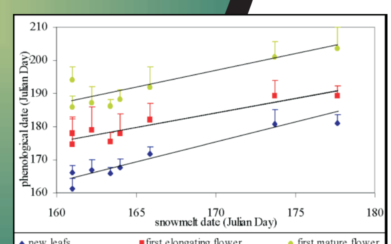
CANTTEX

Canadian Tundra and Taiga Experiment

Ecological Monitoring in the Canadian Arctic

FIELD MANUAL

Part A - Setting up a basic monitoring site



EMAN NORTH

CANTTEX Field Manual

Part A – Setting Up a Basic Monitoring Site

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1.0 Introduction

The Canadian Tundra and Taiga Experiment (CANTTEX) is a group of researchers within universities and several Canadian government departments collaborating to study climate and ecological changes in the North. The aim of CANTTEX is to establish an effective long-term observation network for detecting the effects of climate change on tundra and taiga biota in northern Canada. This document is designed to provide people and agencies with clear, comprehensive, standardized protocols for setting-up and maintaining an ecological monitoring program in northern Canada. The use of these protocols will ensure that information is collected in a scientifically robust manner, and that information from each site will be comparable across the country.

To maximize the value of the network and make set-up and monitoring as simple as possible, three variables have been selected to constitute a basic CANTTEX monitoring program: climate, plant community composition and plant reproductive output. The manual is divided into two parts. Part A contains the methods for setting-up a basic monitoring site and maintaining a monitoring program where information on these variables is collected. Also described in this part of the manual are the Plantwatch protocols for monitoring spring plant ***phenology*** and all sites are encouraged to incorporate this into their monitoring if possible. Part B of the manual describes standardized methods for monitoring many other variables that can be incorporated into your program if resources are available. They are generally more time consuming but will augment the value of the information being gathered at your site. At present, CANTTEX sites are primarily located in tundra vegetation and the focus of this manual is primarily on methods that apply to tundra, but can be easily applied or adapted to taiga systems.

1.1 Background

Most scientists now agree that global warming is taking place, largely due to human activities such as air pollution and deforestation (IPCC 2001). The 1990s was the warmest decade on record and average temperatures continue to increase. Temperature trends are accompanied by considerable changes in precipitation patterns and other elements of the global climate (Maxwell 2002). Computer models designed to simulate global warming predict that changes will be most intense in the North. Recent evidence supports these predictions and indicates that the effects of global warming are going to be witnessed by the current generation (Serezze *et al.* 2000). The formation of a network of integrated research stations is essential to properly monitor the changes in arctic terrestrial ecosystems that will result from climate warming.

The International Tundra Experiment (ITEX) was initiated in 1990. It is a collaborative, multi-site experiment using common monitoring protocols and, initially, temperature manipulation to examine variability in species response across climatic and geographic gradients of tundra ecosystems. Experiments have since expanded to include other manipulations, such as snowdepth duration and fertilization. Given rapid and significant changes in climate in the circumpolar north there is an urgent need for this network. There are currently 5 sites in Canada that are employing ITEX experimental manipulations. More information on ITEX can be found on the iternet at: http://www.itex-science.net/.

The need for cooperation among the few researchers carrying out research and monitoring in the Canadian Arctic led to the establishment of the Canadian Tundra Ecosystem Monitoring Network (CANTEM-Net) at a workshop during the Ecological Monitoring and Assessment Network (EMAN) National Science Meeting in 1999. In January of 2000, the workshop was extended to a full day and the name of the group was changed to the Canadian Tundra and Taiga Experiment (CANTTEX). The name reflects both the range of environments covered by the network of sites and scientists, and the links to ITEX. The aim of CANTTEX is to encourage and facilitate the sharing of ideas, data and information, and to encourage cooperation in research and monitoring initiatives in arctic taiga and tundra ecosystems. CANTTEX encompasses two complementary approaches involving both multiple site comparisons and intensive local focused site studies. The latter focuses on studies of various spatial scales including an experimental component. The former focuses on comparisons of a set of basic biotic measurements along climatic and geographic gradients.

1.2 The Status of Knowledge So Far

At the present time, there are 13 research and monitoring sites in the CANTTEX network (Fig. 1). The sites span a latitudinal gradient from the low arctic alpine site at the Kluane Research Station to Tanquary Fiord at the north end of Ellesmere Island, Canada's most northern landmass. There is also a range in the intensity of monitoring and research among the sites depending on the resources and interests of the agency or people responsible for the site.

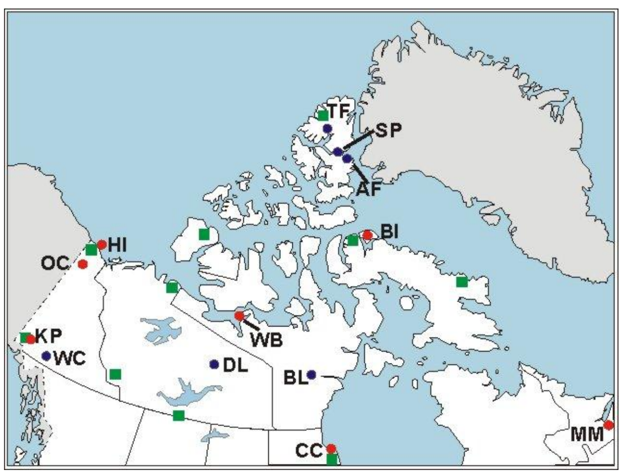


Figure 1. Canadian Arctic showing the locations of current CANTTEX sites (circles) and National Parks (green squares) some of which are operating ecological monitoring programs. High Arctic sites: AF – Alexandra Fiord Lowland, BI – Bylot Island, SP – Sverdrup Pass, TF – Tanquary Fiord; Low Arctic sites: BL – Baker Lake, CC – Churchill Northern Studies Centre, DL – Daring Lake, HI – Hershel Island, OC – Old Crow, WB – Walker Bay; Subarctic alpine sites: KP – Kluane Park, MM – Mealy Mountains, WC – Wolf Creek.

CANTTEX is currently undertaking a synthesis of the results of the monitoring that has taken place in the Arctic to date. Preliminary results are available in a review document available on the EMAN-North website:

http://www.emannorth.ca/

1.3 The Major Questions to be Addressed

The following research questions are related to the multi-site approach of CANTTEX, focusing on comparing patterns and processes along the fundamental climatic gradients. Site specific questions will not necessarily be the same. Some of these questions point to the need for research that is outside of the scope of CANTTEX monitoring, such as paleo-environmental reconstruction.

What are the current patterns of biodiversity in Northern Canada and how do these patterns change over time?

1) What are the patterns of species richness, abundance and vegetation cover along gradients in different arctic ecozones?

2) What are the most important potential direct and indirect effects of climate change on biota in the different northern ecozones?

3) How severe is the potential risk for distinct species, species groups (e.g. endemics), life forms or functional groups to be threatened by climate change because of:

- changing climatic constraints (e.g. change of snow cover patterns, water availability)?
- changing habitat stability (e.g. erosion dynamics)?
- changing biotic interactions (e.g. due to migration of species or a greater abundance of some species within their current range)?

4) What measures are available to prevent climate-induced biodiversity or habitat losses?

Within the last few decades,

5) Are there obvious changes in vegetation cover and vegetation structure within the observed plant assemblages or of particular species?

6) What is the variability of these changes along the fundamental climatic gradients in altitude, latitude and longitude?

7) What are the most likely causes for these changes and can they be related to observed climatic change?

8) Is there an urgent need for measures against climate-induced biodiversity losses; if yes, how can they be applied in a sustainable way?

2.0 Setting-up a New CANTTEX Site

2.1 Introduction

In this section are explained the methods for setting-up a new monitoring site and recording all of the important characteristics of your site. Each site will have its own configuration depending on the characteristics of the area and the type of monitoring being planned. There are many factors that must be taken into account when selecting a location for monitoring and an appropriate layout and number of plots. In addition, the physical properties of the site should be described in detail at this stage. When a new site is set-up, a summary report should be produced detailing: the locations of all monitoring related sites and equipment; the configuration of the plot layout; the descriptions of the physical characteristics of the site; and the monitoring activity that is planned for the site.

