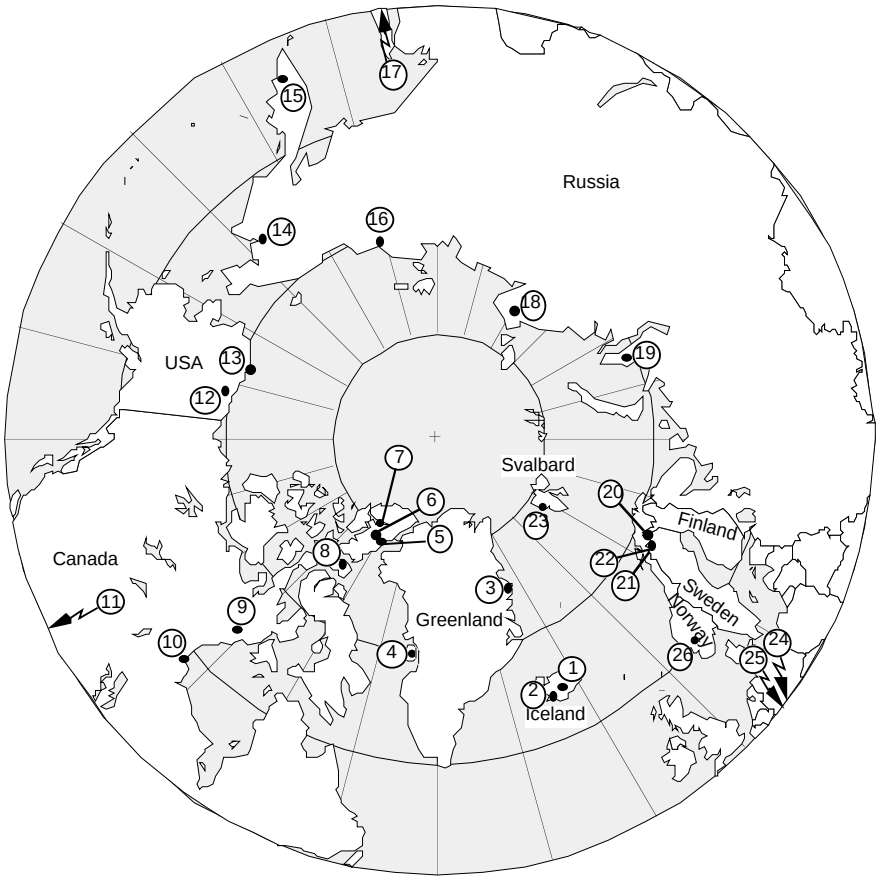
International Tundra Experiment

ITEX
Manual

Second Edition



Edited by
Ulf Molau & Per Mølgaard

Danish Polar Center
June 1996

International Tundra Experiment

ITEX Manual

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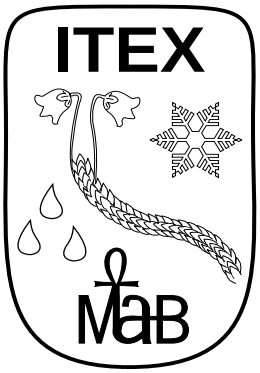

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Content

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FOREWORD

Since the publication of the first edition of the ITEX Manual in 1993, amendments, improved protocols, and entire new chapters have accumulated. Taking the current rapid development within ITEX into account, an improved version of the Manual is an absolute need. A common manual is crucial for co-ordination and conformity in an international program of this size and complexity, comprising about thirty different field sites and research parties in thirteen different countries. The original decision to prepare an ITEX Manual was taken during the Third ITEX Workshop at Boulder, Colorado, March, 1992. A preliminary version was circulated in May, 1992. The manual was critically tested during the summer, and evaluated and revised during the Fourth ITEX Workshop at Oulu, Finland, December, 1992. In the first edition of the ITEX Manual, published by the Danish Polar Center in 1993, the temperature enhancement manipulation was finally standardised, data gathering facilitated, and report forms for all climate measures and plant response variables provided.

In this second edition, the Manual covers not only the basic monitoring and temperature manipulation experiment (ITEX "Level 1"), but also documentation processes, statistical analysis, higher-level studies such as "seed flux", and an introduction to permafrost monitoring. The latter is an outcome of the close and prosperous collaboration between ITEX and the International Permafrost Association (IPA). The basic chapters on climate stations (Molau), experimental designs (Marion), and plant response variables (Molau & Edlund) are only slightly modified from the first edition, and are compulsory for all sites, normative for ITEX from 1993 on. Besides of setting the standards, each of these chapters provides opportunities for modifications and adaptation of ITEX to various kinds of sites (e.g., various chamber sizes, addition of ITEX Corners, a menu of ITEX species to select suitable plants from, etc.). Hopefully, the simplicity will enable implementation and maintenance of the basic program at most of the identified sites. The chapters dealing with permafrost monitoring (Nelson et al.) and monitoring of snow and lake ice (Molau) are optional, but highly recommended to be included in the monitoring at as many sites as possible, since such data provides valuable climatic information. This edition also includes chapters on pollination and insect herbivory (Böcher; Mølgaard and Morewood), which expand the ITEX activities into the arctic fauna as another dependent variable in a changing climate.

As we learned from the latest workshop in Copenhagen May 1996, new chapters are still to be added. Therefore we have decided not to bind this hard copy of the ITEX Manual to make it easier to include additional material. Revision of the Manual and new chapters will automatically be released to the mailing list on the net. However, it is still possible to receive the Manual in print on request to the Danish Polar Center.

We wish to thank the contributing authors of this second edition of the ITEX Manual, as well as all those who have critically read and commented on earlier versions and drafts.

Copenhagen, June 1996

Ulf Molau
Chairman

Per Mølgaard
executive secretary

RESOLUTION

INTERNATIONAL TUNDRA EXPERIMENT

December 5, 1990

As a result of deliberations and concensus achieved at a workshop to design an International Tundra Experiment (ITEX) on December 2—5, 1990, at the Kellogg Biological Station, Michigan State University, U.S.A., the participants from nine countries (Canada, Denmark, Finland, Great Britain, Iceland, Norway, Sweden, United States, USSR) have agreed to submit the following findings and recommendations to their respective organizations and scientific collegues.

Taking into account

1. That the tundra regions represent an important component of the geospere-biosphere, being a sensitive indicator of global change and contributing actively in the functioning of the global climate system;
2. That the understanding of the geophysical and ecological processes that occur in the tundra is an important objective of the international community concerned with global change, biodiversity, environmental protection, and sustainable development;
3. That recent acceleration of international interest and cooperation in arctic and alpine science has opened new possibilities for coordinated international research and analyses;

And recognizing

1. That carefully organized comparisons within and among tundra sites and over time will greatly increase understanding of the ecology of tundra species;
2. That coordinated observations and measurements of a few carefully selected arctic species populations occurring along circumpolar megatransects and environmental gradients are achievable;
4. That an experimental approach to a few selected manipulations of the environment is deemed desirable as a cost effective means to compare species responses to variables relevant to global change;
5. That international exchange of scientists, especially students, is highly desirable to enhance communication and training;

The participants therefore agree

1. That an initial set of selected tundra plant species, measurement protocols and manipulations have been specified for the ITEX experiments starting in 1991 as the result of this international meeting of experts.

They, therefore, recommend

1. That the first ITEX experiment focuses on responses of vascular plant species;
2. That a set of abiotic observations and destructive and non-destructive measurements be carefully specified to determine phenological events, reproductive and vegetative effort, physiological responses, and genetic response to the manipulated and predominant environmental variables during the growing season and over a period of years;
3. That explicit protocols be developed for simple and relatively inexpensive manipulations of air temperature (such as by small greenhouses) and snow cover (as by snow fences) at participating sites;
4. That sets of selected individuals in field transplant gardens be subjected to a common garden (environmental) experiment and assessed in terms of genetic variation within each species population and its phenotypic response in order to evaluate probable adaptations to climate change;
5. The more complex or expensive experiments involving manipulations such as atmospheric CO_2, or soil temperature and reciprocal transplant gardens, fertilizer treatments, or even phytotron experiments may be desirable and practical for some sites;
6. That appropriate coordination of research, communication and synthesis of results be achieved by a small set of coordinators, and by convening of participating principal investigators for periodic assessment workshops, exchanges of scientists and students among sites will facilitate ITEX;
7. That development of an appropriate protocol for the exchange of ITEX data among participants is needed;
8. That funding for research is the reponsibility of each participating country, and may utilize activities already underway, and including Biosphere Reserves, protected areas, and long-term ecological research areas; and
9. That future experiments focusing on other taxa and ecological parameters, including animals, are desirable, and contacts for ITEX established through the MAB Northern Science Network are encouraged.

BASIC HYPOTHESES AND OBJECTIVES

Approved by the Third ITEX Workshop, Boulder, Colorado, March 10, 1992.

The goal of the International Tundra Experiment (ITEX) is **to understand the response of tundra plant species through simple manipulation and transplant experiments to be conducted at multiple arctic and alpine sites**. Objectives and hypotheses related to measurements and simple manipulations are defined as Level 1 within the ITEX hierarchy. Transplant and common garden experiments are considered to be Level 2. The objectives of the proposed research are:

(1) to quantify the change in the environment (i.e., temperature, moisture, and nutrient availability) broughr about by experimental warming,

(2) to quantify the change in the environment from the point of view of the plant by quantifying the shift in phenotypic selection,

(3) to understand the potential of tundra plant populations to adjust to climatic warming, either through acclimation or adaptation, and

(4) to partition the effect of global warming on key phenological, morphological, and physiological traits into environmental and genetic components.

Research Questions

ITEX has four primary research questions. Questions I–III are answerable with the basic manipulation (Level 1); question IV relates to the transplant and common garden experiments. Not all subquestions will be answered at all sites, depending on the particular level of environmental measurement made at the site.

I. How will the selective environment change as a result of experimental warming?
   (a) How will the soil temperature profile change in response to air temperature change? Specifically, will the depth of the active layer increase (in arctic sites)? (Level 1)
   (b) How will factors correlated with temperature change in response to experimental warming? Specifically, will nutrient or water availability change? (Level 2)
   (c) How will community composition change? Will there be a shift in dominance in the experimental plots? (Level 1)

II. Will experimental warming result in a shift in the selective regime?
   (a) Will new character states or combinations of states (i.e., morphological and phenological characters and tissue nutrient concentrations) be favored in a warmer climate? (Level 1)
   (b) Will the selective regime be similar across multiple arctic and alpine sites? (no level - multisite comparison)

III. Are populations of arctic and alpine species able to accommodate warmed climatic conditions over the long term?
   (a) Do measures of population-level response indicate population decline, maintenance, or increase? (Level 1)
   (b) Do phenologic shifts occur in a manner that increases or decreases population vigor? (Level 1)
   (c) Do tissue nutrient concentrations provide an index of population stress (or vigor) within the context of climatic-induced changes in selective regimes? (Level 2)

Questions based on experimental manipulation of natural populations (all Level 2):

IV. Is phenotypic variability in warmed and control plots due to environmental effects, genetic variability, or a combination of the two?
   (a) Is there significant variation among clones within extant populations for traits affecting fitness under warmed conditions? In other words, is there significant heritability (in the broad sense) for traits relevant to global warming?
   (b) Does the expression of genetic variability in relevant traits change as a function of the environment? Is the broad-sense heritability environment-dependent?
   (c) Is there significant genetic variation in response to warming treatments (i.e., genotype x environment interaction)?

Experimental Design

Number of species. The measurement of a single species is acceptable for Level 1, but this species should be selected from the highest priority (1a) species list. If two or more species are measured, then they may all be from the 1b list, and as long as at least one 1a species is included then other species may be added as needed or desired.

Siting: Treatment sites should be placed in areas with uniform soil, plant cover (vegetation), slope angle, and slope exposure.

Treatment period: Treatments should begin at the date of release from snow and continue until late August or the inception of the winter snow period, whichever comes first. Although the working group recognized the validity of using a physiological indicator, such as change in leaf coloration, as the ”best” indication of senescence for an individual species, interspecific and intersite differences indicated that a calendar date would be most consistently applied, and that August 15 was a reasonable compromise for most sites.

Extent of Experiment: A five-year commitment to an experimental site is suggested as a minimum. Sites with on-going long-term programs and personnel, such as field stations, reserves, and long-term ecological research sites, are considered optimum, so that the experiment may be expected to continue beyond the initial five-year period for these sites.

ITEX AT PRESENT: STRUCTURE AND ORGANIZATION

Ulf Molau

The following chapter is a brief summary of the structure of ITEX for the time being, with updated lists of field sites, selected species, and project organization. For further information, please consult the ITEX Update newsletters, available from the Danish Polar Center.

Field Sites

At present, there are more than twenty active ITEX field sites (see Fig. 1), and a few more are in the process of being recognized. The level of commitment and participation in ITEX varies among sites and countries, due to various reasons, such as logistics, staff, funding, accessibility, and floristic properties. The following sites are recognized as active at present:

Austria	Franz Joseph Land
Canada	Baker Lake
	Alexandra Fiord, Ellesmere Island
	Hot Weather Creek, Ellesmere Island
	Truelove Lowland, Devon Island
Finland	Kilpisjärvi
Greenland	Disko Island, W Greenland
	Zackenberg, E Greenland
Iceland	Hveravellir
	Skálafell
	Thingvellir
Japan	Taisetsu Mts., Hokkaido Island
Norway	Ny-Ålesund, Svalbard
	Finse, south-central Norway
Russia	Mt. Dionisiy, Anadyr
	Ragoshniy Peninsula, Chukotka
	Blizni, Taimyr
	Yamal
Sweden	Latnjajaure (Abisko)
Switzerland	Val Bercla
U.S.A.	Barrow, Alaska
	Toolik Lake, Alaska
	Niwot Ridge, Colorado

In addition, sites seem to be underways in Australia and there are also intentions in Bolivia. The first of the Swiss site (Furka Pass, Bidmer) has however been terminated. The Icelandic sites are still at an early stage of implementation. ITEX field work at the Zackenberg site (East Greenland) started in 1995 and the site in Franz Joseph Land will be implemented in the summer of 1996. Several additional high-alpine sites in Japan (Hunshu Island) have also been announced.

Selected ITEX Plant Species

The circumpolar, main ITEX species are given below as Group 1A. The presently most important additional species are included in 1B; these are either more locally distributed and monitored at some site(s) only, or they are subject to ITEX-related research projects (e.g., retrospective growth analysis). Thus, the 1B list is more flexible, and the one given here reflects the most intensively studied additional species at the moment.

Group 1A (circumpolar, main target species)
Carex stans (*C. aquatilis* ssp. *stans*)
Cassiope tetragona
Dryas integrifolia / octopetala
Eriophorum vaginatum (alt. *E. triste*)
Oxyria digyna
Polygonum viviparum
Ranunculus nivalis
Salix arctica / herbacea / polaris / reticulata
Saxifraga oppositifolia
Silene acaulis

Group 1B (additional species)
Acomastylis rossii
Bistorta bistortoides
Carex bigelowii
Diapensia lapponica
Huperzia selago
Hylocomium splendens
Papaver radicatum
Pedicularis lanata (incl. *P. dasyantha*)

Participant Countries and Representatives

Austria	Georg Grabherr, Vienna
Australia	Catherine Pickering, Sidney
Canada	Greg Henry, Vancouver
Denmark	Per Mølgaard, Copenhagen
Finland	Kari Laine, Oulu
Iceland	Ingibjörg Svala Jónsdóttir, Göteborg (Sweden)
Japan	Satoru Kojima, Toyama
Norway	Ørjan Totland, Bergen
Russia	Vladimir Razzhivin, St. Petersburg
Sweden	Ulf Molau, Göteborg
Switzerland	Felix Gugerli, Zürich
U.K.	Phil Wookey, London
U.S.A.	Marilyn Walker, Boulder, CO.

ITEX Steering Committee

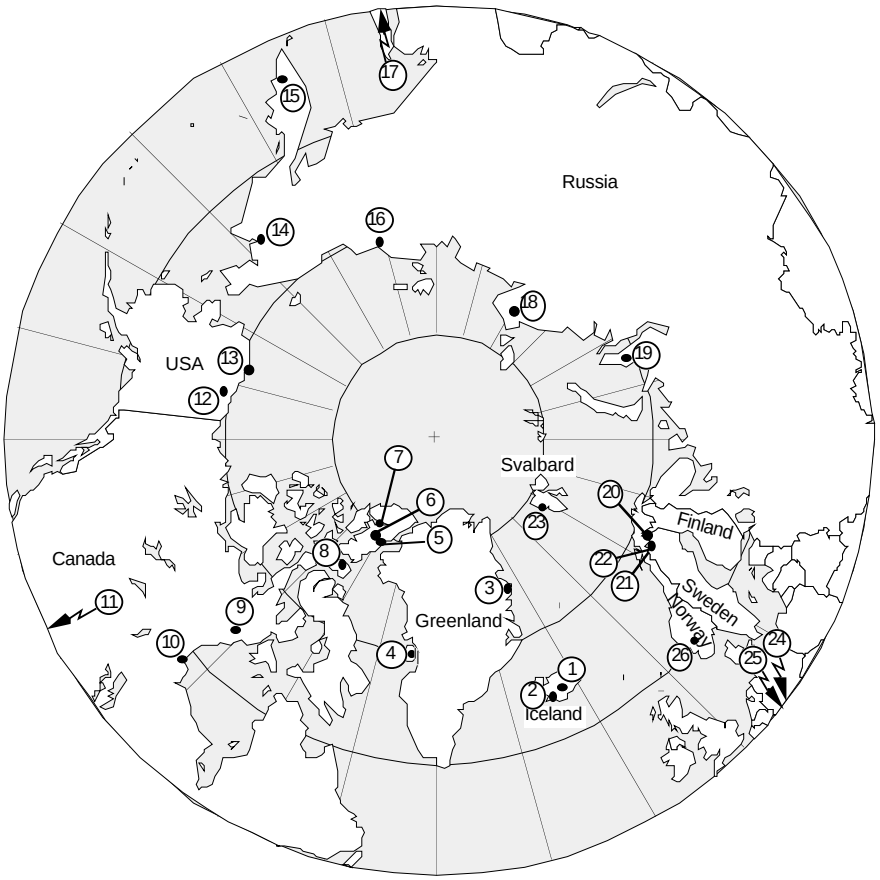
The following Steering Committee members were appointed at the Sixth ITEX Workshop, Ottawa, Canada, April, 1995:

Phil Wookey,	UK, *chair*
Marilyn Walker,	U.S.A., *co-chair*
Per Mølgaard,	Denmark, *co-ordinating secretary*
Greg Henry,	Canada, *member*
Kari Laine,	Finland, *member*
Vladimir Razzhivin,	Russia, *member*
Patrick J. Webber,	U.S.A., *member*
Ulf Molau,	Sweden, *member*

Affiliation, Administration, and Funding

ITEX was created as a MAB (Man-And-the-Biosphere) initiative in 1990, and is an official research project within MAB-NSN (Northern Sciences Network). Furthermore, ITEX is represented in IASC (International Arctic Science Committee), and affiliated with GCTE (Global Change & Terrestrial Ecology), a core program within IGBP (International Geosphere-Biosphere Programme). Since 1993, ITEX also has a profound collaboration with the International Permafrost Association (IPA).

The ITEX secretariat is since May 1992 hosted by the Danish Polar Center (DPC), Strandgade 100, Build. 1, DK-1401 Copenhagen K, Denmark (phone +45-3288 0100/+45-3288 0118; fax +45-3288 0101). DPC takes care of printing and mailing of the newsletter ("ITEX Update", ca. two issues annually) and manuals, updating mailing list, filing of report forms, organization of ITEX meetings, etc. The administration at DPC is financed by shares from national funding bodies in the participant countries, mainly the national MAB boards.



1	Hveravellir, Iceland
2	Mt. sSkálafell, Iceland
3	Zackenberg, Greenland
4	Disko Island, Greenland
5	Alexandra Fjord, Canada
6	Sverdrup Pass, Canada
7	Hot Weather Creek, Canada
8	Baker Lake, Canada
9	Baker Lake, Canada
10	Churchill, Canada
11	Niwot Ridge, USA
12	Toolik Lake, USA
13	Barrow, USA
14	Anadyr, Russia
15	Petropavlovsk, Russia
16	Lower Kolyma, Russia
17	Taisetsu Mts., Japan
18	Taimyr, Russia
19	Yamal, Russia
20	Kilpisjärvi, Finland
21	Abisko, Sweden
22	Latnjajaure, Sweden
23	Ny-Ålesund, Svalbard
24	Val Bercla, Switzerland
25	Furka Pass, Switzerland
26	Finse, Norway

Fig. 1. Circumpolar map of ITEX field sites (compiled by Giles M. Marion).

ITEX CLIMATE STATIONS

Ulf Molau

Preface

During the second ITEX meeting, held at the Danish Polar Center, Copenhagen, Denmark, February 5–6 1992, I was asked to prepare a manual for standardized ITEX climate stations suitable for all ITEX field sites. The resulting manual is based on the experiences from the Swedish ITEX site, Latnjajaure Field Station (LFS) in northernmost Swedish Lapland. At LFS we were running a well equipped automatic climate station plus a traditional manual weather station from June 12 to September 5 in 1991, and we will resume operation in April 1992. The climate station, which is more advanced than will be required for ITEX purposes, is the result of a meteorological long term experiment (five years, 1991–1995) and was designed by Dr. Björn Holmgren, chief meteorologist at the Abisko Scientific Research Station, Sweden. The present manual and report forms are based on our 1991 field work and data analysis, and also on the manual used within the Long Term Ecological Research project (LTER). I thank Dr. Halldor Thorgeirsson, Agricultural Research Institute, Reykjavik, Iceland, and participants of the 3rd ITEX workshop at Boulder, Colorado, 10 March 1992, for discussions and comments on the earlier version. Comments and suggestions for improvement of this manual are most welcome.

Boulder, March 10, 1992

Preface to Version 3.0

This revised version replaces version 2.0 (April, 1992); the chapter dealing with calculations of integrated radiation has been altered, growing degree days (GDD) has been added to the methods, and the monthly report form is fundamentally changed. Especially, I want to thank Barrie Maxwell, Canadian Climate Center, for critical reading of the last draft.

Göteborg, March 30, 1993.

Contents

Introduction

Each ITEX field site is obliged to install a climate station and to collect and communicate data from that station for common use within ITEX. The climate station level 1 (see below) is an absolute minimum in the initial phase at any field site, but installation of a level 2 station should be given high priority.

Objectives

The objectives of standardized meteorological and climatological measurements are: (1) to establish baseline measurements to characterize each ITEX field site and to enable intersite comparisons, (2) to document for ITEX objectives the long-term changes in the physical environment, and (3) to be able to correlate within- and among-year variations in snow-melt and plant response variables with the climatological variations of the site.

Levels of Participation

The diversity of sites with regard to length of vegetation season, accessibility, crew, energy sources, and funding argue against a single standard method. Therefore, ITEX climate recording methods are grouped in two levels (1 and 2) of standard measurements, and with several alternative solutions within level 2. Thus, there will be established degrees of uniformity for intersite comparative data, but with enough flexibility for site-specific requirements and constraints. All ITEX field sites are obligated to participate in the climate recording at *at least level 1 in the initial stage*, and establish level 2 measurements as soon as possible. Level 1 is a simple manual climate station equipped with maximum and minimum thermometers (in a shelter cage) and a precipitation gage, inspected every morning at 0700 hours normal time during the field season. Level 2 ITEX meteorology includes a data logger and several instruments; climate stations can be either entirely automatic or (preferably) a combination of manual and automatic recording. Thickness and duration of snowcover should be monitored along permanent transects or at fixed points or plots at all ITEX sites, but methods need not be standardized due to environmental diversity among sites.

