – 128
128 – 130
130 – 132
132 – 134
134 – 136
135 – 138
138 – 140
140 – 142
100 km

Figure 14-e:

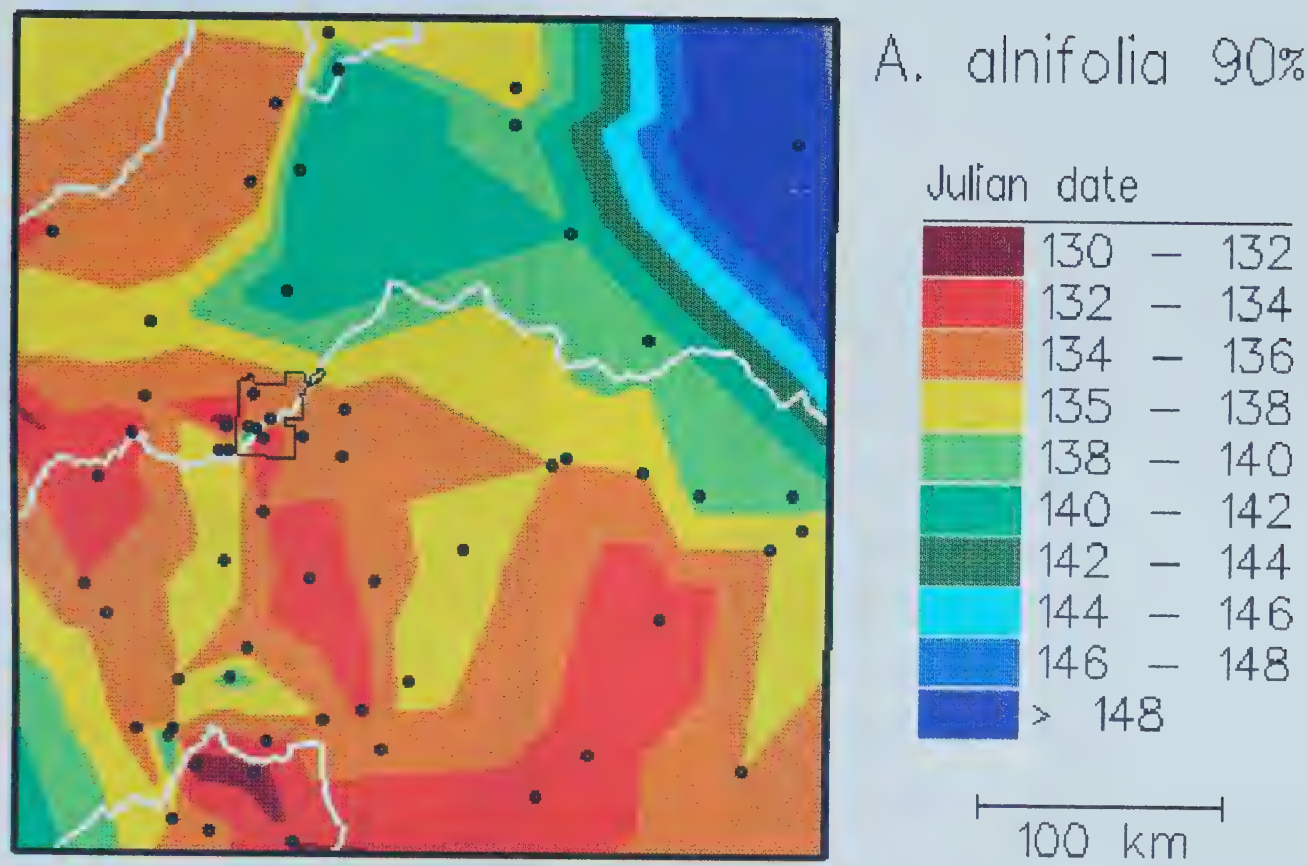
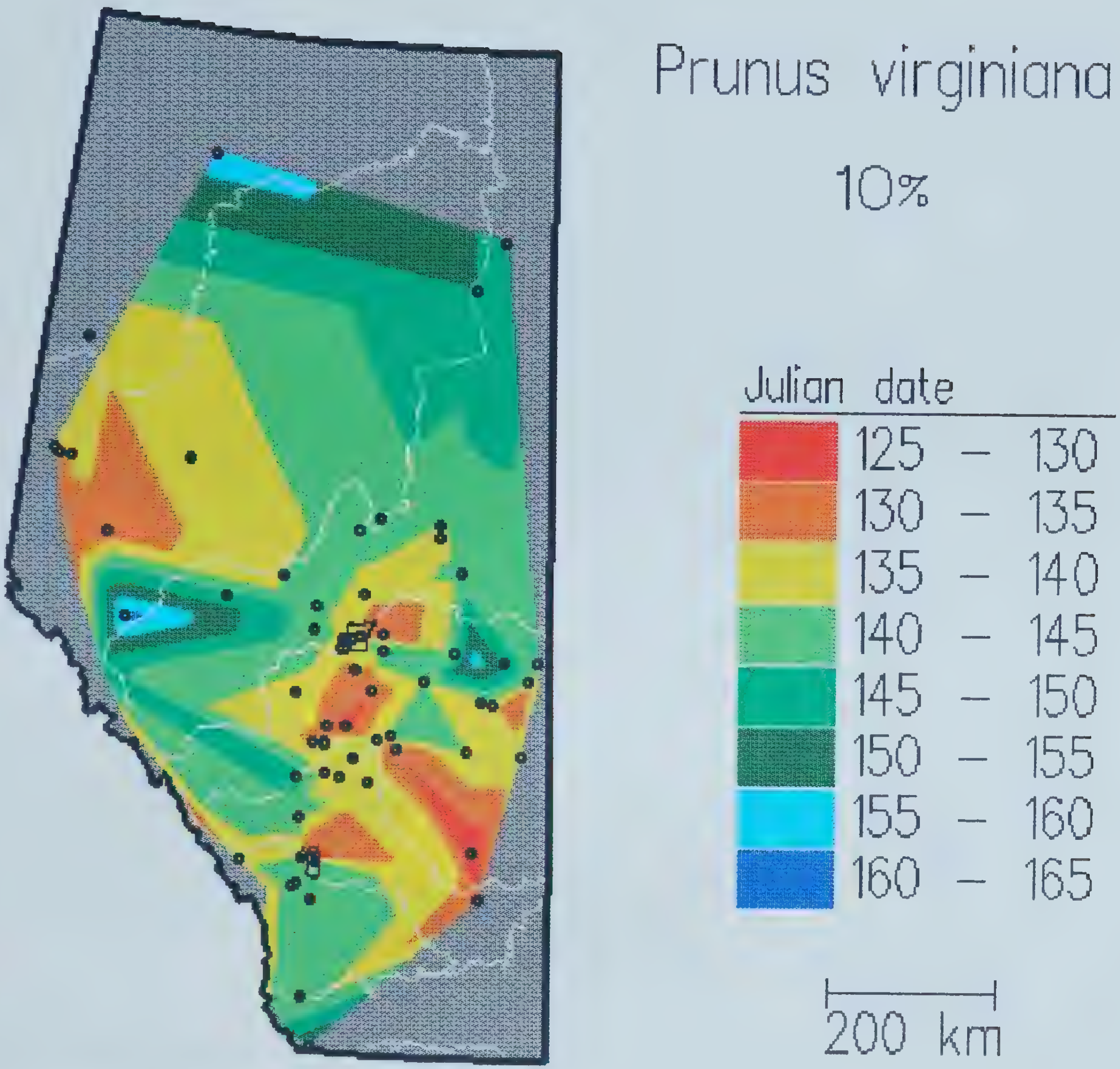

A. alnifolia 90%
Julian date
130 – 132
132 – 134
134 – 136
135 – 138
138 – 140
140 – 142
142 – 144
144 – 146
146 – 148
> 148
100 km

Figure 14-f:



Prunus virginiana
10%
Julian date
125 – 130
130 – 135
135 – 140
140 – 145
145 – 150
150 – 155
155 – 160
160 – 165
200 km


Figure 14-g:

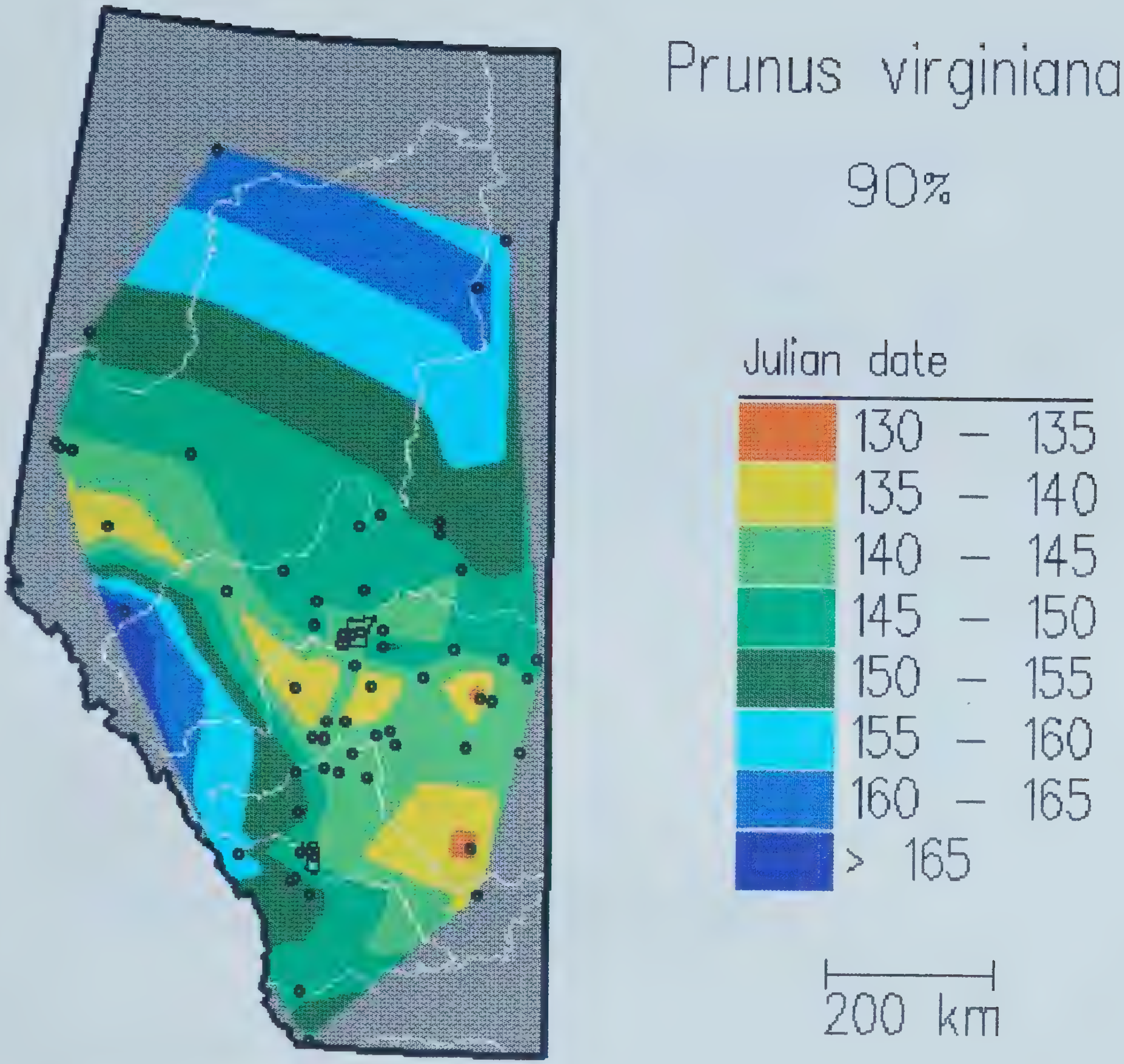

Prunus virginiana
90%
Julian date
130 – 135
135 – 140
140 – 145
145 – 150
150 – 155
155 – 160
160 – 165
> 165
200 km

Figure 14-h:

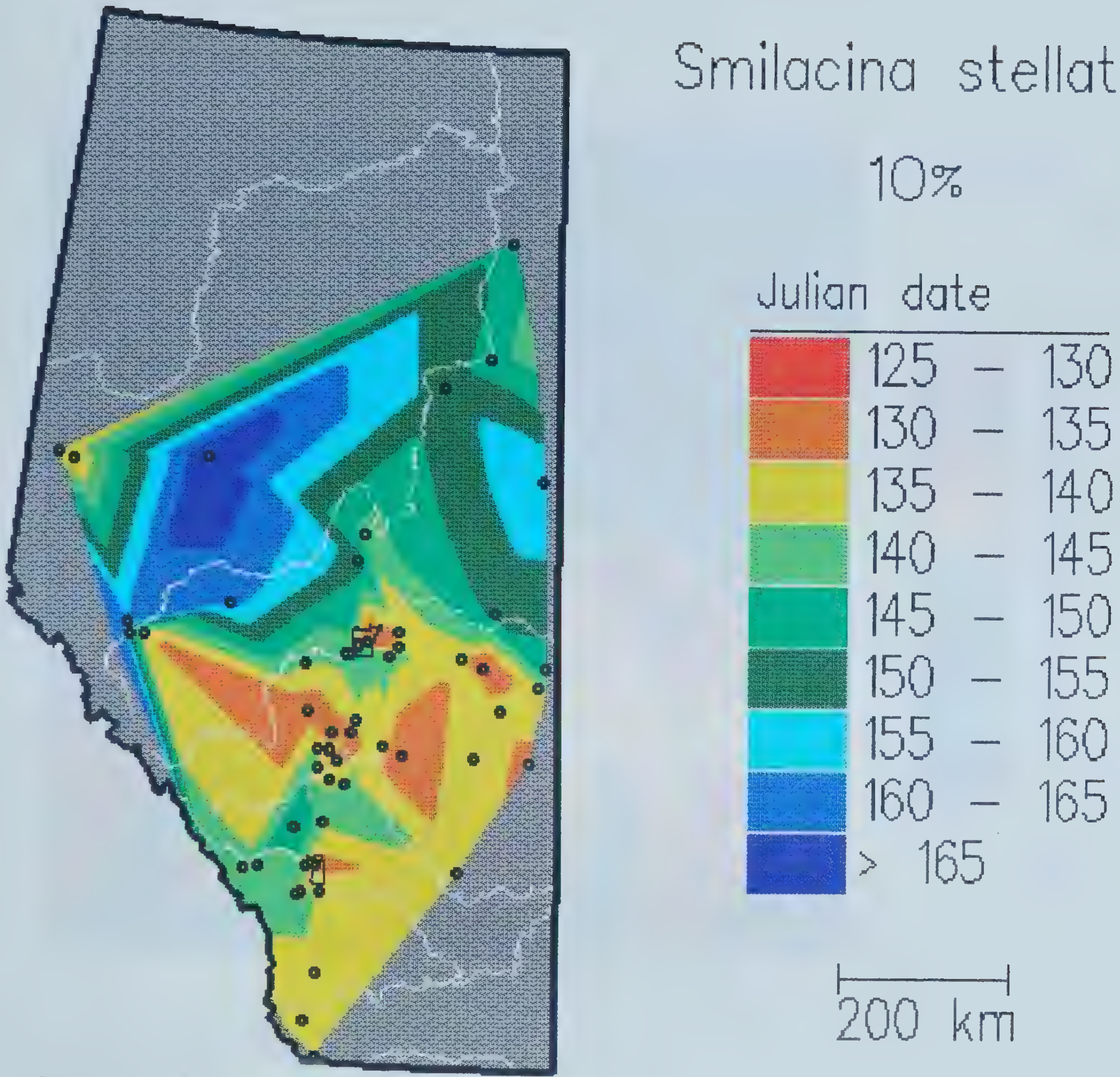

Smilacina stellata
10%
Julian date
125 – 130
130 – 135
135 – 140
140 – 145
145 – 150
150 – 155
155 – 160
160 – 165
> 165
200 km

Figure 14-i:

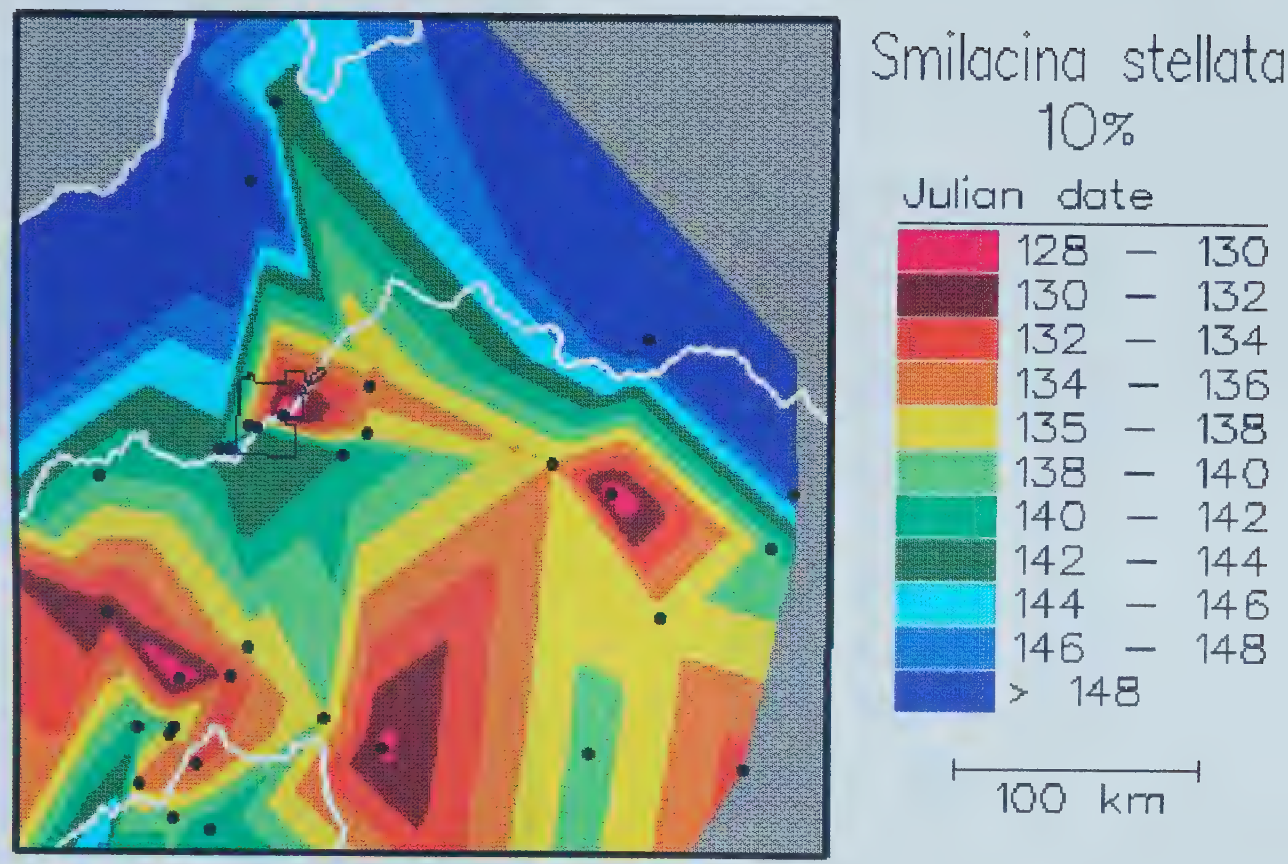

Smilacina stellata
10%
Julian date
128 — 130
130 — 132
132 — 134
134 — 136
135 — 138
138 — 140
140 — 142
142 — 144
144 — 146
146 — 148
> 148
100 km

Figure 14-j:

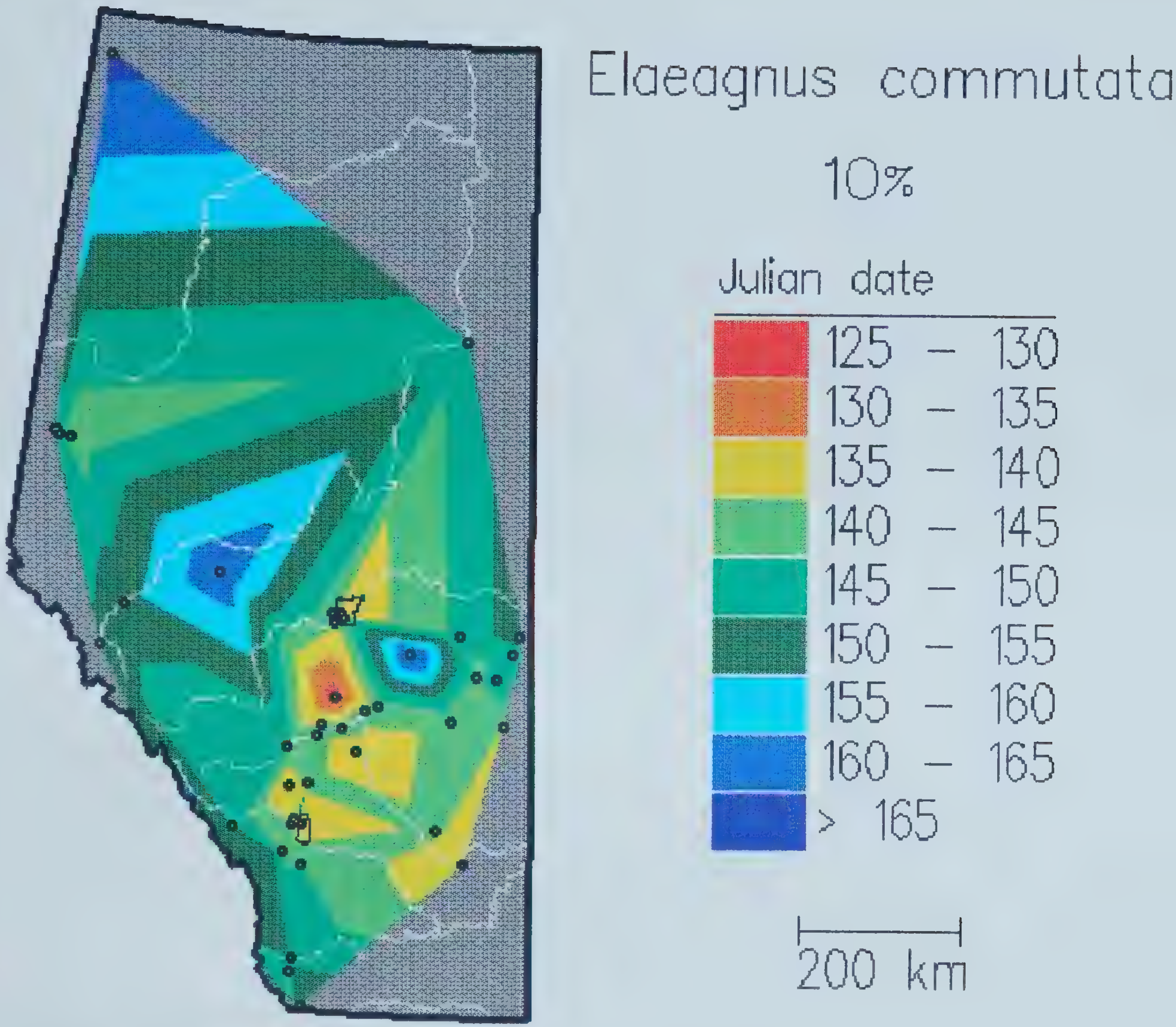

Elaeagnus commutata
10%
Julian date
125 – 130
130 – 135
135 – 140
140 – 145
145 – 150
150 – 155
155 – 160
160 – 165
> 165
200 km

Figure 14-k:

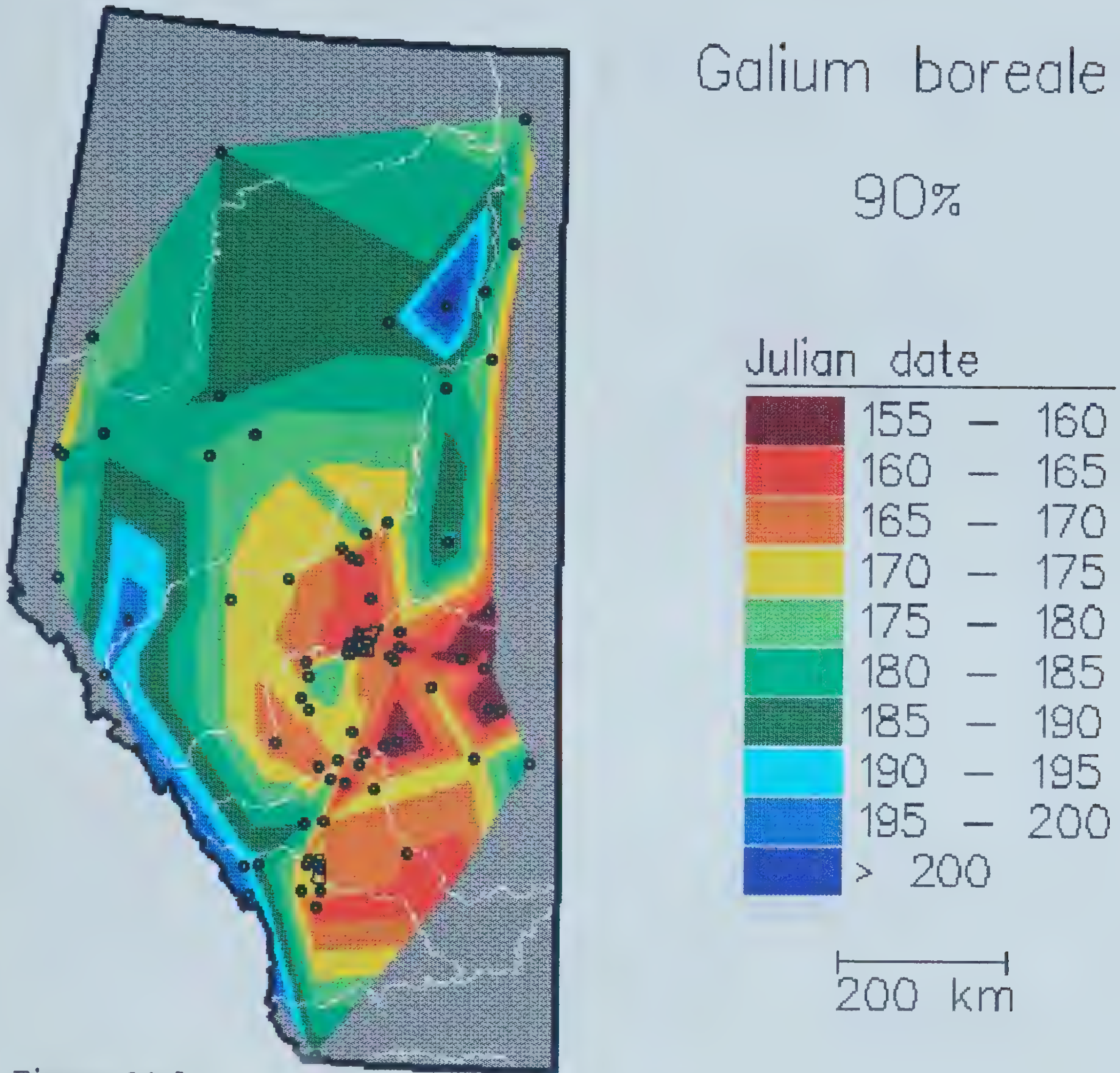
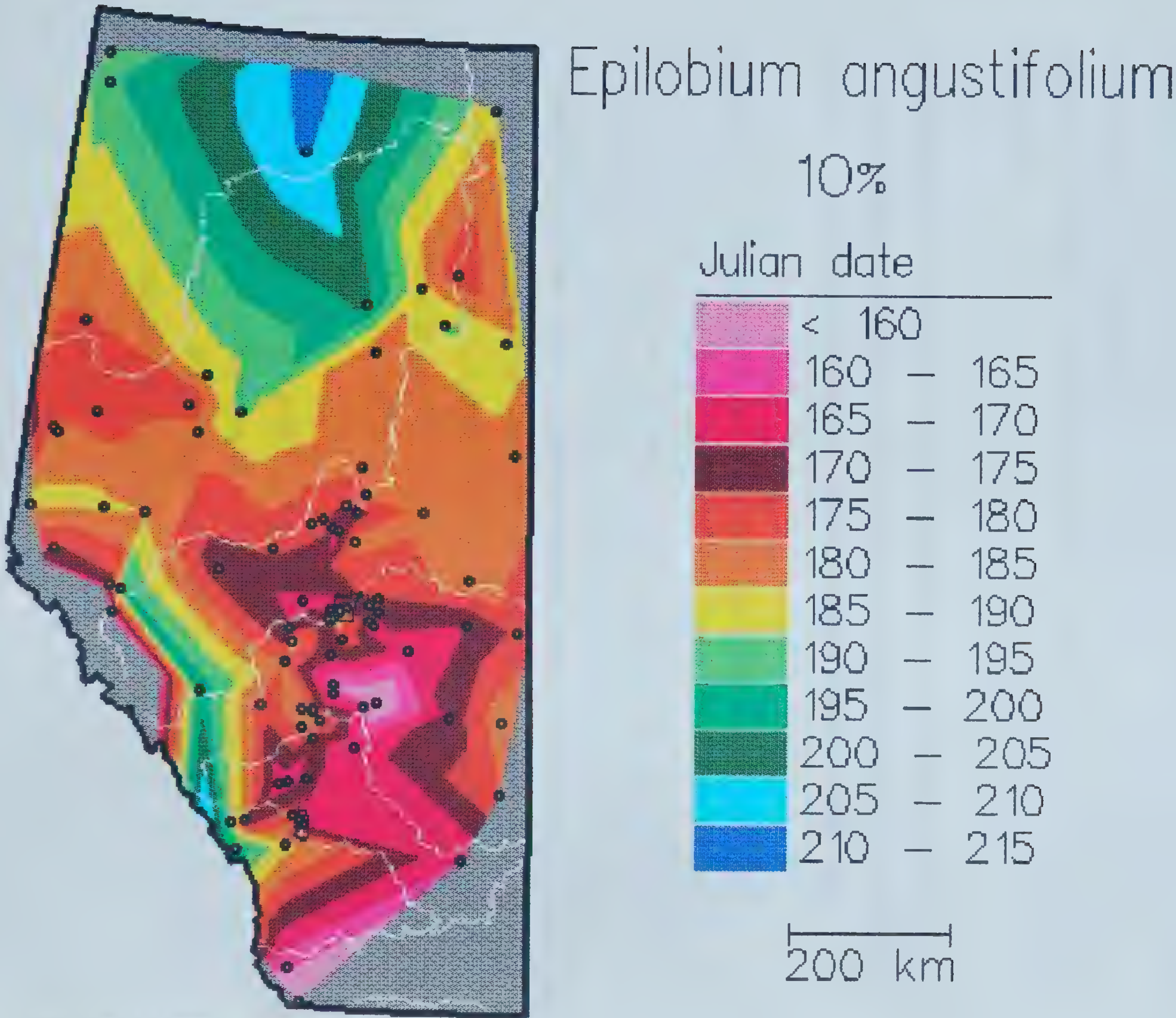

Galium boreale
90%
Julian date
155 — 160
160 — 165
165 — 170
170 — 175
175 — 180
180 — 185
185 — 190
190 — 195
195 — 200
> 200
200 km

Figure 14-1:



Epilobium angustifolium
10%
Julian date
< 160
160 – 165
165 – 170
170 – 175
175 – 180
180 – 185
185 – 190
190 – 195
195 – 200
200 – 205
205 – 210
210 – 215
200 km


Figure 14-m:

Prunus 10 and 90% (Figure 14-g,h): The same pattern is seen in Prunus as is seen in Amelanchier, of earliness along a SE-NW line, and subsequently flowering progressing NE and N and also SW to the foothills and then the mountains.