2.2 Selecting a Monitoring / Research Site

Selecting the location of a new research site and the study plots or plants within the site will depend on many factors including local interests. Ideally, the development of a new research site should be done in cooperation with the other members of CANTTEX. One of the goals of CANTTEX is to establish sites maximizing the spatial coverage of the Arctic and also maximizing the range of environments across temperature and moisture gradients, and ecozones. However, the addition of CANTTEX monitoring at sites that are being established for another primary purpose is welcomed and encouraged. Below is a list of considerations that should be taken into account in site selection.

Research / monitoring sites should have the following properties:

- Not be in a state of successional transition (e.g. open tundra surrounded by forest that is recovering after a recent fire) unless evaluating transitional dynamics is an explicit part of the research program;
- Not be in close proximity to possible disturbances (intensive grazing, close to a mine, at risk of being flooded by a nearby river, etc.);
- Be easily accessible to the people responsible for making observations; and
- A location close to where climate data is already being collected is highly desirable.

2.3 Selecting Locations for Plots

The majority of monitoring activity will require the establishment of permanent plots within which observations will be made from year to year. The location, number and size of specific study plots will depend largely on the type and intensity of monitoring that is taking place at the site. These will be discussed in each section related to the methodology in question. Permanent plots should not be located in stages of successional transition or in areas prone to disturbance. Plot locations should be well represented by the climate station (i.e. not have a climate station on a ridge and study plots in a valley) if possible. Whenever possible, plots should be set up at different points along local gradients maintaining adequate ***replication*** at each point along the gradient. This could be a moisture gradient from wet low lying meadows to areas with drier soils or along an altitudinal gradient. The specific minimum number of plots required for each type of monitoring will be outlined in the sections describing each method. Though the general area in which the plots are to be located should be determined based on the priorities set by the researcher, the exact location of the plots should be located randomly (See Appendix C).

Marking Permanent Plots

Plots need to be permanently marked so that they can be located easily and reliably and so that they are not accidentally disturbed by other people. This is best accomplished by setting up steel or wood posts at the corners of plots with rope or wire running between them to outline the plots. Also, make sure the plot numbers are well marked (e.g. with embossed metal tags) to ensure that observers are recording observations from the correct plots.

2.4 Recording Location Information

The first piece of information required for a description of your research site are the locations where the observations are being made. Then the results can be mapped, and this will also aid in locating plots in future years if markers are lost. Geographic co-ordinates in terms of latitude and longitude or UTM grid location are essential for the general location of the field site. Using a hand-held Global Positioning System (GPS), the coordinates of each study plot can be determined to a reasonable level of accuracy (usually within a few metres). If a GPS is not available, the study site should be located on a standard topographic map and the geographic coordinates (latitude and longitude) determined from the map. Make sure the datum used is included with coordinates. This can be found at the bottom of the topographic map or will be programmed into the GPS.

The elevation of the site is also very important, particularly if sites are placed along a gradient in elevation. The production of a geographically referenced site map showing features such as topography and proximity to water bodies will be very useful when interpreting the results of monitoring. This can be done using the GPS, standard surveying techniques, and/or air photos.

2.5 Baseline Abiotic Data

When interpreting the data from a given site it is important to know as many characteristics of that site as possible. Some of these involve simply recording your visual observations about the site and others require some measurement and sampling. The protocols for gathering climate data are described in section 3. Not all of the information described below needs to be collected in the first year of monitoring. See Appendix A for sample field data forms.

Information on the abiotic environment should include:

- A general description of the topographic setting (is the site in a valley, on a gentle slope, etc.);
- the slope angle at plot locations (should be relatively flat);
- A general description of the local hydrology (proximity to streams, rivers, lakes and ocean);
- A description of the local soils including:
    - Substrate ***lithology***;
    - Depth of soils;
    - Homogeneity of soils across the study area, and
    - If resources exist for chemical analysis of soils, analysis of total carbon and nitrogen in replicate samples would be very useful to characterize the initial conditions at the site; and

- The depth of the active layer at peak season if the site is located over permafrost (this is described in detail in Part B of the manual).

A report describing the establishment of the site would be very valuable. This would ensure that the details of the site set-up are properly recorded, would be a helpful resource for anyone involved in the monitoring or research at the site, and would be useful when collaborating with other agencies. Taking photographs of the site is also useful both for interpreting data and recording changes over time. If a report is produced you are strongly encouraged to send a copy to CANTTEX (see section 10 - contact info).

2.6 Sample Sizes

Determining the sample size required for a particular survey or experiment is a combination of the need for statistical rigour, and the resources available to the researchers. The sample size needed for a particular test can be calculated, but requires estimates of variables of the population of interest. In particular, the researcher needs some estimate of the variability in the data (e.g. standard deviation). This can be achieved with some pre-sampling or from previous studies. In most instances, there is also a desire to determine the difference between means from either experimental treatments, or among sites or years. In these cases, the researcher must also have some understanding of the precision required for the differences (i.e. the smallest detectable difference), the level of significance required (e.g. α=0.05), and the probability that the difference will be significant (i.e. the power of the test). The number of samples will increase with the precision and power required by the researcher, and will be affected by the variability in the measurements. Smaller sample sizes will reduce the researcher's ability to detect small significant differences. Statistical textbooks cover these subjects in detail, and CANTTEX researchers are encouraged to examine the relevant sections and examples in any of the popular statistical textbooks used in biology and ecology (e.g. Sokal and Rolph 1995; Zar 1999).

In addition, the number of samples for measuring vegetation will depend on the species-area relation in the plant communities of interest. To ensure the majority of species in the community are sampled, we can construct a relationship between species richness and number of quadrats (see Figure 2). This relationship will be different for each community type, but the researcher is encouraged to construct a similar relation to ensure that the recommended number of quadrats (see below) will capture most of the species richness in the community.

However, while the required sample size to ensure statistical rigour can be computed, the actual number of samples that can be measured will depend on the time and resources available to the researcher. It is often the case in ecological field studies that the number of samples needed to achieve a desired level of precision and power will put a strain on the time and financial resources of the researcher. Inevitably, the number of samples that can actually be measured will be a compromise. We recommend that researchers establish at least six plots for monitoring vegetation and flower densities in each of the vegetation types at the site. Clearly, if monitoring only occurs in one or two vegetation types, the number of plots can increase. Once established, it is important that monitoring take place in all plots each year (or each monitoring period, if the site is visited infrequently).