Selection of Climate Station Site

The climate station should be located where surface measurements are representatative for the ITEX site. Avoid unusual topographic settings, such as ridges or slopes. The station should be located within an area of uniform surroundings, and at least 30 m from larger buildings and rocks (as a rule, no closer than at least four times the height of the obstruction).

Comparison with Existing Meteorological Station

Co-operation should be established with the permanent meteorological station located closest to the ITEX site. From there, extract daily means for all parameters common to both the ITEX site and the weather station for the time period the climate station has been operating, and run simple regressions for all parameters. This procedure allows extrapolation of values for the ITEX site during periods when the climate station is not in operation. This is commonplace practice (see e.g., Inouye & McGuire 1991), and pilot studies from LFS show that errors are small early and late in the season (May and September).

Observation Record

Original records (e.g., field record forms [Appendix II], THG charts, logger printouts) should be retained by the research group. Copies of month reports (Appendix III) shall be submitted to the ITEX secretariat as soon as possible after completion of a field season. For accuracy of reported values, see below Level 2 ITEX stations and in the examples (Appendix IV).

Level 1 ITEX Climate Stations

An ITEX site may choose to initiate meteorological measurements with Level 1 as a temporary expedient. A level 1 climate station is entirely manual, and consists of (1) a mercury maximum thermometer, (2) a spirit minimum thermometer, and (3) a precipitation gage. The thermometers should be installed in a shelter cage (Stevenson Screen) and the precipitation gage should be equipped with a conical shielding (see below Level 2 for details and installation recommendations). The following data shall be reported: daily values for precipitation (accuracy 0.5 mm) and type of precipitation (rain, snow, etc.), minimum, maximum, and mean temperatures (accuracy 0.1°C), and daily heat accumulation (see below); use ITEX monthly report form (Appendix III).

Level 2 ITEX Climate Stations

Instrumentation

All ITEX field sites should, as soon as possible, establish Level 2 measurements of climate, if possible on a continuous year-round basis. This climate station can be entirely automatic, but a combination with a manual station inspected twice a day is recommended during the vegetation period. In an ITEX Level 2 climate station the following parameters are to be measured:

1. Air temperature (sun protected at 1.5–2 m above ground)
2. Precipitation (0.5–1 m above ground)
3. Wind velocity (at 3.0 m above ground)
4. Global solar radiation
5. Relative humidity (at least during the vegetation period)

The Level 2 station requires a data logger. Configure it to store hourly means, and (if possible) also daily maximum and minimum records for all channels If the station is entirely automatic you will need a heating device for the precipitation bucket recorder; most loggers are equipped with a feed-back output which can be programmed to be triggered by, e.g., temperatures below freezing. Power supply for logger operations can be a problem in remote field sites; use 12 V car batteries which can be recharged by a portable gasoline generator or continuously charged by solar cells and/or wind generators. If year-round operation is attempted, note that solar cells will be out of activity from November until early March in the Arctic.

The heart of the manual part of a climate station is the traditional shelter cage or Stevenson Screen; wooden, white-painted, and ventilated. The shelter box itself should be at ca.1.5 m above ground, the door facing north (to avoid disturbance when inspecting instruments). The cage should contain:

a thermohygrograph (abbreviated THG) with seven-day drum rotation

a mercury maximum thermometer

a spirit minimum thermometer

a psychrometer (for calibration of the THG instrument)

The thermometers should be installed horizontally on hooks inside the cage. In the case of the maximum thermometer, the bulb end should be tilted somewhat downwards. During stormy weather it is advisable to inspect minimum and maximum thermometers more frequently than usual, since vibrations may drastically disturb the records. The THG instrument may be excluded at Level 2 if electronic air temperature logging is reliable and relative humidity of no interest for your site-specific purposes.

The manual part of the climate station also includes a precipitation gage. Install a standard non-recording gage, protected from wind by a shield or funnel-shaped shelter. Recording mechanical precipitation gages (e.g., Hellman apparatus) are difficult to use in the Arctic since they may become severely damaged when freezing with precipitation water in the bucket.

Soil and bedrock temperature probes are not included in the Level 2 design, since data is difficult to compare among sites if probes are not permanently installed at certain depths and soil types. However, soil temperature data may provide very interesting information for seasonal comparisons at any particular site. Note that soil temperature probes may require weeks (bedrock probes several months) after installation to attain stable values. If you have the opportunity to install soil temperature probes, place the sensors at a depth of 0 cm, 5, 10, 20, 40, and 80 cm.

Additional instruments, recommended but not required at the Level 2 ITEX meteorology, are electronic sensors for snow depth, precipitation, relative humidity, atmospheric pressure, wind direction, and photosynthetically active radiation (PAR).

All equipment (masts, shelter cage, etc.) must be carefully secured with steel wires, preferentially attached to the ground in the bedrock or in large rocks (some rock-drilling will thus usually be necessary). Check that all masts are absolutely vertical 3–4 times every season. Cables should be connected in bundles and protected against physical damage (e.g., by strong winds, grazing raindeer, stumbling polar bears, or clumsy scientists).

As soon as your ITEX climate station is installed, please submit a site description and operation program to the ITEX secretariat; photos will also be helpful.

Measurements

When using a combined manual/automatic climate station two daily observations are required (see Appendix III), at 0700 and 1900 hours normal time. Precipitation for the last 24 hours is recorded at the morning observation, and the gage is reset. Maximum and minimum thermometers are reset after the evening reading. The THG instrument (if present) should be calibrated using a psychrometer at least every time drum charts are replaced (once a week), but preferably twice a day. Temperature measurements from minimum and maximum thermometers, THG, and psychrometer should be taken with an accuracy of 0.1°C. Relative humidity should be recorded with an accuracy of 1 percent. Set time marks on drum chart by gently tapping the plotter arms from below.

In the automatic part of the station, the data logger shall measure air temperature at ca. 2.0 m above ground (the sensor sun-sheltered, preferably placed in the shelter cage of the manual station), global solar radiation, and wind speed (+ additional instruments). Configure the logger to store minute averages and to compress data to hour means and, if possible, hour maxima and minima for all instruments. Data derived from automatic stations should refer to diurnal periods 0–24 hrs normal time. Manual readings of maximum and minimum temperatures taken at 1900 hrs normal time will normally refer to the same time period, since temperature minimum usually occurs a few hours after midnight and maximum in early afternoon.

Temperature records from thermocouples and thermistors (usually logged with an accuracy of 0.01°C) should be reported with an accuracy of 0.1°C, global radiation with an accuracy of 1 W/m^2 (1W = 1J/s), integrated (mean) daily radiation effect (R) with an accuracy of 0.1 MJ/m^2, and wind speed with an accuracy of 0.1 m/s. Use the month report form (Appendix III) regardless of design of your Level 2 climate station. Notes on reading errors etc. should be put in the right margin of the report form or as footnotes. Day numbers (Julian dates; see Appendix I) should be used consistently in all ITEX reports.

Calculation of Daily Heat Accumulation and Degree Days

Daily temperature variation basically follows a sinusoidal function. The integrated daily temperature, i.e., the effective heat accumulation (H), therefore equals the daily mean temperature if there is no lower threshold value taken into account, or if the daily minimum temperature is above that threshold. Within ITEX climate monitoring the lower threshold is set to 0°C. Upper threshold values are not considered to apply in the Arctic. When summarized over a sequence of days, the cumulative heat accumulation units are called ”degree days above 0°C” or Thawing Degree Days (abbreviated TDD), and ”degree days above 5°C” or Growing Degree Days (GDD), respectively (Maxwell 1992). TDD has turned out to be the best measure for correlation with snow-melt, whereas GDD shows the best correlation with plant growth. Degree days should preferably be calculated from May 15 (day number 135) until the end of the vegetation period; use extrapolation from data collected from established nearby weather station if your ITEX climate station is not operating that early or late in the season.

The best measures of daily mean temperature will be obtained from automatically logged temperature data (stored as hourly means) as the mean of all 24 hour mean temperatures. Daily means may also be calculated from maximum and minimum (daily amplitude) only, but the temperature curve will often depart from the anticipated sinusoidal shape resulting in error of up to half a degree centigrade. Similarly, daily TDD and GDD values are preferably derived from hourly temperature means. Simply sum up the hourly means when values are above the set threshold (0° and 5°C, respectively), and divide the sum by 24.

If logger data are not available, daily mean temperature from the manual climate station is calculated as half the sum of maximum and minimum temperatures (i.e., 0.5[Tmax + Tmin]). During a day when temperature never rises above 0°C, H of course equals zero. If, however, the maximum temperature is over 0°C but minimum temperature is below 0°C (a common situation in arctic climate stations), a correction is needed since the preset threshold value cuts off the sine curve, leaving the area below the curve smaller than that above it. In this case, the following calculation shall be used (formulas extracted from Watanabe, 1978):

(1) **D = Tmax — Tmin**
(D = difference between maximum and minimum temperature; daily amplitude)

(2) **p = (Tmax — k) / D**
(p = difference ratio, k = threshold value [0 or 5])

(3) Look up the **p** value in Table 1 below and find the corresponding **h** value

(4) **H = h x D**

Table 1. Parameters for rapid calculation of effective heat units (from Watanabe, 1978).

p	h	p	h	p	h	p	h	p	h
0.01	0.00	0.21	0.04	0.41	0.12	0.61	0.22	0.81	0.35
0.02	0.00	0.22	0.04	0.42	0.12	0.62	0.22	0.82	0.35
0.03	0.00	0.23	0.05	0.43	0.13	0.63	0.23	0.83	0.36
0.04	0.00	0.24	0.05	0.44	0.13	0.64	0.24	0.84	0.37
0.05	0.00	0.25	0.05	0.45	0.13	0.65	0.24	0.85	0.38
0.06	0.01	0.26	0.06	0.46	0.14	0.66	0.25	0.86	0.38
0.07	0.01	0.27	0.06	0.47	0.14	0.67	0.25	0.87	0.39
0.08	0.01	0.28	0.06	0.48	0.15	0.68	0.26	0.88	0.40
0.09	0.01	0.29	0.07	0.49	0.15	0.69	0.27	0.89	0.41
0.10	0.01	0.30	0.07	0.50	0.16	0.70	0.27	0.90	0.41
0.11	0.02	0.31	0.08	0.51	0.16	0.71	0.28	0.91	0.42
0.12	0.02	0.32	0.08	0.52	0.17	0.72	0.28	0.92	0.43
0.13	0.02	0.33	0.08	0.53	0.17	0.73	0.29	0.93	0.44
0.14	0.02	0.34	0.09	0.54	0.18	0.74	0.30	0.94	0.45
0.15	0.03	0.35	0.09	0.55	0.18	0.75	0.30	0.95	0.45
0.16	0.03	0.36	0.10	0.56	0.19	0.76	0.31	0.96	0.46
0.17	0.03	0.37	0.10	0.57	0.20	0.77	0.32	0.97	0.47
0.18	0.03	0.38	0.10	0.58	0.20	0.78	0.32	0.98	0.48
0.19	0.04	0.39	0.11	0.59	0.21	0.79	0.33	0.99	0.49
0.20	0.04	0.40	0.11	0.60	0.21	0.80	0.34	1.00	0.50

Calculation of Integrated Global Solar Radiation

On a clear day, the influx of global solar radiation, measured in W/m^2, is described by a sine function, although often somewhat more leptokurtic than the daily temperature curve. In the daily solar radiation curve, there is no lower threshold value to consider. However, distortions caused by fog, clouds, topography, etc., are common, and the simple calculation of the mean radiation (0.5[Rmax + Rmin]) is a poor estimate, especially during intermittent cloudy conditions. Rmin is mostly close to zero or, in late summer, even slightly negative, and can thus be neglected. At each ITEX site carrying out Level 2 climate recording, the relation between daily mean and the optimum solar radiation hour mean should be calculated. This equation can then be used when records (hourly means) are missing in order to extrapolate daily mean from the optimum value alone. For the Latnjajaure Field Station, daily mean radiation equals roughly 0.3 x Rmax.

Integrated radiation (effect) over a day is obtained as follows. The daily mean radiation should be multiplied by 0.0864 ($24x3600x10^{-6}$) to obtain a value for the total energy influx during the day (R), expressed in MJ d^{-1} (1W = $1Js^{-1}$); see Barry 1992 for more information. Since recording of global radiation requires a data logger anyhow, the best measure of integrated radiation is obtainedfrom the mean of all 24 hourly mean values from 0000 to 2300 hours. As in the case of integrated temperature (degree days), the cumulative record should preferably commence on May 15 (day number 135; see above).

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SNOW AND ICE

Ulf Molau

Snow: Cover, Duration, and Disappearance

Introduction

Snow melt procedure during the summer is one of the most important and powerful ecological determinants in the Arctic, and has a huge impact on phytosociological differentiation within any particular area, as well as on reproductive success within species (Billings & Bliss 1959, Holway & Ward 1963, Bell & Bliss 1979, Isard 1986, Galen & Stanton 1991, Kudo 1991, Molau 1993). Climatic change is assumed to induce drastic changes in snow cover in the Arctic: its depth as well as duration (shifting of time for melt-off and onset of accumulation, i.e., changing the length of the vegetation period).

The response variables measured in ITEX plants in monitoring and manipulation experiments will partly be affected by the timing of the snow melt at the study plot or plant individual. Therefore, at any ITEX site, data on snow disappearance date for permanent plots or plant individuals will be most informative. Not all ITEX field parties will have the possibility to monitor snow disappearance, but as many as possible are encouraged to include this is their monitoring program.

Snow disappearance can be measured in two different ways in the field, either by (1) monitoring of disapperance date in permanent plots/points, or by (2) monitoring the progressive melt-off along a permanent snow accumulation transect, such as a north-facing slope, a snow-bed, or perpendicular to a standardized snow fence.

Permanent Plots or Sample Points

Permanent plots for monitoring flowering phenology of ITEX species are suitable also for monitoring of dates of snow disappearance in a number of years. The recommended ITEX norm for recording of the date when *stable* seasonal snow cover finally disappears in any given area or plot follows Foster (1989): "The date of snow cover disappearance is given as the day when 1 inch of snow (2.5 cm) can no longer be measured at the reporting station (plot) and hence only a trace of snow is observed". Any 1x1 or 2x2 m (or other size) squares are suitable for this method. In cases where monitoring is carried out on permanently tagged individuals or branches instead of plots, use the surrounding square meter at each point as the snow monitoring plots. In order to find plots when still snow-covered, mark the corners with sticks, irons, or plastic tubing, long enough to be found in early spring.

Actual date of disappearance of continuous snow cover is the most important measure in this context. However, even better resolution of effects of climatic fluctuation/change will be obtained if you are able to measure also snow depth in the plots prior to final melt-off. In that case, a subsample of 10 random probings should be taken in each plot at even intervals, preferable every third day.

Always when monitoring snow depth or disappearance date, note time (hour) of the day when measures are taken. In plant species with short prefloration periods (e.g., 8–10 days in *Saxifraga oppositifolia*) it is important to have this accuracy; a tolerance of ± 0.5 days of accumulation of solar radiation effect and cumulative degree days may entirely blur the relationship between microclimate and phenology.

Since the design of this kind of snow cover monitoring will vary among ITEX sites depending on the terrain and the species selection, no standard report forms are provided. Make up site- and species-specific report forms and communicate your annual data to the ITEX secretariat.

Permanent Transects

Monitoring of snow cover and disappearance along environmental transects (such as a slope or across a snow-bed) gives a lot more information than just a sample of plots. In flat tundra plain sites, snow gradients can be induced by putting up permanent snow fences. Along the study gradient, one or (preferably) two straight permanent transects should be marked. For example, in a 100 m long transect, permanent sample points are marked at every fifth meter. End points of transects and some of the sampling points in between should be marked with metal tubings or irons, high enough to be visible above the snow at any time of the year. Make a detailed map of your transect (orientation in degrees, level differences profile); use a theodolite for this survey (no need to buy one, it is usually possible to borrow one from collegues at geology, glaciology, or geography departments).

Once the transect is established, it can be used for monitoring of (1) snow depth until final disappearance at each sample point, (2) the progressive movement of the snow front during the season, and (3) the progressive movement of the flowering and fruiting fronts in various species during the season. Prefloration time, the time lag between snow-melt and flowering in a species, can then be correlated with climatic parameters, e.g., integrated solar radiation and growing degree days (GDD). Snow depth should only be recorded at every third day (otherwise the snow cover will be too disturbed); snow and flowering/fruiting fronts should be recorded daily throughout the season. An example of a protocol developed for a 100 m transect belt at Latnjajaure, Sweden, is added to this manual.

Lake Ice

Introduction

Freeze-up and break-up dates of lakes provide useful estimates of air temperature early and late in the seasons. The applicability of this method was thoroughly tested by Palecki and Barry (1986) in an analysis of data for 63 Finnish lakes. Monitoring of ice conditions and surface water temperature requires little extra effort if there are lakes of sufficient size and depth, and located close to an ITEX site. On the other hand, such records, even if incomplete, will provide useful data for seasonal comparison of temperature regime at the site. Melting of lake ice is a relatively inert process, well buffered against short-time temperature fluctuations within the season, and could be a powerful tool for reliable detection of climate change (in any direction). Running 5-year means of break-up dates or the duration of the annual open-water period tend to sufficiently insensitive to the often large differences between consecutive seasons (see Fig. 1–2).

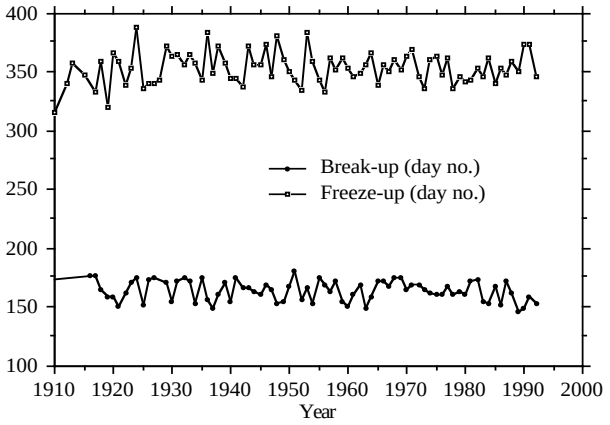

Fig. 1. Ice break-up (lower curve) and freeze-up dates (upper) for Lake Torne, N Sweden, in the years 1910–92. Data from Abisko Scientific Research Station.

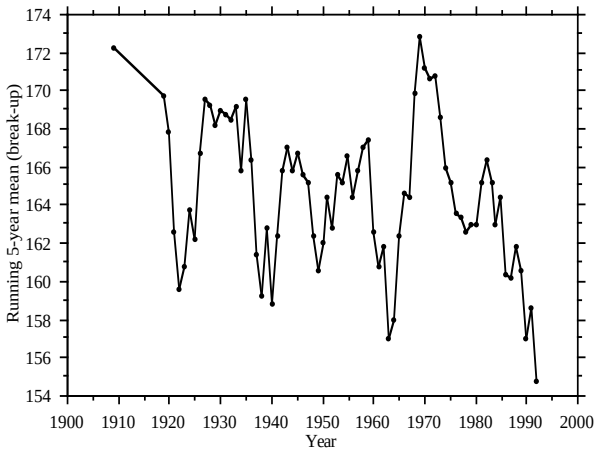

Fig. 2. Running 5-year means of ice break-up in Lake Torne, N Sweden, in the years 1908–92. Data from Abisko Scientific Research Station.

Lake ice break-up and freeze-up dates are primarily governed by average ambient temperature, but distortions may result from thick snow cover in spring and prevailing strong winds in autumn. A good example is provided by the long record (almost 90 years of continuous observation) of Lake Torne, Abisko ITEX site, N Sweden (Fig. 1). The lake has a maximum depth of 169 m and a surface area of 317 km^2; it is long and narrow, and situated at 340 m alt. in a deep valley along the direction of the prevailing westerly winds in the area. The ice is usually snow-free long before break-up, causing little disturbance to the data. Freeze-up in lakes of this size and topographical situation is, however, highly influenced by wind conditions in late autumn and early winter, making those dates somewhat less informative (see Fig. 1).

The opposite conditions are met with at Lake Latnjajaure (at the main Swedish ITEX site), situated close to Lake Torne but at 986 m alt., the surface area is only 1 km^2 but the maximum depth is 43.5 m. Here, break-up dates vary strongly among years due to large variations in snow cover and the fact that much of the lake ice is still snow-covered at the time of break-up. In the autumn, the impact of strong winds retarding final freeze-up is more marginal. In the case of Lake Latnjajaure, there is little correlation between break-up and May and June air temperatures, but surface water temperature during the summer shows high and significant correlation with the climate of the entire season. We lack records for freeze-up, but it is probably strongly correlated with average autumn air temperatures. Thus, the identity of the most informative and reliable data source (i.e., break-up, freeze-up, surface water temperature) varies with size, depth, winter precipitation, and topographical situation of the lake. A pilot study using all variables during the first 2–3 years of monitoring will solve the problem.

Recommended Methods

Select a suitable lake close to the ITEX field site (recommended minimum size: 0.5 km^2 surface area, 5 m depth). Preferably, surface water temperature (uppermost 5 cm), break-up/freeze-up stage, and ice cover should be recorded daily as an addition to the manual weather observation at 1900 hours normal time. Ice cover of lake surface is normally reported with an accuracy of 5–10 percent. For very large lakes, observations are made only for a particular area of the lake in question. A protocol for ITEX lake ice monitoring is provided in Appendix VI. Use the following classification of lake ice stages (modified from Palecki and Barry 1986):

Break-up:	B0	No sign of break-up
	B1	Open water on shore
	B2	Open water offshore
	B3	Ice in movement
	B4	Final break-up
Freeze-up:	F0	No ice formation
	F1	Ice formation on shore
	F2	Ice cover on bays
	F3	Ice within visible range
	F4	Final freeze-up

The dates of final break-up (B4) and freeze-up (F4) are the most commonly used ones in seasonal comparisons. Palecki and Barry (1986) used simple linear regression with these events as dependent variables and mean air temperature the preceding month(s) as the independent ones. For the Finnish lakes, a 5-day displacement of break-up or freeze-up dates resulted from a change of the magnitude of 1.0–1.1°C in mean April and September temperatures, respectively.

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ACTIVE LAYER PROTOCOL

Fritz Nelson, Jerry Brown, Toni Lewkowicz, Al Taylor

Introduction

The active layer, the zone of annual freezing and thawing between the atmosphere and permafrost, is the locus of several important sets of dynamic processes, including biological, pedologic, geomorphic, biogeochemical, and hydrologic. Despite its importance to a wide variety of physical and biological investigations, information about development of the active layer has rarely been collected in a systematic, standardized fashion over large areas.