Smilacina 10% (Figure 14-i): Earliest flowering is in the major cities (Calgary, Red Deer, and Edmonton). The areas of Beaverlodge, Ft. McMurray and Vermilion are also early. The window on central Alberta shows more detail for the area around Edmonton.

Elaeagnus 10% (Figure 14-k): This data set is smaller than most of the others, as seen by the lack of observations in northern Alberta. Again the major cities show earliest flowering.

Galium 90% (Figure 14-l): The earliest areas include the central part of the province east to Vermilion and Wainwright. Note the green tongue of later dates spreading east from the mountains just NW of Calgary (which is outlined in black near the bottom of the map). This matches the location of a band of the cooler montane zone (Natural Regions of Alberta map - Figure 2). The late blooming date shown by the dark blue area in the NE corner of the map is the Ellis River fire tower in the Birch Mountain foothills at 555 m.

Epilobium 10% (figure 14-m): The earliest areas include SW Alberta and the Stettler area. This pattern is what one would expect, except that Athabasca and Jasper seem unusually early. More data are needed for the mountains.

In conclusion, the pattern observed in this 1988 phenology data is not a simple south - north trend. It is roughly similar among species, and shows much more similarity among phases of a species.

The distribution of observation points on these maps shows immediately where plants were observed. This reflects the distributions of the species (Packer, 1983) and the distribution of observers (Figure 11).

This pilot project to map the 1988 data has served to test and refine a suitable GIS mapping method for future use. Further mapping with larger data sets including averaged multi-year data will provide a better understanding of the "green wave" in Alberta.

4.2.3. Synchronization of Species

An examination of timespans between phases for 10 of the best reported blocks in the province revealed that the intervals in Table 18 appeared to be most consistent and to hold promise for future use in phenology. These are 1988 averages in numbers of days for the province as a whole. Once refined over the years, these timespans between species can quickly reveal the relative earliness or lateness of the current stage of the growing season.

Table 18: Synchronization of Species: average timespan between flowering phases of plant species in the flowering sequence, for Alberta, 1988.

| Species, phase | <u>to</u> | Species, phase | timespan | # of areas averaged |
|---|---|---|---|---|
| *P. tremuloides* 90% | | *V. adunca* 10% | 20 days | 6 |
| *T. rhombifolia* 10% | | *A. alnifolia* 10% | 6 days | 5 |
| *A. alnifolia* 10% | | *S. stellata* 10% | 10 days | 7 |
| *A. alnifolia* 90% | | *S. stellata* 10% | 4 days | 7 |
| *A. alnifolia* 10% | | *P. virginiana* 10% | 7 days | 9 |
| *A. alnifolia* 90% | | *P. virginiana* 90% | 8 days | 10 |
| *P. virginiana* 10% | | *E. commutata* 10% | 5 days | 6 |
| *P. virginiana* 90% | | *E. commutata* 90% | 7 days | 5 |
| *G. boreale* 10% | | *A. millefolium* 10% | 6 days | 5 |

## 4.3. Discussion

### 4.3.1. Statistics

The responses from observers do not represent a random sample, which restricts the meaningful use of statistical analysis.
The observer distribution is also not even (Figure 11). Concentrations of observers occur in cities, which are also heat islands with earlier flowering dates than surrounding areas. Distributions of the 15 key phenology species across the province are each different, though most are relatively widespread (Packer, 1983).

Most observers sent data on a selection of the 15 species, and often fewer than three dates for each species were submitted. This limits the types of statistical analysis possible. Concordance of rankings to compare the similarity of species sequences between locations, is a possibility for future analysis (Mark Dale, 1989, pers. comm.).

Frequency distributions:
1988 was hotter than average (Alberta Environment, 1989), and species such as Amelanchier alnifolia, Prunus virginiana, and Smilacina stellata flowered rapidly and show narrow distributions (Appendix 7). In a cool year the width of their flowering distributions would be greater. Some distributions show scattered late flowering dates, which generally are from areas at high altitude or latitude.

Summary Chart:
The plants listed in Table 16 are in the order of their mean 10% flowering across the province. This order varies slightly from the order given on the data sheet sent to observers (Appendix 2). This order still needs to be corrected for the differing range of the species by restricting comparisons to data from the same area. Once many years of data for first flowering have been collected, an accurate estimate of the average sequence can be calculated. The

order may vary slightly from area to area. In Finland and northern Sweden, Sorbus aucuparia (Mountain Ash) generally flowers before Syringa spp. (lilac), but from the south of England down through France and east to Hungary, Syringa flowers first (Schnelle, 1955). (However, this represents a 20 degree latitudinal change, whereas Alberta covers only 10 degrees of latitude from the south to the north boundary.) In Alberta, the results of the hand-mapping averages showed that the average 1988 date for 10% Viola adunca was later than 10% Thermopsis rhombifolia in Calgary, Red Deer and Stettler, but earlier in Wainwright. The sequence in a given year and place can sometimes vary depending on local weather conditions. An unusual hot air mass can cause a "phenological inversion" (Schnelle, 1955), where the usual flowering order for two species can be reversed.

Species showing a standard deviation greater than 11 in 1988 include Populus tremuloides- all phases, Lathyrus ochroleucus- 90%, Galium boreale- 50%, 90%, Linnaea borealis - all phases, Achillea millefolium- all phases, Gaillardia aristata- 50%, 90%, and Epilobium angustifolium- 50% and 90%. There is a trend to later flowering species having larger standard deviations. This reflects more variations in the flowering date for a certain phase, and could mean that flowering happened more slowly across the distribution of these later species, or that there was more difficulty experienced by observers in phase estimation. The exception to this trend is the fast flowering Lilium philadelphicum, with an average s.d. for the three phases of 7.4. Large standard deviations may in fact indicate species that are more sensitive to climate change. But one factor to consider in a comparison of standard deviations between species is the geographic distribution of observations which changes for each species. Once many years of dates are reviewed for one area of the province where all species occur, better conclusions can be drawn about relative merits of species based on variability in the data.

The coefficient of variation (cv) was also calculated for each species/phase, but this coefficient depends on the value of the mean Julian flowering date:

$$cv = \frac{(\text{standard deviation} \times 100)}{\text{mean}}$$

which increases with each sequentially flowering species. Thus this is not a useful coefficient to compare species.

Moran's I statistic:
The lack of significant spatial autocorrelation for phenophases of a species is probably the result of a sparse data set (Table 17). More data are needed to fill in between the known sites, and the 1988 database represents a more detailed surface than this program can fit at present (Johnson, 1990, pers. comm.).

Regression:
More factors are involved in spatial variation in phenology than simply latitude, as shown by the regression graphs (Figure 12). In the future with more years of data, one could find out how much spatial variation within a year is accounted for by latitude, longitude, altitude, slope, aspect, accumulated temperature, etc. using multiple regression.

Reader et al. (1974) had about 300 participants reporting flowering dates for two woody species over 3 years. They found using linear regression that the averaged Cercis canadensis L. (redbud) - Cornus florida L. (dogwood) flowering date was equal to a combination of these independent variables: latitude, longitude, and altitude plus a random error term. When they considered the total range of eastern North America for these two species, all three of these location variables contributed significantly to the regression equation.

### 4.3.2. Mapping

While mapping by hand is a low-cost method which has clearly illustrated the trends of flowering from the southeast to the northwest, it is a time-consuming technique and prone to subjectiveness with respect to area delimitations. Computer mapping is the preferred method.

The linear contour maps show a general progression of flowering development from south central Alberta (with Edmonton, Red Deer and Calgary as early flowering "heat islands"), to the Peace country and SE corner of Alberta, to the northeast and foothills, mountains and northern Alberta (Figures 14 a-m). As Russell (1962) noted in phenological studies of native plants at Winnipeg, Saskatoon and Edmonton, isothermal lines run from the southeast to the northwest across the Prairie Provinces, rather than east-west.

The maps reflect known natural region and vegetation boundaries as seen in Figure 10. The map of the larger scale window of Amelanchier alnifolia 10% (Figure 14-d) shows a tongue of later dates from north of Edmonton to SE of the city. This corresponds fairly closely to the location of a lobe of cooler mixedwood forest in the surrounding central parkland.

The Prunus virginiana 10% map (Figure 14-g) has a very similar colour (flowering) pattern to Amelanchier alnifolia 90% (Figure 14-c). The mean flowering dates for these species are nearly identical; May 17 for Amelanchier alnifolia 90% and May 18 for Prunus virginiana 10%. Exposed to the same weather conditions, it is not surprising that these two shrubs which share similar habitats should have similar development across the province (personal observation).

The contouring program (SPANS) still needs some refinement for use with this phenology data. There is some unwarranted extrapolation to earlier dates along the northeast border in the map of Galium boreale 90% (Figure 14-l), and along the mountainous west boundary in

Epilobium angustifolium 10% (Figure 14-m).

In mapping the data we assume that our sample of flowering timing accurately represents a large population. However, one problem is areas of the maps with little data, for example the maps of Amelanchier alnifolia show gaps in observations in north central Alberta. The mountains within these zones could actually have quite late flowering. Lack of data can also be due to gaps in plant distribution, or to loss of habitat due to agriculture (for example A. alnifolia south and east of Calgary).

In Alberta, the growing season ranges from a maximum of 190 days SW of Medicine Hat to less that 160 days north of Peace River (Dzikowsky and Heywood, 1990). The A. alnifolia 10% map (Figure 14-a) reveals that first flowering occurred across much of the province within a two-week period. This fast pulse of flowering was speeded by greater than average temperatures in the months of April and May (Alberta Agriculture, 1988). But the 30-year normals for the dates for start of the growing season (average daily air temperatures reach 5°C for a 5-day period) show that it crosses the province in a period of one to two weeks (Figure 15). Spring arrives quickly in this province. Alberta's growing season is short, and phenology studies can help subdivide this growing season and clarify the zones of relative warmth and earlier plant development.

The data for some species (eg: P. tremuloides, L. ochroleucus, L. borealis) are difficult to explain. For example, for L. borealis 10%, flowering occurred in Edson at the same time as Fort Smith. For Linnaea 90%, Fort McMurray was reported as earlier than Calgary and Red Deer. Perhaps the longer days of sunshine compensate for the higher latitude. Bird (1978) found in his Alberta study that while flowering in northern areas was slower to start due to later snow melt, the increased spring day length at those greater latitudes soon caused them to catch up to the south. In general, plants at higher latitudes or altitudes have more compressed growing seasons, starting growth later and finishing earlier (Hopkins, 1938).

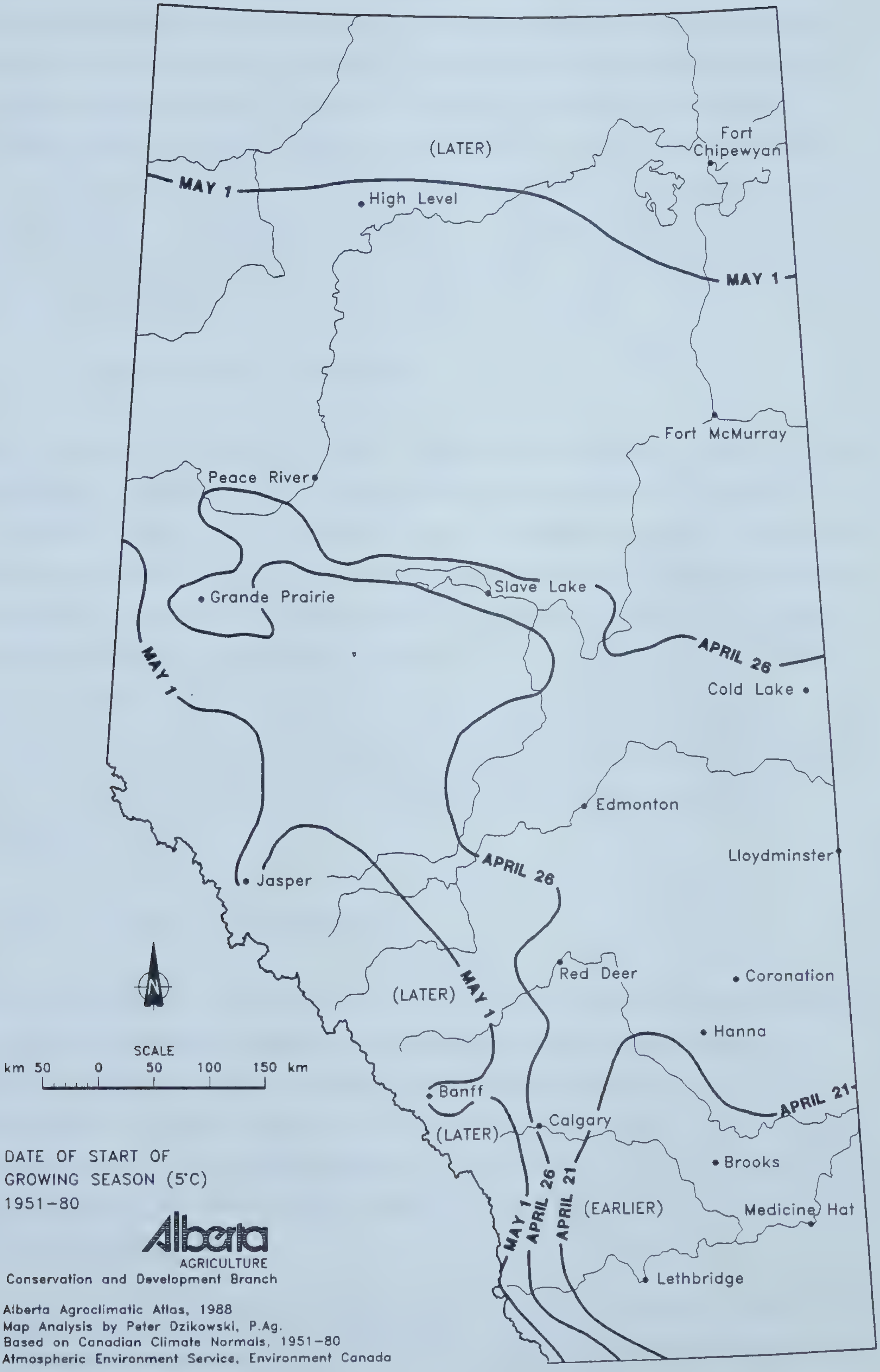



Figure 15: Map of the dates of start of the growing season (temperatures above 5°C).
Source: Dzikowsky and Heywood, 1990, p. 29.

The linear contour mapping represents a very useful technique to illustrate these flowering data. As the numbers of observers and years of observations increase, the mapping of average dates will reveal a "green wave of spring" which is relatively consistent between years. Future mapping possibilities include: correlating flowering dates with climatic (e.g. temperature or degree-day data), topographic, or latitudinal variables; overlaying zones of equal flowering with vegetation zones, ecoregions, or even tourist zones; and combining species flowering times on one map.

### 4.3.3. Synchronization of Species

The intervals in Table 18, with refinement (minimally using 10 year averages), could be used to measure the progress of the season in different areas. They could help us see whether spring is advancing faster or more slowly than usual. This would have immediate use in agriculture (planting times, crop protection), medicine (allergy season prediction) and many other fields. As well it would give survey observers an indication of when to anticipate the next phenological event. Regional averages for phenophases would be more useful than provincial averages, as time intervals between species and even sequence of species can vary across large distances (Schnelle, 1955).

### 4.3.4. Suitability of Species

The 15 plant species used in the survey all have the characteristics of ideal phenology species as outlined in the introduction, to varying degrees. Examining the data reveals that some of the 15 species are better suited to this survey than others. For instance, some species have a faster pulse of flowering. To compare species, one can look for those with a shorter timespan between the 10% and 90% flowering stages.

A small standard deviation would also indicate a faster pulse of flowering across the province. The best way to compare this in

future would be to use one area of the province where all species occur, and compare standard deviations of one phenophase (eg. 10% flowering) among species and among years. The problems of differing observation sites within that area and the amount of data per species, still remain.

The following conclusions are based on the 1988 data. In this year spring was early everywhere, and there was drought in the south. For each species, some of the following parameters are considered: quantity of data, variability of data (standard deviations), distribution across the province (Packer, 1983), and ease of recognition of species and phenophases. Volunteer observers should be canvassed in future for their suggestions and comments on these species.

Anemone patens (Prairie Crocus): Well-distributed, especially across the southern half of the province, this plant was well-reported with over 70 observations for most phases. This is a very popular plant with the rural public, as it is a harbinger of spring and symbolizes the prairie. It is easy to recognize, though early blooms can be hard to find unless one is standing over them in the dead grasses of early spring. Estimating % bloom is a challenge since new flowers continue to emerge from the ground. A technique to help observers is recommended in Appendix 2: "Alberta Wildflowers", p. 4.

The 90% phase of Anemone patens shows some unusually late dates. Some flowering in late summer or fall is often reported by naturalists in Alberta, and is possibly linked to locally abundant moisture (Coupland, 1980; Scotter and Sommerfeldt, 1988).

In Minnesota, A. patens flowers bloom on average 7-9 days, and the whole development cycle from mature flower bud to seed shed averages 38.5 days (Ordway, 1985). Knutson (1979), who describes the flowers as solar-collectors, measured internal temperatures up to 10°C above the ambient temperature. This species is well adapted to natural disturbances. Provincial survey observers occasionally reported in

1987 and 1988 that buds and flowers had been consumed by ground squirrels or ungulates. This plant's reserve of dormant buds is added to annually, allowing the plant to grow new branches if the terminal buds are damaged. The largest, most highly-branched individuals are found at sites which are regularly grazed or burned (Wildeman and Steeves, 1982). Unfortunately this plant has disappeared from many areas in Alberta due to plowing.

Populus tremuloides (Aspen Poplar): A successful pioneer, this species produces multi-stemmed clones. It is the most widely distributed native tree on the continent (Brissette and Barnes, 1984). In Alberta, six weeks elapses between flowering and seed shed, on average (Moss, 1938).

Most of the literature on the phenology of P. tremuloides deals with leafing. While heat accumulation after a required cold period controls leaf flush in this species as in most temperate deciduous trees (Lechowicz, 1984), ecotype greatly influences leafing phenology (McMillan, 1957, Brissette and Barnes, 1984).

This early-flowering species has a wide distribution in Alberta but was less well reported. It has a fast pulse of flowering, as noted previously, but large standard deviations indicate much variability in the data. One factor affecting its flowering phenology could be forest tent caterpillar (Malacosoma disstria Hübner) infestations. Lechowicz (1984) notes that leaf emergence in Populus tremuloides can be advanced a few days by defoliation the previous year.

In instructions to observers, flowering was defined for this species as pollen shed by male catkins. Many late dates were received, which perhaps indicates that some observers were observing female trees. The best time of year to "sex" trees (to borrow a little jargon from our zoological compatriots), is in late winter when grey catkins emerge first on male trees. Just before flowering, identification of female versus male is difficult without a magnifying lens, though many male trees start shedding pollen before the majority of female

catkins appear receptive. After the male trees' pollen shed is complete, recognition is simpler: only the female catkins lengthen and turn green. This recognition problem was addressed in the spring 1990 newsletter, when sketches of male and female flowers and an indication of their timing were sent out (Appendix 9).

Another source of confusion may be the similar species Populus balsamifera which flowers later than P. tremuloides and has male catkins that are larger and brighter red. Sketches or photos of these two species would help observers in future. Some observers indicated that their poplars were tall and that observing flowering required binoculars! Full flowering (complete elongation of the staminate catkin) may prove to be the best phenophase for this species, as Moss (1960) found in his studies of the genus.

Viola adunca (Early Blue Violet): This species was well-reported, and variability of the data was average. Widely distributed in Alberta, this violet ranges from the prairies to the lower alpine regions (Mauer, 1977). Three chromosome races (2n=20, 2n=30, and 2n=40) occur in the province, of which the diploid and tetraploid forms are most common (Packer, 1983). Davis (1980) found that tetraploids were hardier (survival of unhardened seedlings at -6 °C) than diploids. It would be interesting to see if flowering phenology varies between the two races, which grow together in some locations such as the Cypress Hills.

Thermopsis rhombifolia (Golden Bean): This species has a more restricted distribution than most of the key species, being found only south of the North Saskatchewan River. It was less well-reported, though it is easy to find and recognize, adding a blaze of gold to roadsides in spring. The data were fairly consistent (s.d. less than 8). This is a useful phenology species for southern Alberta.

Amelanchier alnifolia (Saskatoon): This is probably the best species of the fifteen. It has a wide distribution in the province. It was very well reported, had a fast pulse of bloom, and showed good consistency in dates for each phase. All phases seem fairly easy to recognize. It shares one problem for phenology with Populus tremuloides and Prunus virginiana - it is a preferred food plant for tent caterpillars.

A. alnifolia has been domesticated on the prairies as a native fruit crop with the development of cultivars over the last decade. In this "extremely cold-resistant taxon" (Junttila et al., 1983), bud-dehardening proceeds slowly under natural conditions, and the diameter of florets before flowering is linearly correlated with the cumulative heat sum above 5°C.

Prunus virginiana (Choke Cherry): This plant has a wide distribution except for extreme northern Alberta and it is easily recognized. Variability in dates was small, and it had a fast pulse of flowering across the province. It was less-well reported (10% and 90% phases had about 65 observations each), but overall it is one of the best species for phenology.

Smilacina stellata (Star-flowered Solomon's-seal): This species was less well- reported though it is widely distributed. This may be due to recognition problems, as the plant is physically variable depending on the habitat (see Appendix 2, Alta. Wildflowers, p.9.) The standard deviations show a fair amount of variability - over 10 for the 50% and 90% phases.

The extensive rhizome systems in this species produce long and short shoots, affording flexibility in exploiting the forest environment. Yearly increments mean that individuals can be aged - the lifespan of a genet can be several hundred years (Antos and Zobel, 1984).

Elaeagnus commutata (Wolf Willow): Low numbers of observations probably reflects observer difficulty in recognizing this species which has small inconspicuous flowers. Once people cue in to its powerful odour they have no further problems! It has a wide distribution especially south of the boreal forest, and is common. It had a fast pulse of flowering in 1988.

Lathyrus ochroleucus (Yellow Pea Vine): This legume is only missing in Alberta in the dry southeast. The standard deviation for the 90% phase was 11.7, which shows considerable variability in estimates. Full flowering can be hard to recognize in this indeterminate inflorescence, as I observed while doing my Whitemud study. This may explain other odd results - the averaging by area revealed that flowering in the Porcupine hills was later than Cold Lake, and though farther south, Lethbridge and Waterton were later still.

Galium boreale (Northern Bedstraw): This well-distributed plant is easy to recognize. It was also well-reported and had a fast pulse of flowering (9.9 days).

Linnaea borealis (Twinflower): This plant is found in mixed coniferous forest and occurs everywhere except the prairie southeast. It occupies a broad spectrum of poor to rich soils, dry to wet conditions, and elevations from about 600 m to 2000 m (Corns and Annas, 1986). It was poorly reported in 1988, and the wide variation in dates received for single locations would indicate that recognition of this species might have been a problem. This problem was addressed in the 1990 reprinting of "Alberta Wildflowers", by adding a sketch of L. borealis to illustrate its small size. Its blooming period seemed well-defined, as determined during the Whitemud Study. This species' prevalence in the mixedwood and boreal forest make it a valuable phenology species for the northern half of the province.

In Europe, this plant has been found to be strongly dependent on conditions of high relative humidity, long snow cover, and cold air

flows (Kohlhaupt, 1963). The widespread stolon system in this species gives it a larger capacity for expansion in favourable conditions than certain rhizomatous species (Antos and Zobel, 1984). Roots are relatively small, however, and this plant can be displaced by taller herbs.