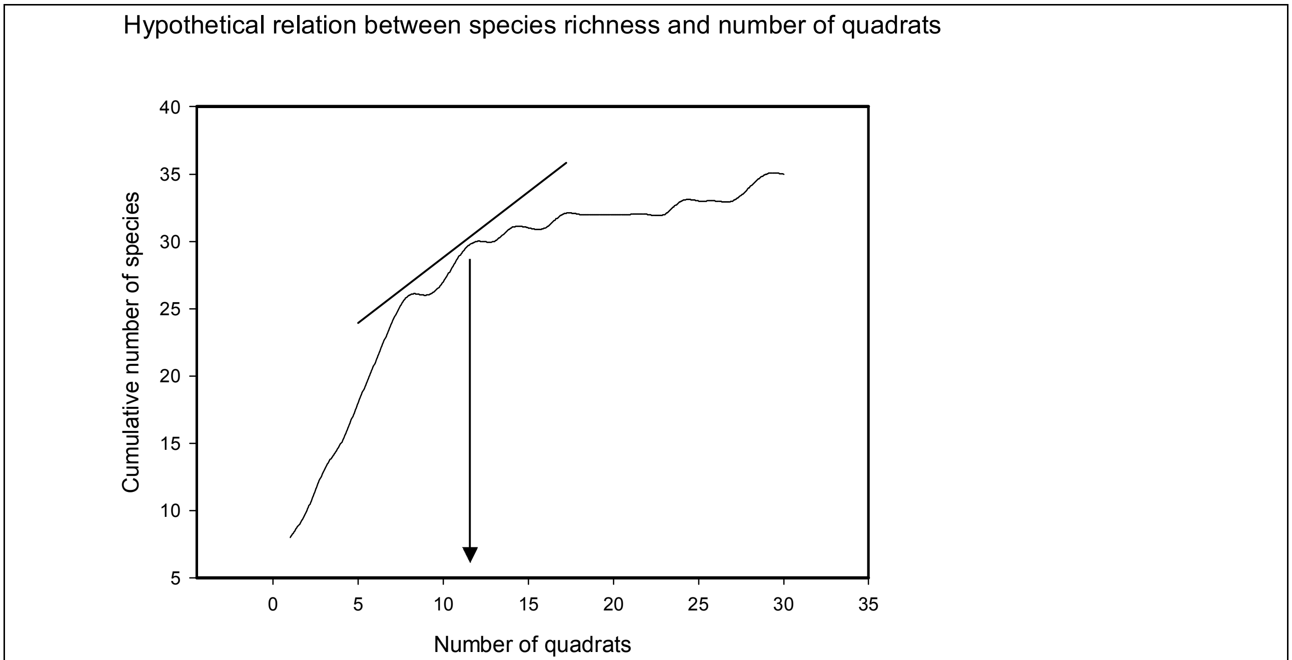


Figure 2. Hypothetical relation between species richness and number of quadrats. In the example, few additional species are found after 12 quadrats are sampled.

For plant-level measurements of phenology, growth and reproduction, the researcher should use the ITEX recommendation of a minimum of 20 randomly chosen individuals of each species. If they are arranged in plots, then the number of plots should be greater than six, with ten as a suitable goal. If possible, randomly choose two or more individuals of the species of interest in the plot. You must insure that the individuals are "independent" - i.e. not branches on the same plant. See Part B for more information on choosing and measuring individuals of major species.

3.0 Climate Monitoring

3.1 Introduction

Whenever possible you should try to locate your study site in the vicinity of an existing climate station, though opportunities for this are rare in the Arctic. The diversity of sites in terms of accessibility, resources and monitoring intensity make the development of a single protocol for climate monitoring unreasonable. However, each site should collect the information described below or be close enough to a meteorological station to use the data. The establishment of an automated meteorological station should be given a high priority if resources are available. The specifications for these are provided in Part B of the manual. Acquiring data from the nearest permanent meteorological station for comparison is also extremely valuable and should be pursued wherever possible.

The objectives of standardized meteorological measurements are the same as for the ITEX program (Molau and Mølgaard, 1996):

(1) to establish baseline measurements to characterize each CANTTEX field site and to enable inter-site comparisons;

(2) to document for CANTTEX objectives the long-term changes in the physical environment; and
(3) to be able to correlate within- and among-year variations in snowmelt and plant response variables with the climatological variations of the site.

3.2 Field Methods

A representative horizontal surface should be selected for the location of the climate station. Unusual topographic features such as ridges or gullies should be avoided and the station should be at least 30 m away from buildings or large rocks. A basic climate station is entirely manual, and consists of (1) a mercury maximum thermometer, (2) a spirit minimum thermometer, and (3) a precipitation gauge. The thermometers should be installed in a ***Stevenson Screen*** at the standard height of 1.5 m and the precipitation gauge should be equipped with a conical shielding. The following data should be reported: daily values for precipitation (accuracy 0.5 mm), type of precipitation (rain, snow, etc.), and minimum and maximum temperatures. Wind speed and dominant direction should be recorded. You can use a hand-held ***anemometer*** or the Beaufort Scale (Table 1). Dominant wind direction should be recorded as a direction from 0 to 360 with 0 being North and the value given should be the direction the wind is coming from. These measurements should be recorded at the same time each day, and preferably twice per day. These sensors can be supplemented or replaced by electronic sensors and data loggers.

Table 1. The Beaufort Scale for recording wind speed. In most cases the references provided in the description will not apply to your study area, so you will have to approximate based on your best guess.

Beaufort Number	Wind Speed (Km/hour)	Description
0	<1.6	Calm: Still: Smoke will rise vertically.
1	1.6 - 4.8	Light Air: Rising smoke drifts, weather vane is inactive.
2	6.4 - 11.3	Light Breeze: Leaves rustle, can feel wind on your face, weather vane is inactive.
3	12.9 - 19.3	Gentle Breeze: Leaves and twigs move around. Light weight flags extend.
4	20.9 - 29.0	Moderate Breeze: Moves thin branches, raises dust and paper.
5	30.6 - 38.6	Fresh Breeze: Moves trees sway.
6	40.2 - 50.0)	Strong Breeze: Large tree branches move, open wires (such as telegraph wires) begin to "whistle", umbrellas are difficult to keep under control.
7	51.5 - 61.2	Moderate Gale: Large trees begin to sway, noticeably difficult to walk.
8	62.8 - 74.0	Fresh Gale: Twigs and small branches are broken from trees, walking into the wind is very difficult.
9	75.6 - 86.9	Strong Gale: Slight damage occurs to buildings, shingles are blown off of roofs.
10	88.5 - 101.4	Whole Gale: Large trees are uprooted, building damage is considerable.

If your site is visited only rarely or if there are not sufficient resources to install a permanent automatic climate station, climate data collected during site visits can be correlated to the closest regional climate station and regression equations used to derive approximations of site climate conditions. Caution should be used if the site is in mountainous terrain as local climate can be strongly affected by topography and altitude.

3.3 Data Entry

Data from a manual weather station should be recorded on a daily basis or as often as is possible on a standard form (an example is provided in Appendix A). As often as possible, the data should be entered into a master spreadsheet on your computer. Remember to keep a back-up of the digital file. See section 7 for general issues and recommendations related to data entry and storage.

4.0 Plant Community Composition

4.1 Introduction

Changes in plant community composition are one of the most important changes predicted to occur with climate change and are already being observed in some parts of the Arctic. An alteration in the composition of the plant cover in a given area will have effects at multiple scales. Ecological processes will be affected, such as nutrient cycling, animal forage quality and quanity, and larger scale climate patterns will be affected as well if, for example, the treeline were to shift northward.

Monitoring plant community composition is a very important and time consuming endeavour, but it only needs to be carried out once every 5 years. In the interests of standardization, CANTTEX is establishing the summer of 2003 as a baseline year and encourages all CANTTEX sites to do a survey of plant community composition in their first year in operation, and again in 2008. Point framing can take between 20 minutes and 2 hours per plot to complete depending on the density of vegetation and the detail with which data are being collected.

4.2 Point Framing

Point framing is a standard method for measuring the composition and abundance of low-stature vegetation such as the forbs, graminoids and dwarf shrubs that characterize arctic tundra. The method described here was designed for the ITEX program and is quantitative and objective. Although it is time consuming, point framing provides a thorough and reliable description of the vegetation cover at a given site. Point framing requires two people and takes between 20 minutes and two hours to complete for each plot depending on the density and diversity of the vegetation.

Point frames are preferably built out of aluminium tubing forming a 1.1 m X 1.1 m square (inside dimensions) but can also be constructed of plastic PVC tubing. Smaller frames can be used but the 1 m X 1 m is preferable. The frame is supported on adjustable legs so that it can be levelled over the area being sampled. Holes are drilled along each side of the frame at 10 cm intervals straight down through the tubing (Figure 3). String, wire, or nylon fishing line is passed through the hole on one side and across to the corresponding hole on the opposite side and drawn taut. Once this is done for each set of holes, the resulting paired grids have 100 intersections of strings at 10 cm intervals.