Ideally, active layer data should be collected at regular intervals from the time of snowmelt until the annual freezeup. These data should be collected to obtain a statistical characterization of active layer thickness in representative terrain and vegetation types, on an interannual basis. The ITEX experiments offer excellent opportunities to obtain long-term records of active layer fluctuations in response to climate and soil factors. Similar goals exist in other international activities, including those of the International Permafrost Association (IPA) and its working groups on Permafrost and Global Change and Periglacial Processes and Environments (see the IPA News Bulletin Frozen Ground, no. 16, December 1994).

The majority of the historical record on thaw depth (at least in the North American Arctic) has been obtained using small-diameter metal rods to probe for the bottom of the active layer. Other methods include frost tubes (Mackay 1973, Rickard and Brown 1972) and measuring and recording ground temperatures; both approaches yield high-quality data, but are necessarily restricted in their ability to provide spatial information. Physical probing has the advantage of being the most practical, low-cost method of nondestructive and areally extensive data collection. However, in coarse and bouldery soils, and in deeper active layers (>1.5 m), probing becomes impractical and other methods should be considered.

Sampling Design

Active layer thickness is known to vary substantially over very short distances. Sampling design is rarely treated explicitly in publications describing studies of thaw depth in the Arctic, but appears to have involved two commonly used methods: 1) linear transects, with measurements made at equal intervals; and 2) unspecified "random" selection of measurement locations. The potential exists for several types of inaccuracy in collecting active layer data using transects, equally spaced observations, and purely random methods. Transects may not be aligned with environmental gradients, leading to erroneous conclusions about spatial patterns of thaw depth and fallacious inferences about environmental controls. In the presence of such spatial regularities as patterned ground, equally spaced observations may lead to serious under- or over-estimates of active layer thickness. Probing locations chosen using a purely random design generally do not provide good areal coverage, and may be difficult to locate. A standardized set of measurements, obtained using an explicitly spatial sampling design, yields information useful for examining interrelations between physical and biological parameters. Grids measuring from 100 to 1000 meters on a side are adequate under most circumstances for making estimates of active layer thickness in representative vegetation.

Extensive experimentation, both in the field and through simulation, indicates that the most effective and economical sampling design is the systematic stratified unaligned (SSU) sampling scheme advocated by Berry and Baker (1968), Iachson (1985) and several other workers, including the comprehensive treatise by Thompson (1992). Validation of the design's effectiveness in the context of active layer variation was demonstrated for northern Alaska in a thesis by Fagan (1995). The SSU design is relatively easy to implement in the field using either pacing or more precisely measured distances to locate individual sampling points. It also provides excellent areal coverage and avoids problems that might otherwise be introduced by the presence of such spatial regularities as sorted or nonsorted patterned ground.

The SSU design, implemented on a series of grids, is consistent with recommendations proposed by the International Permafrost Association for the Circumarctic Active Layer Monitoring program (CALM). For ITEX purposes, the grids should be sampled once each year, at the end of the summer, although more frequent sampling is desirable to gain information about the relation of thaw progression to climate and phenology.

Recommended Procedures

A two-level, active layer measurement program at all ITEX sites is recommended. Level 1 measurements consist of monitoring active layer thickness with a metal rod in close proximity to each ITEX site and an associated grid. Level 2 measurements involve permanently installed devices using a combination of frost tubes and data loggers.

The Level 1 measurement program provides information about the rate and maximum depth of thaw in and around ITEX open-top chamber (OTC) sites. Measurements are made with a thin, rigid metal rod (less than 1 cm in diameter) calibrated in centimeter increments, and pushed vertically into the soil to the depth at which ice-bonded soil provides firm resistance. When removing the rod, extreme care should be taken to prevent disturbance to the soil and

vegetation. The Level 1 program consists of three parts. Two data forms for use in the field are provided as Appendices (See data forms in appendicies VI and VII).

OTC Measurements:

In each of at least 25 OTCs, active layer thickness should be measured at the center point within one day following the onset of snow free conditions. At the beginning of the growing season (first two weeks), measurements should be made daily or at two-day intervals. Thereafter, measurements should be made once during midseason, and again at the end of summer. Data can be recorded and average values computed on the OTC/Control active layer form provided in the appendix to this manual.

Control Measurements:

A total of 100 points per sample period are to be probed in areas immediately surrounding the OTC controls. In the case of 25 OTC sites, four measurements of thaw depth should be made at each control, at approximately seven-day intervals. If there are between 25 and 50 OTCs per site, three measurements per control are adequate. If 50 or more OTCs are available, two measurements per control are adequate. The specific point locations to be probed can be varied slightly from week to week to prevent any cumulative effect from minor disturbances. Care should be taken to prevent disturbance by trampling during the repeated measurements. The control measurements will provide the basis for comparison with the seasonal OTC measurements at each site. The total of at least 100 points at weekly intervals will provide a basis for intersite comparison and an assessment of seasonal progression. Data can be recorded and average values computed on the OTC/Control active layer form provided in the appendix to this manual.

Standard Grid Measurements:

At least one 100 m grid should be positioned to incorporate as many OTC locations as practical. At ITEX sites with widely dispersed OTCs, additional or larger grids may be established. Measurements are made once each summer, at the latest date possible, but prior to the annual freezeup. More frequent measurements are highly desirable, and can be made as time and resources permit.

Step 1:

Establishment of Grid. The SSU sampling design is implemented for a 100 m grid by dividing the area of interest into 100 square subareas (strata), each 10 m on a side. The grid can be established to a sufficient degree of accuracy using compass and pace methods. Mark the four outer corners of the grid with wooden stakes or metal rods that will remain in place permanently. If Global Positioning System (GPS) equipment is available, the locations of these markers should be recorded with the best accuracy possible. Grid intersections can be marked permanently with a series of wooden stakes, which can also serve as sites for supplemental snow, soil or vegetation observations.

Step 2:

Selection of Sampling Locations Within Grid. A standardized set of measurement points, located within the grid cells according to the SSU design, appears on the gridded data form (see appendix to manual) and is used to establish the sampling points. The intersection of the row and column coordinates within each cell represents the sampling location within that unit, and can be located precisely using a steel tape, or with accuracy to about one meter by pacing from the southwest corner of the grid cell. A permanent marker should be placed at each sampling point to insure measurements are made at the same location in subsequent years. The gridded data form can be used with a clipboard for recording thaw-depth measurements in the field and computing the average value per sample interval. If a sampling location is found to be inaccessible or under a water body, this grid cell may be permanently eliminated from consideration.

Step 3:

Measurement. Standing at a sampling location, the observer inserts a metal rod to the depth of resistance and records the value directly on the gridded data form (see appendix). If time permits recording two measurements per site is desirable, as it provides a measure of the robustness of the sample. Such duplicate measurements should be made 1 m apart. If for some reason (e.g., a subsurface stone) the observer considers an observation to be unrepresentative or biased, replacement should be made by turning to the opposite direction (rotating 180) and making another measurement. If a complicating influence (e.g., areas of stony material) extends over the area surrounding the sample location, the observer should move in 1 m increments toward the southwest corner of the grid until its effects can no longer be discerned. The marker for that stratum should be moved to the new location.

Level 2 measurements apply to a limited number of permanent measurement devices installed at OTC sites or landscape or vegetation units representative of the ITEX site. Level 2 measurements have two components:

Frost Tubes:

When read periodically, frost tubes provide information about seasonal progression of thaw and maximum seasonal thaw. A first-year pilot effort will be

made in 1995-96 by providing a limited number of prefabricated frost tubes for use at selected ITEX sites. The location of the frost tubes should be inside the perimeter of the ITEX grid. The exact position of a single frost tube should be determined at the end of the first summer of active layer measurements by selecting a point having the mean active layer depth for the entire grid. Installation details, including observational details, will be provided to those users at a later date.

Soil Temperature Recorders:

Soil temperature can be incorporated into instrumentation currently in use at specific ITEX sites, or can employ miniature data loggers, such as the HOBO manufactured by Onset Computer Corporation (Pocasset, Massachusetts, USA). Soil temperature in OTCs and control sites should be recorded at approximately one- hour intervals, measured at a sensor depth of 15 cm, on a seasonal or annual basis (in the case of the HOBO miniature data logger the time interval is 1.2 hours). Soil temperature data should be summarized using temperature conventions employed in the ITEX Climate Station report forms.

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TEMPERATURE ENHANCEMENT EXPERIMENTS

Giles M. Marion

Introduction

Since the initial ITEX meeting at Kellogg Biological Station (Michigan State University) in December 1990, the manipulation of temperature around tundra plants has been the subject of intense discussions. Over the past two years a number of investigators have field evaluated several designs for manipulating temperature around tundra plant species (Debevec and MacLean 1991; Marion and Pidgeon 1992; Marion et al. 1993). These designs included: greenhouses, open-top chambers, ground covers, and wind shields. Materials used included fabric, plexiglass, fiberglass, and plastic.

At the Boulder meetings (March 1992), a consensus was reached that for the Level I experiments, the temperature manipulations should: (1) be permanent structures that can be left in place year-round, (2) be structurally strong to withstand high winds and extreme cold, (3) give a significant temperature enhancement, and (4) minimize unwanted ecological effects. These constraints virtually forced some type of "open-top" design. Advantages of open-top designs over complete enclosures include: (1) lower temperature extremes, especially on sunny days, (2) better light quality and quantity due to more direct solar radiation to plants, (3) more natural levels of humidity and CO_2 levels around plants, (4) more direct precipitation, and (5) easier access of pollinators and herbivores to plants.

At the 4th ITEX Meeting in Oulu, Finland (December 1992), a consensus was reached that the open-top fiberglass chamber would be the method of choice for temperature manipulation and the "ITEX Corners" would be an alternative design for the ITEX experiments (Fig. 1). The principal advantage of the open-top chambers vis-a-vis the ITEX corners is a greater temperature enhancement because these chambers act both as windshields and solar traps. Advantages of the ITEX corners vis-a-vis the open-top chambers include lower cost, ease of installation, and easier access to plants.

The objective of this section of the ITEX Manual is to describe the construction of the ITEX designs and to recommend how temperature should be measured in the chambers.

Temperature Enhancement Devices

Two open-top enclosures (cone and hexagon) were field tested and are suitable for the ITEX experiments (Fig. 1). The cone and hexagon designs share two important features. First, both are made of Sun-Lite HP (0.040 inch thick), a fiberglass material especially designed for solar applications. This material is made by: Solar Components Corporation, 121 Valley St., Manchester, New Hampshire, 03103 USA (telephone: 603-668-8186). This material has a high solar transmittance in the visible wavelengths (86%) and a low transmittance in the infra-red (heat) range (< 5%). A second feature that these two chambers share is that both have inwardly inclined sides (60° with respect to the horizontal). There are two major

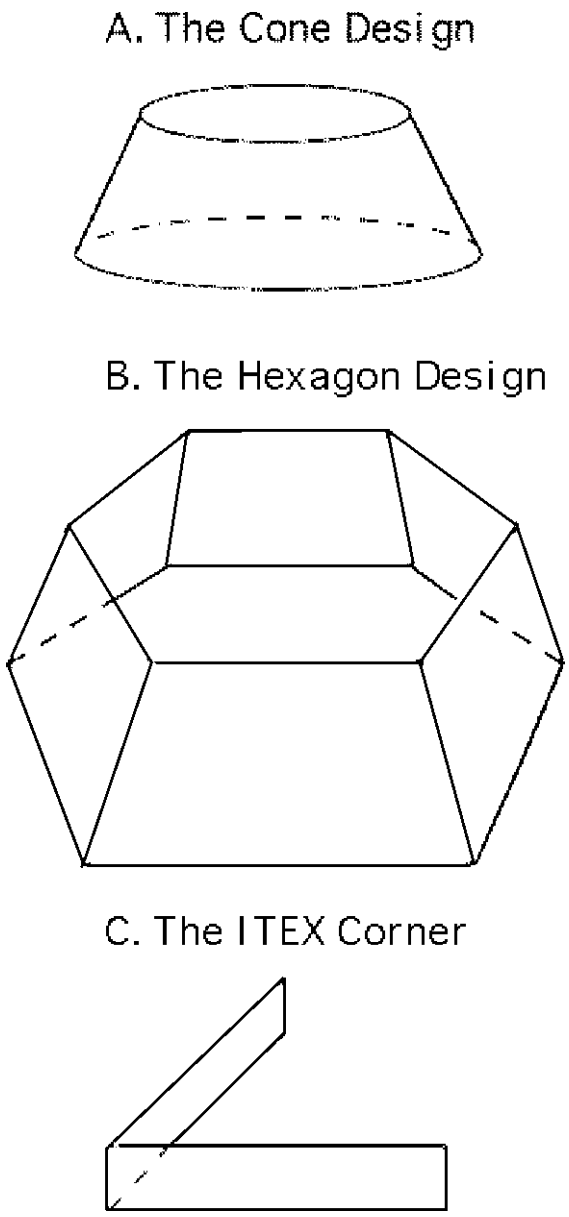

Fig. 1. The ITEX designs.

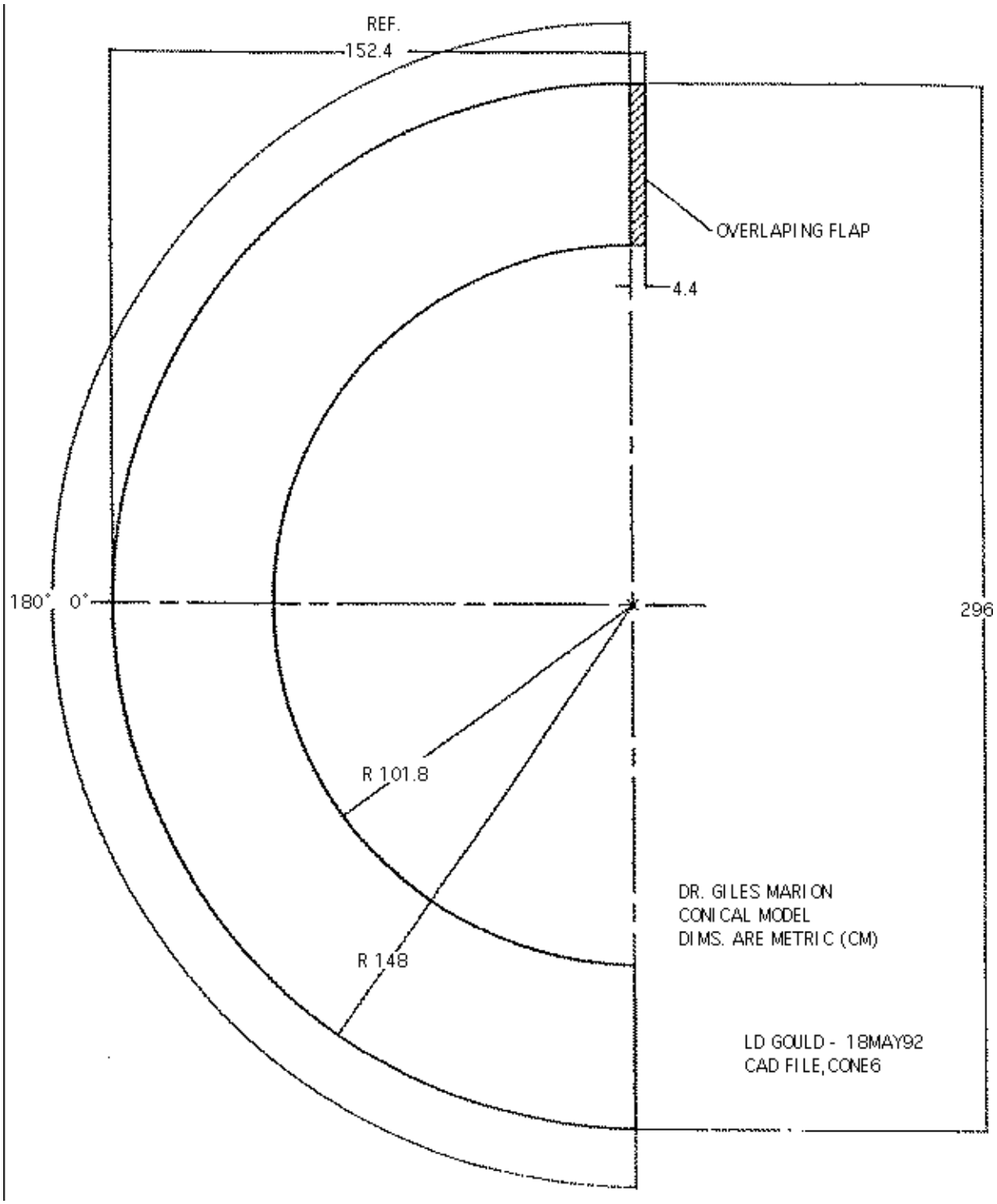

Fig. 2. The two-dimensional pattern for building a 60°, 40 cm tall, 1.48 m basal diameter cone chamber.

reasons for the inclined sides. First, and probably foremost, the inclined sides help trap part of the heat within the chamber like a greenhouse. Second, the inclined sides are more favorable for transmitting solar radiation into the chamber. Optimal transmittance occurs when solar radiation strikes the surface at a right angle.

Advantages of the cone include a simpler design (one piece) which should be structurally stronger with less ground shading than the hexagon. Advantages of the hexagon are that it can be built to larger sizes and is less wasteful of fiberglass material. A disadvantage of both designs is that some sort of portable scaffolding is needed to access the interiors of the chambers for monitoring purposes.

Cone

Figure 2 is a pattern for building the maximum diameter 60°, 40 cm tall cone chamber. The maximum sheet width of the Sun-Lite HP fiberglass is 152.4 cm (5 ft) which limits the maximum basal diameter to 1.48 m. The geometry of a 60° cone is simple in that the arcs that must be cut are exactly 180°, plus a little extra for the overlapping flap (Fig. 2). The Sun-Lite HP fiberglass material is sufficiently flexible that it can be cold bent into the proper cone shape (Fig. 1) and is held together with nuts and bolts. Note that the radius of the 2-dimensional pattern is equal to the diameter of the 3-dimensional cone.

To build a smaller diameter 60° chamber requires specifying the chamber height and diameter; all other dimensions fall out from geometric relations. For example, specifications for a 30 cm tall chamber with a 50 cm top opening are diagrammed in Figure 3. Given the 60 ° angle and the 30 cm height, the hypotenuse is 34.6 cm and the base of the side triangles are 17.3 cm. This leads to a basal diameter of 84.6 cm for a top diameter of 50 cm. The corresponding radii of the 2-dimensional arcs (Fig. 2) would be 84.6 cm and 50 cm, respectively.

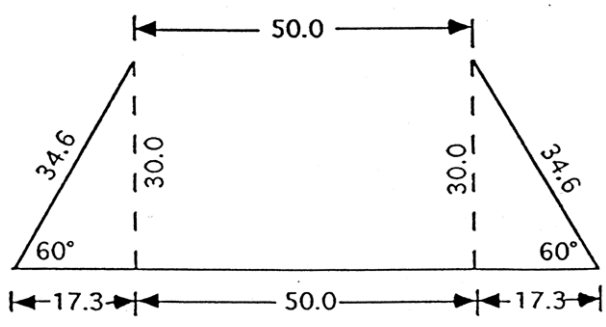

Fig. 3. A schematic for building a 60°, 30 cm tall, 50.0 cm top diameter cone chamber.

Hexagones

Specifications for building a 50 cm tall, 1.5 m open-top hexagon are included in Figures 4 and 5. This is the design currently being used by Greg Henry and Michael Jones on Ellesmere Island, Canada. Building smaller or larger chambers will require appropriate scaling changes. Fixing the 60° inclination of the panels, the height, and a diameter (basal or top) fixes all other dimensions through geometric relations. Michael Jones recommends cold temperature and UV resistant cable ties as ordinary ties experienced some breakage.

An alternative material for the hexagon design is LEXAN™ (or equivalent UV-resistant Polycarbonat Ultra®). The advantage of this material is that it can be cold bended and is almost unbreakable which makes it possible to use a more simple design (Fig. 6). This type isused all around the year at several european sites. Due to material costs this design is more expensive than the fiber-glass hexagone.

The fibre-glass OTC consists of six pieces which have one side bend 60° inwards so the margin will tighten to the next side (Fig. 6). Three pairs of holes are drilled at each side where cable ties fit the sides together (Fig. 6). The lower corner of the overlapping part makes the OTC stick better (freeze winter time) to the ground. The most frequently used size has 60.0 cm side (plus 4.0 cm margin) which gives a side-to-side basal diameter of 104 cm. Other sizes can be calculated using previously descibed geometry. Attachment to ground will be sufficient with three, approx. 3mm, UV-resistant wires (polyuretan) to the ground. Recommended thickness, and most commonly used, of the plexiglass is 3 mm. In Finland, Urban Nordenhäll is using 2 mm material, which is somewhat cheaper but the hexagone will not be as stable as with the thicker one. This has caused some temporal deformation, fromheavy snow-pressure during winter on the OTCs placed in slopes.

ITEX corners

The ITEX corners are designed to shield plants from winds which provides a heating effect immediately around the plant (Fig. 1). The shields are made of translu-cent plexiglass (Lexan) 2 mm in thickness. This material transmits about 90% of the photosynthetically active radiation and is sufficiently flexible to be bent at a right angle. For small rosette plants, a 10 cm high shield with 50 cm sides is recommended with the plant approximately 10 cm from each side. For larger plants these dimensions can be scaled up. Work on Disko Island, Greenland by Per Mølgaard indicated that the corners created the largest temperature enhancement when the opening faces toward the south. This direction provides maximum direct solar radiation to the plant and surrounding ground.

All chambers and corners need to be staked to the ground. Where strong winds prevail, one might also consider guy wiring, especially to windward, for additional protection.