Lilium philadelphicum: The Wood Lily has a large showy inflorescence which is easy to recognize. It is most common on black soil in open or cleared areas of the aspen parkland and can be locally abundant in suitable habitats of the prairie and boreal forest. Its distribution thus includes most of Alberta except for the southeast and north. However, where the soil is plowed or broken this species is lost, and it is also negatively affected by mowing or heavy grazing, herbicide spraying, and picking for bouquets.

Phenologically, this is an early summer species which flowers over a two week period beginning on average in the last half of June (Bird, 1983). Numbers of observations in 1988 were low (under 60 per phase), but showed good consistency with an average standard deviation of 7.4. This is a suitable phenology species only in areas where it grows in patches, as individual plants may not flower every year.

Gaillardia aristata: Brown-eyed Susan is limited to the southern half of Alberta, and perhaps for that reason was less well reported. It is showy (inflorescence up to 10 cm across) and easy to recognize even at highway speeds. The large standard deviations for 50% and 90% flowering would indicate that these phases are hard to estimate. Perhaps only 10% data should be analysed in future years.

Achillea millefolium (Yarrow): This was well-reported and is very common in Alberta. The 90% phase appears to lack "sharpness", with two peaks in the frequency distribution and a high standard deviation (15.08). This is most likely due to the fact that some flowering continues until freeze-up (Leopold and Jones, 1947). The 10% phase may be the most useful for this species as well.

A member of the Composite family, A. millefolium is self-incompatible and insect-pollinated. The species is very complex, consisting of tetraploid and hexaploid races occurring across Canada (Warwick and Black, 1982).

Epilobium angustifolium (Fireweed): Well-reported, this member of the evening-primrose family is easy to recognize and is well-distributed in the province. It is found across much of North America from 25° to 70° latitude (Mosquin, 1966). It forms 6 to 8% of the tall herb strata in Alberta's poplar association, and its rapid appearance after a fire is less likely due to dissemination by seed (which is abundant) than to the presence of dormant woody roots which produce vigourous shoots when provided with adequate nitrates (Moss, 1936).

However, this species is unsuitable in some ways for phenological studies. Ungulates such as deer seek out the edible flower heads, removing buds or flowers. Because the indeterminate inflorescence blooms slowly from the bottom of the spike to the top, the 50% and 90% stages even as defined in "Alberta Wildflowers" seem to lack sharpness. The 1988 90% data have an odd frequency distribution and the smallest number of observations of all three phases. This plant needs further phenophase refinement using the techniques outlined by West and Wein (1971) to achieve reasonable standard deviations. Until that time the 10% data are most valuable.

Future studies should investigate the effects of ramet size in E. angustifolium's flowering phenology. Larger ramets of Aster acuminatus and Clintonia borealis tend to emerge earlier, mature over a longer period, and senesce later (Brown et al., 1985).

With future development of the survey, more species could be added in certain areas to improve the complement of phenological information. The present span of species covers the period from spring to midsummer (early August). It could be expanded to include later flowering species eg: Solidago canadensis, Aster conspicuus, though

identification of the fall composites is fairly difficult for amateurs.

One gap in the present span of species was apparent from the flowering predictions data. It shows that there was an average of 20 days between full bloom of Populus and first bloom of Viola, the next species in the sequence. This indicates that a plant species with full bloom time intermediate between these two species should be sought to fill this gap. It would also be possible to improve the phenological sequence for different parts of the province. In SE Alberta Phlox hoodii is one of the first plants in flower. In mixedwood and boreal forests Cornus canadensis would be an excellent phenology species. Other useful phenology species for parkland habitats are identified in Appendix 4.

To reduce the effects of within-species variation in native species' genotype, the survey could be supplemented with a cloned cultivar. Lilac is hardy in much of Alberta, or a cultivar of Amelanchier (Saskatoon) could be used.

A different approach to the survey's future might be to simplify the survey by requesting dates for a much smaller number of species. This would make it easier to recruit and effectively train a large number of volunteers.

### 4.3.5. Phenophase Selection

The three phases 10%, 50%, and 90% are better suited to some species than others. Kreeb (1977) notes that the 50% and 90% flowering phenophases can be difficult to observe. As pointed out under suitability of species, the 90% phase of Gaillardia, Achillea, and Epilobium yielded more variable dates in 1988. If this large standard deviation continues for single locations over subsequent years, then only the 10% phase should be analysed. It may still be valuable to request the other phases to enhance the reliability of estimates by ensuring that plants are observed over a period of time. The full bloom phase (90%) may provide the best data for species such as Populus, and Prunus.

First bloom needs to be well-described, with cautions against recording early flowering of individual plants in unusually warm microclimates. MacKay's forceful instructions for observation are equally valuable today: "Better no date, NO RECORD, than a WRONG ONE or a DOUBTFUL one. Sports out of season, due to very local conditions not common to at least a small field, should not be recorded except parenthetically" (MacKay, 1899, p.74).

Amelanchier and Prunus have clusters of small flowers. Observers may find it even easier to recognize distinct phenophases if the definitions used for the eastern lilac and honeysuckle survey (Dubé et al; 1984, p.6) were used: "First bloom for lilacs is the date when at least 50% of the flower clusters have at least one open flower (shows photo of stage). "Full bloom for lilac is the date when 95% of the flower clusters no longer have any unopened flowers, but before many of the flowers have withered" (photo is shown). For herbaceous species being observed in the vicinity of a microclimate or weather station, Jackson (1966) defined 90% or more as a "subjective evaluation of the time when practically all (90% or more) of the individuals of a species had flowered that were within a 10 foot radius of the station". This would most likely yield slightly later dates than Dubé's definition above.

### 4.3.6. Sources of Error

In one growing season, variations in phenology between individuals of a species in an area are due not only to weather differences, but also to differences in site (microclimate, soils, etc.) and genotype.

The effects of genotype are difficult to measure. Schnelle (1955, p.45) emphasized that when using native plants "each observation from any one station, if at all possible, should be considered in relation to a neighbouring station". Caprio (1966) notes ecotypic responses in phenology: plants growing in the north do not bloom early despite periods of warmth and thus avoid frost. They then develop faster and mature before fall. If one moved specimens of _Achillea millefolium_ from Lethbridge to High Level, would they survive? Survey results will tell us the average phenological behaviour of species in different areas. The extent of ecotypic variation in their flowering phenology could be determined in future for each of the 15 key species by using common garden experiments, as described by Flint (1974).

Another source of variation which is difficult to quantify is the factor of observer error. One way to quantify human error would be to compare the results of 2 or more independent observers who record dates for the same species in the same location and time period. Leopold and Jones (1947) compared 39 observations taken over four years of phenology records with those of an independent observer in their area, and found that on average the difference between dates was only 2.6 days.

Better instructions to observers will reduce variability, and as time goes by the error should diminish. The more species, observers, years, and locations behind any average, the more the errors balance each other out (Russell, 1962; Leopold and Jones, 1947).

Leopold (Leopold and Jones, 1947, p. 103) notes that "a developmental record for any given species, to be valid through a term of years,

should either a) embrace the entire gamut of site and of genetical constitution, or b) it should be limited to certain individuals which have been selected in advance, and in which site and genetics remain constant. Alternation or mixture of the (a) and (b) types is fatal." For this reason the Alberta survey asks observers to select a patch of plants for each species and to follow these plants through the season.

How much were the observation dates influenced by volunteers' choices of when to observe? If observers were observing only on "days off", one would expect to see a greater number of observations on the weekend (presuming a high proportion of observers have Monday to Friday jobs). A frequency list of observations for each date from mid-March to mid-August was checked and there was not an increased number of observations on weekends. This would indicate that generally, people were observing plants on a more frequent basis. More than half of the observations occurred before May 25th. Bird (1979) noted that he also received most data for early flowering species, and speculated that later in the season volunteer observers were too busy with gardening, farming or holidays.

4.3.7. Comparisons with other Studies

The 1988 Edmonton data from the provincial observers were compared with the 1988 Whitemud Study results and with the following long-term Edmonton data:

Bird, (1982) - 9 year period, 1973-1981, for first flowering.
Russell, (1962) - 25 year period, 1936-1961, for first flowering; and
Moss, (1960) - 32 year period, 1926-1958, for full flowering.

Table 19 shows first and full flowering Edmonton data from three previous phenology studies as well as the averaged 1988 data from the provincial observers and the 1988 Whitemud study data.

Table 19: Comparison of 1988 first and full flowering dates for the 15 provincial survey species (Edmonton data from the Whitemud and provincial studies), with averaged data from three long-term Edmonton studies. Species are listed in the usual order of flowering. Sources: Bird (1982); Moss (1960)- estimated average full bloom dates; and Russell (1962).

| SPECIES: | Anemone patens | Populus tremuloides | Viola adunca | Thermopsis rhombifolia | Amelanchier alnifolia | Prunus virginiana | Smilacina stellata | Elaeagnus commutata |
|---|---|---|---|---|---|---|---|---|
| FIRST FLOWERING | | | | | | | | |
| | month/day | | | | | | | |
| 1988: average 10% flowering from provincial observers: | 4/03 | 4/02 | 4/26 | - | 5/09 | 5/16 | 5/19 | 5/20 |
| # of observations averaged: | 1 | 8 | 6 | - | 5 | 7 | 6 | 4 |
| 1988: Whitemud study: | - | 3/24 | - | - | 5/09 | 5/15 | 5/17 | 5/22 |
| Bird (1982): average date: | 4/16 | 4/15 | 5/04 | 5/11 | 5/14 | 5/21 | 5/26 | - |
| # of years observed: | 6 | 9 | 9 | 6 | 9 | 9 | 9 | - |
| Russell (1962): average date: | 4/25 | 4/27 | - | - | 5/17 | 5/28 | 5/25 | 6/05 |
| # of years observed: | 9 | 26 | - | - | 26 | 23 | 23 | 24 |
| FULL FLOWERING | | | | | | | | |
| 1988: average 90% flowering from provincial observers: | 4/13 | 4/05 | 5/12 | 5/26 | 5/15 | 5/22 | 6/01 | 5/27 |
| # of observations averaged: | 1 | 7 | 7 | 1 | 11 | 7 | 9 | 4 |
| 1988: Whitemud study: | - | 4/09 | 5/16 | - | 5/16 | 5/23 | 6/06 | 5/31 |
| Moss (1960): average dates: | 5/01 | 4/25 | 5/23 | - | 5/19 | 5/31 | - | - |
| # of years observed: | 7 | 32 | 4 | - | 25 | 17 | - | - |

Table 19, continued:

| SPECIES | Lathyrus ochroleucus | Galium boreale | Linnaea borealis | Lilium philadelphicum | Achillea millefolium | Gaillardia aristata | Epilobium angustifolium |
|---|---|---|---|---|---|---|---|
| FIRST FLOWERING | | | | | | | |
| 1988: average 10% flowering from provincial observers: | 5/20 | 6/02 | 6/07 | 6/10 | 6/23 | 6/24 | 6/24 |
| # of observations averaged: | 5 | 7 | 2 | 5 | 7 | 1 | 8 |
| 1988: Whitemud study: | 5/17 | 6/02 | 6/04 | 6/13 | 6/23 | - | 6/25 |
| Bird (1982): average date: | 5/21 | 6/10 | 6/12 | 6/24 | 6/18 | 7/07 | 6/22 |
| # of years observed: | 9 | 9 | 6 | 8 | 9 | 8 | 6 |
| Russell (1962): average date: | - | 6/21 | - | - | 6/27 | - | - |
| # of years observed: | - | 12 | - | - | 18 | - | - |
| FULL FLOWERING | | | | | | | |
| 1988: average 90% flowering from provincial observers: | 6/02 | 6/15 | 6/25 | 6/24 | 7/14 | - | 7/17 |
| # of observations averaged; | 7 | 9 | 2 | 3 | 5 | - | 3 |
| 1988: Whitemud study: | 6/09 | 6/25 | 6/13 | 6/27 | 7/16 | - | 7/16 |
| Moss (1960): average date: | - | - | - | 6/22 | - | - | - |
| # of years observed: | - | - | - | 4 | - | - | - |

First Flowering Comparison:

Russell (1962) published first flowering dates averaged from a 25 year study (1936-1961) done in Edmonton by three sequential observers (staff of Agriculture Canada: M.W. Cormack, S.G. Fushtey, and W.P. Campbell). This data includes seven of the key phenology species. 1988 had earlier flowering than this long-term data for all species, by three weeks for the first two to flower (Anemone patens, Populus tremuloides), by 1 week for Amelanchier alnifolia, and Smilacina stellata, and by 2-3 weeks for Prunus virginiana, Elaeagnus commutata, and Galium boreale. Russell found that the average range in dates received over the 25 years for different phenophases was about a month.

Bird (1982) published 9-year averages of first flowering dates from his phenology survey of the province (1973-1981). Comparisons of the Edmonton data show that most species flowered earlier in 1988: Anemone patens and Populus tremuloides by 2 weeks, and the others by about a week. Achillea millefolium and Epilobium angustifolium were exceptions, where the 1988 dates were later than average. Bird received general flowering dates from members of the public over the years, thus these data are much more likely to contain errors than the studies by Russell and Moss. The data is valuable in that it covers locations all over the province, and in future this database should be combined with the current survey's results for analyses such as determining the required degree-days to induce flowering, regression analyses, etc.

The Whitemud data show good agreement with the averaged 1988 Edmonton dates for 10% flowering from the provincial survey observers. Populus tremuloides is an exception, being 9 days earlier than the provincial average. I suspect that problems in observer identification of male versus female catkins is a factor here.

Full Flowering Comparison:
Moss (1960) published average full flowering dates based on his observations during the 32 year period 1926-1958. The species he studied include six of the phenology species. 1988 dates were earlier for all species except Lilium philadelphicum. Anemone patens and Populus tremuloides were earlier by 2-3 weeks.

The Whitemud Ravine dates were later than the Edmonton averages (provincial observers' data) for almost all species. The only notable exception was Linnaea borealis which was 12 days earlier in Whitemud ravine.

Density of observers in other networks:
To determine the density of observers desirable in the future for this extensive survey, it is useful to look at other studies. The federal Atmospheric Environment Service has about 300 volunteer observers in Alberta. In the 1970's, the U.S.A. weather service had 6000 observers, which represented 1 person per 1500 $km^2$ (Hopp, 1974). The German Weather Service had one phenological observer per 90 $km^2$ (Hopp, 1974). For a projected expansion of their phenology survey from the eastern United States to the whole country, Lieth and Radford (1971) suggested that an optimal density would be 500 observers per U.S. state producing a total of 25,000 data points, which they felt would be easy to achieve with good promotion.

In Alberta, the lower 60% of the province contains most of its population, and this represents about 390,000 $km^2$ of land (Alberta has 644,392 $km^2$ excluding fresh water). If we could achieve 1000 observers in this partly settled area and we assume an even distribution, this would represent about 400 $km^2$ per observer, an area of about 20 km by 20 km (4 townships). This provides a target to work toward over the years ahead.

## 5. Conclusion

Phenology has a long history starting in the Orient and developing considerably in Europe from the 1700's onward. The United States and eastern Canada have benefitted from extensive phenology studies, and the potential for similar programs in Alberta is great.

Two phenology studies, intensive and extensive, were carried out 1987-1988. The intensive phenology study established a flowering sequence for vascular plant species in the Whitemud ravine of southwest Edmonton, an aspen parkland habitat with some boreal-mixedwood species. The timing of reproductive phenophases was illustrated using phenostrips for 77 vascular plant species, arranged in order of first flowering. A plant wheel (phenological circle diagram) illustrated the subseasons of spring, summer and fall delineated by phenophases of selected species.

Flowering in 1988 was earlier than 1987, and both years were earlier than long-term Edmonton averages. Flowering was generally earliest for each species at the top of the ravine, and temperatures measured at three elevations showed that the greatest number of high and low temperatures were recorded at the bottom of the ravine. Species and phenophases were evaluated and the necessary frequency of observations determined to be twice per week during the main growing season (mid-May to mid-August). This intensive study has provided basic phenology for many parkland and boreal species, for which there is little autecological information presently available.

In the extensive study, volunteers across Alberta were recruited to record three flowering dates (10%, 50%, and 90% flowering) for 15 native perennial plant species. Flowering observation data received numbered 1300 (dates) in 1987 and 3000 in 1988. The greatest density of observers was in south-central Alberta. Suitability of species (distribution, speed of flowering, etc.) and phenophases were assessed. The best species were Amelanchier alnifolia and Prunus

virginiana, followed by Anemone patens, Viola adunca, Galium boreale and Lilium philadelphicum. The most useful flowering phenophase was first flowering (10% flowering).

Mapping techniques and statistical techniques were tested, and SPANS mapping on a microcomputer was most successful. Both manual- and computer- produced maps revealed a flowering trend with 1988 flowering starting in south central Alberta and progressing to the east, west and north. A heat island effect (earlier flowering) in cities was evident until mid-June. A pilot regression of selected data sets indicated that while flowering dates increased with latitude in the non-mountainous areas of Alberta, other factors were also involved.

In general, phenological techniques developed in Europe appear to work well in Alberta. A minor problem is the compressed growing season, such that flowering of early species happens rapidly across the province, making a progression harder to see. As well, Alberta's population is relatively sparse compared to Europe, and this means that greater efforts must be made to attract volunteers to fill in the data gaps in the province.

Fields which can benefit from phenology include agriculture, tourism, recreation, climate studies, forestry, entomology, medicine, and environmental education.

BIBLIOGRAPHY

AHLGREN, C.E. 1957. Phenological observations of nineteen native tree species in northeastern Minnesota. Ecology 38:622-628.

AIDE, T.M. 1988. Herbivory as a selective agent on the timing of leaf production in a tropical understory community. Nature 336 (6199):574-575.

ALBERTA AGRICULTURE. 1987. 1988. Alberta Weather Data. Prepared by the Conservation and Development Branch, and based on data from the Atmospheric Environment Service, Environment Canada.

ALBERTA ENVIRONMENT. 1989. Climate of Alberta - report for 1988. Tables of temperature, precipitation and sunshine. Data compiled by the Atmospheric Environment Service, Environment Canada.

ANDERSON, R.C. 1974. Seasonality in terrestrial primary producers. In Phenology and seasonality modeling. Ecological studies: analysis and synthesis, Vol. 8. Edited by H. Lieth. Springer-Verlag, N.Y. pp. 103-111.

ANTOS, J.A. AND ZOBEL, D.B. 1984. Ecological implications of belowground morphology of nine coniferous forest herbs. Bot. Gaz. 145 (4):508-517.

ARAKAWA, H. 1955. Twelve centuries of blooming dates of the cherry blossoms at the city of Kyoto and its own vicinity. Geofis. Pura Applicata-Milano 30:147-150.

ASHTON-TATE. 1986. dBASE III PLUS. 20101 Hamilton Ave., Torrance, Calif. 90502-1319.

AUROI, C. 1975. Etude comparative de quelques associations végétales dans la tourbière du cachot: caractères microclimatiques et phénologie. Bulletin de la Soc. Neuchateloise des Sciences Naturelles 98:125-148.

BASSETT, I.J., HOLMES, R.M. and MACKAY, K.H. 1961. Phenology of several plant species at Ottawa, Ontario, and an examination of the influence of air temperatures. Can. J. Plant Sci. 41:643-652.

BAUM, W.A. 1949. On the relation between mean temperature and height in the layer of air near the ground. Ecology 30:104-107.

BEAUBIEN, E.G. 1991. Phenology, the potential for education. In Proceedings of the second endangered species and prairie conservation workshop, Regina, Saskatchewan, January, 1989. Edited by G.L. Holroyd, G. Burns, and H.C. Smith. Provincial Museum of Alberta Natural History Occasional Paper #15. Edmonton, Alberta. pp.117-121.

BEDDOWS, A.R. 1968. Head emergence in forage grasses in relation to February-May temperatures and the predicting of early or late springs. J. Br. Grassld. Soc. 23:88-97.

BESCHEL, R.E. 1969. When does it happen? FON phenology project. Federation of Ontario Naturalists, Newsletter. Oct. 2. pp. 5-6.

BIRD, C.D. 1974. 1973 flowering dates. Alberta Naturalist 4(1):7-14.

-1975. 1974 Alberta flowering dates. Alberta Nat. 5(1):5-23.

-1976. 1975 Alberta flowering dates. Alberta Nat. 6(1):3-27.

-1977. FAN Phenology Project 1976. Alberta Nat. 7(1):11-29.

-1978. Alberta flowering dates in 1977. Alberta Nat. 8(1):9-26.

-and Marsh, A.H. 1979. 1978 Alberta flowering dates. Alberta Nat. 9, supplement 1:2-19.

-1980. 1979 Alberta flowering dates. Alberta Nat. 10, supplement 1:5-8.

-1981. 1980 Alberta flowering dates. Alberta Nat. 11, supplement 1:3-7.

-1982. 1981 Alberta flowering dates. Alberta Nat. 12, supplement 1:30-34.

-1983. 1982 Alberta flowering dates. Alberta Nat. 13, supplement 1:1-4

BLAIR, B.O. 1978. Predicting corn and soybean yields from multispecies phenology. In Phenology, an aid to agricultural technology. Edited by R.J. Hopp. Vt. Agric. Exper. Sta. Bull. 684, pp. 10-13.

BLAIR B.O., NEWMAN, E.J., AND FENWICK, J.R. 1974. Phenology gardens in Indiana. In Phenology and seasonality modeling. Ecological studies: analysis and synthesis, vol.8. Edited by H. Lieth. Springer-Verlag, N.Y. pp. 45-54.

BLISS, L.C. 1967. Phenology program of the IBP. BioScience 17:712-714.

BRISSETTE, J.C. AND BARNES, B.V. 1984. Comparisons of phenology and growth of Michigan and western North American sources of Populus tremuloides. Can. J. For. Res. 14:789-793.

BROWN, R.L., ASHMUN, J.W., AND PITELKA, L.F. 1985. Within- and between-species variation in vegetative phenology in two forest herbs. Ecology 66 (1):251-258.

BRUNDRETT, M.C. AND KENDRICK, B. 1988. The mycorrhizal status, root anatomy, and phenology of plants in a sugar maple forest. Can. J. Bot. 66:1153-1173.

BUDD, A.C. and CAMPBELL, J.B. 1959. Flowering sequence of a local flora. J. Range Manage. 12:127-132.

CALDWELL, M.L. 1969. Erythronium: comparative phenology of alpine and deciduous forest species in relation to environment. Amer. Midl. Nat. 82:543-558.

CAPRIO, J.M. 1957. Phenology of lilac bloom in Montana. Science 126:1344-1345.

-1966. Pattern of plant development in the western United States. Mont. Agric. Exper. Sta. Bull. 607:1-42.

-1967. Phenological patterns and their use as climatic indicators. In Ground level climatology. Edited by R.H. Shaw. American Assoc. for the Advancement of Science Publications, Washington, D.C. pp. 17-43.

-1971. The solar-thermal unit theory in relation to plant development and potential evapotranspiration. Mont. Agric. Exper. Sta. Circular 251:1-9.

CAPRIO, J.M., MAGNUSON, M.D., AND METCALF, H.N. 1970. Instructions for phenological observations of purple common lilac and red berry honey-suckle. Mont. Agric. Exper. Sta. Circular 250:1-19.

CAPRIO, J.M., HOPP, R.J. AND WILLIAMS, J.S. 1974. Computer mapping in phenological analysis. In Phenology and seasonality modeling. Ecological studies: analysis and synthesis, vol. 8. Edited by H. Lieth. Springer-Verlag, N.Y. pp. 77-82.

CLAUSEN, J., KECK, D.D. and HIESEY, W.M. 1940. Experimental studies on the nature of species. I. The effect of varied environments on western North American plants. Carnegie Institution of Washington Publ. 520. Washington D.C.

CORNS, I.G. AND ANNAS, R.M. 1986. Field guide to forest ecosystems of west-central Alberta. Dept. Supply and Services #FO 42-86/1986E. Canadian Forestry Service, Edmonton.

COUPLAND, R.T. 1980. Ecology of the mixed prairie in Canada. Ecol. Monogr. 20 (4):274-314.

CRIDDLE, N. 1927. A calendar of flowers. Can. Field-Nat. 41:48-55.

CURRAH, R., SMRECIU, A. and VAN DYK, M. 1983. Phase III: Revegetation study, 1983. Friends of the University of Alberta Devonian Botanic Garden, Univ. of Alta., Edmonton, Alta. T6G 2E1.

DAVIS, G. 1980. Some aspects of the physiology and ecology of the chromosome races of Viola adunca J. E. Smith. MSc. thesis, Department of Botany, Univ. of Alberta, 137 pp.

DEFILA, C. 1986. Phaenologische Beobachtungen in der Schweiz. Arboreta Phaenologica, pp. 61-73.

DETHIER, B.E., ASHLEY, M.D., BLAIR, B.O., CAPRIO, J.M., HOPP, R.J. AND ROUSE, J.W. JR. 1975. Satellite sensing of phenological events. SEARCH Agriculture Vol. 6 #1, Atmospheric Sciences I. Northeast Regional Research Publication NE-69. New York State College of Agriculture and Life Sciences. Cornell Univ., Ithaca, N.Y.

DICKINSON, C.E., AND DODD, J.L. 1976. Phenological pattern in the shortgrass prairie. Amer. Midl. Nat. 96:367-378.

DIERSCHKE, H. 1972. On the recording and presentation of phenological phenomena in plant communities. Translated from the German by R. E. Wessell and S. S. Talbot. In Basic problems and methods in phytosociology. 1970 international symposium for vegetation science, Rinteln, West Germany. Published by Dr. W. Junk, the Hague. pp.291-311.

-1983. Symphänologische Artengruppen sommergrüner Laubwälder und verwandter Gesellschaften Mitteleuropas. In Verhandlungen der Gesellschaft für Oekologie (Festschrift Ellenberg). Band XI. Goettingen. pp. 71-87.

DOWNING, T.E. and PARRY, M.L. 1991. Global warming: climate scenarios and international agriculture. In Symposium on the impacts of climatic change and variability on the Great Plains. Calgary, Alberta, September, 1990. Edited by Geoffrey Wall. Department of Geography, University of Waterloo, Ontario. Occasional Paper #12. pp. 43-53.

DUBE, P.A. and CHEVRETTE, J.E. 1978. Phenology applied to bioclimatic zonation in Quebec. In Phenology: an aid to agricultural technology. Edited by R.J. Hopp. Vt. Agric. Exper. Sta. Bull. 684. pp. 33-43.

DUBE, P.A., PERRY, L.P., AND VITTUM, M.T. 1984. Instructions for phenological observations: lilac and honeysuckle. Vt. Agric. Exper. Sta. Bull. 692. Univ. of Vt., Burlington. 8pp.

DZIKOWSKI, P. and HEYWOOD, R.T. 1990. Agroclimatic atlas of Alberta. Alberta Agriculture, Conservation & Development Branch. Agdex #071-1

ECOREGIONS WORKING GROUP. 1989. Ecoclimatic regions of Canada, first approximation. Ecoregions working group of the Canada committee on ecological land classification. Ecological land classification series, #23. Sustainable Development branch, Canadian Wildlife Service, Conservation and Protection, Environment Canada, Ottawa, Ont. 119 pp.

ELLENBERG, H. 1954. Ueber einige Fortschritte der kausalen Vegetationskunde. Vegetatio 5 (6):199-211.

ELLENBERG, H. and ELLENBERG, C. 1974 a. Oekologische Klimakarte, Baden-Württemberg 1:350,000. Landschaftsrahmenprogramm. Karte 1. Ministerium für Ernährung, Landwirtschaft und Umwelt Baden-Württemberg, Stuttgart.