Equipment List for Point Framing:
Point-frame
Level
Ruler or tape-measure to record height of point-frame
Pin
Data sheets
Pencils and eraser
Voucher Envelopes
Field guide and hand lens to help identify plants

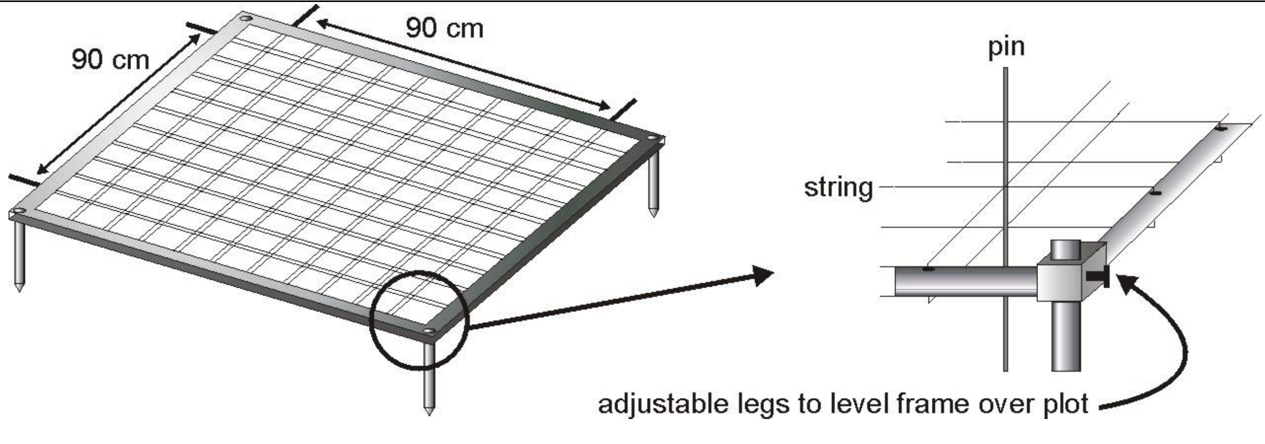


Figure 3. Design of point frame with inset showing position of pin at the intersection of two sets of strings.

The location of the plot should be clearly marked with a permanent metal leg hole or some other marker and details on the orientation of the plot (e.g. "marked leg hole is the southwest corner of the plot") should be recorded so that the same patch can be re-surveyed in the future. The geographic coordinates of the plot will also help locate it in the future (see section 2.4). The point frame should be levelled so that the lower set of strings is just above the height of the tallest plant in the plot. The distance between the frame and the ground should be recorded for each of the corners to provide a sense of the microtopography at the site (see field data form – Fig. 4).

At each of the intersections lower a pin (a surveying pin or knitting needle for example) straight down until it touches the ground (Fig. 3). You should not look at the pin as you lower it to avoid "aiming" it. Once the pin has been lowered one person identifies the species of each plant that comes into contact with the pin and another person records these on the data sheet (example provided in Fig. 3). If abbreviations or other codes are used to record the species, ensure that these are included with the data sheet so that there is no confusion when the data are being entered. A common method is to use the first three letters of the genus name and the first three letters of the species name (i.e. *Saxifraga oppositifolia* is recorded as 'Sax opp'). If the plant material touched by the pin is dead and attached to a standing plant that is either dead or alive, the material is recorded as dead and should have a 'd' after the species designation in the data sheets. Any plant material that is not attached to a standing plant is referred to as 'litter'. If species are encountered with which you are not familiar, find a specimen of the same plant species outside the plot, place it in an envelope, label it, and keep it for future identification. This is called a ***voucher specimen***. The last entry at each point should be the ground cover (i.e. rock, bare ground, litter, moss, lichen, standing water, etc.). The identification of mosses and lichens is difficult and should only be attempted by an experienced bryologist. However, a complete list of all plants should be produced. After all 100 points are completed, the plot should be examined visually and any plant species that are present but were not recorded in the sampling should be written on the bottom of the data sheet to be given a cover value of less than 1% when the data are entered.

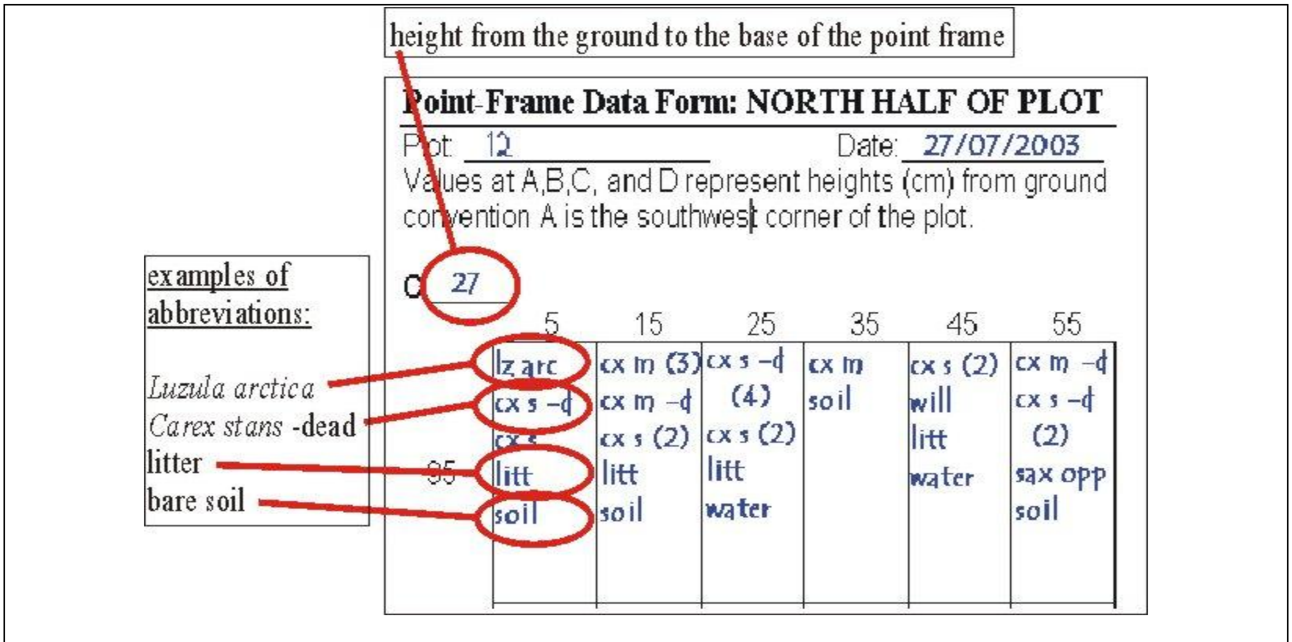


Figure 4. Sample field data form for point-framing. A complete blank version of the form is provided in Appendix A.

Note: Measurement of trees

In addition to the standard surveying of plots, the presence of sporadic trees or tree-islands (groups of small trees surrounded by tundra) where they are near sites should be noted and monitored. This is best done by marking the tree or tree-island in some way and measuring its size. For a single tree, measure its height and diameter at roughly 1.3 m above the ground and for a clump of trees measure the diameter of the island at its widest point and the height and basal diameter of the tallest tree. The height of the tree can be measured using a clinometer which measures angles by looking through an eyepiece at the top of the tree and reading the angle. The height is calculated by $\mathbf{h} = \mathbf{d} (\tan \boldsymbol{\theta}) + \mathbf{e}$, where **h** is the height of the tree, **d** is the distance you were from the tree when you measured the angle, **θ** is the angle read from the clinometer, and **e** is the height of your eyes above the ground.

Be sure to mark the location of the tree-island on your site map as well as the geographic coordinates if you have access to a GPS. The status of cone production and the presence of new seedlings should be monitored. The development of new seedlings should also be noted and monitored. If possible, seedlings should be monitored for growth and survival.