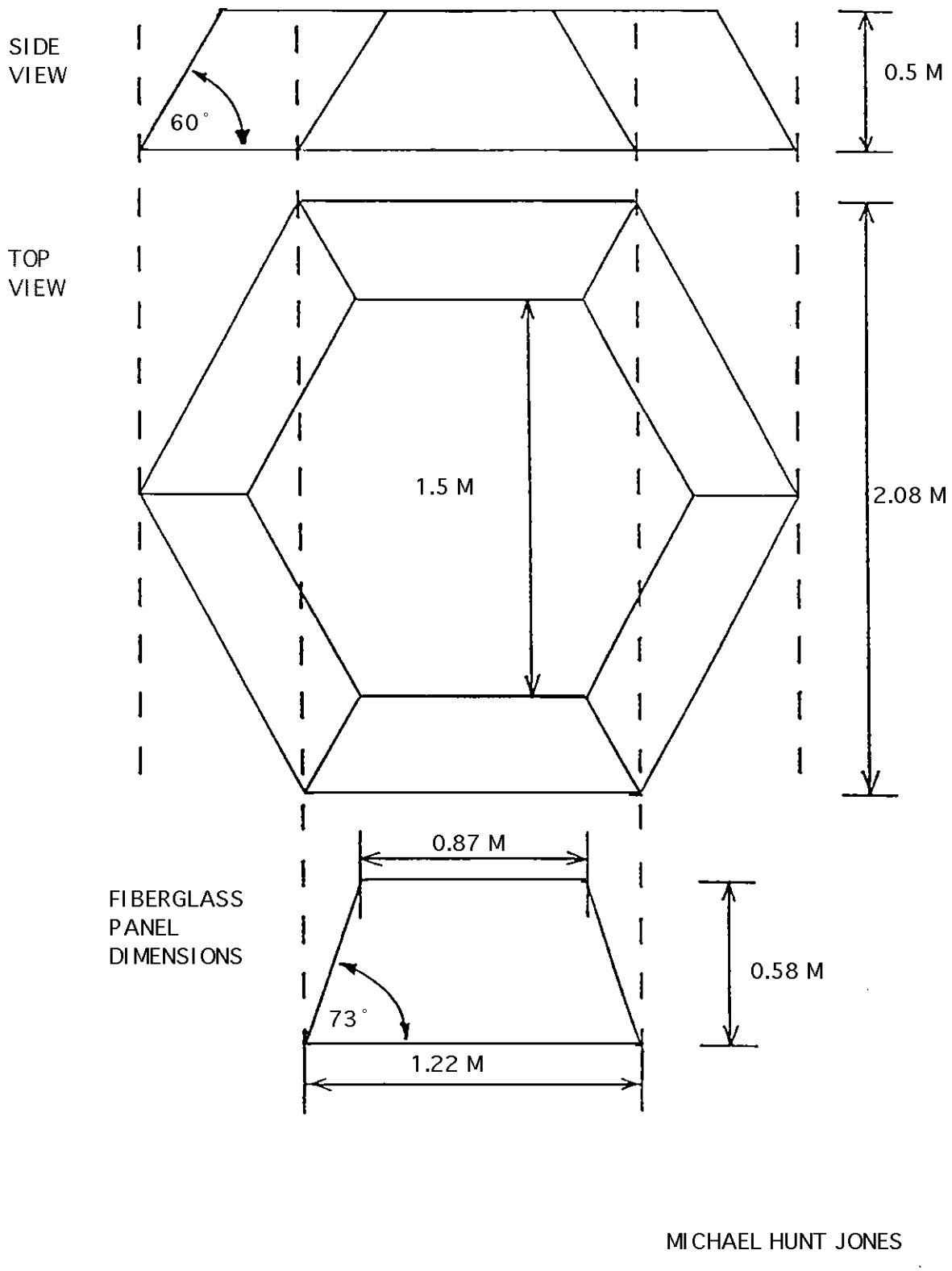

Fig. 4. Schematics for building a 60°, 50 cm tall, 2.08 m basal diameter hexagon chamber.

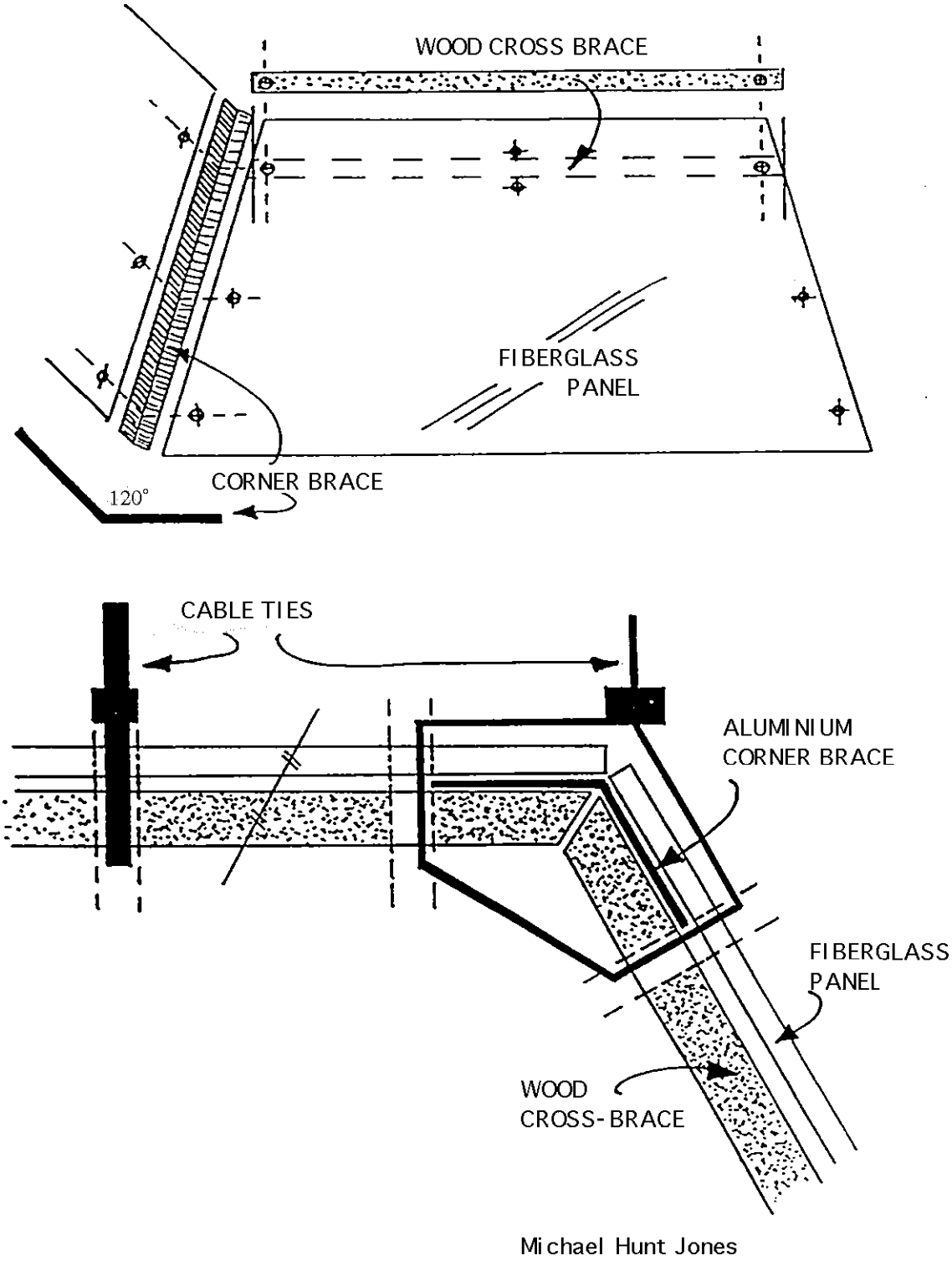

Fig. 5. Schematics for building a 60°, 50 cm tall, 2.08 m basal diameter hexagon chamber.

Temperature Measurements

We recommend that temperatures within chambers and in control areas be monitored hourly with daily minimum, maximum, and mean temperatures recorded. We recommend that soil surface temperature be measured by thermocouples or thermistors in a position shielded from direct solar radiation (e.g., beneath vegetative cover). Within each chamber (or control site), a minimum of 4 temperature sensors should be used with a minimum of 20 replicate chambers (or controls).

The number of replicates (r) needed to detect a difference of a given magnitude (d) is given by:

$$r \geq 2\,(t_0 + t_1)^2\, s^2/d^2$$

where s is the standard error, t_0 is the t value associated with Type I error, and t_1 is the t value associated with Type II error (Steel and Torrie 1960). This equation simplifies to:

$$r \geq 2\,(t_0 + t_1)^2$$

where the difference to be detected (d) is equal to the standard error (s). For a completely randomized experiment with two treatments (warmed versus control) with probabilities of Type I error = Type II error = 0.1, the required sample size = 18 (df = 34). For probabilities of Type I error = Type II error = 0.05, the required sample size = 28 (df = 54). We compromised and selected 20 replicates which provides protection from Type I and II errors of < 0.10.

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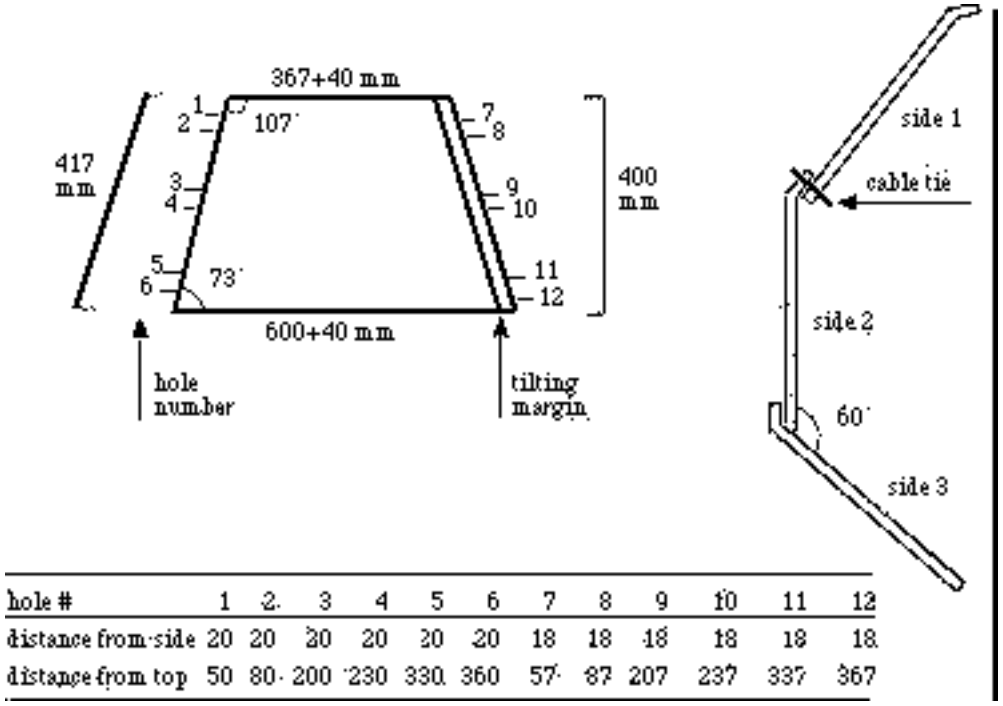

hole #	1	2	3	4	5	6	7	8	9	10	11	12
distance from side	20	20	20	20	20	20	18	18	18	18	18	18
distance from top	50	80	200	230	330	360	57	87	207	237	337	367

Fig. 6. Schematics for one plexiglass OTC side and how they are fitted to each other. Diameter of the holes ca. 4 mm. If hole number 4 and 10 are used as attachement point for the attachment wires then use 5-6 mm holes.

PLANT RESPONSE VARIABLES

Ulf Molau and Sylvia Edlund

Revised version, developed after the 5th ITEX Workshop, St. Petersburg, Russia, March 1994; updated March 1996.

Introduction

This chapter deals with monitoring of the plants' responses to ITEX temperature enhancement with Open-Top Chambers (OTCs) or ITEX Corners. In this context, controls in non-manipulated situations are essential. Furthermore, permanent tagging, also of control plants during the implementation of ITEX, could prove to be extremely valuable in the future as biological monitoring stations during an anticipated climatic change. Therefore, careful tagging of the selected plants using long-lasting materials is important and worth the effort. Note that all ITEX monitoring should be non-destructive, thereby maintaining the informative value of the selected plant individuals for many years.

After the general recommendations for sampling, tagging, etc., the eight ITEX Group 1A species or species groups are presented (one by one, in alphabetical order), and the selected phenological and quantitative response variables defined. The present selection and definition of response variables was approved during the Fourth ITEX Workshop at Oulu, Finland, in December 1992, and updated during the Fifth ITEX Workshop at St. Petersburg, Russia, in March 1994. For each species there is a protocol (ITEX report form) in the Appendices to the Manual (VII–XVI). Each sheet can accomodate eight different phenological dates (P1–P8; all to be given as day numbers [see Appendix 1]), and eight quantitative measurements (Q1–Q8) for 20 experiment plants (in OTCs or ITEX Corners), and 20 control plants. If more than 20 + 20 plants are monitored, just add an extra protocol page and re-number the plants (left column). The blank protocol (Appendix XVII) can be used for Group 1B species, where any suitable response variable can be defined, and for more detailed studies of 1A species if additional variables are desired.

The selected response variables cover events during most of the vegetation period. This does not imply that sites operating over shorter periods of time are excluded; reports on smaller numbers of response variables are equally valuable for among-year and inter-site comparisons as long as the 20 + 20 minimum sampling design applies. Try to include as many of the ITEX species as possible in your monitoring program; even if you are not able to carry out the warming experiment for all of them, your monitored unmanipulated controls may turn out extremely valuable in a near future if the anticipated warming of the Arctic proceeds according to the IPCC prognosis.

All ITEX sites should communicate their results to the respective "species co-ordinator". The resulting publications will be of the multi-author type, including all active collaborators.

Please communicate experiences of the methods, particularly the bad ones, and suggestions for improvement to the authors or to the ITEX secretariat. Comments and additions to the Manual will appear in the ITEX Update newsletter.

General Recommendations

Sampling

Random sampling of study plants is recommended, but in homogeneous habitats with relatively even distribution of plants, a systematic design (e.g., grid-net) is equally adequate and more easy to overlook and manage. Sampling at regular intervals along random transects is often the best method. In cases of sparse distributions, every possible plant will be involved in the monitoring. Controls should be selected in the same way as the typically 20 experiment plants (genets or ramets depending on species, habitat, and growth form); they should be of the same number and represent a similar distribution of size classes and developmental stages, and they should be situated as close as possible to the OTCs or corners without being influenced by their presence (i.e., at least 1 m apart in the case of OTCs, less for ITEX Corners). In order to avoid pseudoreplication (see Hurlbert, 1984) make sure that each plot, OTC, or part of OTC has its own parallel control.

For species with tufted or cushion-like growth forms, entire clones (genets) should be used as monitoring units. In cases where clones are difficult or impossible to discern (as in rhizomatous and mat-forming plants), sample plots should be used instead (0.5 x 0.5 or 1 x 1 m squares). It is often good advice to divide the ground surface covered by an OTC into four quarters, and select the specimen closest to the center of each quarter for monitoring; in that case the control plot beside the OTC should be of the same size and divided in the same way. For woody plants where genets can be difficult to separate or are too large to be handy (e.g., *Cassiope* and *Salix*), branches (ramets) are easy to delimit and should be used as the monitoring units. Note that there is one phenological variable common to all protocols, namely P1: date when the ground is snow free at the sample point.

When chosing sites and plots, try to find those as closely representative of the climate station site as possible. Choose horizontal areas if possible. Avoid areas with extreme aspect. Gentle, north-facing slopes could also be considered; a transect down slope might also be suggested.

Always make detailed map of the sites; use theodolite if available. Please undertake an indepth site description, including location, aspect, materials, drainage, floristic composition, etc. Information on depth and dissappearance of snow at study plots are very valuable, if available (see Snow & Ice). Photographic documentation of sites is extremely valuable, especially in a longer perspective and if photos are adequately filed or published.

Permanent Marking

Each study plant or plot should be labeled with a code number (E1–E20 for experiment plants, C1–C20 for controls). Labeling should be made using metal tags. There are many possibilities, but the most practical ones are (1) soft aluminum write-on tags that you can emboss with a pen, and (2) aluminum DYMO™ bands. More elaborate (and expensive) methods include bird banding rings (for branches of woody plants) and metal signs of the botanical garden type.

For cushion plants and tufted clones ("Sax opp", *Eriophorum vaginatum, Oxyria*, in certain habitats even *Cassiope tetragona* and *Dryas*), use soft steel wire ca. 1 mm diam., 20–30 cm long. Form it into a U-shape, penetrate the soil with one end, some 5 cm from the clone center, and push it down to encircle parts of the root system. Push it out until it surfaces. Attach metal tag, and twist together the ends of the wire.

For tagging ramets of woody plants like *Cassiope tetragona* and *Salix arctica*, just attach the metal label to the stem with wire, making sure it is not too tight. It is good advise to draw a diagrammatic sketch map of each ramet. Annual growth increments are usually easy to delimit; if there are problems seeing where previous growth ceased, consider some kind of marker (e.g., "White Out") to mark ends of branches at the end of the season.

For marking permanent square plots (0.5 or 1 m square), consider corner marks of aluminum profile or stiff, plastic tubing, stuck in the ground to a depth of 0.3–0.5 m with only 2–3 cm visible above ground. Drill holes in the corner marks ca. 1 cm from top and outline the square with 2 mm white polyester rope. An aluminum label with the appropriate code can be attached to one of the corner marks. Again, we recommend drawing a sketch map for each square plot.

If the study site is regularly visited by tourists, don't forget to put up information signs. And if your study area is frequented by grazing animals, it may be necessary to fence the control plots or plants with chicken wire.

Monitoring

All ITEX monitoring should be non-destructive. The response variables are grouped in two main categories, phenological (P) and quantitative (Q), both comprising vegetative as well as reproductive traits. Phenological dates are always recorded as day numbers (Julian dates; see Appendix 1). Plants should be monitored daily, if possible – particularly during periods of rapid change, such as break of dormancy, onset of flowering, and fruit maturation; during periods of slower progress, monitoring every 2–3 days is sufficient. Observations on a particular plant or set of plants should always be made at the same time of day!

For determination of weight of fruits, seeds, leaves, etc., store the plant parts dry in paper bags for two months at room temperature before weighing.

Seed germinability

If possible, make a germination experiment for each species monitored at your site. Pool all seeds after weighing, and divide the entire sample into four weight classes. Subsample by random into four replicate sets of 20 seeds from each class, saw the seeds on filter paper in Petri dishes, soak them with clean water and put the dishes in a randomized block design under 16 hours of light per day at ca. 22°C. Take daily records of the number of germinated seeds per dish and remove the germinated ones instantly. Calculate the mean weight for each weight class. With those results at hand you may now plot seed weight against a fitness parameter (germinability or germination rate); by simple regression calculate the appropriate formula to be applied to your data sheet. Determine the minimum weight for seeds to be germinable at all, and for all sampled seeds above that threshold value, use the formula to convert weight into a more refined estimate of reproductive success (RS). The simplest one is germinability (the percentage of germinable seeds) but a better estimator of RS is relative germination rate (Molau, 1991). Use the formula

$$\text{relGR} = \sum[(S^t - S^{t-1})/(N \times \ln t)]$$

where S^t is the number of seeds germinated until day t, and N is the total number of seeds in the subsample. Replace seed weights in your data matrix with relGR values according to your regression formula. This method was very successfully used for seeds of *Dryas*, *Eriophorum*, and *Ranunculus*, and for *Polygonum* bulbils from Latnjajaure. It is good advice to carry out this experiment once per species at each ITEX site, since seed weight relations with RS estimators may differ among sites within the same species.

Miscellaneous

Take detailed notes on all kinds of disturbances (including timing) on the selected plant individuals, e.g., damages by grazing, fungal infestation, seed predation by insect larvae, etc. Also take notes on occasional snow cover during the summer, and how periods of freezing affect the plants. For example, Cassiope flowers may drop at peak anthesis

if exposed to below-freezing temperatures for several days, thereby spoiling most of the sexual reproduction of the season.

Note the general state of the same species in the area: are the monitored plants in synchrony with their neighbors? Take notes on aberrant phenological events in the area, e.g., early flowering by early emergence from snow or on south-facing slopes. Some of the early-flowering species may have a tendency to re-flower in late summer (late August) if the microsite has been unusually warm. Watch out for this phenomenon, especially in the OTCs. It is not uncommon in *Saxifraga oppositifolia* and may appear also in *Cassiope tetragona*. Flowers of such "second waves" represent bud-break one season too early and are rarely perfect; usually the anthers are poorly developed, and the flowers will thus be functionally female and will not set seed.

Permanently marked genets, ramets, and plots can also be used for monitoring of flowering phenology (pattern, velocity, and density). Simply count the number of open flowers per sample plot at even intervals, daily if possible. Take the records at the same time of the day throughout the flowering period. This simple investigation usually yields very useful results, where the shape of the curve for a population is correlated to reproductive strategies of the species. Early-flowering outbreeders show innate, dome-shaped, unskewed curves, where there is no difference in shape among years, but height of peak flowering (absolute maximum momentaneous number) is correlated to climate and performance. Opportunistic and predominantly selfing species, on the other hand, show more ragged curves. Differences between years or species can be tested with a modified *t*-test (see Molau 1993b for further details).

Take notes on observed insect pollination (note pollinator, timing, and activity). Finally, note natural germinantion of the monitored species. Does it occur at all?

Species-Specific Response Variables

Bistorta vivipara

The Alpine Bistort, *Bistorta vivipara* (L.) S.F. Gray *(former: Polygonum viviparum* L.), is common throughout the Arctic as well as in subarctic and temperate alpine areas. It is a late-flowering species thriving in more nutrient-rich habitats, such as alpine meadows. The inflorescences comprise an unusual mixture of bulbils (vegetative diaspores) in the lower half and sexual flowers in the top portion (sometimes missing). The flowers are mostly female, and sexual reproduction does not occur in most populations, although specimens with hermaphrodite flowers and seed production have been found in the Arctic and the Alps (Bauert 1993)

It possesses rhizomes, and clones (genets) are hard to delineate, even though variation in bulbil color may be helpful. The bulbils are vigorous diaspores, and newly germinated ones are a common sight in seepages and along creeks in late summer. Bulbil weight has turned out to be highly sensitive both to temperature and to nutrient manipulation (Molau, unpubl.; Wookey et al. 1994). Bulbil color reflects genetic variation within and among populations (Bauert 1993), and the bulbils are furthermore an excellent material for cloning in common garden experiments and for allozyme electrophoresis. Germinability of bulbis can be tested in the same way as for seeds (see Plant Response Variables)

Randomly select 20 OTC and control plants in your plots, or divide each plot into four quarters, later selecting the reproductive shoot appearing closest to the center of each quarter as the specimens for monitoring. Make a note if they do not develop an inflorescence in a specifik year, which can be used to compare reproductionintensities between years. Randomly select supplementary individuals for all non-reproducing plants each year in order to achieve a total sample of 20+20 plants with inflorescences. This species, particularly the inflorescences, is also very palatable to grazers, and at some sites fencing of controls with chicken wire can be necessary. Note when infloresences or leaves have been lost due to grazing.

PHENOLOGICAL DATES (day numbers)

P1: Date snow-free

P2: First leaf unrolls (original set of plants)

P3: Inflorescence appears between sheath (=ochrea; original set of plants)

P4: First flower open (original and supplenentary plants)

P5: First bulbil shed (drops off when touched; original and supplement plants)

P6: First seed dispersal (optional, since rarely observed sexual reproduction)

QUANTITATIVE MEASUREMENTS

Q1: Length of inflorescence stalk (at full flower; from ground to top of raceme, in mm)

Q2: Width of largest leaf (in mm)

Q3: Number of leaves per individual

Q4: Number of bulbils per shoot

Q5: Number of flowers per shoot

Q6: Relative proportion of bulbils (Q4/[Q4+Q5])

Q7: Color of bulbils (make up your own, site-specific color scale)

Q8: Mean bulbil weight (mean ± SD, in µg); optional

Carex stans

The rhizomatous sedge *Carex stans* Drej. (= *C. aquatilis* Wahlenb. subsp. *stans* (Drej.)Hult.) is common in moist tundra throughout the High Arctic. Flowering tillers have 1–2 terminal male spikes and 2–3 female spikes (make

sure that the selected ramets are bisexual!). Clones are normally impossible to delineate; for this reason, please identify and mark individual reproductive culms at least 1 m apart (alternatively small sample squares within OTCs and outside for controls). Note age of monitored shoots; they can be aged by the number of attached dead leaves at the base, and at least three age categories are discernable: new shoot, 1 year old, and 2+ years old. Flowering tends to occur in older shoots, and they die off one season after flowering. Leaf growth can be non-destructively monitored by the same method as used for *Eriophorum vaginatum* (see below).