-1974 b. Wuchsklima-Gliederung von Hessen (1:200,000) auf pflanzenphänologischer Grundlage. Hessisches Ministerium für Landwirtschaft und Umwelt, Wiesbaden.

ELLENBERG, H.H. AND STROTT, G.K. 1988. Vegetation ecology of central Europe. 4th ed. Cambridge University Press. 768 pp.

ERSKINE, A.J. 1985. Some phenological observations across Canada's boreal regions. Can. Field-Nat. 99(2):185-195.

FLANAGAN, L.B. AND MOSER, W. 1985. Flowering phenology, floral display and reproductive success in dioecious, Aralia nudicaulis L. (Araliaceae). Oecologia (Berlin) 68:23-28.

FLINT, H.L. 1974. Phenology and genecology of woody plants. In Phenology and seasonality modeling. Ecological studies: analysis and synthesis, vol. 8. Edited by H. Lieth. Springer-Verlag, N.Y. pp. 83-97.

FRANKIE, G.W., BAKER, H.G., AND OPLER, P.A. 1974. Comparative phenological studies of trees in tropical wet and dry forests in the lowlands of Costa Rica. J. Ecol. 62:881-919.

FREITAG, E. 1987. Organization, structure and consequences of an International Phenological Gardens database. Arboreta Phaenologica 32:8-11.

GEIGER, R. 1965. The climate near the ground. Harvard Univ. Press. Cambridge, Mass.

GIBSON, D.W. 1977. Upper Cretaceous and Tertiary coal-bearing strata, Drumheller and Ardley region, central Alberta. GSC paper 76-35:1-41.

GLENDENNING, R. 1943. Phenology, the most natural of sciences. Can. Field-Nat. 57:75-78.

HARDY, W.G. editor. 1967. Alberta, a natural history. Hurtig, Edmonton. 343 pp.

HEGAZY, A. 1987. Perspectives on autecology and population biology of alpine cushion plants. PhD thesis, Botany department, Univ. of Alta., Edmonton. 311 pp.

HENHAPPL, G. 1986. 17 years of the international phenological gardens in the southern Black Forest. In Arboreta Phaenologica #31. Sonderheft zum Internationalen Phänologie-Symposium. Universität für Bodenkultur, Wien, 17-20 Sept. 1986. Edited by F. Schnelle, A. Baumgartner, E. Freitag. pp. 74-76.

HEWITT, G.B. 1980. Plant phenology as a guide in timing grasshopper control efforts on Montana rangeland. J. Range Manage. 33:297-299.

HOLWAY, J.G. AND WARD, R.T. 1965. Phenology of alpine plants in northern Colorado. Ecology 46:73-83.

HOPKINS, A.D. 1918. Periodical events and natural laws as guides to agricultural research and practice. Monthly Weather Review Suppl. #9. U.S. Dept. Agric., Washington. 42 pp.

-1938. Bioclimatics - a science of life and climate relations. U.S. Dept. Agric. Misc. Publ. #280. Washington, D.C. 188 pp.

HOPP, R.J. 1974. Plant phenology observation networks. In Phenology and seasonality modeling. Ecological studies: analysis and synthesis, Vol. 8. Edited by H. Lieth. Springer-Verlag, N.Y. pp. 25-43.

-1978. editor. Phenology: an aid to agricultural technology. Vt. Agric. Exper. Sta. Bull. 684. 51 pp.

HOSIE, R.C. 1973. Native trees of Canada, 7th ed. Canadian Forestry Service. Department of the Environment. Ottawa, Ont. 380 pp.

HUBERMAN, M.A. 1941. Why phenology? J. Forest. 39:1007-1013.

IHNE, E. 1885. Karte der Aufblühzeit von Syringa vulgaris in Europa. Bot. Centralbl. 21:85-88, 116-121, 150-155.

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

JEFFREE, E.P. 1960. Some long-term means from "The Phenological Reports" (1891-1948) of the Royal Meteorological Society. Quart. J. Royal Meteorolog. Soc. 86:95-103.

JOHNSTON, A. 1987. Plants and the Blackfoot. Occasional Paper No. 15, Lethbridge Historical Society, Historical Society of Alberta, P.O. Box 974, Lethbridge, Alta. T1J 4A2.

JUNTTILA, O., STUSHNOFF, C., AND GUSTA, L.V. 1983. Dehardening in flower buds of saskatoon-berry, Amelanchier alnifolia, in relation to temperature, moisture content, and spring bud development. Can. J. Bot. 61:164-170.

JUSTICE, C.O., TOWNSHEND, J.R., HOLBEN, B.N. and TUCKER, C.J. 1985. Analysis of the phenology of global vegetation using meteorological satellite date. Int. J. Remote Sensing. (6) 8:1271-1318.

KAPLER, J.E. 1967. Phenological events associated with the spring emergence of the smaller European elm bark beetle in Dubuque, Iowa. J. Econ. Entomol. 60:50-52.

KATHOL, C.P., AND MCPHERSON, R.A. 1975. Urban geology of Edmonton. Alta. Res. Council. Bulletin 32. Edmonton, Alta.

KNUTSON, R.M. 1979. Flowers that make heat while the sun shines. Natural History 90 (10):75-81.

KOHLHAUPT, P. 1963. Alpenblumen. Farbige Wunder. C. Belser. Verlag. Stuttgart, Germany.

KREEB, K. 1977. Methoden der Pflanzenökologie. Gustav Fischer Verlag. Stuttgart, New York. 235 pp.

LARCHER, W. 1983. Physiological plant ecology, 2nd edition. Springer-Verlag, Berlin.

LAUSCHER, F. and ROLLER, M. 1980. Comparisons of observations in phenological gardens and phenological networks. Sonderdruck aus Int. J. Biometeorol. Suppl. to Vol. 24:85-86.

LAUSCHER, F. 1988. Die Ankunft von Zugvögeln in allen Teilen Norwegens. (Translation: Arrival of migrating birds in all parts of Norway). Self-published. Wien.

LECHOWICZ, M.J. 1984. Why do temperate deciduous trees leaf out at different times? Adaptation and ecology of forest communities. Am. Nat. 124 (6):821-842.

LEOPOLD, A. and JONES, S.A. 1947. A phenological record for Sauk and Dane Counties, Wisconsin, 1935-1945. Ecol. Monogr. 17:81-122.

LETTAU, K. 1987. The Wisconsin Phenological Society. In Arboreta Phaenologica. Mitteilungen der Arbeitsgemeinschaft Internationaler Phaenologischer Gärten. Sonderheft zum Internationalen Phänologie-Symposium. Edited by: F. Schnelle, A. Baumgartner, E. Freitag. pp. 7-9.

LEWIS, W.H. 1976. Temporal adaptation correlated with ploidy in Claytonia virginica. Syst. Bot. 1:340-347.

LIETH, H. 1969. The phenological viewpoint in productivity studies. In Productivity of forest ecosystems, ecology and conservation. Edited by P. Duvigneaud. Proc. Brussels Symp. pp. 71-84.

-1974. editor. Phenology and seasonality modeling. Ecological studies: analysis and synthesis, vol. 8. Springer-Verlag, N.Y. 444 pp.

LIETH, H. and RADFORD, J.S. 1971. Phenology, resource management, and synagraphic computer mapping. BioScience 21:62-70.

LINCOLN, R.J., BOXSHALL, G.A. and CLARK, P.F. 1982. A dictionary of ecology, evolution and systematics. Cambridge University Press, Cambridge, U.K. 298 pp.

LINDSEY, A.A. and NEWMAN, J.E. 1956. Use of official weather data in spring time - Temperature analysis of an Indiana phenological record. Ecology 37:812-823.

LINNAEUS, C. 1751. Philosophia Botanica. Kiesewetter, Stockholm.

LONGLEY, R.W. 1967. Climate and weather patterns. In Alberta, a natural history. Edited by W.G. Hardy. Hurtig, Edmonton. pp. 53-67.

-1980. The climate of Alberta. In A nature guide to Alberta. Edited by D.A. Spalding. Hurtig, Edmonton. pp. 26-28.

MACGREGOR, J.G. 1967. Edmonton. Hurtig Publishing, Edmonton, Alberta.

MACKAY, A.H. 1899. Phenological observations in Canada. Canadian Record of Science 8, 2:71-84.

-1927. The phenology of Nova Scotia, 1923. Trans. Nova Scotia Inst. Sci. 16, Part 2:104-113.

MAHALL, B.E. AND BORMANN, F.H. 1978. A quantitative description of the vegetative phenology of herbs in a northern hardwood forest. Bot. Gaz. 139 (4):467-481.

MALAISSE, F.P. 1974. Phenology of the Zambezian woodland area with emphasis on the Miombo ecosystem. In Phenology and seasonality modeling. Ecological studies: analysis and synthesis, vol. 8. Springer-Verlag, N.Y. pp. 269-286.

MAUER, J.C. 1977. Comparative ecophysiology of the chromosome races in Viola adunca J.E. Smith. MSc thesis, Department of Botany, Univ. of Alta., Edmonton.

MCMILLAN, C. 1957. Nature of the plant community. IV. Phenological variation within five woodland communities under controlled temperatures. Amer. J. Bot. 44:154-163.

MCMILLAN, C. and PAGEL, B.F. 1958. Phenological variation within a population of Symphoricarpos occidentalis. Ecology 39:766-770.

MINSHALL, W.H. 1947. First dates of anthesis for four trees at Ottawa, Ontario, for the period of 1936 to 1945. Can. Field-Nat. 61:56-59.

MITCHENER, A.V. 1948. Nectar & pollen producing plants of Manitoba. Sci. Agric. 28:475-480.

MOLITOR, H. 1987. The Great Code - the folklore and science of using plants as timepieces. Harrowsmith 12 (73):44-52. Camden House Publishing, Camden East, Ontario, Canada.

MORRIS, R.F., WEBB, F.E., BENNETT, C.W. 1956. A method of phenological survey for use in forest insect studies. Can. J. Zool. 34:533-540.

MOSQUIN, T. 1966. A new taxonomy for Epilobium angustifolium L. (Onagraceae). Brittonia 18:167-188.

MOSS, E.H. 1936. The ecology of Epilobium angustifolium with particular reference to rings of periderm in the wood. Amer. J. Bot. 23:114-120.

-1938. Longevity of seed and establishment of seedlings in species of Populus. Bot. Gaz. 99:529-542.

-1960. Spring phenological records at Edmonton, Alberta. Can. Field-Nat. 74:113-118.

MUELLER-DOMBOIS, D. AND ELLENBERG, H. 1974. Aims and methods of vegetation ecology. Wiley and Sons, N.Y. 547 pp.

MULLER, R.N. 1978. The phenology, growth and ecosystem dynamics of Erythronium americanum in the northern hardwood forest. Ecol. Monogr. 48:1-20.

NOGGLE, G.R. 1978. The North Carolina phenology network. In Phenology, an aid to agricultural technology. Edited by R.J. Hopp. Vt. Agric. Exper. Sta. Bull. 684. p. 6.

OBREBSKA-STARKLOWA, B. 1981. An approach to the pheno-climatic typology and its pattern in the mountainous areas of Poland. Int. J. Biometeor. 25 (3):269-279.

OLSON, R. 1985. The climate of Edmonton. Climatological studies #37. The climate of Canadian cities #2. Supply and Services, Canada. #EN57-7/37E.

OPLER, P.A., FRANKIE, G.W. and BAKER, H.G. 1976. Rainfall as a factor in the release, timing, and synchronization of anthesis by tropical trees and shrubs. J. Biogeog. 3:231-236.

ORDWAY, E. 1985. The phenology and pollination biology of Anemone patens (Ranunculaceae) in Western Minnesota. In Part 2: The prairie: past, present and future. Proceedings of the 9th North American Prairie Conference, Minnesota, July 29-August 1, 1984. Edited by G.K. Clambey and R.H. Pemble. Tri-College Univ. Centre for Environmental Studies, North Dakota. pp. 31-34.

PACKER, J.G. 1983. E.H. Moss: Flora of Alberta. 2nd edition edited by J.G. Packer. Univ. of Toronto, Toronto, Ont.

PEARCY, R.W. AND WARD, R.T. 1972. Phenology and growth of Rocky Mountain populations of Deschampsia caespitosa at three elevations in Colorado. Ecology 53 (6): 1171-1178.

PEDERSON, L.H. AND ECKENRODE, C.J. 1981. Predicting cabbage maggot flights in New York using common wild plants. N. Y. S. (Geneva) Agric. Exper. Sta. Bull. 87, 6 pp.

PRIMACK, R.B. 1985. Patterns of flowering phenology in communities, populations, individuals, and single flowers. In The population structure of vegetation. Edited by J. White. Dr. W. Junk, Dordrecht, Netherlands. pp. 571-593.

PRIMAULT, B. 1971. Atlas phénologique, 3rd ed. Institut Suisse de Météorologie. Zurich.

RADFORD, J.R. 1971. Phenological delimitation of the length of the growing season in North Carolina: computer mapping and environmental correlation for spring and fall plant phenophases. MA Thesis, Botany Department, University of North Carolina, Chapel Hill.

RATCLIFFE, M.J. AND TURKINGTON, R. 1989. Comparative phenology of some alpine vascular plant species on Lakeview Mountain, southern British Columbia. Can. Field-Nat. 103 (3): 348-352.

RATHCKE, B. AND LACEY, E.P. 1985. Phenological patterns of terrestrial plants. Ann. Rev. Ecol. Syst. 16:179-214.

RAUNKIAER, C. 1934. The life forms of plants and statistical plant geography. Clarendon Press, Oxford, Eng.

READER, R.J. 1975. Effect of air temperature on the flowering date of dogwood (Cornus florida). Can. J. Bot. 53:1523-1534.

READER, R., RADFORD, J.S., AND LIETH, H. 1974. Modeling important phytophenological events in eastern North America. In Phenology and seasonality modeling. Ecological studies: analysis and synthesis, vol. 8. Springer-Verlag, N.Y. pp. 329-342.

READER, R.J. AND LIETH, H. 1984. Computer-assisted survey and mapping of vegetation attributes. In Sampling methods and taxon analysis in vegetation science. Edited by R. Knapp. Dr. W. Junk, the Hague. pp. 171-179.

ROSENKRANZ, F. 1951. Grundzüge der Phänologie. Verlag Georg Fromme, Wien. 69pp.

ROYAL SOCIETY OF CANADA. 1893. Proceedings for 1892. Proc. and Trans. of the Royal Soc. of Canada Vol.10. Session 3, p. 53-55.

RUSSELL, R. C. 1962. Phenological records of the prairie flora. Can. Plant Disease Survey. 42 (3):162-166.

SAS INSTITUTE. 1985. SAS user's guide: statistics, version 5. SAS institute, Carey, N.C.

SAYN-WITTGENSTEIN, L. 1961. Phenological aids to species identification on air photographs. Canada Dept. of Forestry, Forest Research Branch, Technical Note #104.

SCHNELLE, F. E. 1955. Pflanzen-Phänologie. Akademische Verlagsgesellschaft, Geest & Portig K.-G., Leipzig, Germany.

SCHNELLE, F. E. AND VOLKERT, E. 1974. International phenological gardens in Europe: the basic network for international phenological observations. In Phenology and seasonality modeling. Ecological studies: analysis and synthesis, vol. 8. Edited by H. Lieth. Springer-Verlag, N.Y. pp.383-388.

SCHREIBER, K.-F. 1969. Landschaftsökologische und standortskundliche Untersuchungen im nördlichen Waadtland als Grundlage für die Orts - und Regionalplanung. Stuttgart. Arbeiten der Universität Hohenheim. Band 45.

SCHWARTZ, M.D. AND MAROTZ, G.A. 1986. An approach to examining regional atmosphere-plant interactions with phenological data. J. Biogeog. 13:551-560.

-1988. Synoptic events and spring phenology. Phys. Geog. 9 (2):151-161.

SCOTTER, G.W. AND SOMMERFELDT, B.J. 1988. Late season flowering of prairie crocus in southwestern Alberta. Alta. Nat. 18 (1):21-22.

SMITHBERG, M.H. AND WEISER, C.J. 1968. Patterns of variation among climatic races of red osier dogwood. Ecology 49:495-504.

SOERENSEN, T. 1941. Temperature relations and phenology of the northeast Greenland flowering plants. Meddel. om Groenland 125:1-305.

SOKAL, R.R. AND ODEN, N.L. 1978. Spatial autocorrelation in biology. 1. Methodology. Biol. J. Linn. Soc. 10:199-228.

STEARNS, F.W. 1974. Phenology and environmental education. In Phenology and seasonality modeling. Ecological studies: analysis and synthesis, vol. 8. Edited by H. Lieth. Springer-Verlag, N.Y. pp.425-429.

STEVENS, O.A. 1973. Dates for first flowers. Prairie Nat. 5 (1):1-6.

STRAUB, R.W. AND HUTH, P.C. 1978. Phenological events and the adult European corn borer. In Phenology, an aid to agricultural technology. Edited by R.J. Hopp. Vt. Agric. Exper. Sta. Bull. 684. pp. 27-30.

STRONG, W.L. AND LEGGAT, K.R. 1981. Ecoregions of Alberta. Alberta Energy and Natural Resources, Tech. Rpt.#T/4. 64 pp.

TAYLOR, F.G. 1969. Phenological records of vascular plants at Oak Ridge, Tennesee. Publ.# 315, Oak Ridge Nat'l. Laboratory, Oak Ridge, Tennessee. Internat. Biol. Prog. UC-48. Biology and Medicine. 46 pp.

TYDAC TECHNOLOGIES. 1989. Spatial Analysis System (SPANS), Version 4.3. Reference Guide. Ottawa, Ont.

US/IBP PHENOLOGY COMMITTEE. 1972. Report, July 1972. United States component of the International Biological Program. Environmental coordinating office. Austin, Texas. 54 pp. offset.

VITTUM, M.T. AND HOPP, R.J. 1978. The N.E.- 95 lilac phenology network. In Phenology, an aid to agricultural technology. Edited by R.J. Hopp. Vt. Agric. Exper. Sta. Bull. 684. pp. 1-5.

WAGGONER, PAUL E. 1974. Using models of seasonality. In Phenology and seasonality modeling. Ecological studies: analysis and synthesis, vol. 8. Edited by H. Lieth. pp. 301-322.

WALTER, H. AND LIETH, H. 1967. Klimadiagramm-Weltatlas. VEB Gustav Fischer, Jena.

WARWICK, S.I. AND BLACK, L. 1982. The biology of Canadian weeds 52. Achillea millefolium L. s.l. Can. J. Plant Sci. 62:163-182.

WESELOH, D.V. 1976. A provincial species count day: birds, mammals, and plants in flower. Alberta Nat. 6 (1):47-50.

WEST, N.E. AND WEIN, R.W. 1971. A plant phenological index technique. BioScience 21:116-117

WILDEMAN, A.G. AND STEEVES, T.A. 1982. The morphology and growth cycle of Anemone patens. Can. J. Bot. 60:1126-1137.

WINKLER, E. UND MENNEWEGER, D. 1977. Beiträge zur Phänologie im Innsbrucker Raum für die Jahre 1973-1975. Sonderdruck aus Veröffentlichungen des Museum Ferdinandeum 57:185-219.

Appendix 1: Example of a data sheet for phenological observations, Whitemud ravine

See table 4 in thesis for full names of these species. The genus name only was used when the species was being identified. Numbers at the top refer to locations on the map (Figure 2). Two pages were needed to cover all locations, and 4 pages to hold all the species encountered = 8 pages for each field visit to Whitemud ravine.

The data sheet was used to flag which species were in which location, which helped to remind observers to look for inconspicuous species. On this data sheet, a dot in the square meant the species was present at that location and a smaller square in the top left corner indicated a tagged plant.

Appendix 1

DATE:

← Locations →

| Species ↓ | 14 a | b | c | 15 a | b | 16 a | b | c | 17 | 18 | 19 | 20 a | 20 b | 21 | 5a | 'c | 'b |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ditr | | | | | | | | | | • | | | | | | | |
| Liph | | | | | | | | | • | • | | | | | | | |
| Maca | • | • | | | | | | | • | • | • | | • | | | | |
| Smst | | | • | • | | | | | • | • | | | | | | | |
| Sacu | | | | | | | | | | | | | | | | | |
| Rushes | | | | | | | | | | | | | | | | | |
| Simo | | • | | • | • | | | • | • | • | | | | | | | |
| Poba | | | | | | | | | • | • | | | | | | | |
| Potr | □ | | | • | | | | | □ | • | | | | | | | |
| Salix | | □ | | | □ | | | □ | | | | | | □ | | | |
| Bepa | • | • | | | | | | | | | | | | | | | |
| Coco | | | | | | | | | | | | | | | | | |
| Urdi | | | | | | | | | | | | | | | | | |
| Coum | | | | | | | | | | | | | | | | | |
| Polygonum | | | | | | | | | | | | | | | | | |
| Rumex | | | | | | | | | | | | | | | | | |
| Chenopodium | | | | | | | | | | | | | | | | | |
| Mola | | | | | | • | | | | • | • | | | | | | |
| Sipr | | | | | | | | | | | | | | | | | |
| Stellaria | | | | • | • | | • | | | • | | | | | | | |
| Acru | | • | • | | | | • | | | | | | | • | | | |
| Anca | • | • | | • | | | • | | | | | | | | | | |
| Anri | | | | | | | | | | | | | | | | | |
| Cloc | | | | | | | | | | | | | | | | | |
| Ragm | | | | | | | | | | | | | | | | | |
| Rama | | | | | | | | | | | | | | | | | |
| Thda | • | • | | | | | | | | | | | | | | | |
| Thve | • | | • | | | • | • | | • | • | | • | • | | | | |
| Deso | | | | | | | | | | | | | | | | | |
| Arabis | | | | | | | | | | | | | | | | | |
| Erch | | | | | | | | | | | | | | | | | |
| Thar | | | | | | | | | | | | | | | | | |
| Minu | | | | | | | | | | | | | | | | | |

Appendix 3: Two files from dBASE III PLUS are shown. The first file is the data as it was entered for June 13, 1988, and the second file shows some of these records sorted by species (in this example <u>Linnaea borealis</u>), date, and location. (See ravine map, Figure 2, for locations. Location #25 was used when the observation location was unknown.) Codes are explained below:

| Field | Meaning | Used for: |
|---|---|---|
| Date | Date | calendar date of field observations |
| Spec | Species name | 4 letter code, =first two letters genus + first two letters species name (Table 4) |
| Where | Location | number for each location |
| Sx | Sex | Sex of individual plant observed |
| No | tagged plant | number of tagged plant, or simply "t" if only one tagged plant at that location |
| Str | structure | v = vegetative (leaves, shoots)<br>r = reproductive (flowers, fruits)<br>i = insect consumption (herbivory), % of plant leaves consumed noted<br>(See Tables 7-a and b) |
| Ph | phenophase | numbers indicate stage of development |
| Notes | details | extra information on-for eg: species identification, the exact stage of flowering, pollination vectors, fruit ripening, whether observation refers to a single individual, what type of insect is consuming the observed plant. |

**Appendix 3: Sample of database files used for the Whitemud study data**

| Record# | DATE | SPEC | WHERE | SX | NO | STR | PH | NOTES |
|---|---|---|---|---|---|---|---|---|
| 1131 | 06/13/88 | pepa | 5b | | | v | 6 | leaves |
| 1132 | 06/13/88 | rihu | 11a | | t | r | 13 | smooth green berries |
| 1133 | 06/13/88 | rihu | 11a | | t | r | 12 | fresh flrs at tip |
| 1134 | 06/13/88 | riox | 3 | | | r | 13 | |
| 1135 | 06/13/88 | riox | 3 | | 2 | r | 13 | |
| 1136 | 06/13/88 | riox | 3 | | 3 | r | 13 | |
| 1137 | 06/13/88 | riox | 3 | | 5 | r | 13 | |
| 1138 | 06/13/88 | riox | 6 | | | i | | 5% |
| 1139 | 06/13/88 | libo | 25 | | | | | bumblebee feeding-flrs |
| 1140 | 06/13/88 | arsp | 6 | | | r | 4 | Arabis sp. |
| 1141 | 06/13/88 | libo | 25 | | | r | 4 | 10% r3, 60% r4, 30% r10 |

| Record# | DATE | SPEC | WHERE | SX | NO | STR | PH | NOTES |
|---|---|---|---|---|---|---|---|---|
| 1796 | 06/13/88 | libo | 8 | | t | r | 11 | 90% left |
| 1797 | 06/13/88 | libo | 9 | | | r | 9 | |
| 1798 | 06/13/88 | libo | 25 | | | r | 4 | 10% r3, 60% r4, 30% r10 |
| 1799 | 06/13/88 | libo | 25 | | | | | bumblebee feeding-flrs |
| 1800 | 06/13/88 | libo | 5b | | t | r | 9 | 20% flrs faded, brown |
| 1801 | 06/16/88 | libo | 3 | | | r | 11 | and tagged one |
| 1802 | 06/16/88 | libo | 8 | | t | r | 12 | |
| 1803 | 06/16/88 | libo | 9 | | | r | 11 | |
| 1804 | 06/16/88 | libo | 5b | | | r | 12 | |
| 1805 | 06/20/88 | libo | 3 | | | r | 12 | 40% fresh flrs |
| 1806 | 06/20/88 | libo | 8 | | t | r | 12 | |

Appendix 4: "Best" Species for phenology studies in aspen parkland / boreal mixed-wood habitats of Alberta

| PHENOLOGY SPECIES<br>sex to observe:<br>(m)=male, (f)=female | S=shrub<br>H=herb<br>T=tree | BEST PHENOPHASES<br>Flower Buds | First Flowering | Full Flowering | Fruit Setting | FRUIT first fruits | RIPE all fruits | Seed shed starts | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Achillea millefolium | H | x | x | - | - | - | - | - | - |
| Acer negundo (m) | T | - | x | - | - | - | - | - | dioecious, may not flower every year |
| Actaea rubra | H | - | x | - | - | - | x | - | hard to see plant before flowering |
| Agrimonia striata | H | - | x | - | - | - | - | x (burrs) | flowers from bottom of spike to top |
| Amelanchier alnifolia | S | x | x | x | - | x | - | - | - |
| Anemone canadensis | H | -x | - | - | - | - | - | - | long flowering period |
| Betula papyrifera (m) | T | - | x | x | - | - | - | - | male and female catkins on same tree |
| Clematis occidentalis | S-vine | - | x | x | x | - | - | - | seeds ripen in early autumn |
| Cornus canadensis | H | x | x | x | x | - | x | | watch for tiny flowers inside bracts |
| Corylus cornuta | S | - | x (m) | x (m) | x (f) | - | - | - | squirrels remove nuts early |
| Cornus stolonifera | S | x | x | x | x | - | x | - | some flowering continues all season |
| Disporum trachycarpum | H | - | x | - | x | - | x | - | velvet-textured orange berries |
| Elaeagnus commutata | S | - | x | x | - | - | - | - | heavy sweet odour from flowers |
| Epilobium angustifolium | H | x | x | - | - | x | - | | deer often eat flowering stems |
| Fragaria species (2) | H | - | x | - | - | x | - | - | long flowering period |
| Galium boreale | H | x | x | (x) | - | - | - | x(burrs) | full flowering can be hard to recognize |
| Heracleum lanatum | H | x | x | x | - | - | - | x | top flower umbel blooms first |
| Lathyrus ochroleucus | H | x | x | - | - | - | - | - | more flowers develop as plant grows |
| Lathyrus venosus | H | x | x | - | - | - | - | - | showy blue-purple flowers |