4.3 Data Entry

A sample data sheet for point-framing is provided in Appendix A. Each cell in the table represents one of the intersection points of the strings on the ***quadrat***. Within the cell, list the plant species touched by the pin in order, ending with the ground cover (lichen, moss, rock, soil, etc.). If a lower degree of detail is desired, then you might only record the first (top) 'hit' and the ground cover. If more detail is desired you can divide each species into different parts (leaves, flowers, stems). It is strongly recommended that you record all hits as this gives a much more accurate description of the vegetation. In all cases, you should distinguish between live and dead parts of plants. Any dead material not attached to a live plant is called litter. Two data sheets are required per plot to record all 100 points (Appendix A).

Data entry is a repetitive task but is essential if the data are to be properly stored and analyzed. Many general data entry and storage issues are discussed in section 8. You are encouraged to get in touch with someone from CANTTEX (see section 10 - contact details) if you have any questions or problems. Data entry will require you to set-up a digital database in a spreadsheet program. The database should contain plot summaries of the number of times each species was recorded during point framing (Fig. 5). Be sure to give the spreadsheet an appropriate file name and to save it often as you are entering the data. Once entered make sure to have the data backed-up in at least two places (e.g. a CD and your hard drive). If you use abbreviations for species names, sites, or treatments make sure to have a key to explain the abbreviations to someone who is not familiar with them.

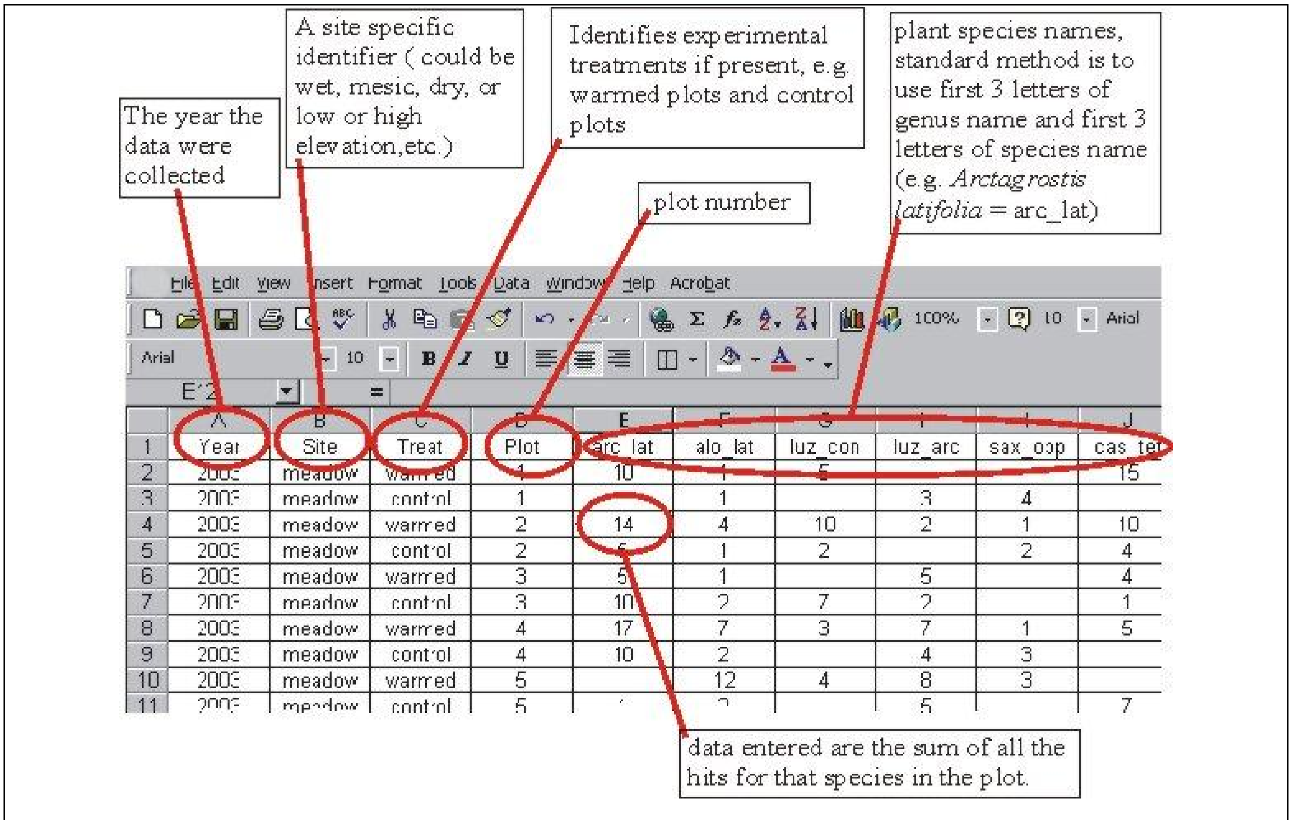


Figure. 5 Example of the set-up for entering vegetation composition data gathered by point-framing.

4.4 Point Transects for Taiga Vegetation

The point framing method will clearly not be practical for tall shrubs or trees. When surveying taiga vegetation the point transect method should be used. Several variations on this method are possible and acceptable as long as the basic principles of random selection of transect location and adequate ***replication*** are maintained. For example, one method would be to pick a point and direction at random. Starting at this point, observations are made every metre for 100 metres by lowering a 1 m tall rod to the ground surface (without aiming it) and every species that touches the rod is recorded according to the methods described in the previous section.

A good source of references can be found in an annotated bibliography produced by the U.S. Department of Agriculture:

C L Elzinga and A G Evenden. 1997. Vegetation Monitoring: an annotated bibliography. USDA Forest Service Intermountain Research Station General Technical Report: INT-GTR-352.

It can be ordered through the internet at:
http://www.fs.fed.us/rm/main/pubs/notsohot_INT/veg_INT.html

5.0 Plant Reproductive Effort

5.1 Introduction

Annual monitoring of some ecological indicators allows a more detailed examination of the relationship between short-term climate variability and plant response as well as an assessment of longer-term trends. A warmer and longer growing season will enhance the ability of many arctic plants to photosynthesize and take-up nutrients, which may in turn allow them to produce more flowers and seeds. This response will play a large part in changes in vegetation composition if some plant species are better able to take advantage of the warmed climate than others. The one common variable that has been selected for annual CANTTEX monitoring is plant reproductive effort which, for the purpose of CANTTEX, is the number of flowers produced by plant species in a given area.

5.2 Field Methods

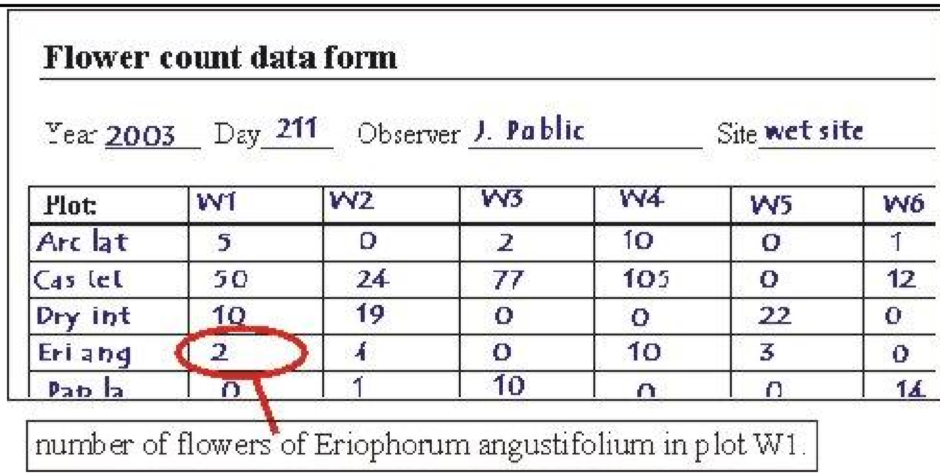
These measurements and observations should be made at peak-season (i.e. when most plants are in full flower), which will be roughly mid to late July in most places. Try to make the observations as close to the same date each year as possible. The most basic measure of reproductive output is the density of flowers for each species, or the number of flowers per surface area. The best way to make these measurements is to either use a point frame (described in section 3.2.1) or to mark out an area in or around each of your plots that is 1 m X 1 m. Try to be consistent and monitor the same plot every year. Within the area defined, count all of the current season's mature flowers and mature fruit for each of the dominant plant species at your site, or, if time and resources allow, for all plant species in your plots. The result is a measure of the flower density (number of flowers per m^2).