If *C. stan*s is not present (alpine and Low Arctic sites), ***Carex bigelowii*** Torr., of the 1B list could be used; it grows in drier situations but shares many properties with *C. stans*. In that case, take voucher herbarium specimens, since *C. bigelowii* is a circumpolar taxonomic complex, not fully understood at present.

PHENOLOGICAL DATES (day numbers)

P1: Date snow-free

P2: Emergence of first new leaf

P3: First stigmas visible

P4: First anthers exposed

P5: First yellowing of leaves

P6: First seed shed

QUANTITATIVE MEASUREMENTS

Q1: Age class of shoot in flower

Q2: Length of flowering stem to base of terminal spike (at full flower; accuracy 1 cm)

Q3: Number of green leaves (at full flower)

Q4: Length of longest leaf (accuracy 1 mm)

Q5: Total green leaf length per tiller (mm)

Q6: Weight of mature utricles (accuracy 0.1 mg ± SD; optional)

Additional data (optional, no protocol provided): Length of all green leaves (measurements should be made periodically throughout the summer and could be time consuming; G. H. R. Henry, pers. comm.).

Cassiope tetragona

The Arctic White Heather, *Cassiope tetragona* (L.) D. Don, the species of the ITEX logotype, is circumpolar and often dominant in the arctic tundra. Clones are sometimes, but not always, easy to delimited. They may grow extremely old, and several hundred years old clones may attain a ring-like shape in homogeneous substrates. For ITEX purposes, please select main, vigorous branches (ramets), tagged close to the ground. Draw diagrammatic sketch maps of the selected ramets (length of all modules, positions of branchings and old flowers). If clones are not discernable, leave at least 1 m between selected ramets.

The leaves are evergreen and last for many years; annual growth increments are usually easy to delimit, and the species has unique properties as a monitoring tool for climate-related retrospective growth analysis (see Callaghan et al. 1989). The species is moderately early-flowering ("early aestival"), and is uncommon on exposed ridges and in late-thawing snowbeds. The flowers are largely self-pollinated, although pollination by bumblebees has been observed. The capsules split open very late in the season and may even over-winter before dehiscence; please look for this.

Manipulation responses in this species have been extensively studied over several years by Havström et al. (1993) at three sites: one in the High Arctic (Svalbard) and two subarctic-alpine sites (low alpine and high alpine, respectively) near Abisko in N Sweden. In unmanipulated plants there were significant altitudinal and latitudinal gradients in vegetative growth variables. Plants at higher altitudes or latitudes produce shorter shoots (annual growth increments), and fewer but heavier leaves than at low altitudes/latitudes. These gradients probably reflect a lower turn-over rate of green leaves at high altitudes/latitudes, governed by shorter snow-free period and growing season, an adaptive adjustment for maintaining a positive carbon balance. Similar response gradients on a smaller scale are observed along a snow-cover gradient at the ITEX site at Latnjajaure (U. Molau, pers. obs.). This is in accordance with the findings of Kudo (1992), who found that life-spans and weight of leaves increased with decreasing snow-free duration in evergreen species, whereas the opposite trend was evident in deciduous species. Havström et al. (1993) report significant positive responses in leaf number per annual growth increment in temperature enhancement experiments at high altitudes/latitudes, but none at the low-alpine site.

Note any tendency for re-flowering, in tagged ramets as well as in the study population in general. Fungal infestation of leaves (whitish, swollen) is common in late summer; note frequency in study ramets.

PHENOLOGICAL DATES (day numbers)

P1: Date snow-free

P2: First coloring of flower buds (whitish-yellow, protruding)

P3: First elongation of pedicels

P4: First open flower

P5: First corolla drop

P6: First capsule splits open – if possible

QUANTITATIVE MEASUREMENTS

Q1: Total number of flowers per ramet

Q2: Total number of developing capsules per ramet

Q3: Fruit:flower ratio (Q2/Q1)

Q4: Length of annual growth increment (main shoot, accuracy 1 mm)

Dryas

The White Dryas or Arctic Avens, *Dryas integrifolia* Vahl, and its close relative *D. octopetala* L. (Mountain Avens) are characteristic of drier tundra sites throughout the Arctic. Both species are woody chamaephytes (dwarf shrubs), and as they agree in most ecological traits, either one can be used for ITEX monitoring. *Dryas integrifolia* is basically Nearctic, whereas *D. octopetala* (here treated in the broad sense, including *D. punctata* Juz.) is almost circumpolar. The plants form tussocks or mats; clones may attain high ages and are often difficult to delineate in the Low Arctic. The leaves may be summer-green or evergreen (take notes!), the margins are entire in *D. integrifolia* and crenate in *D. octopetala*. In interior Alaska there are two distinct ecotypes of *D. octopetala*, often growing almost side by side: besides of the circumpolar small-leafed and deciduous subsp. *octopetala* in fellfield sites, there is a large-leafed evergreen form (subsp. *alaskensis* Hult.) in snowbed sites (see McGraw and Antonovics 1983).

The showy white flowers are heliotropic and mainly pollinated by flies. They are usually perfect and comprise numerous bright yellow stamens and green pistils. The flowers are usually weakly protandrous (Philipp et al. 1990) and self-compatible, even though seed set is highly reduced when selfed (U. Molau, unpubl. data). *Dryas integrifolia* is usually andromonoecious (i.e., most genets produce some male (or female-sterile) flowers in addition to the perfect ones). Purely male flowers are rare in *D. octopetala*, but this species appears in gynodioecious populations in some areas (i.e., populations with a certain fraction of male-sterile (functionally female) genets); such populations are not uncommon in subarctic Fennoscandia (U. Molau, pers. obs.). The plumed seeds (achenes) are dispersed by wind. The plumes of fruiting styles twist together at first, but untwist at maturity.

For ITEX monitoring, choose 20 clones (tufts) for temperature enhancement experiments and 20 for controls; if the growth form is matted, select 20 + 20 plots (0.5 m square), or use at laest 5 OTCs + 5 equal-sized control plots beside the OTC, divide their ground surface into four quarters, and select the plants closest to the centers of each quarter for monitoring.

PHENOLOGICAL DATES (day numbers)

P1: Date snow-free

P2: First leaf erected

P3: Appearance of first color (white tip) of flower bud (= bud break)

P4: First open flower

P5: Last petal shed (pull gently if needed)

P6: First twisting of maturing seeds (or observation of no twist at all)

P7: First seed dispersal (pull the elongated, barbed styles gently)

P8: First yellowing or browning of leaves (summer-green forms)

QUANTITATIVE MEASUREMENTS

Q1: Dimension (area) of clone (accuracy 0.1 m^2); if square plots are used, give plot size instead

Q2: Total number of flowers per clone or plot

Q3: Length of longest new leaf (at the time of petal shed; petiole not included; accuracy 1 mm)

Q4: Length of pedicel (from axil to base of flower; at the time of petal shed; accuracy 1 mm); if entire clones are monitored, give mean length ± SD of all pedicels.

Q5: Number of seeds per flower (optional)

Q6: Mean seed weight (± SD) in µg (optional)

Q7: Seed yield per flower (Q5 x Q6; optional)

Q8: No. of flowers (of total) destroyed by caterpilars

Note any insect predation on leaves, flowers, or seeds, since this can interrupt normal development. Be especially aware of the presence of the aphid *Mysus polaris* on the roots (may be dificult to detect) and caterpillars of the moth *Sympistis zetterstedtii* on the sexual parts of the flowers, and of the seed bug *Nysius groenlandicus* on the seeds (Achenes) Also take notes on the floral structure of the population (gynodioecious, andromonoecious) and whether plants are ever- or summer-green.

WARNING: Avoid male-sterile clones in gynodioecious populations of *D. octopetala*; these have flowers with the androecium reduced to a ring of 1–2 mm high, brownish staminoides.

Eriophorum vaginatum

The Sheathed Cottongrass, *Eriophorum vaginatum* L., forms compact upstanding tussocks in marshy and peaty areas, often in permafrost areas with a thin active layer. The clones (genets) are easy to tell apart, and tussocks should be used as monitoring units for ITEX. The culms are normally 20–40 cm tall, and the heads are solitary and not subtended by leafy bracts. The species is relatively early-flowering throughout its range, and has been subject to intense investigation in Alaska (e.g., Chester and Shaver

1982, Fetcher and Shaver 1983, Lariguadrie and Kummerow 1991, Mark et al. 1985, McGraw 1993, Murray and Miller 1982, Shaver et al. 1986, Tissue and Oechel 1987). Prior to an experiment, cut all old heads away (wool may persist for years after poor summers and cause confusion) in order to create a blank base-line.

According to our experiences from Latnjajaure (Molau, unpubl. data), the inflorescences are close to the ground when in flower, an the subsequent elongation of the shafts reflects the proportion of fertilization of the ovules. OTCs may restrict pollen-flow in this wind-pollinated species, and we got a smaller elongation of shafts in the OTCs than in the control plants. Thus, the length of inflorescence shafts cannot be used as a response variable related to experimental warming, but is informative with regard to reproductive success.

Try to select tussocks of the same size for experiment and control; we have indications that growth (leaf length) and tussock size are positively correlated.

Leaf growth per tiller can be monitored non-destructively following a method elaborated at Toolik Lake in Alaska by Gus Shaver and collaborators; this method has also been successfully used at Latnjajare. Select a tiller in the central part of the tussock; try to find a tiller that is clearly delimited from neighboring ones and shows no sign of being close to flowering (tillers live for about 4 years after which they produce a torpedo-shaped leaf sheeth in the center containing the inflorescence bud in late summer; after flowering the subsequent season that tiller will die and be replaced by doughter tillers). Normally a vegetative tiller of average size comprises a number of dead persistent leaves around a few (usually 2–4) live ones (mean life span of individual leaves is a little more than 1 year). Now gently cut all the dead leaves at a similar height close to the tiller base. This will leave you with a "stub" that can be used as a base-line on which a mm-scale ruler can rest when the length of each live leaf is measured. The first census should be made at thawing time, and the progress monitored at even intervals throughout the growing season. We have used 10d intervals, but even 30d intervals would give decent results. Mark the tiller so that you can easily spot it – we use colored plastic paper clips with the central portion removed, put around the tiller base and fastened in the tussock with a piece of thin steel wire. Number the live leaves (i.e., leaves with some green portion) starting from the oldest live leaf (the one with least green). It is recommended that you measure green and dead portions of all leaves, as you then easily will recognize every individual leaf the next time. Give numbers to new leaves as they appear. Add constantly to your base-line by cutting leaves as they die. With this data set, you can calculate the total annual leaf growth in the tiller. You will also be able to calculate senescence rate, live leaf number, average life spans of individual leaves, and turnover.

Seed weight gives nice results in this species, and the seeds are easy to handle. Remove the pappus (wool) before weighing.

Eriophorum vaginatum is essentially circumpolar, but rare in the semi-arid Arctic, e.g., Ellesmere Island. Where *E. vaginatum* is absent, *E. triste* (Th. Fr.) Hadac & Löve (= *E. angustifolium* Honck. subsp. *triste* (Th. Fr.) Hult.) can be used as an alternative species; note that this taxon is rhizomatous, and sample plots, not tussocks, have to be selected as monitoring units.

PHENOLOGICAL DATES (day numbers)

P1: Date snow-free

P2: Appearance of first inflorescence bud

P3: First open flower (= first anthers exposed)

P4: First seed shed

QUANTITATIVE MEASUREMENTS

Q1: Diameter of tussock (average, horizontal, to tips of leaves); accuracy 1 cm

Q2: Number of flowering stalks per tussock

Q3: Mean length of 10 longest leaves (from tip of sheath to apex) ± SD; accuracy 1mm

Q4: Tiller growth (total annual leaf production per tiller in mm; optional)

Q5: Seed : Ovule ratio (optional)

Q6: Seed weight (mean ± SD; accuracy 0.01 mg; optional)

WARNING: In some areas, *E. vaginatum* is reported to be gynodioecious, where male-sterile plants have vestigial stamens about 1 mm long including the filaments (Stevens and Blackstock 1993). For ITEX purposes, select clones with normal anthers only.

Oxyria digyna

The Mountain Sorrel, *Oxyria digyna* (L.)Hill, is common throughout the Arctic and also widespread in subarctic and temperate alpine areas. It grows in wide variety of adverse or disturbed habitats, often in damp situations, and is the only typically late-flowering species among the ITEX 1A plants. For further details on the ecology of the species, see Humlum (1981).

It has short fleshy yellow rhizomes, and clones (genets) may sometimes be hard to delineate, especially in late snowbeds. Each clone produces one or several compound paniculate racemes, but some plants do not flower every year. The tiny flowers are open when the bushy red stigma is visible. The fruit is a flattened nut with a winged pericarp.

Select dense and distinct clones for ITEX purposes; do not use situations with many small flowering individuals in dense stands. Look for old inflorescences or stalks to find reproductive clones. *Oxyria* plants, particularly the inflorescences, are very palatable to grazers, and at some sites fencing of controls with chicken wire can be neces-

sary. Do not abandon a vigorous clone if it should not be flowering for a year or two, also 0 inflorescences is a quantitative measurement of interest to ITEX. Note when infloresences or leaves have been lost due to grazing.

PHENOLOGICAL DATES (day numbers)

P1: Date snow-free

P2: First leaf unrolls

P3: First visible inflorescence (at ground level between petioles)

P4: First flower open

P5: First seed dispersal (i.e., when fruits fall off easily by touching the plant)

QUANTITATIVE MEASUREMENTS

Q1: Number of inflorescences per clone (0, 1, 2, etc.)

Q2: Length of inflorescence stalk (at full flower; from ground to base of raceme, in mm)

Q3: Width of largest leaf (in mm)

Q4: Number of mature fruits per plant (harvest in paper bags, one per clone)

Q5: Mean fruit weight (weigh all fruits from a clone, dried at room temperature, as a single batch, calculate mean fruit weight; accuracy 0.1 mg).

Ranunculus nivalis

The Snow Buttercup, *Ranunculus nivalis* L., is almost circumpolar, often abundant in moist tundra, flowering near the edge of the melting snow. Prefloration time (i.e., period from thawing to flowering) is rather short, 5–15 days depending on weather conditions. Individual plants (clones) may be hard to delineate; in those cases select square plots and mark individual flowering stalks at least 0.5 m apart for monitoring.

The flowers are born singly on erect pedicels. The flowers are robust, open, and easy-to-handle. Flies are the main pollinators, and despite some self-compatibility, insect visits are required for seed set (U. Molau, unpubl. data). The fruits are one-seeded nutlets; usually there are 30–70 nutlets per flower. For further details, see Philipp et al. (1990).

PHENOLOGICAL DATES (day numbers)

P1: Date snow-free

P2: Flower open (attaining bowl shape)

P3: Last petal shed

P4: First seed dispersal (NB! Start harvesting nutlets at this point)

P5: First yellowing of leaves

QUANTITATIVE MEASUREMENTS

Q1: Height of flowering shoot from ground to base of flower (in mm)

Q2: Width of largest basal leaf (in mm)

Q3: Number of nutlets per flower (harvest in seed bags)

Q4: Mean weight of nutlets (± SD, in µg; optional)

Q5: Seed yield (Q3 x Q4)

Q6: Seed : Ovule Ratio

WARNING: Do not confuse with other co-occurring *Ranunculus* species; at Latnjajaure *R. acris* L. starts flowering in the same square plots about two weeks after the last *R. nivalis* petal has been shed.

Salix

No arctic willow is even close to being circumpolar in distribution. Since they constitute such an important counterpart of the tundra vegetation, four different dwarf-shrub species with roughly the same ecological properties have been selected: *Salix arctica* Pall., *S. herbacea* L., *S. polaris* Wahlenb., and *S. reticulat*a L. Together they cover the entire Arctic, and one or two, sometimes three, of these species will be present at each ITEX field site. We recommend that each site undertake monitoring of at least one *Salix* species.

All willows are perfectly dioecious, but the frequency distribution of the sexes may vary among populations (see Crawford and Balfour 1983) and year (M.A. Lohiluoma pers. obs.). As in all arctic plants with spatial gender separation, they are generally early-flowering. Nevertheless, plants of *S. herbacea* (the species having the widest ecological amplitude of the four) are commonly found even in late-thawing snowbeds – but with highly reduced reproductive success. High abortion rates are common, since all four species obviously need insect vectors for a decent seed set.

The flowers are borne in catkins, the size and density of which vary strongly among the four species. Female catkins of *S. arctica* and *S. reticulata* are dense, many-flowered, and ± cylindrical; in *S. herbacea* and *S. polaris* they are loose, few-flowered (3–10 flowers per catkin), and rounded with the capsules spreading. Because of the differences in female catkin morphology, the response variables listed below have been differentiated with regard to species: length of mature catkin (measured from top to the axil of the closest subtending leaf [i.e., including catkin shaft]) in *S. arctica* and *S. reticulata*, number of flowers (capsules) in the other two species.

Capsular dehiscence is easily recorded: they will start to split open from the apex, and as the two valves separate and recurve, the white wool of the seeds becomes visible. Investigating reproductive success, in terms of counting mature seeds and aborted seeds and ovules, needs some further guidelines. Because seed wool will obscure observation in dry stage, capsules should be dissected in

water with some detergent added. The best way is to investigate capsule contents in a stereo lens with the sample (in water in a Petri dish) illuminated from beneath. It is also possible to count the seeds in a few drops 50% alcohol solution with light from above. Normaly, three classes of ovules/seeds are easy to identify: (1) large, filled seeds (1–2 mm long), (2) ± empty seeds of the same size (late embryo abortions), and (3) small unfilled ones (less than 0.5 mm long) representing unfertilized ovules (U. Molau, pers. obs.). Investigate 10 capsules per ramet if available. Capsules with more than 10 seeds are rare. Note any signs of seed predation.

The length of annual growth increments is usually easy to measure since the shots system is sympodial. Use main shoots and take measurements late in the season when growth has ceased (distance from last sprouting point to end of terminal wintering leaf bud). Samples for leaf weight should be taken just when they start to become yellow; sample entire leaves (with petioles intact) in paper bags and store dry at room temperature two months before weighing.

When undertaking ITEX monitoring of willows, select branches (ramets) as monitoring units. Select 20 branches (different individuals) of each sex per species for temperature enhancement experimentation, and the same amount for controls. Since flower formations occurs the year before flowering it is possible to determine the sex by dissect one single leaf bud Two standard protocols are provided in the Appendices to this Manual: one for females and one for males. Some species-specific variables are not included in the standard protocols; take additional notes on back sides!

In prostrate willows it is often difficult to cope with postulated sample sizes, since sex expression does not come as one of the first traits of the season. When you start up your sampling of willows, over-sampling is good advice. Sex determination is a problem in early stages, and we would encourage any enlargements by 50–100 %.

PHENOLOGICAL DATES (day numbers)

P1: Date snow-free (plant or plot)

P2: First leaf bud burst (for the first year sex determination may be done later)

P3: First pollen shed (of all males) / First stigmas visible (females)

P4: All pollen shed (males) / Onset of seed dispersal (females; capsules split open at top, white wool visible)

P5: First yellowing of leaves

P6: Last green leaf turning yellow

P7: All leaves shed (optional)

P8: Onset of seed dispersal (capsules split open, wool visible)

Make note of the activity of wooly-bear caterpillars on a seperate sheet

QUANTITATIVE MEASUREMENTS

Q1: Total number of flowering catkin per monitored branch

Q2: Annual growth increment (accuracy 1 cm in *S. arctica*, otherwise 1 mm)

Q3: Length of longest leaf (petiole included; accuracy 1 mm)

Q4: Weight of largest leaf (with petiole; accuracy 0.1 mg)

(Q5–Q8: females only)

Q5: Total number of mature catkins per branch

Q6: *S. arctica/reticulata*: length of mature catkins from axil of subtending leaf (mean ± SD; accuracy 1 mm)

S. herbacea/polaris: number of capsules per catkin (mean ± SD)

Q7: Fruit:flower ratio of catkins (number of mature fruits divided by original number of flowers, given as mean ratio ± SD per branch). Alternatively use whole catkins instead of flowers, i.e. mature:flowering ratio of catkins.

Q8: Seed : Ovule ratio (mean ± SD; optional)

Additional records: *Salix arctica*: (1) measure maximum diameter of entire plant (between opposite branch tips); (2) diameter of branch at base (use calipers; accuracy 0.1 mm). For all species, note insect predation and damage (rolled leaves, holes, seed predation, egg deposits, larval grazing of leaf margins) and fungal growth (calculate percentage of infested leaves). On a separate sheet, make two additional columns for females (Q9–10), accomodating the number of flowering catkins (Q9) and the ratio flowers per catkin (Q10).

Woolly-bear caterpillars (*Gynaephora groenlandicasee pg. 30*) are important predators on the leaf buds and young catkins early in the season. For the reproductive succes as well as for the vegetative growth the number and activity of the caterpillars is of great importance. When they are present in the *Salix* plots, notes should be taken of the woolly-bear caterpillar on a seperate sheet.

Saxifraga oppositifolia

The Purple Saxifrage, *Saxifraga oppositifolia* L., is perhaps the best-known of all circumpolar arctic and alpine plants. Nevertheless, investigations on its ecology and reproductive biology are surprisingly sparse. Recently, flowering phenology, mating system, and reproductive success of *S. oppositifolia* were studied in a north Swedish population at the Latnjajaure ITEX site (Stenström and Molau 1992). The flowers normally have five purple

petals (color varies among genets), ten stamens, and a bi-lobed gynoecium with two styles. The leaves are small, evergreen, and densely packed on the shoots, making quantitative vegetative measurements difficult. Individual clumps (clones, genets) are normally easy to delimit, and should be used as sampling units in ITEX. In moist habitats the growth form is often more matted, and genets may be hard to separate; avoid such sites.

Saxifraga oppositifolia is one of the earliest flowering plants of the Arctic; depending on weather conditions and latitude, records of prefloration time range from 5 to 15 days. The flower buds are developed during the preceding season (August) and normally over-winter in a highly developed stage, with colored petals and differentiated ovules, but with pollen at the PMC stage (Sørensen 1941). Flower opening can be a lengthy process, and the opening buds may (depending on weather conditions, especially radiation climate) remain at a cylindrical stage for days. Mikael Stenström (pers. comm.) suggests that flowers should be regarded as open when they are accesible for pollinators, i.e., when petals start to spread distally and stigmas become visible.

Saxifraga oppositifolia possesses exceptional intrinsic properties for experimentation and monitoring. The stigmas are purplish, but the pollen is bright orange. The plants are strongly protogynous, and the gynoecium will be receptive for 3–4 days before the anthers dehisce and the orange pollen is exposed. At that time, stylar receptivity is rapidly declining, and no further seed set will result. Since flowering in *Saxifraga oppositifolia* clones is almost synchronous, the entire clones will be functionally entirely unisexual: female at first for 3–4 days, then males. Self-pollination is thus extremely rare under natural conditions. Bumblebees are the main pollinators, but flies seem to be important as well.

The stamens retain a purplish color until the anthers start to dehisce and the bright orange pollen mass is exposed. Since also the stigmas are light purple-colored, pollination events are easy to trace, and the deposited orange pollen grains might even be countable with a good hand lens; at least, presence of orange grains on stigmatic surfaces imply that pollination has taken place.