Appendix 4, continued:

| PHENOLOGY SPECIES<br>sex to observe:<br>(m)=male, (f)=female | S=shrub<br>H=herb<br>T=tree | BEST PHENOPHASES<br>Flower Buds | First Flowering | Full Flowering | Fruit Setting | FRUIT first fruits | RIPE all fruits | Seed shed starts | Comments |
|---|---|---|---|---|---|---|---|---|---|
| Lilium philadelphicum | H | - | x | (x) | - | - | - | x | may not flower annually |
| Linnaea borealis | H | x | x | x | - | - | - | - | leaves evergreen, semi-woody plant |
| Lonicera dioica | S | x | x | x | - | - | - | - | - |
| Maianthemum canadensis | H | x | x | x | - | - | - | - | plant hard to find after mid-summer |
| Mertensia paniculata | H | - | x | - | - | - | - | - | - |
| Mitella nuda | H | - | x | - | - | x | - | - | black seeds |
| Picea glauca | T | - | x (m) | x (m) | - | - | - | - | male and female flowers on same tree |
| Populus balsamifera | T | - | x (m) | x (m) | - | - | - | x (f) | dioecious, may not flower annually |
| Populus tremuloides | T | - | x (m) | x (m) | - | - | - | x (f) | dioecious, may not flower annually |
| Prunus pensylvanica | S | x | x | x | - | - | x | - | fruit red, generally sparse in Edmonton |
| Prunus virginiana | S | x | x | x | - | - | - | - | fruit black, generally abundant |
| Pyrola asarifolia | H | x | x | x | x | - | - | - | - |
| Pyrola elliptica | H | x | x | x | x | - | - | - | looks similar to PYAS, flowers later |
| Shepherdia canadensis | S | - | x | x | - | - | x | - | use hand lense-tiny flowers, dioecious |
| Smilacina stellata | H | - | x | x | x | - | - | - | - |
| Solidago canadensis | H | x | x | - | - | - | - | - | - |
| Thalictrum dasycarpum | H | x (m) | x (m) | x (m) | x (f) | - | - | - | dioecious |
| Thalictrum venulosum | H | x (m) | x (m) | - | x (f) | - | - | - | dioecious |
| Ulmus americana | T | - | x | x | - | - | - | x | may not flower annually; introduced |

Appendix 4, continued:

| PHENOLOGY SPECIES sex to observe: (m)=male, (f)=female | S=shrub H=herb T=tree | Flower Buds | First Flowering | Full Flowering | Fruit Setting | FRUIT first fruits | RIPE all fruits | Seed shed starts | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | BEST PHENOPHASES | | | | | | | |
| Viburnum edule | S | x | x | x | - | - | x | - | fruit green-yellow-peach-then red |
| Viburnum opulus | S | x | x | x | x | - | x | - | bracts go white, then inner flowers open |
| Vicia americana | H | - | x | - | - | - | - | - | - |
| Vicia cracca | H | - | x | - | - | - | - | - | - |
| Viola adunca | H | - | x | (x) | - | - | - | - | - |
| Viola canadensis | H | - | x | - | - | - | - | - | very long flowering period |

As well, cultivated species suitable for phenology which grow well in the aspen parkland include:

| LATIN | COMMON NAME |
|---|---|
| Syringa spp. | lilac varieties |
| Prunus tomentosa | Nanking Cherry |
| Prunus padus commutata | Mayday Tree |
| Crataegus spp. | Hawthorn |
| Malus spp. | Crabapples |
| Pinus spp. | Pine (tree or shrub) |
| Cotoneaster spp. | Cotoneaster (shrub) |
| Caragana spp. | Caragana (shrub) |
| Sorbus spp. | Mountain Ash |

Appendix 5: Phenology survey promotion (1987-1990)

NEWSPRINT

| | | |
|---|---|---|
| March 23, 1987 | article | Red Deer Advocate |
| April 10, '87 | paragraph in nature column by C. and J. Finlay | Edmonton Journal, Calgary Herald |
| April 24, '87 | few paragraphs | Lethbridge Herald |
| early May '87 | article sent to all weekly papers Alberta (cost=$100) | |
| May 31, '87 | article in Environment Week promotion literature | all major papers, Alta. |
| June 10, '87 | article | High Prairie "Mirror" |
| June 19, '87 | paragraph in nature column | Edmonton Journal |
| March 18, 1988 | paragraph in nature column | Edmonton Journal |
| March 31, '88 | paragraph in nature column | Edmonton Journal |
| April 1990 | article in the "Northern Report", p.8 | High Prairie "Mirror" |
| April 6, '90 | nature column | Edmonton Journal |

NEWSLETTERS (from clubs, societies, or government departments)

| | | |
|---|---|---|
| March 1987 | article in "Environment Week News" | Alberta Environment |
| March '87 | article: p.7-8, vol.7 (2), Alberta Science Teacher | Alberta Teachers' Association |
| May '87 | 3 paragraphs, newsletter #1, | Edmonton Natural History Club |
| spring '87 | article in the "Alberta Naturalist" vol 17 (1), p.31 | Federation of Alberta Naturalists |
| summer '87 | article: Edmonton Chapter, CPAWS, vol.4,#1, p.13 | Canadian Parks and Wilderness Society |
| August '87 | "Phenology in Your Garden", by J. Craig and E. Beaubien in quarterly: "Kinnikinnick", vol.5, #9, pp.258-264 | Friends of the Devonian Botanic Garden |
| December '87 | article in "The Legacy") | Recreation, Parks, and Wildlife Foundation |
| April 1988 | paragraph in a Barrhead teachers' publication | |
| March '88 | article in newsletter to Natural Areas stewards | Alta. Forestry, Lands and Wildlife |
| March '88 | paragraph in "In Focus" | Alberta Education |
| spring '88 | article in "Edmonton Naturalist" | Edmonton Natural History Club |
| spring '88 | article in supplement to the "Alberta Naturalist" | Federation of Alberta Naturalists |
| May 5 '88 | front page "Folio", photo and short byline | University of Alberta |
| March 15, 1989 | paragraph | Boreal Institute for Northern Studies |

Appendix 5, continued:

SPECIAL PUBLICATIONS

| | | |
|---|---|---|
| March, 1987 | "Directory of Cooperative Naturalists Projects - a guide to volunteers for 1987", ed. by G.R. Burns and G.L. Holroyd | Canadian Wildlife Service |
| Spring, 1988 | article in a teachers manual entitled "Alberta Wildflowers" | Trans-Alta Utilities, Calgary |

TALKS and PAPERS PRESENTED

| | |
|---|---|
| January, 1987 | announcement at Federation of Alberta Naturalists workshop, Red Deer |
| March 7, '87 | talk to 20 Junior Field Naturalists, John Janzen Nature Centre |
| May 22, '87 | talk to 15 teachers, workshop of Environmental and Outdoor Education Council of Alberta, Edmonton |
| May 23, '87 | to 25 people taking my "Spring Wildflowers" course at Elk Island National Park |
| April 22, 1988 | to 90 people at "Spring Wildflowers" talk, Provincial Museum of Alberta<br>check presentation by funder: Recreation, Parks and Wildlife Foundation |
| April 28, '88 | to 15 people at founding meeting of Edmonton Plant Study Group |
| January 1989 | Paper presented (80 people): Endangered Species Conference, Regina, Saskatchewan, on "Phenology and Education" |
| February 15, '89 | to 100 District Agriculturalists, etc. at Crop Protection workshop, Alberta Agriculture, Edmonton |
| February 16, '89 | to 30 people, Departmental Seminar, Botany Department, U. of Alberta |
| May 14, '89 | to 30 people - Spring Wildflower slide show, John Janzen Nature Centre, Edmonton |
| May 17, '89 | to 50 people - Spring Wildflower talk, Calgary Field Naturalists, Calgary |
| August '89 | to 25 people at conference, Toronto: American Institute of Biological Sciences, as part of Climate Change program |
| April 1990 | two 20-minute talks (35 people) : Volunteer Steward Conference, Natural areas program of Forestry, Lands and Wildlife |

RADIO

| | |
|---|---|
| April 21, 1987 | Radio Interview, CBC |
| April 11,12, 1988 | short promotion, CBC noon show |

POSTER OR EXHIBIT: where displayed:

| | |
|---|---|
| October 2, 1988 | Boreal Institute for Northern Studies, U. of Alberta |
| October 5, 1988 | Provincial Museum of Alberta |
| January, 1989 | Provincial Museum of Saskatchewan, Endangered Species Conference |
| January 28, 1990 | Boreal Circle Society, Provincial Museum |

Appendix 6: dBASE III PLUS program to average 1988 dates for 10% flowering of _Anemone patens_, for the Edmonton area. The data used is from the 1988 provincial phenology survey; 88JJBLO is the name of the database file. The program first converts calendar dates to Julian dates.

```
Close All
Public MLEAP
Public MNORM
Public MMONTH
Public ZIZ
MLEAP='JAN000FEB031MAR060APR091MAY121JUN152JUL182AUG213SEP244OCT274NOV305DEC335'
MNORM='JAN000FEB031MAR059APR090MAY120JUN151JUL181AUG212SEP243OCT273NOV304DEC334'
MMONTH="M"+"LEAP"
USE 88JBBLO
Set filter to spec="ANEPA"
Average Val(Substr(&MMONTH,(At(Upper(Left(CMonth(Day),3)),&MMONTH)+3),3))+ day(d
ay) ALL FOR spec = "ANEPA" .and. ph = " 1" .and. township>=50 .and. township<=55
 .and.  range >=22 .and. range <=28 .and. meridian = 4 to ZIZ
```

Appendix 7: Frequency distributions: frequencies of flowering dates (in Julian days) for three flowering phases (10%, 50%, and 90%) of the fifteen provincial survey species, 1988.

# Appendix 7: Frequency Distributions

## Anemone patens

### 10%

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 1 | 1 | 1.39 | 1.39 |
| 85 | 4 | 5 | 5.56 | 6.94 |
| 90 | 11 | 16 | 15.28 | 22.22 |
| 95 | 21 | 37 | 29.17 | 51.39 |
| 100 | 20 | 57 | 27.78 | 79.17 |
| 105 | 11 | 68 | 15.28 | 94.44 |
| 110 | 1 | 69 | 1.39 | 95.83 |
| 115 | 0 | 69 | 0.00 | 95.83 |
| 120 | 1 | 70 | 1.39 | 97.22 |
| 125 | 1 | 71 | 1.39 | 98.61 |
| 130 | 0 | 71 | 0.00 | 98.61 |
| 135 | 0 | 71 | 0.00 | 98.61 |
| 140 | 1 | 72 | 1.39 | 100.00 |
| 145 | 0 | 72 | 0.00 | 100.00 |
| 150 | 0 | 72 | 0.00 | 100.00 |
| 155 | 0 | 72 | 0.00 | 100.00 |
| 160 | 0 | 72 | 0.00 | 100.00 |
| 165 | 0 | 72 | 0.00 | 100.00 |
| 170 | 0 | 72 | 0.00 | 100.00 |
| 175 | 0 | 72 | 0.00 | 100.00 |
| 180 | 0 | 72 | 0.00 | 100.00 |
| 185 | 0 | 72 | 0.00 | 100.00 |
| 190 | 0 | 72 | 0.00 | 100.00 |
| 195 | 0 | 72 | 0.00 | 100.00 |
| 200 | 0 | 72 | 0.00 | 100.00 |
| 205 | 0 | 72 | 0.00 | 100.00 |
| 210 | 0 | 72 | 0.00 | 100.00 |
| 215 | 0 | 72 | 0.00 | 100.00 |
| 220 | 0 | 72 | 0.00 | 100.00 |

### 50%

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 1 | 1 | 1.69 | 1.69 |
| 95 | 8 | 9 | 13.56 | 15.25 |
| 100 | 18 | 27 | 30.51 | 45.76 |
| 105 | 21 | 48 | 35.59 | 81.36 |
| 110 | 6 | 54 | 10.17 | 91.53 |
| 115 | 2 | 56 | 3.39 | 94.92 |
| 120 | 0 | 56 | 0.00 | 94.92 |
| 125 | 2 | 58 | 3.39 | 98.31 |
| 130 | 0 | 58 | 0.00 | 98.31 |
| 135 | 0 | 58 | 0.00 | 98.31 |
| 140 | 0 | 58 | 0.00 | 98.31 |
| 145 | 1 | 59 | 1.69 | 100.00 |
| 150 | 0 | 59 | 0.00 | 100.00 |
| 155 | 0 | 59 | 0.00 | 100.00 |
| 160 | 0 | 59 | 0.00 | 100.00 |
| 165 | 0 | 59 | 0.00 | 100.00 |
| 170 | 0 | 59 | 0.00 | 100.00 |
| 175 | 0 | 59 | 0.00 | 100.00 |
| 180 | 0 | 59 | 0.00 | 100.00 |
| 185 | 0 | 59 | 0.00 | 100.00 |
| 190 | 0 | 59 | 0.00 | 100.00 |
| 195 | 0 | 59 | 0.00 | 100.00 |
| 200 | 0 | 59 | 0.00 | 100.00 |
| 205 | 0 | 59 | 0.00 | 100.00 |
| 210 | 0 | 59 | 0.00 | 100.00 |
| 215 | 0 | 59 | 0.00 | 100.00 |
| 220 | 0 | 59 | 0.00 | 100.00 |

### 90%

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 5 | 5 | 6.85 | 6.85 |
| 100 | 7 | 12 | 9.59 | 16.44 |
| 105 | 16 | 28 | 21.92 | 38.36 |
| 110 | 22 | 50 | 30.14 | 68.49 |
| 115 | 11 | 61 | 15.07 | 83.56 |
| 120 | 5 | 66 | 6.85 | 90.41 |
| 125 | 2 | 68 | 2.74 | 93.15 |
| 130 | 2 | 70 | 2.74 | 95.89 |
| 135 | 0 | 70 | 0.00 | 95.89 |
| 140 | 1 | 71 | 1.37 | 97.26 |
| 145 | 2 | 73 | 2.74 | 100.00 |
| 150 | 0 | 73 | 0.00 | 100.00 |
| 155 | 0 | 73 | 0.00 | 100.00 |
| 160 | 0 | 73 | 0.00 | 100.00 |
| 165 | 0 | 73 | 0.00 | 100.00 |
| 170 | 0 | 73 | 0.00 | 100.00 |
| 175 | 0 | 73 | 0.00 | 100.00 |
| 180 | 0 | 73 | 0.00 | 100.00 |
| 185 | 0 | 73 | 0.00 | 100.00 |
| 190 | 0 | 73 | 0.00 | 100.00 |
| 195 | 0 | 73 | 0.00 | 100.00 |
| 200 | 0 | 73 | 0.00 | 100.00 |
| 205 | 0 | 73 | 0.00 | 100.00 |
| 210 | 0 | 73 | 0.00 | 100.00 |
| 215 | 0 | 73 | 0.00 | 100.00 |
| 220 | 0 | 73 | 0.00 | 100.00 |

## Populus tremuloides

### 10%

FREQUENCY BAR CHART

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 3 | 3 | 4.92 | 4.92 |
| 85 | 3 | 6 | 4.92 | 9.84 |
| 90 | 10 | 16 | 16.39 | 26.23 |
| 95 | 14 | 30 | 22.95 | 49.18 |
| 100 | 8 | 38 | 13.11 | 62.30 |
| 105 | 7 | 45 | 11.48 | 73.77 |
| 110 | 3 | 48 | 4.92 | 78.69 |
| 115 | 2 | 50 | 3.28 | 81.97 |
| 120 | 5 | 55 | 8.20 | 90.16 |
| 125 | 1 | 56 | 1.64 | 91.80 |
| 130 | 4 | 60 | 6.56 | 98.36 |
| 135 | 1 | 61 | 1.64 | 100.00 |
| 140 | 0 | 61 | 0.00 | 100.00 |
| 145 | 0 | 61 | 0.00 | 100.00 |
| 150 | 0 | 61 | 0.00 | 100.00 |
| 155 | 0 | 61 | 0.00 | 100.00 |
| 160 | 0 | 61 | 0.00 | 100.00 |
| 165 | 0 | 61 | 0.00 | 100.00 |
| 170 | 0 | 61 | 0.00 | 100.00 |
| 175 | 0 | 61 | 0.00 | 100.00 |
| 180 | 0 | 61 | 0.00 | 100.00 |
| 185 | 0 | 61 | 0.00 | 100.00 |
| 190 | 0 | 61 | 0.00 | 100.00 |
| 195 | 0 | 61 | 0.00 | 100.00 |
| 200 | 0 | 61 | 0.00 | 100.00 |
| 205 | 0 | 61 | 0.00 | 100.00 |
| 210 | 0 | 61 | 0.00 | 100.00 |
| 215 | 0 | 61 | 0.00 | 100.00 |
| 220 | 0 | 61 | 0.00 | 100.00 |

### 50%

FREQUENCY BAR CHART

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 2 | 2 | 3.45 | 3.45 |
| 90 | 4 | 6 | 6.90 | 10.34 |
| 95 | 8 | 14 | 13.79 | 24.14 |
| 100 | 11 | 25 | 18.97 | 43.10 |
| 105 | 9 | 34 | 15.52 | 58.62 |
| 110 | 9 | 43 | 15.52 | 74.14 |
| 115 | 3 | 46 | 5.17 | 79.31 |
| 120 | 3 | 49 | 5.17 | 84.48 |
| 125 | 5 | 54 | 8.62 | 93.10 |
| 130 | 2 | 56 | 3.45 | 96.55 |
| 135 | 2 | 58 | 3.45 | 100.00 |
| 140 | 0 | 58 | 0.00 | 100.00 |
| 145 | 0 | 58 | 0.00 | 100.00 |
| 150 | 0 | 58 | 0.00 | 100.00 |
| 155 | 0 | 58 | 0.00 | 100.00 |
| 160 | 0 | 58 | 0.00 | 100.00 |
| 165 | 0 | 58 | 0.00 | 100.00 |
| 170 | 0 | 58 | 0.00 | 100.00 |
| 175 | 0 | 58 | 0.00 | 100.00 |
| 180 | 0 | 58 | 0.00 | 100.00 |
| 185 | 0 | 58 | 0.00 | 100.00 |
| 190 | 0 | 58 | 0.00 | 100.00 |
| 195 | 0 | 58 | 0.00 | 100.00 |
| 200 | 0 | 58 | 0.00 | 100.00 |
| 205 | 0 | 58 | 0.00 | 100.00 |
| 210 | 0 | 58 | 0.00 | 100.00 |
| 215 | 0 | 58 | 0.00 | 100.00 |
| 220 | 0 | 58 | 0.00 | 100.00 |

### 90%

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 5 | 5 | 7.58 | 7.58 |
| 95 | 11 | 16 | 16.67 | 24.24 |
| 100 | 11 | 27 | 16.67 | 40.91 |
| 105 | [illegible] | 36 | 13.64 | 54.55 |
| 110 | 9 | 45 | 13.64 | 68.18 |
| 115 | 4 | 49 | 6.06 | 74.24 |
| 120 | 6 | 55 | 9.09 | 83.33 |
| 125 | 1 | 56 | 1.52 | 84.85 |
| 130 | 6 | 62 | 9.09 | 93.94 |
| 135 | [illegible] | 63 | 1.52 | 95.45 |
| 140 | 2 | 65 | 3.03 | 98.48 |
| 145 | 0 | 65 | 0.00 | 98.48 |
| 150 | 0 | 65 | 0.00 | 98.48 |
| 155 | 1 | 66 | 1.52 | 100.00 |
| 160 | 0 | 66 | 0.00 | 100.00 |
| 165 | 0 | 66 | 0.00 | 100.00 |
| 170 | 0 | 66 | 0.00 | 100.00 |
| 175 | 0 | 66 | 0.00 | 100.00 |
| 180 | 0 | 66 | 0.00 | 100.00 |
| 185 | 0 | 66 | 0.00 | 100.00 |
| 190 | 0 | 66 | 0.00 | 100.00 |
| 195 | 0 | 66 | 0.00 | 100.00 |
| 200 | 0 | 66 | 0.00 | 100.00 |
| 205 | 0 | 66 | 0.00 | 100.00 |
| 210 | 0 | 66 | 0.00 | 100.00 |
| 215 | 0 | 66 | 0.00 | 100.00 |
| 220 | 0 | 66 | 0.00 | 100.00 |

Appendix 7, continued:

# Viola adunca

## 10%

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 1 | 1 | 1.33 | 1.33 |
| 100 | 1 | 2 | 1.33 | 2.67 |
| 105 | 2 | 4 | 2.67 | 5.33 |
| 110 | 3 | 7 | 4.00 | 9.33 |
| 115 | 2 | 9 | 2.67 | 12.00 |
| 120 | 24 | 33 | 32.00 | 44.00 |
| 125 | 22 | 55 | 29.33 | 73.33 |
| 130 | 12 | 67 | 16.00 | 89.33 |
| 135 | 3 | 70 | 4.00 | 93.33 |
| 140 | 3 | 73 | 4.00 | 97.33 |
| 145 | 2 | 75 | 2.67 | 100.00 |
| 150 | 0 | 75 | 0.00 | 100.00 |
| 155 | 0 | 75 | 0.00 | 100.00 |
| 160 | 0 | 75 | 0.00 | 100.00 |
| 165 | 0 | 75 | 0.00 | 100.00 |
| 170 | 0 | 75 | 0.00 | 100.00 |
| 175 | 0 | 75 | 0.00 | 100.00 |
| 180 | 0 | 75 | 0.00 | 100.00 |
| 185 | 0 | 75 | 0.00 | 100.00 |
| 190 | 0 | 75 | 0.00 | 100.00 |
| 195 | 0 | 75 | 0.00 | 100.00 |
| 200 | 0 | 75 | 0.00 | 100.00 |
| 205 | 0 | 75 | 0.00 | 100.00 |
| 210 | 0 | 75 | 0.00 | 100.00 |
| 215 | 0 | 75 | 0.00 | 100.00 |
| 220 | 0 | 75 | 0.00 | 100.00 |

FREQUENCY

## 50%

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 1 | 1 | 1.39 | 1.39 |
| 110 | 0 | 1 | 0.00 | 1.39 |
| 115 | 2 | 3 | 2.78 | 4.17 |
| 120 | 7 | 10 | 9.72 | 13.89 |
| 125 | 14 | 24 | 19.44 | 33.33 |
| 130 | 24 | 48 | 33.33 | 66.67 |
| 135 | 17 | 65 | 23.61 | 90.28 |
| 140 | 4 | 69 | 5.56 | 95.83 |
| 145 | 1 | 70 | 1.39 | 97.22 |
| 150 | 2 | 72 | 2.78 | 100.00 |
| 155 | 0 | 72 | 0.00 | 100.00 |
| 160 | 0 | 72 | 0.00 | 100.00 |
| 165 | 0 | 72 | 0.00 | 100.00 |
| 170 | 0 | 72 | 0.00 | 100.00 |
| 175 | 0 | 72 | 0.00 | 100.00 |
| 180 | 0 | 72 | 0.00 | 100.00 |
| 185 | 0 | 72 | 0.00 | 100.00 |
| 190 | 0 | 72 | 0.00 | 100.00 |
| 195 | 0 | 72 | 0.00 | 100.00 |
| 200 | 0 | 72 | 0.00 | 100.00 |
| 205 | 0 | 72 | 0.00 | 100.00 |
| 210 | 0 | 72 | 0.00 | 100.00 |
| 215 | 0 | 72 | 0.00 | 100.00 |
| 220 | 0 | 72 | 0.00 | 100.00 |

FREQUENCY

## 90%

FREQUENCY BAR CHART

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 5 | 5 | 5.43 | 5.43 |
| 125 | 6 | 11 | 6.52 | 11.36 |
| 130 | 22 | 33 | 23.91 | 35.87 |
| 135 | 25 | 58 | 27.17 | 63.04 |
| 140 | 17 | 75 | 18.48 | 81.52 |
| 145 | 6 | 81 | 6.52 | 88.04 |
| 150 | 4 | 85 | 4.35 | 92.39 |
| 155 | 3 | 88 | 3.26 | 95.65 |
| 160 | 3 | 91 | 3.26 | 98.91 |
| 165 | 0 | 91 | 0.00 | 98.91 |
| 170 | 1 | 92 | 1.09 | 100.00 |
| 175 | 0 | 92 | 0.00 | 100.00 |
| 180 | 0 | 92 | 0.00 | 100.00 |
| 185 | 0 | 92 | 0.00 | 100.00 |
| 190 | 0 | 92 | 0.00 | 100.00 |
| 195 | 0 | 92 | 0.00 | 100.00 |
| 200 | 0 | 92 | 0.00 | 100.00 |
| 205 | 0 | 92 | 0.00 | 100.00 |
| 210 | 0 | 92 | 0.00 | 100.00 |
| 215 | 0 | 92 | 0.00 | 100.00 |
| 220 | 0 | 92 | 0.00 | 100.00 |

FREQUENCY

# Thermopsis rhombifolia

## 10%

FREQUENCY BAR CHART

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 1 | 1 | 1.82 | 1.82 |
| 110 | 2 | 3 | 3.64 | 5.45 |
| 115 | 6 | 9 | 10.91 | 16.36 |
| 120 | 14 | 23 | 25.45 | 41.82 |
| 125 | 15 | 38 | 27.27 | 69.09 |
| 130 | 15 | 53 | 27.27 | 96.36 |
| 135 | 2 | 55 | 3.64 | 100.00 |
| 140 | 0 | 55 | 0.00 | 100.00 |
| 145 | 0 | 55 | 0.00 | 100.00 |
| 150 | 0 | 55 | 0.00 | 100.00 |
| 155 | 0 | 55 | 0.00 | 100.00 |
| 160 | 0 | 55 | 0.00 | 100.00 |
| 165 | 0 | 55 | 0.00 | 100.00 |
| 170 | 0 | 55 | 0.00 | 100.00 |
| 175 | 0 | 55 | 0.00 | 100.00 |
| 180 | 0 | 55 | 0.00 | 100.00 |
| 185 | 0 | 55 | 0.00 | 100.00 |
| 190 | 0 | 55 | 0.00 | 100.00 |
| 195 | 0 | 55 | 0.00 | 100.00 |
| 200 | 0 | 55 | 0.00 | 100.00 |
| 205 | 0 | 55 | 0.00 | 100.00 |
| 210 | 0 | 55 | 0.00 | 100.00 |
| 215 | 0 | 55 | 0.00 | 100.00 |
| 220 | 0 | 55 | 0.00 | 100.00 |

FREQUENCY

## 50%

FREQUENCY BAR CHART

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 3 | 3 | 5.66 | 5.66 |
| 120 | 5 | 8 | 9.43 | 15.09 |
| 125 | 14 | 22 | 26.42 | 41.51 |
| 130 | 15 | 37 | 28.30 | 69.81 |
| 135 | 14 | 51 | 26.42 | 96.23 |
| 140 | 2 | 53 | 3.77 | 100.00 |
| 145 | 0 | 53 | 0.00 | 100.00 |
| 150 | 0 | 53 | 0.00 | 100.00 |
| 155 | 0 | 53 | 0.00 | 100.00 |
| 160 | 0 | 53 | 0.00 | 100.00 |
| 165 | 0 | 53 | 0.00 | 100.00 |
| 170 | 0 | 53 | 0.00 | 100.00 |
| 175 | 0 | 53 | 0.00 | 100.00 |
| 180 | 0 | 53 | 0.00 | 100.00 |
| 185 | 0 | 53 | 0.00 | 100.00 |
| 190 | 0 | 53 | 0.00 | 100.00 |
| 195 | 0 | 53 | 0.00 | 100.00 |
| 200 | 0 | 53 | 0.00 | 100.00 |
| 205 | 0 | 53 | 0.00 | 100.00 |
| 210 | 0 | 53 | 0.00 | 100.00 |
| 215 | 0 | 53 | 0.00 | 100.00 |
| 220 | 0 | 53 | 0.00 | 100.00 |