For ***dioecious*** species such as *Salix* species you should record whether the flowers are female or male (recorded as F and M). For the *Dryas* species the number of fertilized and non-fertilized flower heads should be noted. Fertilized flower heads contain a swirl of tall plumes on the top after the flower has senesced, which is the product of successful fertilization, while unfertilized flowers produce either very reduced plumes or none. In the data sheet for *Dryas*, the numbers of viable flowers are noted first, with the non-viable ones noted underneath in parentheses. More intensive measures specific to individual plant species are described in Part B of the manual.

> Tip: For species such as *Cassiope tetragona* that can produce a lot of flowers, divide your plot into subplots (quarters) and count each one separately so that if you lose track you don't have to recount the entire plot. Using a hand-held counter will help keep track of the number of flowers as you are going through the plot.

5.3 Data Entry

A sample field data form is provided in Appendix A and shown as it should be filled out in Figure 6. You may want to modify it to suit the specific needs of your site. The format for computer data entry should be the same as for point framing (Fig. 5). In your database column headings might read **sal_arc_f** and **sal_arc_m** to distinguish between female and male flowers of *Salix arctica*, and **dry_int_f** and **dry_int_a** to distinguish fertilized and aborted flowers of *Dryas integrifolia*. Again, make sure you have a key for your abbreviations to make sure they are not misinterpreted by another person. The key should be appended to the data as another table in the spreadsheet.



Flower count data form

Year 2003 Day 211 Observer J. Public Site wet site

Plot	W1	W2	W3	W4	W5	W6
Arc lat	5	0	2	10	0	1
Cas tet	50	24	77	105	0	12
Dry int	10	19	0	0	22	0
Eri ang	2	4	0	10	3	0
Pap la	0	1	10	0	0	14

Figure 6. Field data entry form for entering flower counts. A blank form is provided in Appendix A.

6.0 PlantWatch Vegetation Phenology

6.1 Introduction

Phenology refers to the timing of major events in the annual cycle of a plant such as the timing of flowering and fruit production. Monitoring phenology is important because it reflects the duration of active photosynthesis and is important to pollinators and herbivores. Plant phenology has been shown to be sensitive to changes in summer warmth and growing season length. PlantWatch is an impressive network of volunteer observers monitoring plant phenology across the country. You are encouraged to implement phenology monitoring if time and resources are available. It involves selecting the plant species listed below that are found preferably within your plots or adjacent to them and monitoring the progress of flower blooming in the spring. Monitoring phenology requires visits to plots every 1 to 2 days in the spring/early summer to track the phenological development of the plant species being monitored. If resources are available you are encouraged to undertake more detailed phenological observations including leaf phenology which is described in detail in Part B of this manual. There are other observations described in the second part of the manual, including snow and ice phenology and permafrost depth monitoring.

More information on PlantWatch including thorough descriptions and photographs of plant species at their website:http://www.naturewatch.ca/english/plantwatch/why_monitor.html

Information on PlantWatch in the North can be found at:
http://pooka.nunanet.com/~research/plantwatch.htm

6.2 Field Methods

The first step is to select the plant species that you are going to monitor. The species monitored by PlantWatch are listed below. If there are other dominant species that are not listed below you should consult Part B of the manual to see detailed methods for monitoring phenology for other species. If you are unsure about the identification of plant species consult a field guide, a local naturalist, a PlantWatch regional co-ordinator or CANTTEX (see section 10 - contact details).

Make your observations on a plot by plot basis such that first bloom is the first flower open in the plot and mid bloom is when roughly half the flowers in the plot have opened. Specific descriptions of stages for each plant species are described below. Record any environmental details listed on the data sheet. This includes notes on weather, the plant's location and any other interesting information on insects or animals affecting the plant.

6.3 Plant Species and Stage Descriptions

The common names of the plants are given first followed by the scientific names in parentheses. Flowers open means that the petals have separated and the inner parts of the flowers are visible. Where it says (3 places) means that at least three flowers within the plot have reached this stage.

Arctic Lupine (*Lupinus arcticus*)

First bloom: when the first flowers are open in the observed plants (3 places).
Mid bloom: when 50% of the flowers are open in the observed plants.

Bearberry / kinnikinnick (*Arctostaphylos uva-ursi*)

First bloom: when the first flowers open like little pink "lips" at the tip (3 places).
Mid bloom: when 50% of the flowers on observed plants are open at the tip.

Cloudberry / bake-apple / salmonberry (*Rubus chamaemorus* L)

First bloom: when the first flowers are open in the observed plants (3 places).
Mid bloom: when 50% of the flowers are open in the observed plants.

Cranberry / lowbush cranberry / lingonberry (*Vaccinium vitis-idaea*)

First bloom: when the first flowers are open in the observed plants (3 places).
Mid bloom: when 50% of the flowers are open in the observed plants.

Dandelion (*Taraxacum officinale*)

First bloom: when the first flowers are open in the observed plants.
Mid bloom: when the first seed-head opens, forming a white, fluffy ball of seeds.

Labrador tea (*Rhododendron groenlandicum*, formerly *Ledum groenlandicum*)

First bloom: when the first flowers are open in the observed plants (3 places).
Mid bloom: when 50% of the flowers are open in the observed plants.

Mountain avens / arctic and alpine dryas / white mountain avens (*Dryas integrifolia / Dryas octopetala*)
First bloom: when the first flowers are open in the observed plants.
Mid bloom: when 50% of the flowers are open in the observed plants.

Prickly Saxifrage / three-toothed saxifrage (*Saxifraga tricuspidata*)
First bloom: when the first flowers are open in the observed plants (3 places).
Mid bloom: when 50% of the flowers are open in the observed plants.

Prairie crocus / prairie anemone / pasque flower (*Anemone patens*)
First bloom: when the first flowers are open in the observed plants.
Mid bloom: when most blooms are open, very few are still emerging from the soil, and the stem between the flower and the stem leaf is about 3 cm long.

Purple saxifrage / French knot moss, (*Saxifraga oppositifolia*)
First bloom: when the first flower is open in the observed plants.
Mid bloom: when the first flower petal on any individual flower wrinkles or loses its colour in the observed plants.

6.4 Data Entry

A sample field data entry form is provided in Appendix A. You may need to alter it to suit the layout of your monitoring program. The date for each plot should be recorded and entered separately as a day of the year number (1-365 with January 1st as day 1). PlantWatch data submission will be the average of the values recorded at your plots. The data entry form developed by PlantWatch has been included in this Manual in Appendix A, as well. One of these is filled out for each species and each site if you have more than one. If you have experimental treatments do no include these in data you send to PlantWatch. PlantWatch data can be entered directly on their website.

Note: Data in the form of dates should be recorded as the day of the year they occurred (often erroneously referred to as Julian Day). Thus, January 1st is day 1, and December 31st is day 365 in a typical year and day 366 in a leap year. Appendix C provides a table to convert dates to day numbers.

7.0 Data Entry, Storage and Analysis

Sample data sheets for recording observations are provided in Appendix A but you are encouraged to develop your own to suit the specific purposes of your field site. Field data sheets are best photocopied onto water resistant paper (e.g. Rite in the Rain) to reduce the chances of damage to the sheet and loss of the data. This type of paper also makes data recording in rainy weather easier. Field recording forms should always have room for "Comments" to allow observers to record any factors that might impact the observations such as switching tags to a new plant, an unexpected disturbance at the site, etc.