Capsule dehiscence is easy to monitor in *Saxifraga oppositifolia* if you know where to look. Capsules start to open at the end of the common part, between the two divergent stylar beaks. Collect half of the capsules (at least 5–10) dry in seed bags for subsequent weighing of the seeds; pickle the remaining fruits in 70% alcohol for later determination of seed number and number of aborted embryos and ovules (hyaline).

Make notes of the presense of the seed bug *Nysius groenlandicus*

PHENOLOGICAL DATES (day numbers)

P1: Date snow-free

P2: First flower open

P3: First pollination (first orange pollen on stigma)

P4: First anther dehiscence (orange pollen exposed)

P5: First petal fading (wrinkled or devoid of color)

P6: Last petal fading

P7: First capsule open (splits at top between apical beaks)

QUANTITATIVE MEASUREMENTS

Q1: Vegetative growth (5 shoots per genet; mean ± SD, accuracy 1 mm)

Q2: Total number of flower buds (at beginning of season)

Q3: Total number of flowers per individual

Q4: Number of pollinated flowers in clone at the time first anther opens

Q5: Number of mature fruits (presence of seeds in a capsule is easily detected by sqeezing the capsule gently between two fingers)

Q6: Number of seeds per capsule (mean ± SD; optional)

Q7: Total number of flower per capsule (mean ± SD; optional)

Additional records: Take notes on eventual events of re-flowering later in the season (date of first occurrence, number of flowers, degree of perfectness of flowers [functionally female?]).

Silene acaulis

The Moss Campion, *Silene acaulis* L., is common throughout the Arctic as well as in subarctic and temperate alpine areas. It is a relatively early-flowering species, mainly pollinated by bumblebees, although butterflies (*Colias* and *Erebia* species) may be locally important . The seed bug (*Nysius groenlandicus*) may be detrimental to the seed set within annual fluctuations of importance for plant reproduction

The species normally forms dense tussocks (clones), easily delineated. However, the species is gynodioecious, and all populations are made up of a mixture of female and hermaphrodite clones; sometimes even purely male cones may appear (Alatalo & Molau, unpubl.). Seed set is usually much reduced in hermaphrodite clones. If you undertake ITEX monitoring and experimentation of this species, please make a good assessment of sex ratio in your population. Also, since the species is essentially gynodioecious, it is good advice to extend the sample size to 20+20 clones (20 females, 20 hermaphrodites); use additional copies of the standardized protocol for this purpose.

For monitoring of flowering (optional), make an extra protocol and count the numbers of open flowers per clone every second day.

PHENOLOGICAL DATES (day numbers)

P1: Date snow-free

P2: First open flower

P3: First open anther

P4: First stigma receptive

P5: First capsule cracks open (at top)

QUANTITATIVE MEASUREMENTS

Q1: Size of cushion (acuracy 1 cm)

Q2: Number of flowers

Q3: Number of capsules

Q4: Fruit : Flower Ratio (Q3/Q2)

Q5: Number of seeds per capsule (mean ± SD)

Q6: Seed:ovule ratio (mean ratio per clone ± SD; optional)

Q7: Flowers female (F) or hermaphrodite (H), or proportions thereof

Q8: No. of seed bug (*Nysius groenlandicus*) present on the cushion (optional)

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VOUCHER SPECIMENS OF ITEX PLANTS

Remember to ship your ITEX plants to the VOUCHER COLLECTION !

As agreed at the 6. ITEX workshop voucher specimens of all ITEX plants from all ITEX sites should be send to the Herbarium in Fairbanks, where they will be kept as a reference for the validity of the experimenters taxa.

Address:

ITEX VOUCHERS

Museum

University of Alaska

Fairbanks, AK 99775

USA

ITEX INSECT: *GYNAEPHORA GROENLANDICA / G. ROSSII*

Per Mølgaard and Dean Morewood

Woolly-bear caterpillars, *Gynaephora groenlandica,* are important predators on the leaf buds and young catkins of *Salix* spp. early in the season. Field observations have shown a strong preference for *Salix* arctica, and for the reproductive success as well as for vegetative growth of the willows, the number and activity of the caterpillars may be of great importance. When present in the ITEX plots, especially those with *Salix* spp., notes should be taken on the *Salix* sheets or on the sheets especially designed for *Gynaephora* observations.

The life cycle of this moth is exceptional as it may take several years to develop from first instar larva to adult insect. In Greenland, on Disko Island, outbreaks were seen in 1978 (Kristensen, pers. comm.) and again in 1992 (Mølgaard pers. obs.), which indicates fluctuations with peak populations with 14 years interval, which is similar to the life cycle duration at Alexandra Fjord (Kukal and Kevan, 1987). During this long developmental time the larvae are exposed to parasitism, which may be as important as climate in population regulation of this high arctic insect.

The caterpillars emerge early in the season and obviously they feed almost exclusively on *Salix* buds. A preference for male leaf buds and young male catkins has been seen, which probably adds to an explanation of the female biased distribution of the two gender in *Salix arctica* observed on several localities in Greenland (Christensen and Mølgaard, 1991). The caterpillars orientate themselves in a preferred direction, which has been related to the predominant wind (Kevan et al. 1982) or to insolation (M°lgaard, upubl.) in order to maintain optimal conditions for metabolism under basking (Kukal, 1990).

Based on the potential impact the caterpillars may have on the plants in combination with the extraordinary life history of *Gynaephora* we consider it valuable for the ITEX activities and recommend that the woolly bear caterpillar is included as the first 'ITEX insect'. Detailed observations over the range of ITEX sites may throw light on the feeding habit, the impact on the plants, the influence on the *Salix* male/female ratio, the insect life cycle and periodicity of 'outbreks', and the background for the preferred orientation.

Species identification

Two species of *Gynaephora* (Lepidoptera:Lymantriidae) are found in North America, *G. groenlandica* (Wocke) and *G. rossii* (Curtis). Collectively, their geographic distribution ranges from eastern Greenland across arctic North America to Siberia, and includes isolated populations in alpine areas of New England, the southern Rocky Mountains, and Japan (see map). A third species, *G. selenitica* (Esper), is found in Europe but may not occur at tundra sites. The two North American species occur together at many sites in the Canadian Arctic and may be separated by the following characteristics.

EGGS: Eggs themselves may be indistinguishable morphologically; however, egg masses are often laid on cocoons, which differ between the two species (see below).

LARVAE: Because of their small size and their tendency to stayout of site, newly-hatched larvae are unlikely to be encountered in the field unless found when they are still on the cocoons where the eggs from which they hatched were laid. Older larvae may be separated according to the form and colour patterns of the larval hairs. Larvae of *G. groenlandica* have long hairs that range from dark brown to golden yellow, depending on how recently they have moulted, and have two distinct tufts of black followed by two of yellow on the back (these are often replaced by four tufts of black fringed with yellow in the final instar) as well as a black tuft at the tail end. The larval hairs of *G. groenlandica* have small barbs along the shaft but are not plumose.

Larvae of *G. rossii* have shorter hairs and have black hair tufts fringed with yellow along the back, but have no black tuft at the tail end and usually appear greyish overall because they have grey plumose hairs that are slightly longer than the black tufts. The differences in form and colour patterns of the larval hairs become visible after the first larval moult and become progressively more distinct with each subsequent moult.

COCOONS: Cocoons of *G. groenlandica* are broadly oval and range in colour from off-white to deep yellow or occasionally grey. They are constructed in two separate layers with a distinct air space between the two layers and are approximately 2.5-4.0 cm in length by 1.5-2.5 cm in width. Cocoons of *G. rossii* are more narrowly oval and range in colour from light to dark grey. They are constructed in a single layer and are approximately 2.0-3.0 cm in length by 1.0-1.5 cm in width. Larval hairs are incorporated into the structure of the cocoons, giving them their overall colours, and the difference in form of the hairs (plumose or not; see above) may be seen if cocoons are torn open and the torn edges examined under magnification.

ADULTS: Both species are medium-sized greyish moths and have similar wing patterns; however, the wing patterns of *G. rossii* are generally quite bold and include a broad black band along the margin of the hindwings whereas the wing patterns of *G. groenlandica* are very faint and generally lack the black border on the hindwings completely (see Plate 1 in Ferguson 1978).

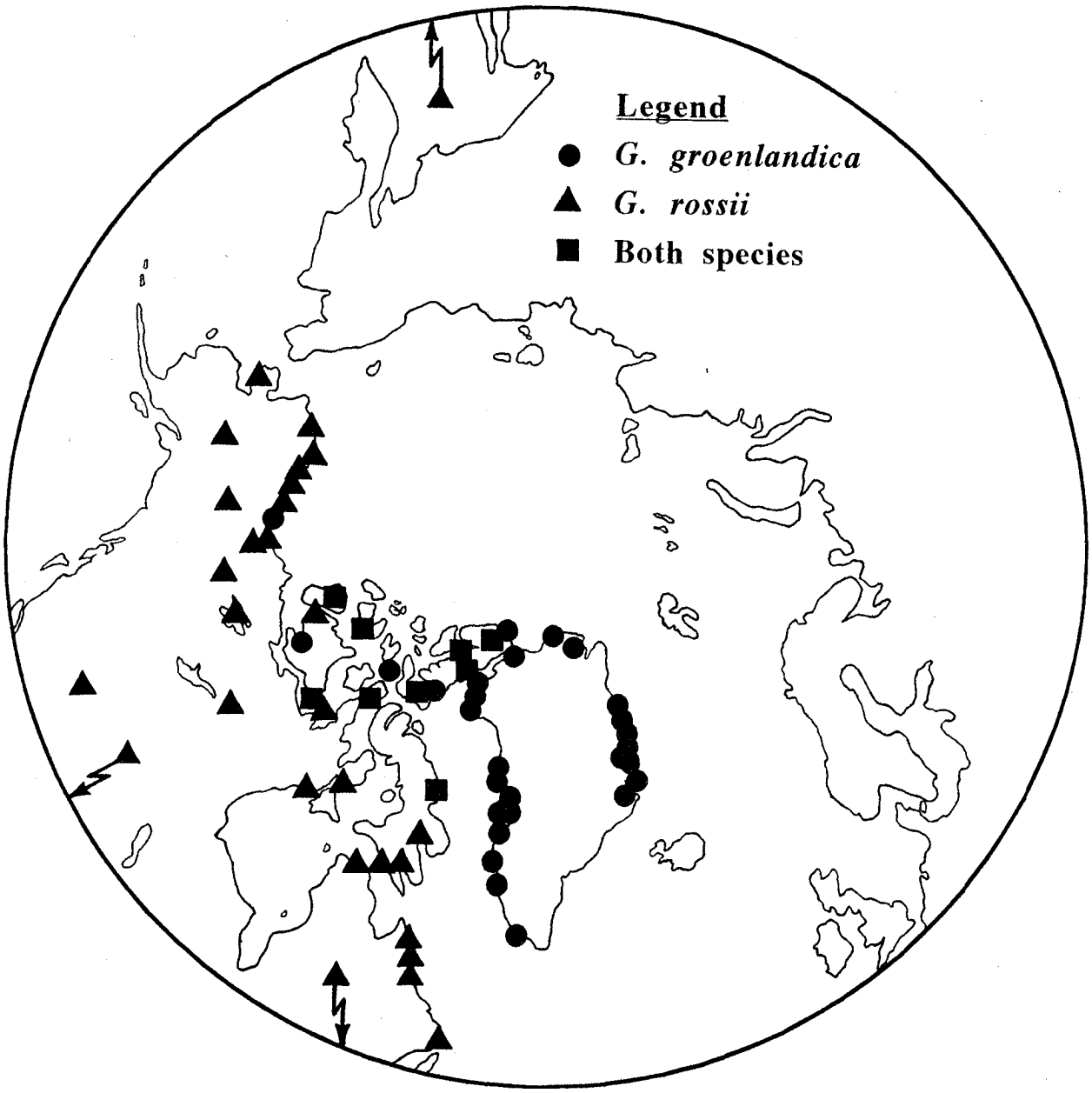

Fig. 1: *Geographic distribution of* G. groenlandica *and* G. rossii*, compiled from Wolff (1964), Ryan and Hergert (1977), and personal observations.* Gynaephora rossii *is also known from Siberia but specific records could not be obtained in time to include here.*

Activity of 'free-ranging' *Gynaephora* may be monitored within ITEX plots using the data sheet included in the manual. In order to follow development and activity over the longer term the insects must be confined in some way to prevent escape and allow for monitoring on an individual basis. Larvae may be confined in the field by constructing 'corrals'. Both 15-cm aluminum flashing and 10-cm plastic lawn-edging have been used for this purpose at Alexandra Fiord and have proven effective in confining the larvae. Great care must be taken that there are no gaps that might allow the larvae to escape by crawling under the corral walls. Walls may be secured in place using tent pegs or wire and these should be placed along the outside of the corrals walls; otherwise the larvae may climb them. Corrals may be constructed in any size; however, for single or a few larvae, a diameter of approximately one metre is recommended and may be used in combination with OTCs.

PHENOLOGICAL DATES

P1: First day snow-free

P2: First caterpillar

P3: First *Salix* leaf bud burst (male/female)

P4: First flower out (male: pollen shed/ female stigma visible)

P5: First pupae

P6: First adult (male/female)

P7: Mating

P8: Egg laying female

QUANTITATIVE MEASUREMENTS

Q1: Length of caterpillar (or stage, may be difficult if they curl up)

Q2: Orientation of basking caterpillar (nearest 5° on compass, however not usable at Ellesmere Island))

Q3: Colour (yellow/brown/black, to give information on moulting rythm)

Q4: Number of caterpillars feeding on male *Salix* (buds/ leaves/catkins) per unit area, plant or shoot

Q5: Number of caterpillars feeding on female *Salix* (buds/ leaves/catkins) per unit area, plant or shoot

Q6: Number of caterpillars feeding on other plant species (per unit area)

Q7: Estimate of density (caterpillars/unit area; high/low)

Q8: Orientation of pupae

Note: With respect to Q8: Orientation of pupae, the last shed larval skin remains in a clump at the tail end of the pupa within its cocoon - this can be seen with appropriate lighting (the cocoons are translucent) or felt by gently squeezing the cocoon - and this may be used to determine which way the pupa is 'heading'.

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FURTHER INSECT STUDIES

By Jens Böcher

In connection with the establishment of an ITEX program integrated in the Zackenberg Basic monitoring program (at the Zackenberg Research Station in Northeast Greenland) we have decided to include a few insect observations in the ITEX phenological observations (Meltofte and Thing 1995). Accordingly, I suggest that a certain number of insect studies are incorporated in the general ITEX program.

Pollination

The most important insect/plant relationship is pollination, which influences population dynamics for plants as well as for insects. A change in temperature is likely profoundly to change the frequency of insect visits and the taxonomical composition of pollinators (Kevan 1972; Philipp et al. 1990). It is therefore suggested that some simple quantitative/qualitative measure of insect visitation to the flowers of the ITEX plants is initiated, so that numbers of insect visits/flower/hour may be established.

Methods

1. All instances of herbivory should be noted during the routine observations, and the plants should be carefully examined in order to reveal attacks by sucking insects (e.g. aphids on *Dryas*, psyllids on *Salix*). Samples of such herbivores should be taken and preserved in 70 % alcohol for later identification by specialists. In cases where a significant portion of leaf area has been eaten, this should be stated (as a rough percentage) and, if possible, the insect species responsible should be caught and identified.

2. In all the plots where *Dryas* flowering is studied, the number (percentage) of flowers attacked by the caterpillars of *Sympistis zetterstedtii* (or other moths) should be recorded, possibly differentiated into "slightly affected", "partly destroyed", and "totally destroyed" in accordance with the quantity of the gynoecium eaten.

3. Presence in the studied plots of *Nysius groenlandicus* must be recorded, and the number of bugs occurring in the flowers and fruits noted. When infected, samples of seeds should be collected for later microscopic analysis.

4. A measure of pollination frequency may be obtained by counting the total visits payed by insects to a fixed number of flowers during a time unit, for instance half an hour, during optimal weather conditions: clear sun and weak wind, and in the middle of the day (e.g. 10 A.M.- 4 P.M.). The initial identification of the insects in the field should be carried out to a certain level, for instance:

1) "small flies" (mainly including *Spilogona* spp.)
2) empidids flies
3) syrphid flies
4) blow flies
5) mosquitos
6) midges
7) butterflies (could be subdivided)
8) moths (could be subdivided)
9) bumble bees

Samples of pollinating insects might be collected by net and pooter, preserved in alcohol and identified by specialists.

Insect herbivory

Even though insect foraging on arctic plants generally is negligible (Downes 1965), in some cases this factor must be of great importance - for the single plant individual as well as for plant populations in large areas. A few examples from Greenland may illustrate this.

1. Insect herbivory of vegetative parts

A number of insect taxa do in fact live from the vegetative parts of arctic plants, either devouring leaf tissue (most butterflies and moths, many beetles and flies) or by sucking cell content or phloem juice (aphids, scale insects, psyllids, plant hoppers, most true bugs, thrips).

It is often difficult to detect the presence of sucking insects due to their small size and concealed habits, and even more difficult to assess their impact on the viability of the food plants. As an example: In high arctic Greenland the aphid *Myzus polaris* lives on the hidden parts and roots of *Dryas octopetala*, and is not easily detected, (Meltofte and Thing 1995). Ignorance of the existence of this herbivorous relationship may interfer seriously with the ITEX results obtained.

2. The noctuid moth *Sympistis zetterstedtii*

In both West Greenland (Disko) and Northeast Greenland (Zackenberg) extensive predation of the larva of this circumpolar arctic moth on the sexual parts of the flowers of *Dryas (integrifolia* and *octopetala*) has been observed. The intensity varies greatly from year to year, possibly in a cyclic manner. In some years no caterpillars can be found in the flowers, in others up to (at least) 70 % of the flowers in a population may be destroyed (Philipp et al. 1990;

Meltofte and Thing 1995). Obviously, this aspect must be taken into account when the outcome of the sexual reproduction of *Dryas* is considered.

3. The Greenlandic Seed Bug (*Nysius groenlandicus*)

This species of Heteroptera is found all over Greenland and is abundant especially in inland sites with a warm, dry summer climate (more than 100/m^2 is not uncommon), but it may also be abundant during periods with sunny summers in coastal areas (Böcher 1976). The species is furthermore common in Iceland and in alpine areas of Scandinavia, possibly with a wide arctic/alpine total distribution in the Palaearctic Region.

Like most members of the family Lygaeidae, *Nysius groenlandicus* feeds exclusively on seeds (Böcher 1972). The effect of this has never been studied, but most probably the viability of the seeds is thereby totally destroyed. Often, cushions of *Silene acaulis* with ripe capsules are densely populated by bugs, and up to ten individuals have been found in one capsule of *Melandrium triflorum*, and 25 in one capitulum of *Taraxacum croceum*. At least in Greenland it is therefore essential to obtain an idea of presence and number of *Nysius groenlandicus* in the ITEX plots as far as seed production is concerned. In other arctic/alpine areas other lygaeid species ought to be considered.

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COMMUNITY BASELINE MEASUREMENTS FOR ITEX STUDIES

By Marilyn Walker

Measurement of species cover before and during ITEX manipulations is critical to the inter-pretation of the species data. Observed responses may be due as likely to changes in the biotic environment caused by shifts in species abundance and competitive regime as to changes in the abiotic environment. It is also important that the compositional data be based on a quantitative measure such as percentage cover rather than on a visual estimate or cover-abundance scale, as these may be too coarse to detect change. In particular, the Braun-Blanquet cover-abundance scale, which is very appropriate for relevés that conform to minimal sampling areas (in terms of complete community representation within the sample), is inappropriate for small-scale studies such as ITEX, which encompass much less than the minimal area required for the community.

The recommended standard method for ITEX plots is a fixed, square point frame, with 100 measurements spaced equidistantly within the frame. The frame size can vary slightly to fit your chamber configuration, but in most cases should range between 75 and 100 cm on a side. The distance between points is determined by the side length of the frame divided by 10, so that a 75 cm frame has points separated by 7.5 cm, and a 100 cm frame has points separated by 10 cm. Placing the points much closer than 7 cm will result in oversampling of a very small area and repeated sampling of the same individuals in many ecosystems (this will happen in any case, but as the size gets smaller it becomes more of a problem).

Construction details

(see Figure 1): The frame is constructed of 3-sided angular aluminum tubing, approximately 2 cm across and 2 mm in thickness. Four pieces cut to the length of the frame sides plus 2 x the width of the material (if you use material that is 2 cm across and wish to make a 1 m frame, the pieces should be 100 + (2x2) = 104 cm) are mitered 90 deg at the corners. Thus, the inside measure of the frame is the important dimension. Corners are stabilized using 90 deg angle braces on the outside, and also with cross braces across the bottom of the frame, approximately 15 cm out from the side (i.e., forming a triangle in the corner of the frame). Screws are used to attach braces to the frame. The four corners of the frame are assigned a letter code A, B, C, and D in the following manner: A in the lower left, B in the lower right, C in the upper left, and D in the upper right. Adhesive metric measuring tape is attached permanently to the top of each side of the frame, with the numbers running from A to B and C to D and from A to C and B to D. The tape is used to identify a coordinate system for recording and tracking data. Small (approx. 1-1.5 mm diameter) holes are drilled at appropriate sampling intervals through the center of each side of the frame. For a 100 cm frame, the first hole is drilled 5 cm from the left side, continuing every 10 cm. For a 70 cm frame, the first hole is drilled 3.5 cm from the left side, continuing every 7 cm. Holes should be drilled very cleanly in order to avoid ripping or tearing the string with rough edges. The frame can now be strung with nylon fishing line. We have found white line to be the easiest to see and work with. String each distance with a separate piece, otherwise breaks will result in having to restring the entire frame. String is drawn through both holes on one side of the frame, stretched across the center until taut, and then strung through both holes on the other side. This results in two parallel sets of strings running across the top and bottom of the frame. Four intersecting strings then define each sampling point within the frame. Attach a small bubble level to each side of the frame in the center.

Legs are made of solid aluminum rods approximately 1.5 cm diameter; length should be great enough to allow the frame to be placed level on the steepest slope likely to be encountered in your study. We have found 1 m long legs to work in almost any situation, but shorter (50 cm) legs are easier to use. Having two sets of legs, one long and one short, is the most flexible solution. Holes are drilled in each corner of the frame approximately 1 mm greater than the leg diameter. Legs are placed through the holes, with the pointed end down, and stabilized with rubber grommets that fit snugly around the legs (they should move up and down the legs only when minor force is exerted) placed on either side of the frame.

Permanent marking plates and leg holes are also part of the construction. Four leg holes and 3-4 permanent marking plates are needed for each plot. These will remain in the field. Leg holes and marking plates are both made of small, flat circles, of rustproof material, approximately 3 cm in diameter. These are available through forestry supply catalogs as marking tags. For the permanent marking plates, a cross, with a precise 90 deg angle, should be stamped on the center of the tag. Three to four small holes are drilled around the perimeter of the tag. These are used to fasten the tag to the ground using nails. The hole should be large enough to let the nails through easily, but smaller than the head of the nail. The leg holes are similarly drilled for nails, and a circle is drilled through their center such that the legs of the frame can fit easily through it.