FREQUENCY

## 90%

FREQUENCY BAR CHART

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 1 | 1 | 1.89 | 1.89 |
| 115 | 1 | 2 | 1.89 | 3.77 |
| 120 | 1 | 3 | 1.89 | 5.66 |
| 125 | 3 | 6 | 5.66 | 11.32 |
| 130 | 16 | 22 | 30.19 | 41.51 |
| 135 | 16 | 38 | 30.19 | 71.70 |
| 140 | 10 | 48 | 18.87 | 90.57 |
| 145 | 5 | 53 | 9.43 | 100.00 |
| 150 | 0 | 53 | 0.00 | 100.00 |
| 155 | 0 | 53 | 0.00 | 100.00 |
| 160 | 0 | 53 | 0.00 | 100.00 |
| 165 | 0 | 53 | 0.00 | 100.00 |
| 170 | 0 | 53 | 0.00 | 100.00 |
| 175 | 0 | 53 | 0.00 | 100.00 |
| 180 | 0 | 53 | 0.00 | 100.00 |
| 185 | 0 | 53 | 0.00 | 100.00 |
| 190 | 0 | 53 | 0.00 | 100.00 |
| 195 | 0 | 53 | 0.00 | 100.00 |
| 200 | 0 | 53 | 0.00 | 100.00 |
| 205 | 0 | 53 | 0.00 | 100.00 |
| 210 | 0 | 53 | 0.00 | 100.00 |
| 215 | 0 | 53 | 0.00 | 100.00 |
| 220 | 0 | 53 | 0.00 | 100.00 |

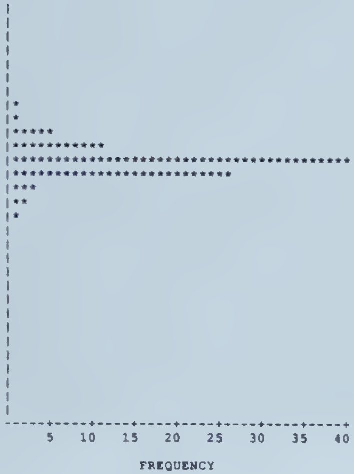
FREQUENCY

Appendix 7, continued:

# Amelanchier alnifolia

## 10%

FREQUENCY BAR CHART



| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM PERCE |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0. |
| 85 | 0 | 0 | 0.00 | 0. |
| 90 | 0 | 0 | 0.00 | 0. |
| 95 | 0 | 0 | 0.00 | 0. |
| 100 | 0 | 0 | 0.00 | 0. |
| 105 | 0 | 0 | 0.00 | 0. |
| 110 | 1 | 1 | 1.11 | 1. |
| 115 | 1 | 2 | 1.11 | 2. |
| 120 | 5 | 7 | 5.56 | 7. |
| 125 | 11 | 18 | 12.22 | 20. |
| 130 | 40 | 58 | 44.44 | 64. |
| 135 | 26 | 84 | 28.89 | 93. |
| 140 | 3 | 87 | 3.33 | 96. |
| 145 | 2 | 89 | 2.22 | 98. |
| 150 | 1 | 90 | 1.11 | 100. |
| 155 | 0 | 90 | 0.00 | 100. |
| 160 | 0 | 90 | 0.00 | 100. |
| 165 | 0 | 90 | 0.00 | 100. |
| 170 | 0 | 90 | 0.00 | 100. |
| 175 | 0 | 90 | 0.00 | 100. |
| 180 | 0 | 90 | 0.00 | 100. |
| 185 | 0 | 90 | 0.00 | 100. |
| 190 | 0 | 90 | 0.00 | 100. |
| 195 | 0 | 90 | 0.00 | 100. |
| 200 | 0 | 90 | 0.00 | 100. |
| 205 | 0 | 90 | 0.00 | 100. |
| 210 | 0 | 90 | 0.00 | 100. |
| 215 | 0 | 90 | 0.00 | 100. |
| 220 | 0 | 90 | 0.00 | 100. |

## 50%

FREQUENCY BAR CHART

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 1 | 1 | 1.18 | 1.18 |
| 120 | 1 | 2 | 1.18 | 2.35 |
| 125 | 5 | 7 | 5.88 | 8.24 |
| 130 | 22 | 29 | 25.88 | 34.12 |
| 135 | 36 | 65 | 42.35 | 76.47 |
| 140 | 15 | 80 | 17.65 | 94.12 |
| 145 | 3 | 83 | 3.53 | 97.65 |
| 150 | 1 | 84 | 1.18 | 98.82 |
| 155 | 1 | 85 | 1.18 | 100.00 |
| 160 | 0 | 85 | 0.00 | 100.00 |
| 165 | 0 | 85 | 0.00 | 100.00 |
| 170 | 0 | 85 | 0.00 | 100.00 |
| 175 | 0 | 85 | 0.00 | 100.00 |
| 180 | 0 | 85 | 0.00 | 100.00 |
| 185 | 0 | 85 | 0.00 | 100.00 |
| 190 | 0 | 85 | 0.00 | 100.00 |
| 195 | 0 | 85 | 0.00 | 100.00 |
| 200 | 0 | 85 | 0.00 | 100.00 |
| 205 | 0 | 85 | 0.00 | 100.00 |
| 210 | 0 | 85 | 0.00 | 100.00 |
| 215 | 0 | 85 | 0.00 | 100.00 |
| 220 | 0 | 85 | 0.00 | 100.00 |

## 90%

FREQUENCY BAR CHART

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 1 | 1 | 0.89 | 0.89 |
| 130 | 13 | 14 | 11.61 | 12.50 |
| 135 | 53 | 67 | 47.32 | 59.82 |
| 140 | 27 | 94 | 24.11 | 83.93 |
| 145 | 11 | 105 | 9.82 | 93.75 |
| 150 | 4 | 109 | 3.57 | 97.32 |
| 155 | 1 | 110 | 0.89 | 98.21 |
| 160 | 2 | 112 | 1.79 | 100.00 |
| 165 | 0 | 112 | 0.00 | 100.00 |
| 170 | 0 | 112 | 0.00 | 100.00 |
| 175 | 0 | 112 | 0.00 | 100.00 |
| 180 | 0 | 112 | 0.00 | 100.00 |
| 185 | 0 | 112 | 0.00 | 100.00 |
| 190 | 0 | 112 | 0.00 | 100.00 |
| 195 | 0 | 112 | 0.00 | 100.00 |
| 200 | 0 | 112 | 0.00 | 100.00 |
| 205 | 0 | 112 | 0.00 | 100.00 |
| 210 | 0 | 112 | 0.00 | 100.00 |
| 215 | 0 | 112 | 0.00 | 100.00 |
| 220 | 0 | 112 | 0.00 | 100.00 |

# Prunus virginiana

## 10%

FREQUENCY BAR CHART

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 1 | 1 | 1.61 | 1.61 |
| 125 | 3 | 4 | 4.84 | 6.45 |
| 130 | 8 | 12 | 12.90 | 19.35 |
| 135 | 6 | 18 | 9.68 | 29.03 |
| 140 | 32 | 50 | 51.61 | 80.65 |
| 145 | 6 | 56 | 9.68 | 90.32 |
| 150 | 2 | 58 | 3.23 | 93.55 |
| 155 | 1 | 59 | 1.61 | 95.16 |
| 160 | 3 | 62 | 4.84 | 100.00 |
| 165 | 0 | 62 | 0.00 | 100.00 |
| 170 | 0 | 62 | 0.00 | 100.00 |
| 175 | 0 | 62 | 0.00 | 100.00 |
| 180 | 0 | 62 | 0.00 | 100.00 |
| 185 | 0 | 62 | 0.00 | 100.00 |
| 190 | 0 | 62 | 0.00 | 100.00 |
| 195 | 0 | 62 | 0.00 | 100.00 |
| 200 | 0 | 62 | 0.00 | 100.00 |
| 205 | 0 | 62 | 0.00 | 100.00 |
| 210 | 0 | 62 | 0.00 | 100.00 |
| 215 | 0 | 62 | 0.00 | 100.00 |
| 220 | 0 | 62 | 0.00 | 100.00 |

## 50%

FREQUENCY BAR CHART

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCEN |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.0 |
| 85 | 0 | 0 | 0.00 | 0.0 |
| 90 | 0 | 0 | 0.00 | 0.0 |
| 95 | 0 | 0 | 0.00 | 0.0 |
| 100 | 0 | 0 | 0.00 | 0.0 |
| 105 | 0 | 0 | 0.00 | 0.0 |
| 110 | 0 | 0 | 0.00 | 0.0 |
| 115 | 0 | 0 | 0.00 | 0.0 |
| 120 | 0 | 0 | 0.00 | 0.0 |
| 125 | 1 | 1 | 2.04 | 2.0 |
| 130 | 2 | 3 | 4.08 | 6.1 |
| 135 | 4 | 7 | 8.16 | 14.2 |
| 140 | 19 | 26 | 38.78 | 53.0 |
| 145 | 16 | 42 | 32.65 | 85.7 |
| 150 | 4 | 46 | 8.16 | 93.8 |
| 155 | 2 | 48 | 4.08 | 97.9 |
| 160 | 0 | 48 | 0.00 | 97.9 |
| 165 | 1 | 49 | 2.04 | 100.0 |
| 170 | 0 | 49 | 0.00 | 100.0 |
| 175 | 0 | 49 | 0.00 | 100.0 |
| 180 | 0 | 49 | 0.00 | 100.0 |
| 185 | 0 | 49 | 0.00 | 100.0 |
| 190 | 0 | 49 | 0.00 | 100.0 |
| 195 | 0 | 49 | 0.00 | 100.0 |
| 200 | 0 | 49 | 0.00 | 100.0 |
| 205 | 0 | 49 | 0.00 | 100.0 |
| 210 | 0 | 49 | 0.00 | 100.0 |
| 215 | 0 | 49 | 0.00 | 100.0 |
| 220 | 0 | 49 | 0.00 | 100.0 |

## 90%

FREQUENCY BAR CHART

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 1 | 1 | 1.49 | 1.49 |
| 135 | 4 | 5 | 5.97 | 7.46 |
| 140 | 17 | 22 | 25.37 | 32.84 |
| 145 | 24 | 46 | 35.82 | 68.66 |
| 150 | 12 | 58 | 17.91 | 86.57 |
| 155 | 6 | 64 | 8.96 | 95.52 |
| 160 | 0 | 64 | 0.00 | 95.52 |
| 165 | 2 | 66 | 2.99 | 98.51 |
| 170 | 1 | 67 | 1.49 | 100.00 |
| 175 | 0 | 67 | 0.00 | 100.00 |
| 180 | 0 | 67 | 0.00 | 100.00 |
| 185 | 0 | 67 | 0.00 | 100.00 |
| 190 | 0 | 67 | 0.00 | 100.00 |
| 195 | 0 | 67 | 0.00 | 100.00 |
| 200 | 0 | 67 | 0.00 | 100.00 |
| 205 | 0 | 67 | 0.00 | 100.00 |
| 210 | 0 | 67 | 0.00 | 100.00 |
| 215 | 0 | 67 | 0.00 | 100.00 |
| 220 | 0 | 67 | 0.00 | 100.00 |

Appendix 7, continued:

## Smilacina stellata

### 10%

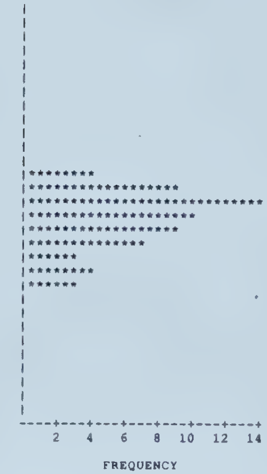

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM PERCE |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0. |
| 85 | 0 | 0 | 0.00 | 0. |
| 90 | 0 | 0 | 0.00 | 0. |
| 95 | 0 | 0 | 0.00 | 0. |
| 100 | 0 | 0 | 0.00 | 0. |
| 105 | 0 | 0 | 0.00 | 0. |
| 110 | 0 | 0 | 0.00 | 0. |
| 115 | 0 | 0 | 0.00 | 0. |
| 120 | 2 | 2 | 3.28 | 3. |
| 125 | 0 | 2 | 0.00 | 3. |
| 130 | 4 | 6 | 6.56 | 9. |
| 135 | 18 | 24 | 29.51 | 39. |
| 140 | 20 | 44 | 32.79 | 72. |
| 145 | 6 | 50 | 9.84 | 81. |
| 150 | 4 | 54 | 6.56 | 88. |
| 155 | 3 | 57 | 4.92 | 93. |
| 160 | 3 | 60 | 4.92 | 98. |
| 165 | 0 | 60 | 0.00 | 98. |
| 170 | 1 | 61 | 1.64 | 100. |
| 175 | 0 | 61 | 0.00 | 100. |
| 180 | 0 | 61 | 0.00 | 100. |
| 185 | 0 | 61 | 0.00 | 100. |
| 190 | 0 | 61 | 0.00 | 100. |
| 195 | 0 | 61 | 0.00 | 100. |
| 200 | 0 | 61 | 0.00 | 100. |
| 205 | 0 | 61 | 0.00 | 100. |
| 210 | 0 | 61 | 0.00 | 100. |
| 215 | 0 | 61 | 0.00 | 100. |
| 220 | 0 | 61 | 0.00 | 100. |

### 50%


| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 4 | 4 | 7.14 | 7.14 |
| 135 | 7 | 11 | 12.50 | 19.64 |
| 140 | 17 | 28 | 30.36 | 50.00 |
| 145 | 9 | 37 | 16.07 | 66.07 |
| 150 | 7 | 44 | 12.50 | 78.57 |
| 155 | 4 | 48 | 7.14 | 85.71 |
| 160 | 5 | 53 | 8.93 | 94.64 |
| 165 | 1 | 54 | 1.79 | 96.43 |
| 170 | 1 | 55 | 1.79 | 98.21 |
| 175 | 0 | 55 | 0.00 | 98.21 |
| 180 | 1 | 56 | 1.79 | 100.00 |
| 185 | 0 | 56 | 0.00 | 100.00 |
| 190 | 0 | 56 | 0.00 | 100.00 |
| 195 | 0 | 56 | 0.00 | 100.00 |
| 200 | 0 | 56 | 0.00 | 100.00 |
| 205 | 0 | 56 | 0.00 | 100.00 |
| 210 | 0 | 56 | 0.00 | 100.00 |
| 215 | 0 | 56 | 0.00 | 100.00 |
| 220 | 0 | 56 | 0.00 | 100.00 |

### 90%

90




| JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 4 | 4 | 6.35 | 6.35 |
| 140 | 9 | 13 | 14.29 | 20.63 |
| 145 | 14 | 27 | 22.22 | 42.86 |
| 150 | 10 | 37 | 15.87 | 58.73 |
| 155 | 9 | 46 | 14.29 | 73.02 |
| 160 | 7 | 53 | 11.11 | 84.13 |
| 165 | 3 | 56 | 4.76 | 88.89 |
| 170 | 4 | 60 | 6.35 | 95.24 |
| 175 | 3 | 63 | 4.76 | 100.00 |
| 180 | 0 | 63 | 0.00 | 100.00 |
| 185 | 0 | 63 | 0.00 | 100.00 |
| 190 | 0 | 63 | 0.00 | 100.00 |
| 195 | 0 | 63 | 0.00 | 100.00 |
| 200 | 0 | 63 | 0.00 | 100.00 |
| 205 | 0 | 63 | 0.00 | 100.00 |
| 210 | 0 | 63 | 0.00 | 100.00 |
| 215 | 0 | 63 | 0.00 | 100.00 |
| 220 | 0 | 63 | 0.00 | 100.00 |

## Elaeagnus commutata

### 10%


| MIDPC JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 1 | 1 | 2.22 | 2.22 |
| 130 | 1 | 2 | 2.22 | 4.44 |
| 135 | 3 | 5 | 6.67 | 11.11 |
| 140 | 13 | 18 | 28.89 | 40.00 |
| 145 | 14 | 32 | 31.11 | 71.11 |
| 150 | 5 | 37 | 11.11 | 82.22 |
| 155 | 3 | 40 | 6.67 | 88.89 |
| 160 | 0 | 40 | 0.00 | 88.89 |
| 165 | 5 | 45 | 11.11 | 100.00 |
| 170 | 0 | 45 | 0.00 | 100.00 |
| 175 | 0 | 45 | 0.00 | 100.00 |
| 180 | 0 | 45 | 0.00 | 100.00 |
| 185 | 0 | 45 | 0.00 | 100.00 |
| 190 | 0 | 45 | 0.00 | 100.00 |
| 195 | 0 | 45 | 0.00 | 100.00 |
| 200 | 0 | 45 | 0.00 | 100.00 |
| 205 | 0 | 45 | 0.00 | 100.00 |
| 210 | 0 | 45 | 0.00 | 100.00 |
| 215 | 0 | 45 | 0.00 | 100.00 |
| 220 | 0 | 45 | 0.00 | 100.00 |

### 50%


| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 1 | 1 | 3.03 | 3.03 |
| 135 | 2 | 3 | 6.06 | 9.09 |
| 140 | 3 | 6 | 9.09 | 18.18 |
| 145 | 11 | 17 | 33.33 | 51.52 |
| 150 | 4 | 21 | 12.12 | 63.64 |
| 155 | 6 | 27 | 18.18 | 81.82 |
| 160 | 2 | 29 | 6.06 | 87.88 |
| 165 | 1 | 30 | 3.03 | 90.91 |
| 170 | 3 | 33 | 9.09 | 100.00 |
| 175 | 0 | 33 | 0.00 | 100.00 |
| 180 | 0 | 33 | 0.00 | 100.00 |
| 185 | 0 | 33 | 0.00 | 100.00 |
| 190 | 0 | 33 | 0.00 | 100.00 |
| 195 | 0 | 33 | 0.00 | 100.00 |
| 200 | 0 | 33 | 0.00 | 100.00 |
| 205 | 0 | 33 | 0.00 | 100.00 |
| 210 | 0 | 33 | 0.00 | 100.00 |
| 215 | 0 | 33 | 0.00 | 100.00 |
| 220 | 0 | 33 | 0.00 | 100.00 |

### 90%


| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 0 | 0 | 0.00 | 0.00 |
| 140 | 5 | 5 | 10.87 | 10.87 |
| 145 | 9 | 14 | 19.57 | 30.43 |
| 150 | 15 | 29 | 32.61 | 63.04 |
| 155 | 7 | 36 | 15.22 | 78.26 |
| 160 | 4 | 40 | 8.70 | 86.96 |
| 165 | 2 | 42 | 4.35 | 91.30 |
| 170 | 2 | 44 | 4.35 | 95.65 |
| 175 | 1 | 45 | 2.17 | 97.83 |
| 180 | 0 | 45 | 0.00 | 97.83 |
| 185 | 1 | 46 | 2.17 | 100.00 |
| 190 | 0 | 46 | 0.00 | 100.00 |
| 195 | 0 | 46 | 0.00 | 100.00 |
| 200 | 0 | 46 | 0.00 | 100.00 |
| 205 | 0 | 46 | 0.00 | 100.00 |
| 210 | 0 | 46 | 0.00 | 100.00 |
| 215 | 0 | 46 | 0.00 | 100.00 |
| 220 | 0 | 46 | 0.00 | 100.00 |

Appendix 7, continued:

## Lathyrus ochroleucus

### 10%

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 4 | 4 | 5.56 | 5.56 |
| 140 | 13 | 17 | 18.06 | 23.61 |
| 145 | 26 | 43 | 36.11 | 59.72 |
| 150 | 11 | 54 | 15.28 | 75.00 |
| 155 | 5 | 59 | 6.94 | 81.94 |
| 160 | 6 | 65 | 8.33 | 90.28 |
| 165 | 4 | 69 | 5.56 | 95.83 |
| 170 | 2 | 71 | 2.78 | 98.61 |
| 175 | 1 | 72 | 1.39 | 100.00 |
| 180 | 0 | 72 | 0.00 | 100.00 |
| 185 | 0 | 72 | 0.00 | 100.00 |
| 190 | 0 | 72 | 0.00 | 100.00 |
| 195 | 0 | 72 | 0.00 | 100.00 |
| 200 | 0 | 72 | 0.00 | 100.00 |
| 205 | 0 | 72 | 0.00 | 100.00 |
| 210 | 0 | 72 | 0.00 | 100.00 |
| 215 | 0 | 72 | 0.00 | 100.00 |
| 220 | 0 | 72 | 0.00 | 100.00 |

FREQUENCY

### 50%

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 0 | 0 | 0.00 | 0.00 |
| 140 | 5 | 5 | 10.87 | 10.87 |
| 145 | 11 | 16 | 23.91 | 34.78 |
| 150 | 12 | 28 | 26.09 | 60.87 |
| 155 | 5 | 33 | 10.87 | 71.74 |
| 160 | 1 | 34 | 2.17 | 73.91 |
| 165 | 6 | 40 | 13.04 | 86.96 |
| 170 | 2 | 42 | 4.35 | 91.30 |
| 175 | 4 | 46 | 8.70 | 100.00 |
| 180 | 0 | 46 | 0.00 | 100.00 |
| 185 | 0 | 46 | 0.00 | 100.00 |
| 190 | 0 | 46 | 0.00 | 100.00 |
| 195 | 0 | 46 | 0.00 | 100.00 |
| 200 | 0 | 46 | 0.00 | 100.00 |
| 205 | 0 | 46 | 0.00 | 100.00 |
| 210 | 0 | 46 | 0.00 | 100.00 |
| 215 | 0 | 46 | 0.00 | 100.00 |
| 220 | 0 | 46 | 0.00 | 100.00 |

FREQUENCY

### 90%

| JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 0 | 0 | 0.00 | 0.00 |
| 140 | 2 | 2 | 2.70 | 2.70 |
| 145 | 6 | 8 | 8.11 | 10.81 |
| 150 | 13 | 21 | 17.57 | 28.38 |
| 155 | 11 | 32 | 14.86 | 43.24 |
| 160 | 11 | 43 | 14.86 | 58.11 |
| 165 | 6 | 49 | 8.11 | 66.22 |
| 170 | 14 | 63 | 18.92 | 85.14 |
| 175 | 4 | 67 | 5.41 | 90.54 |
| 180 | 4 | 71 | 5.41 | 95.95 |
| 185 | 2 | 73 | 2.70 | 98.65 |
| 190 | 1 | 74 | 1.35 | 100.00 |
| 195 | 0 | 74 | 0.00 | 100.00 |
| 200 | 0 | 74 | 0.00 | 100.00 |
| 205 | 0 | 74 | 0.00 | 100.00 |
| 210 | 0 | 74 | 0.00 | 100.00 |
| 215 | 0 | 74 | 0.00 | 100.00 |
| 220 | 0 | 74 | 0.00 | 100.00 |

FREQUENCY

## Galium boreale

### 10%

| MIDPOI JULDAT | FREQ | CUM. FREQ | PERCENT | CUM. PERCEN |
|---|---|---|---|---|
| [illegible] | 0 | 0 | 0.00 | [illegible] |
| [illegible] | 0 | 0 | 0.00 | [illegible] |
| [illegible] | 0 | 0 | 0.00 | [illegible] |
| [illegible] | 0 | 0 | 0.00 | [illegible] |
| [illegible] | 0 | 0 | 0.00 | [illegible] |
| [illegible] | 0 | 0 | 0.00 | [illegible] |
| [illegible] | 0 | 0 | 0.00 | [illegible] |
| [illegible] | 0 | 0 | 0.00 | [illegible] |
| [illegible] | 0 | 0 | 0.00 | [illegible] |
| [illegible] | 0 | 0 | 0.00 | [illegible] |
| [illegible] | 0 | 0 | 0.00 | [illegible] |
| [illegible] | 1 | 1 | 1.25 | [illegible] |
| [illegible] | 4 | 5 | 5.00 | [illegible] |
| [illegible] | 6 | 11 | 7.50 | [illegible] |
| [illegible] | 12 | 23 | 15.00 | [illegible] |
| [illegible] | 19 | 42 | 23.75 | [illegible] |
| [illegible] | 16 | 58 | 20.00 | [illegible] |
| [illegible] | 8 | 66 | 10.00 | [illegible] |
| [illegible] | 8 | 74 | 10.00 | [illegible] |
| [illegible] | 3 | 77 | 3.75 | [illegible] |
| [illegible] | 2 | 79 | 2.50 | [illegible] |
| [illegible] | 0 | 79 | 0.00 | [illegible] |
| [illegible] | 1 | 80 | 1.25 | [illegible] |
| [illegible] | 0 | 80 | 0.00 | [illegible] |
| [illegible] | 0 | 80 | 0.00 | [illegible] |
| [illegible] | 0 | 80 | 0.00 | [illegible] |
| [illegible] | 0 | 80 | 0.00 | [illegible] |
| [illegible] | 0 | 80 | 0.00 | [illegible] |

FREQUENCY

### 50%

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 0 | 0 | 0.00 | 0.00 |
| 140 | 0 | 0 | 0.00 | 0.00 |
| 145 | 0 | 0 | 0.00 | 0.00 |
| 150 | 4 | 4 | 5.80 | 5.80 |
| 155 | 7 | 11 | 10.14 | 15.94 |
| 160 | 8 | 19 | 11.59 | 27.54 |
| 165 | 12 | 31 | 17.39 | 44.93 |
| 170 | 14 | 45 | 20.29 | 65.22 |
| 175 | 9 | 54 | 13.04 | 78.26 |
| 180 | 7 | 61 | 10.14 | 88.41 |
| 185 | 2 | 63 | 2.90 | 91.30 |
| 190 | 4 | 67 | 5.80 | 97.10 |
| 195 | 1 | 68 | 1.45 | 98.55 |
| 200 | 1 | 69 | 1.45 | 100.00 |
| 205 | 0 | 69 | 0.00 | 100.00 |
| 210 | 0 | 69 | 0.00 | 100.00 |
| 215 | 0 | 69 | 0.00 | 100.00 |
| 220 | 0 | 69 | 0.00 | 100.00 |

FREQUENCY

### 90%

| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 0 | 0 | 0.00 | 0.00 |
| 140 | 0 | 0 | 0.00 | 0.00 |
| 145 | 0 | 0 | 0.00 | 0.00 |
| 150 | 1 | 1 | 1.23 | 1.23 |
| 155 | 5 | 6 | 6.17 | 7.41 |
| 160 | 10 | 16 | 12.35 | 19.75 |
| 165 | 11 | 27 | 13.58 | 33.33 |
| 170 | 21 | 48 | 25.93 | 59.26 |
| 175 | 10 | 58 | 12.35 | 71.60 |
| 180 | 5 | 63 | 6.17 | 77.78 |
| 185 | 8 | 71 | 9.88 | 87.65 |
| 190 | 4 | 75 | 4.94 | 92.59 |
| 195 | 3 | 78 | 3.70 | 96.30 |
| 200 | 2 | 80 | 2.47 | 98.77 |
| 205 | 1 | 81 | 1.23 | 100.00 |
| 210 | 0 | 81 | 0.00 | 100.00 |
| 215 | 0 | 81 | 0.00 | 100.00 |
| 220 | 0 | 81 | 0.00 | 100.00 |

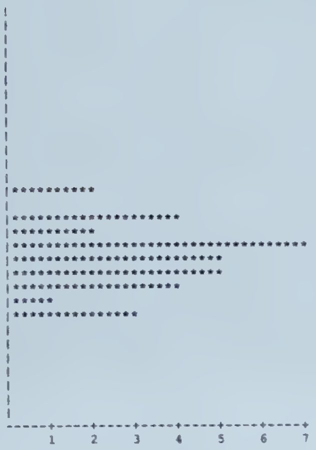
FREQUENCY

Appendix 7, continued:

## Linnaea borealis

### 10%

FREQUENCY BAR CHART




| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 0 | 0 | 0.00 | 0.00 |
| 140 | 2 | 2 | 6.06 | 6.06 |
| 145 | 0 | 2 | 0.00 | 6.06 |
| 150 | 4 | 6 | 12.12 | 18.18 |
| 155 | 2 | 8 | 6.06 | 24.24 |
| 160 | 7 | 15 | 21.21 | 45.45 |
| 165 | 5 | 20 | 15.15 | 60.61 |
| 170 | 5 | 25 | 15.15 | 75.76 |
| 175 | 4 | 29 | 12.12 | 87.88 |
| 180 | 1 | 30 | 3.03 | 90.91 |
| 185 | 3 | 33 | 9.09 | 100.00 |
| 190 | 0 | 33 | 0.00 | 100.00 |
| 195 | 0 | 33 | 0.00 | 100.00 |
| 200 | 0 | 33 | 0.00 | 100.00 |
| 205 | 0 | 33 | 0.00 | 100.00 |
| 210 | 0 | 33 | 0.00 | 100.00 |
| 215 | 0 | 33 | 0.00 | 100.00 |
| 220 | 0 | 33 | 0.00 | 100.00 |

### 50%

FREQUENCY BAR CHART


| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM PERCE |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0. |
| 85 | 0 | 0 | 0.00 | 0. |
| 90 | 0 | 0 | 0.00 | 0. |
| 95 | 0 | 0 | 0.00 | 0. |
| 100 | 0 | 0 | 0.00 | 0. |
| 105 | 0 | 0 | 0.00 | 0. |
| 110 | 0 | 0 | 0.00 | 0. |
| 115 | 0 | 0 | 0.00 | 0. |
| 120 | 0 | 0 | 0.00 | 0. |
| 125 | 0 | 0 | 0.00 | 0. |
| 130 | 0 | 0 | 0.00 | 0. |
| 135 | 0 | 0 | 0.00 | 0. |
| 140 | 1 | 1 | 3.23 | 3. |
| 145 | 0 | 1 | 0.00 | 3. |
| 150 | 1 | 2 | 3.23 | 6. |
| 155 | 2 | 4 | 6.45 | 12. |
| 160 | 6 | 10 | 19.35 | 32. |
| 165 | 1 | 11 | 3.23 | 35. |
| 170 | 8 | 19 | 25.81 | 61. |
| 175 | 2 | 21 | 6.45 | 67. |
| 180 | 3 | 24 | 9.68 | 77. |
| 185 | 2 | 26 | 6.45 | 83. |
| 190 | 3 | 29 | 9.68 | 93. |
| 195 | 1 | 30 | 3.23 | 96. |
| 200 | 1 | 31 | 3.23 | 100. |
| 205 | 0 | 31 | 0.00 | 100. |
| 210 | 0 | 31 | 0.00 | 100. |
| 215 | 0 | 31 | 0.00 | 100. |
| 220 | 0 | 31 | 0.00 | 100. |

### 90%

FREQUENCY BAR CHART


| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 0 | 0 | 0.00 | 0.00 |
| 140 | 0 | 0 | 0.00 | 0.00 |
| 145 | 1 | 1 | 2.70 | 2.70 |
| 150 | 0 | 1 | 0.00 | 2.70 |
| 155 | 1 | 2 | 2.70 | 5.41 |
| 160 | 3 | 5 | 8.11 | 13.51 |
| 165 | 4 | 9 | 10.81 | 24.32 |
| 170 | 7 | 16 | 18.92 | 43.24 |
| 175 | 4 | 20 | 10.81 | 54.05 |
| 180 | 7 | 27 | 18.92 | 72.97 |
| 185 | 3 | 30 | 8.11 | 81.08 |
| 190 | 4 | 34 | 10.81 | 91.89 |
| 195 | 2 | 36 | 5.41 | 97.30 |
| 200 | 0 | 36 | 0.00 | 97.30 |
| 205 | 1 | 37 | 2.70 | 100.00 |
| 210 | 0 | 37 | 0.00 | 100.00 |
| 215 | 0 | 37 | 0.00 | 100.00 |
| 220 | 0 | 37 | 0.00 | 100.00 |

## Lilium philadelphicum

### 10%

FREQUENCY BAR CHART


| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 0 | 0 | 0.00 | 0.00 |
| 140 | 1 | 1 | 1.79 | 1.79 |
| 145 | 0 | 1 | 0.00 | 1.79 |
| 150 | 1 | 2 | 1.79 | 3.57 |
| 155 | 5 | 7 | 8.93 | 12.50 |
| 160 | 11 | 18 | 19.64 | 32.14 |
| 165 | 18 | 36 | 32.14 | 64.29 |
| 170 | 13 | 49 | 23.21 | 87.50 |
| 175 | 4 | 53 | 7.14 | 94.64 |
| 180 | 3 | 56 | 5.36 | 100.00 |
| 185 | 0 | 56 | 0.00 | 100.00 |
| 190 | 0 | 56 | 0.00 | 100.00 |
| 195 | 0 | 56 | 0.00 | 100.00 |
| 200 | 0 | 56 | 0.00 | 100.00 |
| 205 | 0 | 56 | 0.00 | 100.00 |
| 210 | 0 | 56 | 0.00 | 100.00 |
| 215 | 0 | 56 | 0.00 | 100.00 |
| 220 | 0 | 56 | 0.00 | 100.00 |

### 50%

FREQUENCY BAR CHART


| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 0 | 0 | 0.00 | 0.00 |
| 140 | 0 | 0 | 0.00 | 0.00 |
| 145 | 0 | 0 | 0.00 | 0.00 |
| 150 | 1 | 1 | 2.13 | 2.13 |
| 155 | 0 | 1 | 0.00 | 2.13 |
| 160 | 6 | 7 | 12.77 | 14.89 |
| 165 | 8 | 15 | 17.02 | 31.91 |
| 170 | 11 | 26 | 23.40 | 55.32 |
| 175 | 13 | 39 | 27.66 | 82.98 |
| 180 | 6 | 45 | 12.77 | 95.74 |
| 185 | 2 | 47 | 4.26 | 100.00 |
| 190 | 0 | 47 | 0.00 | 100.00 |
| 195 | 0 | 47 | 0.00 | 100.00 |
| 200 | 0 | 47 | 0.00 | 100.00 |
| 205 | 0 | 47 | 0.00 | 100.00 |
| 210 | 0 | 47 | 0.00 | 100.00 |
| 215 | 0 | 47 | 0.00 | 100.00 |
| 220 | 0 | 47 | 0.00 | 100.00 |

### 90%

FREQUENCY BAR CHART


| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 0 | 0 | 0.00 | 0.00 |
| 140 | 0 | 0 | 0.00 | 0.00 |
| 145 | 0 | 0 | 0.00 | 0.00 |
| 150 | 0 | 0 | 0.00 | 0.00 |
| 155 | 0 | 0 | 0.00 | 0.00 |
| 160 | 2 | 2 | 3.45 | 3.45 |
| 165 | 5 | 7 | 8.62 | 12.07 |
| 170 | 13 | 20 | 22.41 | 34.48 |
| 175 | 17 | 37 | 29.31 | 63.79 |
| 180 | 9 | 46 | 15.52 | 79.31 |
| 185 | 8 | 54 | 13.79 | 93.10 |
| 190 | 3 | 57 | 5.17 | 98.28 |
| 195 | 0 | 57 | 0.00 | 98.28 |
| 200 | 1 | 58 | 1.72 | 100.00 |
| 205 | 0 | 58 | 0.00 | 100.00 |
| 210 | 0 | 58 | 0.00 | 100.00 |
| 215 | 0 | 58 | 0.00 | 100.00 |
| 220 | 0 | 58 | 0.00 | 100.00 |

Appendix 7, continued:

# Gaillardia aristata

## 10%

FREQUENCY BAR CHART


| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 0 | 0 | 0.00 | 0.00 |
| 140 | 1 | 1 | 2.50 | 2.50 |
| 145 | 0 | 1 | 0.00 | 2.50 |
| 150 | 0 | 1 | 0.00 | 2.50 |
| 155 | 7 | 8 | 17.50 | 20.00 |
| 160 | 8 | 16 | 20.00 | 40.00 |
| 165 | 9 | 25 | 22.50 | 62.50 |
| 170 | 5 | 30 | 12.50 | 75.00 |
| 175 | 6 | 36 | 15.00 | 90.00 |
| 180 | 2 | 38 | 5.00 | 95.00 |
| 185 | 2 | 40 | 5.00 | 100.00 |
| 190 | 0 | 40 | 0.00 | 100.00 |
| 195 | 0 | 40 | 0.00 | 100.00 |
| 200 | 0 | 40 | 0.00 | 100.00 |
| 205 | 0 | 40 | 0.00 | 100.00 |
| 210 | 0 | 40 | 0.00 | 100.00 |
| 215 | 0 | 40 | 0.00 | 100.00 |
| 220 | 0 | 40 | 0.00 | 100.00 |

## 50%

FREQUENCY BAR CHART


| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 0 | 0 | 0.00 | 0.00 |
| 140 | 0 | 0 | 0.00 | 0.00 |
| 145 | 0 | 0 | 0.00 | 0.00 |
| 150 | 1 | 1 | 2.56 | 2.56 |
| 155 | 1 | 2 | 2.56 | 5.13 |
| 160 | 3 | 5 | 7.69 | 12.82 |
| 165 | 7 | 12 | 17.95 | 30.77 |
| 170 | 9 | 21 | 23.08 | 53.85 |
| 175 | 5 | 26 | 12.82 | 66.67 |
| 180 | 4 | 30 | 10.26 | 76.92 |
| 185 | 4 | 34 | 10.26 | 87.18 |
| 190 | 2 | 36 | 5.13 | 92.31 |
| 195 | 2 | 38 | 5.13 | 97.44 |
| 200 | 0 | 38 | 0.00 | 97.44 |
| 205 | 0 | 38 | 0.00 | 97.44 |
| 210 | 0 | 38 | 0.00 | 97.44 |
| 215 | 1 | 39 | 2.56 | 100.00 |
| 220 | 0 | 39 | 0.00 | 100.00 |

## 90%

FREQUENCY BAR CHART


| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 0 | 0 | 0.00 | 0.00 |
| 140 | 0 | 0 | 0.00 | 0.00 |
| 145 | 0 | 0 | 0.00 | 0.00 |
| 150 | 0 | 0 | 0.00 | 0.00 |
| 155 | 2 | 2 | 4.08 | 4.08 |
| 160 | 0 | 2 | 0.00 | 4.08 |
| 165 | 3 | 5 | 6.12 | 10.20 |
| 170 | 10 | 15 | 20.41 | 30.61 |
| 175 | 11 | 26 | 22.45 | 53.06 |
| 180 | 6 | 32 | 12.24 | 65.31 |
| 185 | 2 | 34 | 4.08 | 69.39 |
| 190 | 8 | 42 | 16.33 | 85.71 |
| 195 | 2 | 44 | 4.08 | 89.80 |
| 200 | 0 | 44 | 0.00 | 89.80 |
| 205 | 1 | 45 | 2.04 | 91.84 |
| 210 | 1 | 46 | 2.04 | 93.88 |
| 215 | 2 | 48 | 4.08 | 97.96 |
| 220 | 1 | 49 | 2.04 | 100.00 |

# Achillea millefolium

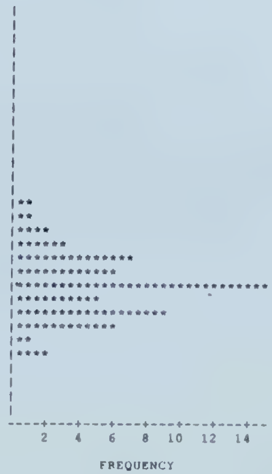
## 10%

FREQUENCY BAR CHART


| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 2 | 2 | 2.27 | 2.27 |
| 140 | 0 | 2 | 0.00 | 2.27 |
| 145 | 1 | 3 | 1.14 | 3.41 |
| 150 | 3 | 6 | 3.41 | 6.82 |
| 155 | 8 | 14 | 9.09 | 15.91 |
| 160 | 11 | 25 | 12.50 | 28.41 |
| 165 | 13 | 38 | 14.77 | 43.18 |
| 170 | 18 | 56 | 20.45 | 63.64 |
| 175 | 10 | 66 | 11.36 | 75.00 |
| 180 | 13 | 79 | 14.77 | 89.77 |
| 185 | 5 | 84 | 5.68 | 95.45 |
| 190 | 3 | 87 | 3.41 | 98.86 |
| 195 | 1 | 88 | 1.14 | 100.00 |
| 200 | 0 | 88 | 0.00 | 100.00 |
| 205 | 0 | 88 | 0.00 | 100.00 |
| 210 | 0 | 88 | 0.00 | 100.00 |
| 215 | 0 | 88 | 0.00 | 100.00 |
| 220 | 0 | 88 | 0.00 | 100.00 |

## 50%

FREQUENCY BAR CHART




| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 0 | 0 | 0.00 | 0.00 |
| 140 | 0 | 0 | 0.00 | 0.00 |
| 145 | 1 | 1 | 1.72 | 1.72 |
| 150 | 1 | 2 | 1.72 | 3.45 |
| 155 | 2 | 4 | 3.45 | 6.90 |
| 160 | 3 | 7 | 5.17 | 12.07 |
| 165 | 7 | 14 | 12.07 | 24.14 |
| 170 | 6 | 20 | 10.34 | 34.48 |
| 175 | 15 | 35 | 25.86 | 60.34 |
| 180 | 5 | 40 | 8.62 | 68.97 |
| 185 | 9 | 49 | 15.52 | 84.48 |
| 190 | 6 | 55 | 10.34 | 94.83 |
| 195 | 1 | 56 | 1.72 | 96.55 |
| 200 | 2 | 58 | 3.45 | 100.00 |
| 205 | 0 | 58 | 0.00 | 100.00 |
| 210 | 0 | 58 | 0.00 | 100.00 |
| 215 | 0 | 58 | 0.00 | 100.00 |
| 220 | 0 | 58 | 0.00 | 100.00 |

## 90%

FREQUENCY BAR CHART


| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 0 | 0 | 0.00 | 0.00 |
| 140 | 0 | 0 | 0.00 | 0.00 |
| 145 | 1 | 1 | 1.28 | 1.28 |
| 150 | 0 | 1 | 0.00 | 1.28 |
| 155 | 3 | 4 | 3.85 | 5.13 |
| 160 | 3 | 7 | 3.85 | 8.97 |
| 165 | 4 | 11 | 5.13 | 14.10 |
| 170 | 8 | 19 | 10.26 | 24.36 |
| 175 | 5 | 24 | 6.41 | 30.77 |
| 180 | 17 | 41 | 21.79 | 52.56 |
| 185 | 9 | 50 | 11.54 | 64.10 |
| 190 | 11 | 61 | 14.10 | 78.21 |
| 195 | 5 | 66 | 6.41 | 84.62 |
| 200 | 2 | 68 | 2.56 | 87.18 |
| 205 | 4 | 72 | 5.13 | 92.31 |
| 210 | 5 | 77 | 6.41 | 98.72 |
| 215 | 1 | 78 | 1.28 | 100.00 |
| 220 | 0 | 78 | 0.00 | 100.00 |

Appendix 7, continued:

# *Epilobium angustifolium*

## 10%

SPECIES=EPIAN FLOWER=10

FREQUENCY BAR CHART


| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 0 | 0 | 0.00 | 0.00 |
| 140 | 0 | 0 | 0.00 | 0.00 |
| 145 | 0 | 0 | 0.00 | 0.00 |
| 150 | 1 | 1 | 1.11 | 1.11 |
| 155 | 1 | 2 | 1.11 | 2.22 |
| 160 | 3 | 5 | 3.33 | 5.56 |
| 165 | 10 | 15 | 11.11 | 16.67 |
| 170 | 14 | 29 | 15.56 | 32.22 |
| 175 | 18 | 47 | 20.00 | 52.22 |
| 180 | 16 | 63 | 17.78 | 70.00 |
| 185 | 16 | 79 | 17.78 | 87.78 |
| 190 | 4 | 83 | 4.44 | 92.22 |
| 195 | 3 | 86 | 3.33 | 95.56 |
| 200 | 3 | 89 | 3.33 | 98.89 |
| 205 | 0 | 89 | 0.00 | 98.89 |
| 210 | 1 | 90 | 1.11 | 100.00 |
| 215 | 0 | 90 | 0.00 | 100.00 |
| 220 | 0 | 90 | 0.00 | 100.00 |

## 50%

SPECIES=EPIAN FLOWER=50

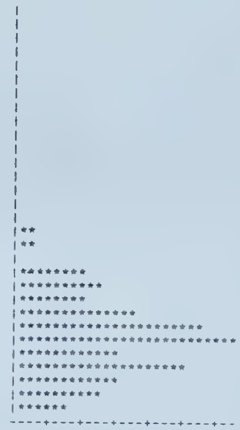
FREQUENCY BAR CHART


| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 0 | 0 | 0.00 | 0.00 |
| 140 | 0 | 0 | 0.00 | 0.00 |
| 145 | 0 | 0 | 0.00 | 0.00 |
| 150 | 0 | 0 | 0.00 | 0.00 |
| 155 | 0 | 0 | 0.00 | 0.00 |
| 160 | 1 | 1 | 1.22 | 1.22 |
| 165 | 3 | 4 | 3.66 | 4.88 |
| 170 | 5 | 9 | 6.10 | 10.98 |
| 175 | 13 | 22 | 15.85 | 26.83 |
| 180 | 13 | 35 | 15.85 | 42.68 |
| 185 | 13 | 48 | 15.85 | 58.54 |
| 190 | 12 | 60 | 14.63 | 73.17 |
| 195 | 10 | 70 | 12.20 | 85.37 |
| 200 | 7 | 77 | 8.54 | 93.90 |
| 205 | 3 | 80 | 3.66 | 97.56 |
| 210 | 1 | 81 | 1.22 | 98.78 |
| 215 | 0 | 81 | 0.00 | 98.78 |
| 220 | 1 | 82 | 1.22 | 100.00 |

## 90%

SPECIES=EPIAN FLOWER=90

FREQUENCY BAR CHART




| MIDPOINT JULDATE | FREQ | CUM. FREQ | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| 80 | 0 | 0 | 0.00 | 0.00 |
| 85 | 0 | 0 | 0.00 | 0.00 |
| 90 | 0 | 0 | 0.00 | 0.00 |
| 95 | 0 | 0 | 0.00 | 0.00 |
| 100 | 0 | 0 | 0.00 | 0.00 |
| 105 | 0 | 0 | 0.00 | 0.00 |
| 110 | 0 | 0 | 0.00 | 0.00 |
| 115 | 0 | 0 | 0.00 | 0.00 |
| 120 | 0 | 0 | 0.00 | 0.00 |
| 125 | 0 | 0 | 0.00 | 0.00 |
| 130 | 0 | 0 | 0.00 | 0.00 |
| 135 | 0 | 0 | 0.00 | 0.00 |
| 140 | 0 | 0 | 0.00 | 0.00 |
| 145 | 0 | 0 | 0.00 | 0.00 |
| 150 | 0 | 0 | 0.00 | 0.00 |
| 155 | 1 | 1 | 1.32 | 1.32 |
| 160 | 1 | 2 | 1.32 | 2.63 |
| 165 | 0 | 2 | 0.00 | 2.63 |
| 170 | 4 | 6 | 5.26 | 7.89 |
| 175 | 5 | 11 | 6.58 | 14.47 |
| 180 | 4 | 15 | 5.26 | 19.74 |
| 185 | 7 | 22 | 9.21 | 28.95 |
| 190 | 11 | 33 | 14.47 | 43.42 |
| 195 | 13 | 46 | 17.11 | 60.53 |
| 200 | 6 | 52 | 7.89 | 68.42 |
| 205 | 10 | 62 | 13.16 | 81.58 |
| 210 | 6 | 68 | 7.89 | 89.47 |
| 215 | 5 | 73 | 6.58 | 96.05 |
| 220 | 3 | 76 | 3.95 | 100.00 |

Appendix 8: The Julian calendar

For each month, the left column is calendar dates, the right column the Julian dates. For the 1988 Julian dates (1988 was a leap year) add one day to every Julian day after February 28.
eg: March 1 is day 61; May 1 is day 122.

| Jan. | | Feb. | | Mar. | | Apr. | | May | | June | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 001 | 1. | 032 | 1. | 060 | 1. | 091 | 1. | 121 | 1. | 152 |
| 2. | 002 | 2. | 033 | 2. | 061 | 2. | 092 | 2. | 122 | 2. | 153 |
| 3. | 003 | 3. | 034 | 3. | 062 | 3. | 093 | 3. | 123 | 3. | 154 |
| 4. | 004 | 4. | 035 | 4. | 063 | 4. | 094 | 4. | 124 | 4. | 155 |
| 5. | 005 | 5. | 036 | 5. | 064 | 5. | 095 | 5. | 125 | 5. | 156 |
| 6. | 006 | 6. | 037 | 6. | 065 | 6. | 096 | 6. | 126 | 6. | 157 |
| 7. | 007 | 7. | 038 | 7. | 066 | 7. | 097 | 7. | 127 | 7. | 158 |
| 8. | 008 | 8. | 039 | 8. | 067 | 8. | 098 | 8. | 128 | 8. | 159 |
| 9. | 009 | 9. | 040 | 9. | 068 | 9. | 099 | 9. | 129 | 9. | 160 |
| 10. | 010 | 10. | 041 | 10. | 069 | 10. | 100 | 10. | 130 | 10. | 161 |
| 11. | 011 | 11. | 042 | 11. | 070 | 11. | 101 | 11. | 131 | 11. | 162 |
| 12. | 012 | 12. | 043 | 12. | 071 | 12. | 102 | 12. | 132 | 12. | 163 |
| 13. | 013 | 13. | 044 | 13. | 072 | 13. | 103 | 13. | 133 | 13. | 164 |
| 14. | 014 | 14. | 045 | 14. | 073 | 14. | 104 | 14. | 134 | 14. | 165 |
| 15. | 015 | 15. | 046 | 15. | 074 | 15. | 105 | 15. | 135 | 15. | 166 |
| 16. | 016 | 16. | 047 | 16. | 075 | 16. | 106 | 16. | 136 | 16. | 167 |
| 17. | 017 | 17. | 048 | 17. | 076 | 17. | 107 | 17. | 137 | 17. | 168 |
| 18. | 018 | 18. | 049 | 18. | 077 | 18. | 108 | 18. | 138 | 18. | 169 |
| 19. | 019 | 19. | 050 | 19. | 078 | 19. | 109 | 19. | 139 | 19. | 170 |
| 20. | 020 | 20. | 051 | 20. | 079 | 20. | 110 | 20. | 140 | 20. | 171 |
| 21. | 021 | 21. | 052 | 21. | 080 | 21. | 111 | 21. | 141 | 21. | 172 |
| 22. | 022 | 22. | 053 | 22. | 081 | 22. | 112 | 22. | 142 | 22. | 173 |
| 23. | 023 | 23. | 054 | 23. | 082 | 23. | 113 | 23. | 143 | 23. | 174 |
| 24. | 024 | 24. | 055 | 24. | 083 | 24. | 114 | 24. | 144 | 24. | 175 |
| 25. | 025 | 25. | 056 | 25. | 084 | 25. | 115 | 25. | 145 | 25. | 176 |
| 26. | 026 | 26. | 057 | 26. | 085 | 26. | 116 | 26. | 146 | 26. | 177 |
| 27. | 027 | 27. | 058 | 27. | 086 | 27. | 117 | 27. | 147 | 27. | 178 |
| 28. | 028 | 28. | 059 | 28. | 087 | 28. | 118 | 28. | 148 | 28. | 179 |
| 29. | 029 | 29. | 059 | 29. | 088 | 29. | 119 | 29. | 149 | 29. | 180 |
| 30. | 030 | | | 30. | 089 | 30. | 120 | 30. | 150 | 30. | 181 |
| 31. | 031 | | | 31. | 090 | | | 31. | 151 | | |

| July | | Aug. | | Sept. | | Oct. | | Nov. | | Dec. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 182 | 1. | 213 | 1. | 244 | 1. | 274 | 1. | 305 | 1. | 335 |
| 2. | 183 | 2. | 214 | 2. | 245 | 2. | 275 | 2. | 306 | 2. | 336 |
| 3. | 184 | 3. | 215 | 3. | 246 | 3. | 276 | 3. | 307 | 3. | 337 |
| 4. | 185 | 4. | 216 | 4. | 247 | 4. | 277 | 4. | 308 | 4. | 338 |
| 5. | 186 | 5. | 217 | 5. | 248 | 5. | 278 | 5. | 309 | 5. | 339 |
| 6. | 187 | 6. | 218 | 6. | 249 | 6. | 279 | 6. | 310 | 6. | 340 |
| 7. | 188 | 7. | 219 | 7. | 250 | 7. | 280 | 7. | 311 | 7. | 341 |
| 8. | 189 | 8. | 220 | 8. | 251 | 8. | 281 | 8. | 312 | 8. | 342 |
| 9. | 190 | 9. | 221 | 9. | 252 | 9. | 282 | 9. | 313 | 9. | 343 |
| 10. | 191 | 10. | 222 | 10. | 253 | 10. | 283 | 10. | 314 | 10. | 344 |
| 11. | 192 | 11. | 223 | 11. | 254 | 11. | 284 | 11. | 315 | 11. | 345 |
| 12. | 193 | 12. | 224 | 12. | 255 | 12. | 285 | 12. | 316 | 12. | 346 |
| 13. | 194 | 13. | 225 | 13. | 256 | 13. | 286 | 13. | 317 | 13. | 347 |
| 14. | 195 | 14. | 226 | 14. | 257 | 14. | 287 | 14. | 318 | 14. | 348 |
| 15. | 196 | 15. | 227 | 15. | 258 | 15. | 288 | 15. | 319 | 15. | 349 |
| 16. | 197 | 16. | 228 | 16. | 259 | 16. | 289 | 16. | 320 | 16. | 350 |
| 17. | 198 | 17. | 229 | 17. | 260 | 17. | 290 | 17. | 321 | 17. | 351 |
| 18. | 199 | 18. | 230 | 18. | 261 | 18. | 291 | 18. | 322 | 18. | 352 |
| 19. | 200 | 19. | 231 | 19. | 262 | 19. | 292 | 19. | 323 | 19. | 353 |
| 20. | 201 | 20. | 232 | 20. | 263 | 20. | 293 | 20. | 324 | 20. | 354 |
| 21. | 202 | 21. | 233 | 21. | 264 | 21. | 294 | 21. | 325 | 21. | 355 |
| 22. | 203 | 22. | 234 | 22. | 265 | 22. | 295 | 22. | 326 | 22. | 356 |
| 23. | 204 | 23. | 235 | 23. | 266 | 23. | 296 | 23. | 327 | 23. | 357 |
| 24. | 205 | 24. | 236 | 24. | 267 | 24. | 297 | 24. | 328 | 24. | 358 |
| 25. | 206 | 25. | 237 | 25. | 268 | 25. | 298 | 25. | 329 | 25. | 359 |
| 26. | 207 | 26. | 238 | 26. | 269 | 26. | 299 | 25. | 330 | 26. | 360 |
| 27. | 208 | 27. | 239 | 27. | 270 | 27. | 300 | 27. | 331 | 27. | 361 |
| 28. | 209 | 28. | 240 | 28. | 271 | 28. | 301 | 28. | 332 | 28. | 362 |
| 29. | 210 | 29. | 241 | 29. | 272 | 29. | 302 | 29. | 333 | 29. | 363 |
| 30. | 211 | 30. | 242 | 30. | 273 | 30. | 303 | 30. | 334 | 30. | 364 |
| 31. | 212 | 31. | 243 | | | 31. | 304 | | | 31. | 365 |

Appendix 9: Spring 1990 newsletter sent to flowering date survey observers

University of Alberta
Edmonton

Department of Botany

Canada T6G 2E9

B414 Biological Sciences Centre, Telephone (403) 492-3484

ALBERTA FLOWERING DATE SURVEY

Spring Newsletter 1990

Greetings and thank you to all wildflower watchers, and welcome to new observers!