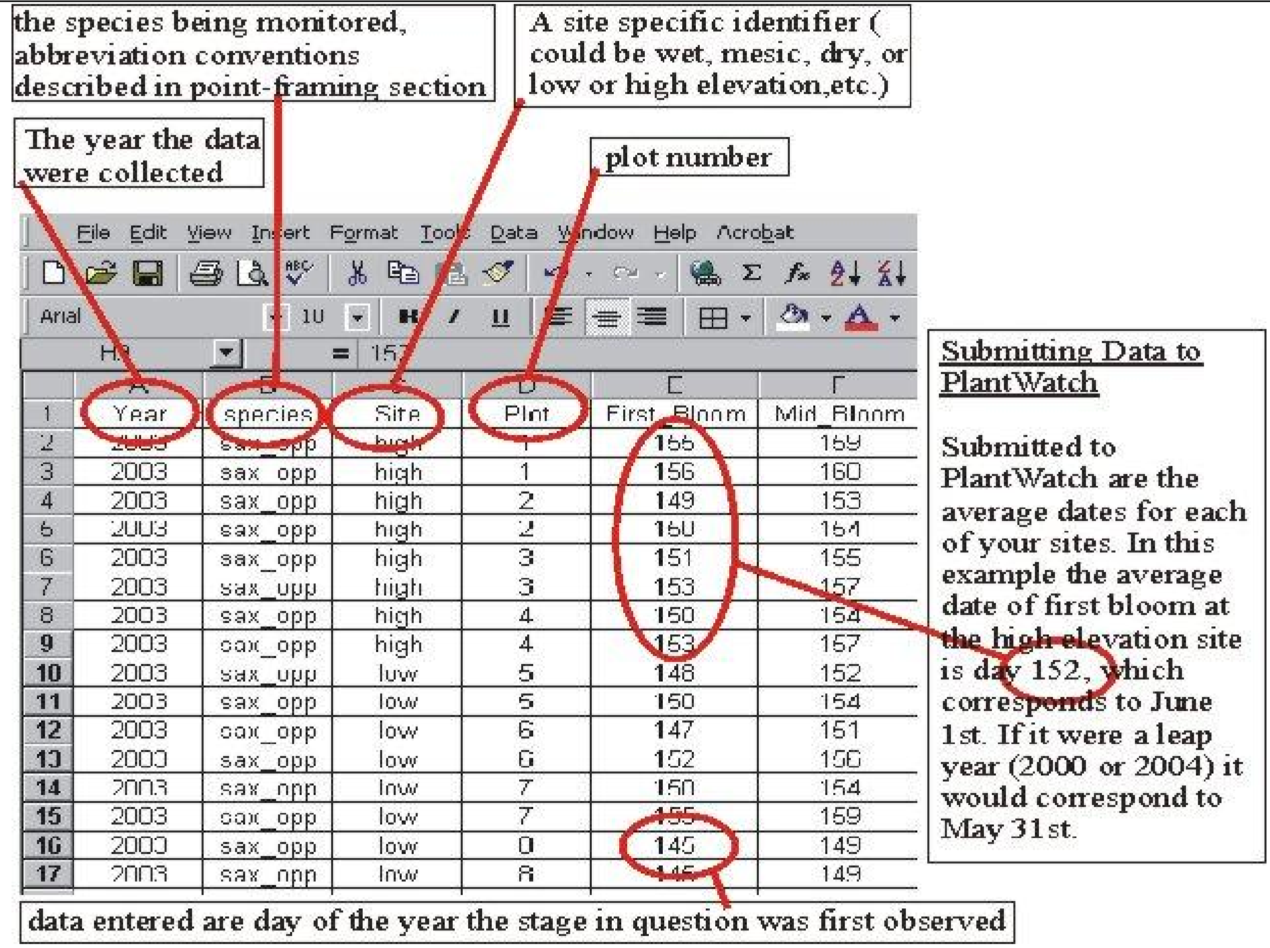


Figure 7. Spreadsheet layout for entering phenology data.

It is very important to have the data entered comprehensively and consistently at the end of each field season. All too often in the past, data collected through hard work have been lost because they were not entered promptly and properly. The most efficient method is to set up a data entry form or spreadsheet that matches the data recording forms used in the field. This makes data entry easier and facilitates checking the accuracy of data entered with what appears on the form. Spreadsheets software usually allows multiple sheets so consider using the following format for each variable:

Sheet 1 – site description
Sheet 2 – relevant abbreviations and notes on data formatting
Sheet 3 – Data for all years compiled into one comprehensive table
Sheet 4 and subsequent – data for each individual year

In some cases, you will use your spreadsheet to calculate values. For example, you may want to calculate the average number of flowers counted in all plots. When using formulas in spreadsheets be very careful that the cells included in the formula are the ones you intended, that the formula has copied correctly to other cells, and that the function you have specified is the correct one. Once a calculation has been made, it is a good idea to convert the formula to the value of the result of the calculation. This will prevent confusion and errors if the source data are changed or moved.

Data files should be given appropriate names such as DL_phenology_dryint (Daring Lake CANTTEX site data on *Dryas integrifolia* phenology). Make sure that data are backed-up in at least two places (on a hard-drive, server, and on diskettes or CDs) and that in any change of the person or people responsible for those data, they are made aware of the status, format, and location of all collected data. Also, make sure that there is a standard location for storing original data sheets in case values need to be checked or to re-enter data if computer files are lost. It is a good idea to make photocopies of the original sheets and use the photocopies for data entry.

In our efforts to maintain the most up-to-date information on the status of CANTTEX sites, trends in data collected, and to minimize the possibility of data being lost, CANTTEX has set up a data archive to store and, when possible and appropriate, analyze data from the contributing sites. Once data has been entered at the end of each field season, please send the relevant files to Greg Henry (see section 10 Contact Information).

8.0 Frequently Asked Questions

Questions and problems that are communicated to CANTTEX will be addressed and posted on the CANTTEX website as they arise at http://www.emannorth.ca/. They will be included in this section in future editions of this manual.

If I can't find a tagged plant, what should I do?

-If one of your plants or tags goes missing, you will have to select another plant at random. Make sure to give it a new number so that you know that it is a different plant being monitored.

What should I do if I can't define an individual plant?

-For some mat and tussock forming species, it will be impossible to determine an individual. In these cases you should use wooden skewers and string to outline a 10 cm X 10 cm area that will be the unit of observation for that individual.

9.0 References

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10.0 Contact Information

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APPENDIX A: Sample Data Sheets

What follows are sample data sheets that you can use for data entry, or use as a model to develop your own forms for use in the field. You might require more columns to differentiate between the different types of sites that you have or between experimental treatments. Blank column headings are there to customize forms such as including other climate variables being monitored or to fill in dominant plant species in the flower count field data sheet. It is recommended that you copy the forms onto water resistant paper (e.g. Rite in the Rain) to minimize the risk of forms being damaged in inclement weather. The data sheets include:

General Site Description
Description of Monitoring Design and Plot Layout
Monthly Climate Report Form
Point-Frame Data Form: North Half of Plot
Point-Frame Data Form: South Half of Plot
Flower Count Data Form
Phenology Data Form
PlantWatch Observation Form

General Site Description Form*

Year:_______ Observer:____________________________ .

Site name:	
Date established:	
Geographic coordinates:	
Elevation:	
Agency:	
Primary contact:	
Address:	
Email:	

Topographic setting:	
Local hydrology:	
Local geology:	
Local vegetation:	
Local soils including permafrost:	

*When complete send copy to: Greg Henry (See Contact Information)

Description of Monitoring Design and Plot Location*

Year:_______ Observer:_____________________________ .

Name of plot cluster:	
Type of monitoring / manipulations:	
Number of control plots:	
Number of manipulated plots:	
Number of plant species monitored:	
Frequency of monitoring:	
Slope angle at plot location:	
General description of vegetation at site:	
Sketch of site: *Include treatment and control plots, approximate scale, plot numbers, orientation (north arrow), and any other relevant features*	

*When complete send copy to: Greg Henry (See Contact Information)

Monthly Climate Report Form*

Site: _________________ Year:____________ Month: _________________ .