Data sheets

Data sheets consist of a grid of 100 squares (or rectangles) arranged in a 10 x 10 matrix on the page. It is helpful to have a dashed line through the horizontal center of each

square. Each square is used to record the information from a single point, and are arranged spatially to match their arrangement on the frame. The X and Y axes of the matrix, on both top and bottom and left and right sides, should be labeled with the appropriate coordinates. For example, in a 100 cm square, X coordinates should begin on the left with 5, and continue with 15, 25, 35, etc., up to 95. Y coordinates begin at the bottom row and continue upward in a similar manner. Thus, the lower left square is defined as 5,5, corresponding to the string intersection at 5,5 on the frame. The letters A, B, C, and D are written on each corner of the data sheet corresponding to their position on the frame (A in lower left, B lower right, etc.), and a small line for recording is drawn next to each letter. The bottom of the data sheet should have a section entitled "Other species" and a place to record the names of species in the plot that were not encountered. There should also be a section for recording notes.

Set-up

Remove the chamber if present. Slip a leg hole marker over each leg, and place the frame on the ground with the "A" corner in the southwest. The legs may be driven gently into the substrate to help stabilize the frame. Adjust the frame so that it is above the canopy and not disturbing it, and roughly level by sliding the corners of the frame up and down on the rubber grommets (it should not be precise at this time). Nail the leg holes into the substrate. Now level the frame precisely and stabilize the corners. To do this, begin at the "A" corner (or anywhere, it doesn't matter), and firmly clamp the frame to the legs with a C-clamp around the rubber grommets holding the legs in place. Level the AB side precisely, and clamp the B corner down. Continue around each side in the same manner; the final side should be level with no further adjustment. If it is not, you will need to make a minor adjustments until all four sides are precisely level. The final set-up step is to place the permanent marking tags inside the plot. These tags will replace the underlying vegetation, and should be placed in a relatively flat, stable position, ideally at the four corner points of the frame, but at least three positions. At each of these points, place the tag on the ground, and line the cross on the tag up precisely with the intersection of the strings at that point. Nail the tag to the ground. Be careful not to bump or reposition the frame during this process or during the recording. It is very important that the tags be placed in a stable spot and that they be located precisely. Although only two tags are necessary to relocate the frame, the additional points provide additional security in the case of disturbance.

Recording

Before recording for each point, measure the distance from the ground surface to the bottom of the frame at corners A, B, C, and D, and record on the data sheet. For each point, record the following information: Site down to the first species encountered, and call it out. Measure the distance from the bottom string intersection to the point to the nearest 0.5 cm. The scribe should record the species code** and distance in the top half of the square for that point. Then gently move the point away, being careful to minimize disturbance to the canopy, until you can site the "ground" surface, which may actually be a moss or lichen carpet, a litter layer, bare soil, rock, or even a leaf or branch of a shrub. Again, call out the species and measure the distance from the bottom string intersection to the point. Record these values on the bottom half of the square. In many cases, there will be no "second" hit. In all cases, record an X for a permanent marker, but still measure the distance.

** species codes: 6 or 8 letter species codes can be used by combining the first letters of the genus with those of the species. However, it is critical to keep track of the codes as they are developed and to assure that they uniquely identify all of your species. D. Murray and V. Razzhivin have offered to make the Panarctic flora codes available to ITEX.

Unless otherwise noted, the assumption is that the species hit was live, and that the hit was on leaf or other green material (unless the species is a moss or lichen). If this is not the case, the following letter codes should be added to the data sheet immediately following the species code: d (dead - meaning that entire specimen is dead but still attached to the substrate), w (woody), sd (standing dead - meaning a non-green portion of a vascular plant, such as a brown leaf, attached to a living plant). In some cases more than two of these may be used, for example if a woody branch of a completely dead Dryas octopetala were encountered, it would be recorded as dryoct w d. If a leaf of the same plant were encountered, it would simply be dryoct d. Detached material, whether green or alive, should be recorded simply as litter, except in the case of certain lichen species that do not attach to the substrate.

The final point of information that should be recorded is a subjective determination of the repeatability of the sample, that is, does the caller think that if the sample were repeated in a year, and the plot very precisely relocated, that the same species (or lack of species, such as rock), would be recorded there? Determination of this subjective measure requires a combination of common sense and some knowledge of the species. For example, a hit that is firmly in a solid, single species Sphagnum mat, or a rock, will be very repeatable. Upper hits may occasionally be in this category, for example a large leafed species such as Rubus chamaemorus will likely regrow over the same position in future years. Similarly, a dense shrub cover will most likely be there again, although the hit will be on a new leaf. If the caller believes this to the case, he should say "good" after calling out the species name, and the scribe should circle the species code on the data sheet. This information is not used in any cover calculations but may prove invaluable in future years when sampling is repeated. A change of the "good" hits may be taken more seriously as a true indication of change at that point than the other hits.

Once all the points have been recorded, the caller and scribe should do a visual search of the plot for species present but not encountered. These are recorded as present at the bottom of the data sheet, and will be given a value of less than 1% cover.

The most common mistake that can occur in the recording phase, and one which wastes a lot of time, is for the scribe to record the data in the wrong location on the sheets. This may happen for many reasons, such as lack of clarity about starting a new point, the caller losing track of where he is and skipping to a new row or column, etc. We recommend beginning at the 5,5 coordinate and continuing across the first row, then moving up to 95,10, and back down the 10 row. The caller and scribe should always verify with each other when a new row is begun. If there is disagreement, then it can be straightened out before serious damage is done. Once the first half of the frame is done, the caller should move to the other side, and both parties should again verify the starting point and direction of movement across the frame. The scribe should be careful not to get confused by the fact that he will begin writing in the lower left corner of the data sheet, rather than the upper left, and that he may sometimes move right to left and other times left to right.

Take down and future use

The legs should be carefully removed from the hole markers in order to avoid disturbing the markers. The leg hole and permanent markers can be used to precisely relocate the plot in the future.

Calculation of cover values

Calculate an index of absolute cover for each species as the total number of hits on that species divided by (100 minus the number of permanent tags) times 100. This is not a true measure of absolute cover, since points intermediate between the top and bottom of the canopy are not included. Species present but not encountered can be assigned a value of <1% cover. Standing dead specimens should be included in the cover values, but dead specimens should be excluded.

Calculation of microtopography

Simplification: If time is a serious constraint, the following measures can be considered optional. Deleting any of these measures will necessarily result in a loss of information and in increased difficulty in interpretation of results, however there are always trade-offs to be made in time invested and information. At the very minimum, the critical information is relative cover for all experimental and control plots. The following deletions will still maintain that basic information.

1. The frame does not have to be precisely relocated each time. However, the information on change will be much more coarse.
2. Height is not necessary unless information on canopy structure is desired

SEED RAIN MONITORING AT ITEX SITES

Ulf Molau

When scaling up ITEX monitoring to include community-level dynamics, the potential for recruitment of local and immigrant species from seed is one of the main issues. The seed source at any site is composed of two elements: the seed rain and the resident seed bank. The following chapter deals with the first of these, the seed rain (or, preferably, diaspore rain, since the technique allows us to trap all kinds of functional diaspores, such as seeds, bulbils, and fragments of mosses and lichens).

A well-established technique in arctic and alpine environments is to use non-sticky seed traps that do not need continuous care. The best material available at present is plastic grass-turf resembling door mats, e.g. AstroTurf™. Since we are interested not only in the local, autoctonous diaspore rain, but also in the current alloctonous influx of potential immigrant species in a warmer climate, larger traps than normal should be employed. I recommend the following design:

At each ITEX field site, set up a number (ten or more) of seed trap stations. Each station should contain four 0.5 x 0.5 m chunks of door mat located at the corners of a 2x2 m square. Also rectangular traps are OK if it saves material when cutting larger pieces of mat, provided that each individual trap has a surface of at least 0.25 m^2 (larger traps are fine, but less handy). The traps should be fastened to the ground with steel wire in the corners. The replicate station can be placed in different plant communities or along altitudinal transects (if present) at your site.

Most diaspore dispersal will take place in late summer / early autumn and during the winter. The traps should ideally be visited twice a year: as soon as possible after thawing (to catch the winter dispersal), and at the very end of the growing season. If only one visit is possible, make this directly after thawing. Gently lift the seed traps and bring them to the field lab. Dry the seed traps indoors for a day or so. When sampling the diaspores, turn the traps upside down over a dark cloth , paper, or plastic sheet. Tap the entire lower surface gently with a hammer. Gather all particles in a paper bag (one bag per trap). If diaspores still stick in the trap, use a clean brush. Replace traps at the stations immediately.

Identification of diaspores is best made with a reference collection of diaspores from the area, collected from identified plants.. Once set up this can serve as reference for many years. After identification of the diaspores, they should be reported as numbers per m^2 and year. Germination tests can be carried out in filter paper in Petri Dishes at room temperature, but many arctic and alpine species need special treatment (e.g., hibernation, cutting, HCl-treatment) for germination, biasing the result. Seeds collected at the end of the growing season can be hibernated in the sample bags to improve germinability (except in a few cases where seed viability is extremely short, e.g., *Salix*). For this purpose, install a ”hibernation cabinet” at your site. We have used a plastic mailbox with drainage holes in the bottom and a padlock to keep the lid in place, attached to a pole just above the ground in a place where it stays entirely snow-covered through most of the winter. The sample bags are picked up at thawing, the seeds sown immediately. Such controlled natural hibernation gives better results than simulated hibernation in freezers.

GERMINABLE SEED/PROPAGULE BANKS

MONITORING AT ITEX SITES

Esther Lévesque, Manon N. Desforges, Glenda A. Jones and Gregory H.R. Henry

Objectives and concerns

Knowledge of the availability and abundance of viable seeds in tundra soils is important to an understanding of community processes in a stable or in a changing environment. This includes the actual recruitment from this seed bank into seedlings, juvenile and then adult population.

The study of the seed bank can be laborious if information on the total seed bank over a number of years is to be obtained. For the purpose of ITEX, we need background information on the size and the diversity of seed banks, this would require repeated sampling over a number of years as part of a long-term monitoring program at ITEX sites. Estimates of the **germinable seed (or propagule) bank** would then allow identification of the seedlings to species. This method is suggested for community level studies as it is less tedious than the direct counting of seeds (Simpson et al., 1989) and has given good results in previous arctic and alpine studies (e.g. Freedman et al., 1982; Fox, 1983; Diemer and Pock, 1993; Lévesque and Svoboda, 1995). For the people interested, the **total seed bank** could also be determined after germination by extraction of the seeds and viability tests (Malone, 1967). (For information about the propagule bank for bryophytes, read Lewis-Smith, 1993)

Seed banks are very heterogenous in time and in space (Thompson and Grime, 1979). A standardization of methods between studies has been recommended in the literature (Simpson et al., 1989) and is definitely necessary to allow comparisons among sites and among years in ITEX. Unfortunately, as pointed out by Simpson et al. (1989) it is unreasonable to expect people to use exactly the same method at each site. The range in seed dormancy and other germination requirements between habitats and species makes it impossible. Nevertheless, the method should have a baseline that is comparable between sites and this is what the present protocol is attempting to outline. Here is a list of concerns and background information to consider when planning a seed bank experiment. Please, consider these as well as to the literature cited at the end of this section.

1) There is a lot of variability in seed abundance in soils. A sample collected in the vicinity of a recently flowering individual is likely to have a much higher number of seeds than one collected away from an immediate seed source.

*** REPLICATION is IMPORTANT. Many small samples are better than few larger ones (Benoit et al. 1989)

2) The dormancy properties and longevity of seeds in arctic and alpine soils is relatively little known. Propagules from a large number of species have been able to germinate in the conditions recommended in this manual but it is likely that the requirements for germination of certain species are not met.

*** GERMINABLE seed bank is different from TOTAL seed bank.

3) In relation to (2), the timing of collection of samples and the preservation of samples are important (e.g. if most seeds are shed late in the season a collection early would exclude the current year's crop while a late one would be dominated by it!)

*** Description of time of sampling and consistency (between years) are important

Protocol

In the field:

If the samples are to be collected once in the season, it would be best to do so shortly after snowmelt. The seeds of the previous year would have had a vernalization period and would not have been swamped by the current year's crop. It may be possible to process the samples directly in the field (Diemer and Prock, 1993). If the samples need to be shipped south and processed later, a collection late in the season might be more suitable (to limit time of storage in the field).

The minimum frequency of sampling for a monitoring effort should be once every 3 to 5 years. In the control sites, at least 30 random samples should be collected (this is obviously not suitable in an OTC except if destructive measurements are planned or at the end of the experiment. In this case, following the paired plots design, 2 samples per plot would give 20 samples per treatment).

The samples should be relatively small and kept separate. In soft-substrate sites where it is possible to use soil cores, 7-10cm diameter cores are probably most suitable. In rocky sites it was found convenient to collect the soil of a 10cm x 10cm quadrat with a trowel. In general the top 1cm of soil is recommended for the dry sites, a depth to 3-5cm and up to 10cm was often sampled in alpine and forest tundra (Archibold, 1984; Morin and Payette, 1988; Diemer and Prock, 1993). It is suggested that each layer be kept separate because it would be best if we could compare the uppermost soil seed bank in all sites on the same basis. It is always possible to combine the results later on (suggested divisions, if possible: 1) first centimetre, 2) from 1-3cm, 3) 3-5cm 4) 5-10cm).

Seed banks are usually given in seeds/m^2 while, in fact, the numbers depend on the depth of the samples (i.e. seeds/m^2 per 1cm depth would be different from seeds/m^2 per 3cm depth). In the case of polar desert sites, seeds were found extremely rarely at depths > 1cm (Lévesque unpublished). In an alpine area, Morin and Payette (1988)

determined that 85% of the total seed bank of a 10cm deep core was found in the top 3cm. Thus we recommend sampling the top 1cm in polar desert and a minimum of 3cm for more productive sites (including meadows).

If the samples are not processed in the field, proper storage of soil samples is critical to ensure that seeds do not respire or start to germinate prior to the set up of a germination experiment. In general, drying the samples in the field (in a dark and cool environment) reduces the weight of the samples and minimizes the risk of germination during transport. Samples should then be stored in a dark cool environment as much as possible. A 2-3 month freezing treatment has often been given to samples before germination (Marchand and Roach, 1980; Fox, 1983; Archibold, 1984), and is recommended especially for samples collected late in the season. Certain species may not germinate after a freezing treatment because of their short viability (e.g. *Salix planifolia*; Bliss, 1958) or because of their particular dormancy characteristics. The analysis of the total seed bank, or the germination of a set of samples rapidly after collection might enable these problems to be addressed. Site-specific (and species-specific) problems should be considered before starting the experiment (see Simpson et al, 1989).

In the laboratory:

The following method assumes the availability of a greenhouse or of a growth chamber and has been adapted from the method of Ron Rollo, supervisor of the UBC Botanical Garden's nurseries. We do not recommend a method using a lid (because it is faster and easier for watering and for monitoring seed germination) but some concern should be given to the risk of contamination of the samples, especially if there are potential seed sources in the vicinity of the experiment. Pots with sterilised soil, to serve as controls, should be placed between the pots with samples (Archibold, 1984; Diemer and Prock, 1993). We used 24h light to germinate high arctic samples, slightly different light conditions may be suitable for other sites. In the literature, for alpine and low arctic sites, 16h to 18h seems to have been used with success (Leck, 1980; Archibold, 1984). Temperature near ambient (20-25˚C) is recommended as it has been shown to be near optimum for a number of species. Temperature and light intensity and quality should be monitored.

Each soil sample should be passed through a standard sieve. We used a 2mm mesh sieve, but if some seeds are likely to be larger than that a larger sieve should be used. Fleshy fruits may need to have their seeds separated from the berry (Komulainen et al., 1994). Here the idea is to make the samples more homogenous, to eliminate the rocks and allow the growth conditions to be more similar between samples. It also reduces the volume of the sample and allows more samples to be processed in a given space! This might be impractical for certain soils with high organic matter content, total samples should then be used. For optimal germination, the layer of soil for germination should be thin (<1cm; Fox, 1983) so, depending on the size of the pots and the space available in the greenhouse, the use of subsamples might be necessary. In this case, the total weight of the sample and that of the portion used (subsample) should be taken (0.01g accuracy) to allow conversion of seedlings/subsample to seedlings/sample to seedlings/m^2.

Pots of approximately 10cm x 10cm x 3cm or deeper, with drainage holes should be filled to 2/3 with sterile potting soil. The size of the pots depends mostly of the space available and the size of the sample, deeper pots allow for better rooting zone and are recommended. The sieved sample can be spread on top of this soil (in a thin layer, less than 1cm) covered then by a thin layer of silica aquarium sand (or blasting sand) to keep the surface from drying.

Each pot should be thoroughly watered and put in the greenhouse for approximately 2 months, or until no more new germination is observed over a consecutive 7-10 days period. Germination should be monitored frequently (daily or every 2-3 days, this is especially critical at the beginning), the new seedlings recorded (noting if they are monocotyledons or dicotyledons) and the pots watered if necessary. The samples can be kept in these pots until identification is possible.

Many emerged seedlings will need to be grown until flowering to be correctly identified. To ensure that these plants can grow without too much competition, the previously identified plants should be removed from the densely populated pots. Some voucher specimens should also be preserved.

Calculations:

Once all germinations have been recorded and the seedlings identified, the germinable seed bank value (number of seeds per m^2) at each site, for each species (and in each layer), can be derived from the following relationship

$$G = g \times A$$

and if you used subsamples:

$$G = g_b \times (Wt_a/Wt_b) \times A$$

Where G=germinable seed bank (seeds/m^2); g and g_b=number of germinated seedlings in a sample or in a subsample respectively; Wt_a=weight of the subsample (portion used in germination trial); Wt_b=total weight of sample. The multiplication factor A is used to convert the area of the samples to $1m^2$.

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EXPERIMENTAL DESIGN AND STATISTICAL ANALYSIS IN ITEX

Jill Johnstone, Ulf Molau, and Giles Marion

This is a brief introduction on how to design experiments and perform statistical analysis of data sets generated from ITEX manipulations in the field. Suggested readings are included in the References

1. Experimental design

If your experiment is set up in accordance with the ITEX Manual, you will have a set of manipulated plant individuals (temperature enhancement by means of OTCs or ITEX Corners) and an equal number of controls. In order to avoid pseudoreplication (Hurlbert 1984) each temperature enhancement chamber should be considered as one experimental unit. Experimental plants and controls can be selected systematically according to some geometric design, or chosen at random. The plots in each pair should have roughly the same species composition and similar edaphic conditions.

The ITEX setup accords with a BACIP design, decoded as Before-After-Control-Impact-Paired comparison (Osenberg et al. 1994, Underwood 1994). Since many of the identified response variables are predetermined the year before, some of the first-year records (e.g., flower numbers, ovule numbers, leaf number, etc.) will represent "Before" conditions. Phenological traits are likely to be affected already during the first year of treatment, whereas quantitative responses may show different short-term (1–2 yr) and long-term reactions. Phenological responses are not expected to change by experimentation with time, but may vary substantially among consecutive years due to ambient climatic fluctuations.

If the target plant species or community is subjected to more than one treatment factor (e.g., temperature enhancement, fertilizer, shade), a fully factorial randomized block design is recommended (see Sokal & Rohlf 1987). First, outline major blocks (replicates of the entire experimental program) in homogeneous sites. Within each block, experimental plots should be selected systematically or by random, and given code numbers. Then distribute the different combinations of treatments by some random procedure (e.g., lottery). If you have the factors, A, B, and C, you will need eight plots (2^3) in a minimum size block: A00, 0B0, 00C, AB0, 0BC, A0C, ABC, 000 (0 = factor not applied; 000 = control plot). Additional control plots are recommended, also for use in the future if other treatments are added

In order to follow community-level changes, an adequate documentation of the "Before" composition of the plant cover has to be carried out. Initial detailed mapping (documentative analysis) and photographs of all plots at the onset of experimentation is absolutely essential (see Walker, this volume).

2. Statistical analysis

2.1. Diagnostics and transformations

Methods of parametric analysis, such as analysis of variance (ANOVA), are based on assumptions of population characteristics, namely, samples must be drawn from normally-distributed populations with homoscedastic variance. Therefore, before using parametric tests, data distributions should be examined for departures from normality and inequality of error variance across the data set (heteroscedasticity). This can quickly be done using histograms or normality plots, and there are also statistical tests that can be used to check for departures from the assumptions of parametric statistics. Sometimes non-normal distributions may be 'fixed' using log, square root, or arcsin transformations, which often will simultaneously correct heteroscedasticity. In general, when a transformation is needed, measurement data should be log-transformed, counts should be squareroot-transformed, and ratios (quotients) arcsin-transformed. In cases where a) sample sizes are too small to adequately test for adherence to parametric assumptions or b) transformations are not able to produce normal distributions with homoscedastic variance, non-parametric tests should be used in the statistical analysis. It is also useful to use medium plots (box plots or box-and-whiskers) plots in portraying non-normal data, rather than mean and standard error plots.

2.2 Data filtering

In some cases, one may not wish to use the entire data set for testing factor effects. Such cases may included testing for effects on total shoot elongation when some percentage of the monitored individuals did not elongate or examining effects on seed:ovule ratios where some plants may have produced ovules that did not develop to mature seeds. In these instances, it may be more biologically meaningful to remove 'null' observations in order to understand effects on positive observations. If such 'data filtering' is to be used, it is important to also explicitly examine possible factor effects on the frequency of null observations. One way to accomplish this is through a separate analysis on the proportion of null observations.

2.3 Parametric analysis - Analysis of variance

It is always better to use a multivariate ANOVA to analyze a complex experiment rather than "hordes" of simple t-tests or correlation analyses, or a slew of simple ANOVAs. Multiple t-tests on the same data set, or some similar analysis, will affect the probability levels of the test

statistics, and must be corrected for. The simplest way to do this is to use a multivariate ANOVA.

When using unbalanced ANOVA models, it is recommended to use a Type III sum of squares in the analysis where it is appropriate. The default SS is usually Type I; with such analysis, the order in which effects are specified in the model statement will affect how the sum of squares is calculated. Type III does not take into account the order of effects, and therefor is more robust in situations where a clear order is not apparent (such as in a combined analysis of site, year and treatment effects).

2.3.1 Nesting plot sub-samples

It should be noted that, for the ITEX standard experiment, the plots (chambers) are the true replicates. Subsampling within chambers is good (improves accuracy of mean estimates), but these subsamples should not be treated as replicates: this is pseudoreplication. Variance attributed to within-plot samples can be examined using a nested ANOVA design, where samples are nested within plots. This will not change the significance of effects tested using only plot means, but will give some idea of the importance of sub-plot variation. In nested designs, it is important to use correct error terms (see below).

2.3.2 Repeated measures

Because of autocorrelation between dates, comparisons using data collected at different dates (within a season) from the same plots should be analyzed using a 'repeated measures' (split-plot in time) ANOVA model.

2.3.3 Fixed vs. Random effects

The difference between fixed and random effects is subtle, but important. When analyzing random effects (Type II ANOVA), one makes inferences about the variance among populations, and the analysis is not focused on mean treatment effects. The calculation of the estimated mean squares also is different between fixed and random effects, and under some circumstances, inclusion of random effects in a mixed ANOVA model may result in some effects and interactions being un-testable.