This survey, which collects flowering dates for 15 Alberta wildflowers, began in 1987 and will continue over the years ahead through the Botany Department, University of Alberta. The survey uses plants as weather instruments - an effective way to gather information on current climatic conditions and the potential for plant growth in different regions. Understanding the normal timing of plant development for areas of Alberta can help us make better decisions in agriculture, horticulture, forestry, recreation, tourism and human health. Most European countries have had observer networks gathering these phenology dates for years - 200 years in some countries! Here in Alberta we hope to expand our network to 1000 observers within 10 years.

Please keep the enclosed "Alberta Wildflowers" booklet for use in future years. Observers will receive a fresh data sheet every spring. If you let me know names and addresses of other potential observers, I'll be delighted to send them a booklet, too.

Here are a few tips to help you in observing flowering. The sketch on page 14 shows how tiny Twinflowers really are. It is best for the survey if your flowering dates reflect conditions over a broad area (eg: 10 by 10 km). Full flowering, or 90%, should be recorded when almost all of the flowers are open, and before they have started to wither.

Poplars are tricky; we need to know the difference between male and female trees. Only the male trees should be observed for flowering. Here's a great suggestion from the McKinstrys in Oyen, Alberta: in early spring, bring a small branch from your poplar tree(s) (label with tape if more than one) into the house and set in a jar of water. Soon the grey tufts (catkins) get longer, turning pinkish and then pale yellow as they shed a yellow powder (pollen) at the slightest touch. (Place a dark paper or cloth under jar.) If you see pollen, then you have a male tree branch. Outdoors, the wind quickly blows pollen away, so try this to be sure of your tree. The sketches on the back of this page give approximate outdoor times for stages of catkin development. Note: if catkins turn green, the tree is female.

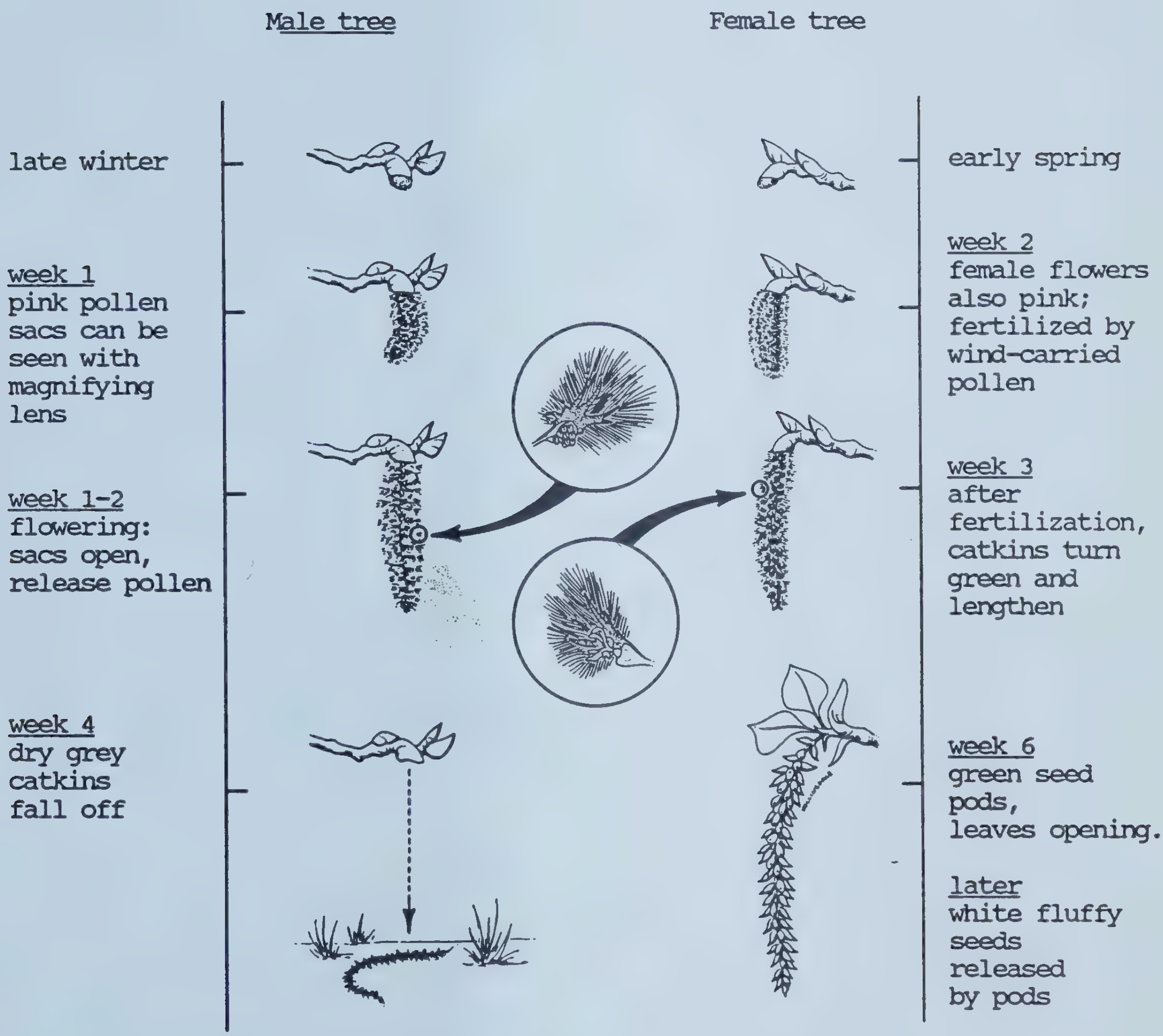
Thanks very much to all wildflower watchers. It is only through your dedication to recording each season's progress that we gain an understanding of our Alberta "green wave of spring"!

Elisabeth Beaubien (office: 492-5520, home: 438-1462)

Appendix 9, continued:

## Aspen Poplar — Populus tremuloides

### Catkin development



eation, Parks and Wildlife Foundation

ıe walks
ıld you
et life of
nature
me of our
help to
Alberta.

ew
. These
ı learn
ıtdoors
nd
tual every
ou'll be
ery year,
vith the
un and
asuring,
can
and also

include
way
, retired
s or the

the study
y year in
vey, we
perta
owering
wering
compared
er that
formation
getables,

## A flowering date survey

Do you enjoy the outdoors? Do springtime walks and wildflowers appeal to you? How would you like a chance to learn more about the secret life of plants? Keep your finger on the pulse of nature by joining Albertans who record when some of our native wildflowers bloom. We need your help to chart the "green wave" of spring across Alberta.

## Why watch wildflowers?

By watching these plants, you'll gain a new interest and awareness of living things. These observations take little time and help you learn about wildflowers while you enjoy the outdoors on a regular basis. It's addictive! You'll find yourself looking forward to this spring ritual every year. As one of a network of observers, you'll be kept informed of results of the survey every year, and you'll be able to compare your area with the rest of the province. Students can have fun and learn through observing wildflowers, measuring, recording, and making hypotheses. They can compare their dates with other schools, and also use them in science fairs.

Others who may enjoy the survey include farmers, ranchers, acreage owners, highway workers, foresters, gardeners, naturalists, retired people, and those who walk in city parks or the countryside.

## How are the dates used?

This is a phenology survey. Phenology is the study of the timing of events that happen every year in the lives of plants or animals. In this survey, we want to know the dates when certain Alberta wildflowers start to bloom. We put the flowering dates on maps to show zones of equal flowering and climate. The dates from each year are compared to ten-year averages to determine whether that spring was early, average, or late. This information is used to predict the best time to plant vegetables,

or crops, in order to get greatest yields and accurately predict insect outbreaks. This information has uses in many areas including climate studies, forestry, satellite sensing and human health.

The survey will also show us the remaining areas where some of our disappearing wildflowers, such as Prairie Crocus and Wood Lily, are still found. These pockets of natural habitat are important to wild plants and animals. Your contribution may help us keep such areas in a natural state.

## What should I observe?

Check through the flowers shown here to see which ones occur near you and that you can observe every 2 to 3 days as they are starting to bloom. You may not have all these plants in your area. Even if you can only record a few dates, this will be very useful.

The flowers are listed here in the approximate order in which they bloom. The earliest spring flowers, like Prairie Crocus and Aspen Poplar, are shown first. For most plants "flowering" means that flower buds are open and petals can be seen. Shedding of pollen (yellow powder released in a small cloud when the branch is moved), is a useful sign of flowering, especially in the aspen poplar tree which has no colourful petals. Record the dates when 10%, 50%, and then 90% of the flower buds are open. See the descriptions of Prairie Crocus, Aspen Poplar and Fireweed for important details on how to observe and record flowering dates.

## Where do I look for the flowers?

Pick a location you can visit regularly. The flower habitat descriptions will tell you where you might look for each type of plant. Choose plants, if possible, that are growing on relatively flat ground. Those on a north-facing cool slope will often flower later and those on a south-facing warm slope generally will flower earlier than those on level ground.



For the smallest plants, observe an area of about 2 metres by 2 metres (6 ft by 6 ft) which contains these plants. For larger plants (Solomon's-Seal, Wood Lily, Brown-Eyed Susan, and Fireweed), an area of about 5 m by 5 m (5 yd by 5 yd) is best. For bushes and trees, please observe at least 2 plants from different stands. Use the same group of plants (e.g. a patch of crocuses) for your first, mid-, and full flowering observations.

## When should I be out looking?

Prairie Crocus and Aspen Poplar sometimes start flowering as early as late March in southern Alberta. Visit your site frequently during and after snow melt so that you will see the plants start to flower. In general, if you check your site at least every 2 to 3 days you should catch the important dates.

## Prairie Crocus

Windflower, Crocus Anemone
*Anemone patens* L. var *wolfgangiana* (Bess.) Koch

These blue purple **flowers**, up to 4 cm (1½ in) in diameter when open, appear in very early spring. The hairy stem grows up to 10-40 cm (4-16 in) after flowers open. Later, grey green leaves appear. The **habitat** includes sandy soils on the prairie and dry open woods. Regular burning seems to encourage this plant but plowing eliminates it. Because the plants can cause blisters, in some Indian groups it was used for practical jokes. The plant was called 'crocus' by English settlers because it reminded them of the crocus at home in England. Now it is the floral emblem of Manitoba.

**How to observe:**
Use small rocks or sticks to mark off an observation area of 2 m x 2 m. Count the flowers every few days until the number of flowers stops increasing (full bloom).



## Aspen Poplar

Trembling Aspen
*Populus tremuloides* Michx.

These **trees** have light green or whitish bark. Large trees can be blackish at the base. The height of the trees ranges from 3-25 m (10-80 ft). Look beneath the tree for last year's leaves, to make sure they match the leaf shape shown here. The trees are either male or female. The male **flowers** or catkins appear before the new leaves, grey and woolly like miniature lamb's tails. The catkins lengthen to 4-6 cm (1½-2⅜ in) long and 3 mm (⅛ in) wide. As they lengthen, their colour changes from grey to pinkish to pale yellow, as pollen is dropped.

**How to observe:**
Watch for the first date when the catkins release a small cloud of yellow pollen when the branch is touched slightly. Flowering can be over in 2-3 days, so watch your trees carefully in early spring! Aspen **habitat** includes any reasonably moist area. Our native people ate the inner bark, which is very nourishing, sweet and tender, when cooked. The bark contains an active ingredient found in aspirin, and was used to treat fevers. Elk and beaver are very fond of this inner bark.

**Early Blue Violet**
*Viola adunca* J.E. Smith

These bluish purple **flowers** are up to 2 cm (¾ in) across. Note the purple lines on the three lower petals and the white beards on the two side petals. The stems which support the flowers also have leaves attached. The **plant** grows 4 to 10 cm (1½-4 in) tall. The **leaves** are 1 to 3 cm (⅜-1¼ in) wide. Its **habitat** includes open woods and prairie.
**Similar species:**
Do not confuse with Bog Violet (*Viola nephrophylla*) which prefers wetter areas than Early Blue Violet. It has a similar flower, but blooms later and the flower stem has no leaves. Violets were the favourite flowers of Napoleon and Mohammed. Our Blackfoot Indians used the blue colour to dye arrows.



**Golden Bean**
Buffalo Bean, Prairie Bean, Golden Banner
*Thermopsis rhombifolia* (Nutt.) Richards

These bright yellow **flowers**, each 12 mm (½ in) across, together form a dense spike. The **plant** is 15-50 cm (6-20 in) high and has dark green leaves with 3 leaflets, each leaflet 2-3 cm (¾ to 1¼ in) long. Its **habitat** is open sandy areas in prairie and aspen forest where the water table is high. The name Buffalo Bean shows us the Indians' knowledge of phenology. They used its flowering time to indicate that buffalo bulls were now fat and ready for the spring hunt. Flowers and seeds (beans), which form later, should not be eaten. This plant benefits from a partnership with fungi and bacteria in the soil – the fungus provides minerals and the bacteria take nitrogen from the air and enrich the soil.

**Saskatoon**
June-berry, Service-berry, Shadbush, Indian Pear (N.S.), Chuckly Pear (Nfld.)
*Amelanchier alnifolia* Nutt.

These showy white **flowers** (9-12 mm or ⅜-½ in wide), have 5 petals. This shrub or small tree grows 1-8 m (3-26 ft) tall. The **leaves** are oval, 2-5 cm (¾-2 in) long. Its **habitat** includes poplar forest and moist ravines in prairies. Our Indians used an eyewash made from the inner bark to cure snow blindness. The branch tips are a good winter food for deer, elk and moose. The sweet, edible berries were regarded as the most important vegetable food of the Blackfoot Indians, and were used for making pemmican.



**tar-flowered Solomon's Seal**
olomon Plume, Wild Spikenard
*milacina stellata* (L.) Desf.

he white **flowers** have six petals which form a oose spike at the end of a leafy stem. Each flower s up to 6 mm (¼ in) wide. The **plant** has erect, ften curved, stems 15 to 20 cm (6-8 in) long, ccasionally up to 45 cm (18 in). The size and shape f the leaves are very variable depending on where e plant is growing. In bright light the leaves are tiff as in this photo. In shade they are limp and rger, as in the sketch. The berries are greenish ith dark stripes, and turn red in early fall. The **abitat** includes woodlands, open meadows, and hores of sandy marshes. The berries were eaten y some Indian tribes, but they are sickly sweet nd were not highly prized. However, bears are ery fond of these berries and livestock readily raze on the plants.
ee sketch on back page.

**Choke Cherry**
*Prunus virginiana* L. var. *melanocarpa* [A. Nels.] Sarg.

These white **flowers**, each 1-1.5 cm (3/8-5/8 in) across, hang in dense popsicle-shaped clusters up to 15 cm (6 in) long. This **bush** or small tree has a trunk up to 4 cm (1½ in) wide and a height, generally, of 2-4 m (6-13 ft). The berries are red to bluish black. Its **habitat** includes aspen groves, ravines, and the edges of creeks.
**Similar plants:**
Do not confuse with May Day Tree, *P. Padus commutata*, a domestic species planted near houses. It has very similar flowers but blooms earlier than Choke Cherry. Do not confuse with Pin Cherry, *P. pensylvanica*, which has flowers in flat-topped clusters.
Choke Cherry sticks were used by Plains Indians for roasting game. The wood didn't burn easily and added spice to the meat. The dried berries were used to make a tea, said to be especially good for coughs or colds. More recently a "cherry" toothpaste made from this plant was available.



**Yellow Pea Vine**
Cream-coloured Vetchling, White Pea Vetch, Wild Sweet Pea, Vetchling
*Lathyrus ochroleucus* Hook.

These **flowers** are yellow to white, each 1.5 cm (5/8 in) long. Five to ten pea-like flowers form a cluster. The **plant** has climbing stems which are up to 1 m (3 ft) long. Seeds form in pods 4 cm (1½ in) long. Its **habitat** is moist forest and clearings. The Ojibwa Indians used the root as an "Indian potato." Livestock readily eat this plant. It comes back quickly when protected from livestock. Some Indian groups ate the peas, but in large quantities they cause a headache due to a narcotic.
See sketch on back page.

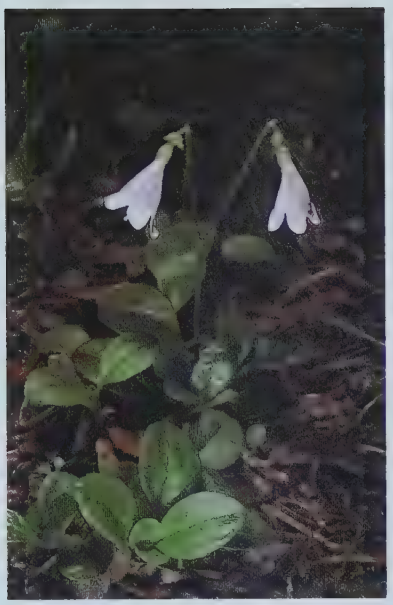
**Wolf Willow**
Silverberry
*Elaeagnus commutata* Bernh. ex Rydb.

The flowering time of this shrub is announced by a strong sweet scent. The small flowers are yellow on the inside and silvery on the outside. The **leaves** are 3-8 cm (1¼-3 in) long, and the shrub height is usually under 2 m (6½ ft) high. The fruit is a dry silvery berry. Wolf Willow's **habitat** includes moister edges of prairies, dry hillsides and open fields in aspen forest. Like Golden Bean, this plant has a partnership with nitrogen-fixing bacteria and enriches the soil. The berries were used by Blackfoot Indians to make seed necklaces. Children suffering from frostbite were treated with a strong solution made from the bark. Our native people discovered the bush had a bad smell when burned. Those who used it for firewood were chided for being lazy.



**Northern Bedstraw**
*Galium boreale* L.

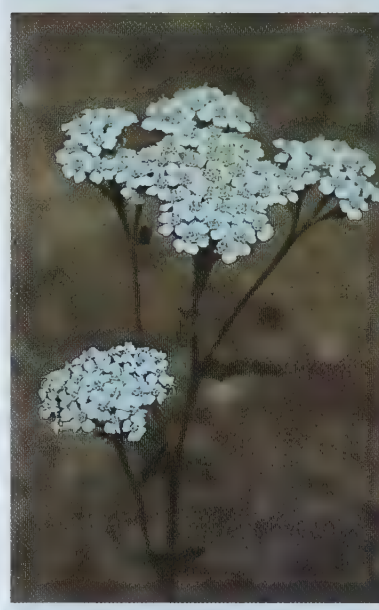
The fragrant **flowers** are white, 3 mm (⅛ in) wide, and shaped like a cross with 4 petals. The **plant** stands 20-60 cm (8-24 in) tall. The **leaves** are arranged in groups of 4, each group encircling the stem. The **habitat** includes forest, roadside, and moist prairie. The plains and northern Indians used a purple or red dye from the roots to colour porcupine quills. Settlers used dried bedstraw plants to stuff mattresses. Tea made from this plant was even used as a wash to "remove" freckles!



**Twinflower**
*Linnaea borealis* L.

The bell-shaped **flowers** are pinkish white, small (3 mm or ⅛ in across), and fragrant, especially towards evening. The stem is 5-10 cm (2-4 in) high. The low, creeping plant has leaves which stay green all winter beneath the snow, and are 1-1.5 cm (⅜-⅝ in) wide. Its **habitat** is rich moist woods, coniferous or mixed, in open or semi-shaded areas. This was the favourite plant of Carolus Linnaeus, the father of our scientific naming system for plants. It is found in northern forests around the world.





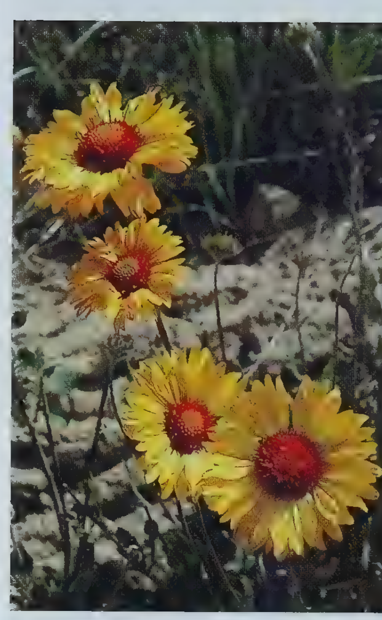
**Common Yarrow**
Milfoil, Yarrow
*Achillea millefolium* L.

These **flowers** are white (or rarely, light pink). Many small flowers form a roundish-topped dense cluster about 4 cm (1½ in) across. The **plant** is about 30-70 cm (12-28 in) tall and strongly scented. The **leaves** are fern-like, hairy, and blue-green. Its **habitat** is mainly where the soil has been turned over (disturbed areas). Yarrow is very common and known around the world. In ancient times it was frequently used in wars to stop the bleeding of wounds. In Greece it is a symbol of war. Achilles is said to have used it to staunch his soldiers' wounds. Our Rocky Mountain Indians used the mashed roots as a local anaesthetic.

**Western Wood Lily**
Western Red Lily, Tiger Lily
*Lilium philadelphicum* L. var. *andinum* (Nutt.) Ker.

These orange **flowers** are 6-10 cm (2⅜-4 in) across. There is usually one flower per plant, but two or three are not uncommon. The **leaves** are narrow and pointed. The **plant** is about 30-60 cm (12-24 in) tall. Its **habitat** includes moist meadows, edges of aspen groves and roadside ditches. This is Saskatchewan's floral emblem. We must protect our remaining lilies! When the flower is picked or mowed the food-producing leaves are removed and the plant dies. This beautiful flower has disappeared in many areas.





**Brown-eyed Susan**
Wild Gaillardia, Blanket Flower
*Gaillardia aristata* Pursh

The golden rays surround a purplish brown centre, forming a **flower** head up to 10 cm (4 in) across. The **plant** grows to a height of 20-80 cm (8-32 in), and is covered by greyish green hairs. The lower **leaves** are lance-shaped, the others toothed. Its **habitat** is grassland, dry open woods, roadsides and railway grades. The Blackfoot Indians rubbed these flower heads on rawhide bags to waterproof them. They also used the large flowers as absorbant spoons to feed soups to the sick and invalid.
See sketch on back page.

**Fireweed**
Great Willow-herb, Narrow-leaved Fireweed
*Epilobium angustifolium* L.

Many large pink to light purple **flowers** form a long terminal spike. Each flower is 1.2-3 cm (½-1¼ in) wide. The **plants** are tall, 90-180 cm (3-6 ft) and often form large colonies. The **leaves** are long and narrow. Each seed released from the long pods has a tuft of hairs to carry it on the breeze. Fireweed's **habitat** includes burned areas and other disturbed areas, gravel bars, roadsides, and open woods. This is the floral emblem of Yukon. Indians used the young shoots as a cooked vegetable, and combined down from seeds with duck feathers or mountain goat wool to make blankets. The flower buds are "ice-cream food" for deer in summer.
Sketch: flower spike with two seed pods, (see last page)

**How to observe fireweed:**
10% flowering: 10% of the plants with flower buds have at least one flower open.

50% flowering: almost all the flowering plants have a few seed pods forming at the bottom.



90% flowering: most of the flowering plants have equal numbers of pods and open flowers.

## Where can I get more help identifying these plants?

These field guide books are very useful:

*Wildflowers Across the Prairies* by F.R. Vance, J.R. Jowsey, and J.S. McLean. 1984. Western Producer Prairie Books, Saskatchewan.

*Wildflowers of the Canadian Rockies* by G.W. Scotter and H. Flygare. 1986. Hurtig, Edmonton.

*Wildflowers of Alberta* by R.G.H. Cormack. 1977. Hurtig, Edmonton.

Naturalists and gardeners within your community may be able to help you.

## Questions?

Please write or call with any question or comments you have. Don't hesitate to send pressed plants or photos for identification.

**Address:**
Wildflower Survey
Department of Botany
University of Alberta
Edmonton, Alberta
T6G 2E9

**Phone number:**
Botany Office
(403) 492-3484

**Acknowledgements:**

Thanks to the following for making this project possible:

The Recreation, Parks and Wildlife Foundation for financial support of this brochure.

The Boreal Institute for Northern Studies for financial support.

Drs. Walter Moser, Keith Denford, and Charles Bird, for inspiration and advice.

The Natural Sciences and Engineering Research Council of Canada, for support of K. Denford.

The University of Alberta Devonian Botanic Garden for artwork (sketches by John R. Maywood) on pages 21, 22 .

Diane Hollingdale for Twinflower sketch, page 14.

Nada Zeljković for design and layout.

Photo credits: Cover, Prairie Crocus by Lorna Allen; page 4, L. Allen; page 5, E. Beaubien; page 11, P. McIsaac.

All other photos by Hälle Flygare, from ***Wildflowers of the Canadian Rockies***, by G.W. Scotter and H. Flygare, 1986, Hurtig Publishers, Edmonton.

2nd edition, "Alberta Wildflowers, a Flowering Date Survey" by Elisabeth Beaubien.

February, 1990



Star-flowered Solomon's Seal

Yellow Pea Vine

Brown-eyed Susan

Fireweed

**Alberta Wildflowers - Flowering Date Surv**

Observer's name(s) ______

Mailing address ______

______ Posta

**Location of observations:**

Legal description or closest roads, so that location ca
other locations, please note which dates and describ

Section: ______ Township: ______

______

______

| **Species** | **Flowering dates** | | |
|---|---|---|---|
| flower buds open: | First 10% 1 in 10 | Mid 50% half | |
| Prairie Crocus * *Anemone patens* | | | |
| Aspen Poplar * *Populus tremuloides* | | | |
| Early Blue Violet *Viola adunca* | | | |
| Golden Bean *Thermopsis rhombifolia* | | | |
| Saskatoon *Amelanchier alnifolia* | | | |
| Star-flowered Solomon's-seal *Smilacina stellata* | | | |
| Choke Cherry *Prunus virginiana* | | | |
| Wolf Willow *Elaeagnus commutata* | | | |
| Yellow Pea Vine *Lathyrus ochroleucus* | | | |

** See "how to observe" in Alberta Wildflowers book*
**Even a few dates recorded above will be valuable.**

*form continues on the other side*

shaded areas for office use

Observation year

pointed on a map. If some observations were from
ocations too.

nge: Meridian:

**Remarks**

Any observations, e.g. effects of insects or weather,
sunny or shady locations, etc.

| Species | Flowering dates | | |
|---|---|---|---|
| flower buds open: | First 10% 1 in 10 | Mid 50% half | Full 90% almost |
| Northern Bedstraw *Galium boreale* | | | |
| Twinflower *Linnaea borealis* | | | |
| Common Yarrow *Achillea millefolium* | | | |
| Western Wood Lily *Lilium philadelphicum* | | | |
| Brown-Eyed Susan *Gaillardia aristata* | | | |
| Fireweed * *Epilobium angustifolium* | | | |

** See "how to observe" in Alberta Wildflowers booklet.*
**Even a few dates recorded above will be valuable.**

Please mail by **September 30** to:
Department of Botany
University of Alberta
Edmonton, Alberta T6G 2E9

*Thank you for this contribution to our understanding of v*

## Remarks

Any observations, e.g. effects of insects or weather, sunny or shady locations, etc.

*flowers.*

# Alberta Wildflowers

*A Flowering Date Survey*

Appendix 2

University of Alberta
Edmonton T6G 2E1