Date	Day No.	Tmax	Tmin	Tav	Precip.		Notes
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							
31							

*When complete send copy to: Greg Henry (See Contact Information)

Point-Frame Data Form: NORTH HALF OF PLOT

Plot: _________________ Date:______________ Recorded by:__________________.

Values at A,B,C, and D represent heights (cm) from ground surface to bottom of point-quadrat frame. By convention A is the southwest corner of the plot.

C ______ **D** ______.

	5	15	25	35	45	55	65	75	85	95	
95											95
85											85
75											75
65											65
55											55
	5	15	25	35	45	55	65	75	85	95	

A ______ **B** ______.

Comments:____.

____.

Computer data entry by:___________________ Date: _____________ Rekey?____________________.

Point-Frame Data Form: SOUTH HALF OF PLOT

Plot: _________________ Date:______________ Recorded by:___________________.

Values at A,B,C, and D represent heights (cm) from ground surface to bottom of point-quadrat frame. By convention A is the southwest corner of the plot.

C ______ **D** ______.

	5	15	25	35	45	55	65	75	85	95	
45											45
35											35
25											25
15											15
5											5
	5	15	25	35	45	55	65	75	85	95	

A ______ **B** ______.

Comments:____.

____.

Computer data entry by:___________________ Date: _____________ Rekey?_____________________.

Flower count data form*

Year _______ Day_____ Observer _________________ Site_____________________ .

Plot:								
species								
Notes								

*When complete send copy to: Greg Henry (See Contact Information)

Phenology data form*

Species __________ Year ________ Observer ________________ Site ___________.

Site	Plot	First Bloom	Mid Bloom	Notes

*When complete send copy to: Greg Henry (See Contact Information)

PlantWatch Observation Form

Observer

Name: _
Address: _
City/Town: _
Province/Territory: _ _ _ _ _ _ _ _ _ _ _ _ Postal Code: _ _ _ _ _ _ _ _ _ _ _ _ _
Phone: _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ E-mail: _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
Age: [ ] 5-10 [ ] 11-15 [ ] 16-20 [ ] 21-30 [ ] 31-55 [ ] 56 and over

Plant Observed

Name of Plant: _
_ _

Flowering Phase

First Bloom (month/day/year): _
Mid Bloom (month/day/year): _

Leafing

Leafing (month/day/year): _

Plant Location *(remember to give each location a unique name e.g. schoolyard, backyard)*

Location Name: _
Closest city or town: _
Province/Territory: _
Latitude: ______ ° ______ ‘ ______ “ N Longitude: ______ ° ______ ‘ ______ “ W
Elevation (if known): _ _ _ _ _ _ _ _ _ _ _ _ (metres)

Habitat Type

[ ] Deciduous forest [ ] Marsh, bog, wetland
[ ] Coniferous forest [ ] Farmland
[ ] Mixed forest [ ] Residential garden/lawn
[ ] Tundra/barren [ ] Schoolyard
[ ] Grassland

Optional Details

Sun Exposure: [ ] sunny and open area [ ] in half shade [ ] shaded all day
Plant is located on: [ ] flat area [ ] gentle slope [ ] steep slope
Slope faces (circle one): N NE E SE S SW W NW

Comments

_ _
_ _
_ _

Thank you for participating in PlantWatch

As soon as your observations are complete, mail your data sheet to your regional coordinator or enter your dates on the web at www.plantwatch.ca. By submitting on the web you can cut down on paper and see your dates added instantly to the PlantWatch maps. Remember, every observation counts — reporting even one flowering date for one plant is a great contribution.

Appendix B: Dates and Day Numbers

The following shows the day numbers that correspond to the dates in the summer months. The values given are for a normal year; during a leap year add 1 to each day number.

May	Day Number	**June**	Day Number	**July**	Day Number	**August**	Day Number
1	121	1	152	1	182	1	213
2	122	2	153	2	183	2	214
3	123	3	154	3	184	3	215
4	124	4	155	4	185	4	216
5	125	5	156	5	186	5	217
6	126	6	157	6	187	6	218
7	127	7	158	7	188	7	219
8	128	8	159	8	189	8	220
9	129	9	160	9	190	9	221
10	130	10	161	10	191	10	222
11	131	11	162	11	192	11	223
12	132	12	163	12	193	12	224
13	133	13	164	13	194	13	225
14	134	14	165	14	195	14	226
15	135	15	166	15	196	15	227
16	136	16	167	16	197	16	228
17	137	17	168	17	198	17	229
18	138	18	169	18	199	18	230
19	139	19	170	19	200	19	231
20	140	20	171	20	201	20	232
21	141	21	172	21	202	21	233
22	142	22	173	22	203	22	234
23	143	23	174	23	204	23	235
24	144	24	175	24	205	24	236
25	145	25	176	25	206	25	237
26	146	26	177	26	207	26	238
27	147	27	178	27	208	27	239
28	148	28	179	28	209	28	240
29	149	29	180	29	210	29	241
30	150	30	181	30	211	30	242
31	151			31	212	31	243

Appendix C: Random Number Table

The random number table below can be used when selecting plot locations or plants to be monitored.

10	27	53	23	54	04	26	47
28	41	50	88	83	39	94	89
34	21	42	02	80	05	84	46
61	81	77	23	53	44	42	28
61	15	18	54	90	07	52	59
91	76	21	64	75	39	56	29
00	97	79	06	53	01	30	48
36	46	18	94	78	08	67	25
88	98	99	50	91	43	46	02
04	37	59	21	69	92	55	91
63	62	06	41	16	29	79	30
78	47	23	90	54	12	14	23
87	68	62	43	66	59	50	36
47	60	92	77	95	48	61	12
56	88	87	41	44	50	81	33
02	57	45	67	68	77	06	75
31	54	14	17	67	46	14	01
28	50	16	36	67	24	59	96
63	29	62	50	86	86	92	48
45	65	58	51	74	44	44	12
39	65	36	70	76	30	49	61
73	71	98	04	79	79	08	94
72	20	56	11	77	97	09	89
75	17	20	76	48	26	53	87
37	48	26	29	89	06	45	47
68	08	60	72	01	02	97	17
14	23	02	67	17	10	18	99
49	08	98	44	67	19	41	72
78	37	96	43	65	09	56	16
37	12	06	68	76	44	91	58
14	29	34	04	47	87	59	25
58	43	09	36	10	05	12	09
10	43	28	70	00	90	43	14
44	38	67	54	07	17	38	81
90	69	88	51	20	11	78	95
41	47	59	62	31	68	84	45
91	94	10	19	56	79	14	40
80	06	14	66	34	22	24	31
67	72	54	48	19	80	75	24
59	40	77	27	09	53	85	38
05	90	24	95	20	37	71	71
44	43	35	98	31	77	59	66
61	81	80	82	98	55	08	57
42	88	31	05	24	27	10	12
77	94	07	39	01	49	96	91
78	76	30	16	50	23	88	09
87	76	19	81	90	18	57	72
91	43	59	47	46	01	17	73
84	91	05	73	47	41	91	16
87	41	77	83	12	73	36	59

APPENDIX D: Glossary

Anemometer: A device used to measure wind speed.

Dioecious: Plant species having separate male and female flowers, sometimes on separate plants.

Lithology: The type of rock that underlies the study area. This can most often be found on maps of the geology of the region.

Phenology: Phenology refers to the timing of the stages in the life cycle of an organism or phenomenon. Plant phenology, therefore, refers to the dates on which certain phases of a plant's life cycle start or end.

Quadrat: A area (usually square) used as a sampling plot or location.

Replication: Ensuring that a sufficient number of individuals or number of plots are being measured or monitored to be confident in the consistency of the results.

Stevenson Screen: Standard housing for manual meteorological instruments. It consists of a ventilated, white box elevated 1.5 m from the ground surface.

Voucher specimen: A plant collected in the field to be retained for identification. The specimen is usually mounted and deposited in a university or government herbarium.