In the basic ITEX approach, treatment and year both represent fixed effects (see Sokal & Rohlf 1987). The treatment (OTC or Corner) in passive designs, as in ITEX, is a crude one, and the magnitude of its effects (temperature, humidity, etc.) will vary within and between sets of plots due to edaphic and climatic differences at various scales. From a statistical point of view, however, experiment should be regarded as a "perturbation" and used as a fixed effects. "Year" as source of variation is also a fixed effect, particularly in arctic and alpine situations, where summer seasons are discrete and short events, separated by long winters (for further discussion, see Sokal & Rohlf 1987).

2.3.4 How to build ANOVA models

In the situation when you have paired experiment and control plots, the analysis is simple and may turn out at a high resolution. The design follows Sokal and Rohlf (1987), a paired comparison ANOVA. Its basic design is the following (assuming 20 experimental plots and 20 controls):

Source of variation	Degrees of freedom
Treatment	1
Plot	19
Remainder	

or if monitored over two or more years

Source of variation	Degrees of freedom
Treatment	1
Year	1
Treatment * year	1
Plot	19
Remainder	

The "Remainder" is the error term for significance testing for all factors. This is not a mixed-model ANOVA; the responses of the individual plants are parallel through time (Sokal & Rohlf 1987), and there is no interaction with time or treatment. The error term is called "Remainder" here, rather than "Residual", since it is not the normal experimental error (variance at plant level at each sample point in time) which is assumed to be zero in this design (Sokal & Rohlf 1987). Treatment is of course a fixed effect (two categories possible, OTC and control) and so is year, as the set is sampled at well-defined, equal intervals (1 year, i.e., once per season; again Sokal & Rohlf 1987). Thus we are dealing with a special case of a simple Model I ANOVA.

You may also analyse these pair-wise data samples with a Paired Sample t-test, but the result would be less informative without partitioning of the variance (Sokal & Rohlf 1987).

If you have an experimental design where more than one plant has been sampled in each plot, the only appropriate method of analysis to accomodate variation among individual plants or shoots is a nested ANOVA model. Here you nest plants (by number or other nominal identification) within each plot. If you have 20 experimental and 20 control plants, the design would optimally be:

Source of Variation	Degrees of Freedom
Error Term	
Treatment	1
MS (Treatment)	
Plant (Treatment)	19
MS Residual	
Residual	

Note that in many statistical software packages you cannot alter the error terms, and the results will be flawed. Examples of good software are SAS and SPSS for PC and SuperANOVA and Statistica for the Mac.

2.4 Nonparametric analysis

Use of nonparametric statistics should not be considered a severe limitation to your analysis. In cases where the sampled population follows parametric assumptions, parametric tests are more robust; however, where populations deviate from these assumptions, non-parametric tests provide more robust results, and may detect effects which would not be significant under mis-used parametric analyses. An excellent discussion of types and usage of nonparametric analysis for ecologists may be found in Potvin and Roff (1993). In particular, rank-transformations may provide a very useful option for applying complex ANOVA models to non- conformist data sets (for examples, see Conover and Iman, 1981).

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EVOLUTIONARY RESPONSE

Kent E. Schwaegerle

Evolutionary response of plant populations depends on 1) the presence of genetic variation in traits relevant to climate change and 2) the magnitude and direction of natural selection in future environments. This chapter reviews recent studies on the genetics and evolution of plant populations and outlines the variety of methods that can be used to assess possible evolutionary responses of arctic plants to climate change.

There is considerable evidence that arctic plant populations harbor high levels of genetic variation relevant to climate change (review in McGraw and Fetcher 1992). Ecotypic variation has been observed in a surprising number of arctic plant species, and genotypic variation in metric traits (morphology, phenology, life history, etc) is generally characteristic of plant species that rely heavily on clonal reproduction. In contrast, several recent studies of metric variation in sexual plant populations suggest that the heritability of many traits may often be near the threshold of experimental detectability (Mitchell-Olds 1986, Schwaegerle and Levin 1991, Stratton 1992, Platenkamp and Shaw 1992). These studies suggest that plant populations may often harbor little or no variation at genetic loci influencing morphological and life-history traits. This is particularly true for fitness traits (Platenkamp and Shaw 1992) such as those relevant to climate change. The apparent disparity in levels of heritable variation between plants with predominantly sexual reproduction and plants with significant clonal reproduction may reflect several problems. First, there are good theoretical reasons to expect higher levels of genetic variation in late successional, long-lived species than in early successional species (Odum 1969, Loveless and Hamrick 1984). Second, genetic analysis of quantitative traits has been performed almost exclusively on annual plant species; little is known about narrow-sense heritability of metric traits in clonal species. And third, little is known about the persistence of environmental effects in clonal plant material (Hume and Cavers 1981, Foster et al. 1984, Schwaegerle 1996) that would upwardly bias estimates of genotypic variation in populations of clonal species.

1. Genetic variation within and among populations

Perhaps the best method for determining the capacity of arctic plants to adapt to future environments is to examine the types of evolutionary changes that have occurred in the past. Conditions vary widely in the range of most arctic plant species so that plants experience a broad range of selective regimes. The extent to which these populations have adapted to local conditions may be our best indicator of their capacity for future evolutionary change. Reciprocal transplant and common garden experiments can be used to measure divergence among populations from contrasting environments (e.g. Shaver et al. 1986, Matyas 1994, Schmidtling 1994, Stettler et al. 1994). These studies can focus on growth (see Sultan 1992, Sultan and Bazzaz 1993) and/or physiological response (e.g. Chapin and Oechel 1983, Blais and Lechowicz 1989, but also see Chapin and Shaver 1996). Reciprocal transplant experiments uniquely can provide a measure of how critical these evolutionary differences are to the persistence of a population at a site (see McGraw and Antonovics 1983).

Evolutionary response to selection is a direct function of genetic variation within populations. In long-lived plant species immediate evolutionary response to environmental change may depend upon genetically based differences among extant genotypes. Individual plants in the field may vary in phenological, physiological, and morphological traits that differentially influence their success in alternate environments. Common garden experiments using clonal propagation of individual genotypes can be used to assess genetic differences in traits relevant to environmental change. These methods are described by Platenkamp and Shaw (1992), Sultan and Bazzaz (1994), and Schwaegerle (1996). In contrast, long term response to selection depends upon sexual recombination among extant clones and hence the narrow-sense heritability of traits. Estimation of narrow- sense heritabilities is more involved than assessing genotypic variation. Falconer (1989; Chapter 6-11) provides an introduction to these methods (also see Mitchell-Olds and Rutledge 1986).

Although evolution of arctic plant populations depends on genetic variation in quantitative, polygenic traits (morphology, phenology, physiology, etc), a variety of molecular techniques may also shed light on the capacity of these populations to adapt to future environments. Phylogenies constructed from DNA sequence data or restriction fragment length polymorphisms can reveal biogeographic affinities and the evolutionary history of a species. Alternatively, allozyme electrophoresis can provide information on breeding systems and/or gene flow within and among populations. In contrast with the transplant and common garden experiments described above, these methods often involve considerable time and expense and only indirectly address the problem of evolutionary response to climate change.

2. Change in the selective regime

The evolution of arctic plant populations depends on the direction and magnitude of natural selection in future environments. The extent to which experimental warming results in a shift in the selective regime and the similarity

of this selective regime among ITEX sites can be assessed using methods developed by Lande and Arnold (1983) and others (Wade and Kalisz 1990, Rausher 1992, and references therein). These methods can reveal morphological and life-history traits (or combinations of traits) that are favored by natural selection. Field manipulations such as ITEX chambers can provide estimates of the force of natural selection on arctic plant populations in future environments. Most importantly, these analyses can be conducted with only the plant response data prescribed by Molau and Edlund in the ITEX Manual.

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INTERSITE MONITORRING (ITEM) OF INTERANNUAL VARIATIONS

Matthias Diemer, Esther Lévesque and Gus Shaver

Objectives and concerns

Aside from level I and II measurements of plant growth, phenology and meteorology a need exists for additional standardized measurements to quantify annual variation within and among sites. This should facilitate the determination of similarities and distinctions between sites and years, based on population or ecosystem traits (cf. Shaver et al. 1986). Emphasis is placed on simple, integrative parameters and experiments, which can be made in a) brief, annual visits to a site, b) are not strongly dependent on a narrowly defined time period and c) do not require continuous monitoring. This will allow monitoring of a larger number of sites/communities (even ones without OTCs), improve our understanding of regional variability and our ability to detect and predict change.

We distinguish five topics, namely 1) non-destructive plant measurements, 2) destructive harvests, 3) simple experiments, 4) climatic observations and 5) biotic observations. We understand these measurements as an extension of community measurements (see Manual).

One of the difficulties in relating ITEX data to other published sources on growth or productivity is the lack of a reference area (e.g. cm2, m2). This deficiency should be addressed and remedied in topics 1) and 2), making accessible a wide range of data (e.g. IBP, LTERS, MaB).

Preliminary protocol

This is a first draft and we encourage you to try out these approaches in the field. We would appreciate your feedback and suggestions for developing a definitive protocol.

1) Non-destructive plant measurements

Non-destructive measurements should be carried out in designated reference plots (could be identical to plots utilized for community baseline measurements, see manual). Ideally several reference plots should be established per field site or plant community. (Refer to section on community baseline measurements for permanently staking plots). Generally a square meter plot should be sufficient for most non-destructive parameters, however one may want to expand or reduce this size (nested plots) depending upon plant density. Regardless, results should be expressed per square meter area. Ideally all species should be surveyed, however if that is not possible focus on ITEX plant species and dominant herbs and graminoids at the site.

In sites with sparse vegetation cover two possiblities exist: use of large plot sizes, or alternatively collect data from 15-20 plants. Use of the latter involves a loss of the reference (ground) area, but we feel this shortcoming is superior to no data at all.

Population density, structure and turnover processes - phenological development and population structure tend to be rhythmic or episodic (seedling recuitment, flowering) in many actic and alpine plant species. It is important to document these cycles; these data also serve as a baseline for interpreting the effects of climate warming

Parameters:

a) Plant density per species and plot: count the number of shoots/plants per plots. This may require use of nested plots, however make sure that the nested plot is representative of entire plot (randomization and visual evaluation). It's better to use several nested plots and to use the subplot mean to extrapolate to plot basis.

b) Number of flowering shoots/plants per species and plot: tabulate the abundance of flowering individuals per reference area.

c) Proportion of reproductive to vegetative shoots/plants per species: determine the ratio of flowering to non-flowering shoots on an area basis, by dividing b) by a) minus b). Flowering phenologies in arctic alpine species often tend to be cyclical. These cycles are dependent on the age structure of the population (cf. Carlsson & Callaghan 1990) and/or on climatic factors.

d) Seedling density: count the number of seedlings per species and area. Notice: in many instances seedling distributions are clumped (Diemer 1992, Spence 1990). Therefore a number of small plots (e.g. 10*10cm) gives a better estimate than one large plot. If seedlings cannot be identified, mark several individuals with colored cocktail stirrers for subsequent identification.

e) Age structure: estimates of c) and d) provide a good indication of age structure (i.e. reproductive, vegetative shoots and seedlings). In some cases it is possible to distinguish additional age classes, based on size or morphology (Callaghan & Emanuelsson 1985, Carlsson & Callaghan 1990).

f) Mortality: increased population turnover via enhanced growth may affect mortality. Hence it may be valuable to estimate the density of dead shoots, provided that it is possible to distinguish current-year or overwintering mortality from shoots or plants which died previously. It is possible to use markers (tags, cocktail stirrers) to distinguish shoots which died in different years.

Reproduction and reproductive success - in some years weather conditions or the absence of pollinators may prevent seed set.

Parameters

a) Pollination visits: count the number of pollinator visits per area and time period. Since pollinator activity is dependent upon weather conditions and daytime, try to make observations under similar conditions. Record these along with rates of pollination visits for major species (number m-2 h-1). This parameter is in fact strongly dependent upon timing within the growing season, but we felt that these data are vital in the context of seed production.

b) Proportion of aborted to fertile flowers: at the stage of seed set determine the ratio of aborted and fertile flowers.

c) Seed production: determine fruit : flower ratio and seed number, as described in Manual (Plant response variables). Knowledge of flowering plant density (see above) permits extrapolation on area basis.

2) Destructive measurements

These should not be carried out in permanent plots, but in undisturbed adjacent areas. They serve to relate non-destructive growth measurements to estimates of biomass via allometric relationships and seperate analyses. In some instances it may be desirable to harvest individual shoots or branches from within OTCs or Control plots, however these disturbances should be kept to a minimum.

Parameters

a) Leaf growth: in graminoids it is usually quite simple to establish allometric relationships between leaf length and leaf area or mass. Often 15-20 specimens representing a broad range of leaf lengths are sufficient to obtain high regression coefficients ($R2 > 0.9$, see also Croy & Dix 1984). Measure leaf length preferrably in the field prior to removal. Leaf area measurements can be carried out with commercial leaf area meters (LiCor, CID, ADC), hand scanners or graph paper. For dry weight determination samples should be dried at 80 °C for 24h - try to dry samples as soon as possibe after harvesting, particularily if they are used for additional chemical analyses (see d)). Allometric relationships are generally quite robust and can be extended over years. Care should be taken to apply them to OTCs based on material from Control plots, since simulated warming may increase not only change leaf length, but also specific leaf area. For herbaceous plants, allometric relationships can be established using non-destructive measures, such as leaf breadth, breadth * length, or length of longest lamina (compound leaves).

b) Shoot or branch growth: in woody species annual increments can be determined from bud scars, in some cases retrospectively. Allometric relationships relating leader length and diameter to biomass can easily be established (cf. Shaver 1981, Shaver 1989).

c) Litter, standing dead biomass: these analyses can be carried out on a shoot/plant or on an area basis. In the latter case simply clip a 10*10 cm patch and determine dry mass.

d) Leaf samples for isotopic analysis: J. Welker volunteered to carry out analyses of stable isotopic composition (13C, 15N) of leaf tissue. 13C gives an indication of the integrated water and CO_2 supply over a leaf's lifespan, thus permitting an approximation of OTC effects on leaf carbon gain. Leaf samples (2-3 leaves/plot) should be collected toward the end of the growth period, oven dried (80 °C) and sent to Jeff. He has also indicated interest in obtaining soils samples, but should be contacted directly concerning details on sampling and handling.

3) Simple experiments

Here we describe two very simple experiments which can be used to quantify ecosystem-level responses to warming. In addition an experiment aimed at testing the extent of outcrossing is included.

a) Decomposition: increased soil temperatures increase microbial breakdown and thus decomposition, provided that tissue quality (C:N ratio) is not altered substantially. Two methods are available to quantify decomposition, namely use of litter bags or wooden dowels (tongue depressers). Both methods involve determination of dry mass loss per given time interval. In the case of litter bags, litter samples are weighed and placed in mesh bags (mesh size ca. 1mm) and exposed in the field. Make sure that bags are secured at the soil surface (use inert 'nails') and that replicates can be identified. In the case of wooden dowels replicates can be identified via permanent waterproof markers. Use a minimum of 5 replicates to incorporate microsite variation.

b) Root growth: an estimate of belowground responses to warming can be obtained via so-called ingrowth cores. These are mesh cylinders (mesh size 1-2mm) filled with root-free soil, which are sunk into holes in the soil (diameter 20-25mm, depth 10-15cm). Mesh bags are removed at intervals from the soils and the dry mass of roots, which grew into the mesh is determined. Make sure to mark the location of the ingrowth cores and cut off roots alongside the outer perimeter of the mesh bag with a knife, prior to removal. Use sifted soils from the core holes to fill ingrowth bags. Although root ingrowth is not a direct measure of belowground productivity (Hansson & Andren 1986), it is an easy, relatively non-invasive means for quantifying responses of warming on root dynamics. Before applying the method within OTCs, we recommend that you try it out elsewhere first, since little data is available from arctic soils.

c) Emasculation of anthers: experimental removal of anthers can be used to test the extent of outcrossing in plant species. We suggest that seed mass and number of emasculated flowers be compared to non-manipulated controls. Since OTCs tend to serve as a barrier for wind pollination and reduce or even concentrate insect pollinators it is important to determine the extent of outcrossing particularily in ITEX plant species.

4) Climatic observations

In order to link results of 1) to 3) to climatic conditions in the current or previous years an effort should be made to obtain integrated measures of annual climatic variation. In addition to the ITEX climatic data (GDD), date of ice breakup or thawdepth (see Manual), we recommend use of year-round records of standard meteorological data. These data used for interannual intrasite and intersite comparison need not necessarily be local - even regional data from weather service stations could be utilized, particularily in cases where presence at the field site is intermittent. In these cases we recommend calibration of local weather data (i.e. short-term local site data) with those of a nearby permanent weather station. Regressions can by used to estimate local climate, although in some instances monthly means are sufficient. In mountainous terrain care should be taken with these correlations, since altitude, topography and exposition can have profound influences on local climate.

Note: In a number of species flower and leaf primordia are pre-formed, thus current year growth and reproductive status more accurately reflects climatic conditions of the preceeding year.

5) Biotic observations

Other climate-related observations of biotic activity (first appearance of birds, hatching dates, insect phenology - see Manual) could be used to augment climatic observations.

Analyses

We recommend that the methodology described above should be incorporated into the standard ITEX protocol. These data will provide a basis for comparisons among and within sites, that extends far beyond the present scope of comparisons (i.e. ITEX species, climate-related data) to include population, community and ecosystem properties. It should for example permit a detailled study of regional and annual patterns of flowering rhythms, biomass accumulation and decomposition, at the same time incorporating the effects of simulated warming.

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Appendices

Tables and Protocols

Appendix I

DATES AND DAY NUMBERS

Use day numbers (Julian dates) throughout in all ITEX reports (climate stations, snow, ice, plant response variables). The numbers provided below are for the field season during normal years; for leap years, add 1 to all day numbers.

Date	Day Number	Date	Day Number
1 May	121	1 July	182
5 May	125	5 July	186
10 May	130	10 July	191
15 May	135	15 July	196
20 May	140	20 July	201
25 May	145	25 July	206
30 May	150	30 July	211
31 May	151	31 July	212
1 June	152	1 August	213
5 June	156	5 August	217
10 June	161	10 August	222
15 June	166	15 August	227
20 June	171	20 August	232
25 June	176	25 August	237
30 June	181	30 August	242
		31 August	243
		1 September	244

ITEX Climate Stations
Field Record Form (Manual or manual/automatic station)

Date: / **Year:** **Day number**: .....

0700 hours normal time **Cloudiness** (0/8 – 8/8)**:** .... /8 **Type**: .....
Precipitation (0700–0700 hrs): ..... mm***** Type of precipitation: ..... Reset!

Max.temp: ..... °C **Min.temp**: ..... °C (Do not reset!)
Min. thermometer **actual temp**.: ..... °C

THG: Actual temperature: ..... °C RH: ..... % (Set marks on recorder chart!)

Psychrometer; dry bulb: ..... °C; wet bulb: ..... °C

Signature: .....

1900 hours normal time **Cloudiness** (0/8 – 8/8)**:** .... /8 **Type**: .....

Max.temp: ..... °C **Min.temp**: ..... °C Now reset both!

Max. and min. thermometers after **reset**: ..... °C (=actual temp.)

THG: Actual temperature: ..... °C RH: ..... % (Set marks on recorder chart!)

Psychrometer; dry bulb: ..... °C; wet bulb: ..... °C

Signature: .....

To be **transferred** to the monthly ITEX Climate Station Report:

Precipitiation (0700 – 0700 hours): ..... mm

Highest and lowest temperature records, **Tmax**: ..... °C, **Tmin**: ..... °C

Daily mean temperature, **m**: ..... °C
Calculate m as mean of hour temperature means (datalogger) or from max/min data as
m = (Tmax + Tmin) / 2

Daily heat accumulation, **H**: ..... degrees > 0°C TDD; ..... degrees > 5°C GDD
If Tmin > 0°C (or 5°C for GDD) then H = m for TDD and GDD
If Tmax < 0°C/5°C then H = 0
If Tmin < 0°C/5°C but Tmax > 0°C/5°C, calculate H from the sum of hour means above the threshold divided by 24, or with Watanabe's formula

From automatic station also:

Maximum wind speed: ..... m/s Mean wind speed: ..... m/s

Global solar radiation, **Rmax**: ..... W/m^2, **Rmean**; ..... W/m^2

Integrated global solar radiation, **R** : ..... MJ/m^2
R = (mean of hour means of global radiation 0000 – 2400 hours) x 0.0864
If too many values are missing, R ≈ 0.0864 (Rmax) / 3

***** No precipitation: – Some, but unmeasurable (< 0.05 mm): 0.0

Monthly Report form **ITEX Climate Station**

Site: ..... Country: ..... Year: 19..... Month: .....

Recording of precipitation (man/aut): ..... Max and min temperatures (man/aut): .....

Calculations of daily mean temp, TDD, and GDD

(from max-min amplitude [ampl] or hour means of logged data [integr]): .....

Date	Day No.	Precipi-tation (mm)*	Tmax °C	Tmin °C	Mean temp °C	TDD	GDD	Wind max m/s	Wind mean m/s	Max rad. W/m²	Accum. radiation **R** (MJ/m²)
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
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24											
25											
26											
27											
28											
29											
30											
31											

* NB! Precipitation (manual) recorded at 0700 hours on the next day; h = hail, r = rain, s = snow.

Notes:

Month totals. **Precipitation:** ..... mm **Global radiation** ∑R: .....MJ/m²

Temperature: max: ..... °C min: ..... °C mean : ..... °C

∑TDD: ..... degree days > 0°C ∑GDD: ..... degree days > 5°C

Report form ITEX Climate Station

Site: **Latnjajaure** Country: **Sweden** Year: **1992** Month: **April**

Recording of precipitation (man/aut): — Max and min temperatures (man/aut): aut
Calculations of daily mean temp, TDD, and GDD
(from max-min amplitude [ampl] or hour means of logged data [integr]): ampl day 92–109, integr 110–

Date	Day no.	Precip. mm*	Tmax °C	Tmin °C	Mean temp.	TDD	GDD	Wind max m/s	Wind mean m/s	Max. rad. W/m^2	Accum. rad. (R) MJ/m^2
1	92		*–8.2*	*–11.0*	*–9.6*	*0.00*	*0.00*				
2	93		*–7.6*	*–12.2*	*–9.9*	*0.00*	*0.00*				
3	94		*–8.4*	*–17.4*	*–12.9*	*0.00*	*0.00*				
4	95		*–7.3*	*–15.4*	*–11.4*	*0.00*	*0.00*				
5	96		*–7.6*	*–15.4*	*–11.5*	*0.00*	*0.00*				
6	97		*–6.1*	*–15.5*	*–10.8*	*0.00*	*0.00*				
7	98		*–3.3*	*–13.7*	*–8.5*	*0.00*	*0.00*				
8	99		*–1.8*	*–9.8*	*–5.8*	*0.00*	*0.00*				
9	100		*–1.1*	*–8.4*	*–4.8*	*0.00*	*0.00*				
10	101		*–0.5*	*–12.5*	*–6.5*	*0.00*	*0.00*				
11	102		*+0.9*	*–4.4*	*–1.8*	*0.16*	*0.00*				
12	103		*–1.2*	*–9.8*	*–5.5*	*0.00*	*0.00*				
13	104		*–3.3*	*–10.4*	*–6.9*	*0.00*	*0.00*				
14	105		*–3.5*	*–9.6*	*–6.6*	*0.00*	*0.00*				
15	106		*–5.5*	*–14.9*	*–10.2*	*0.00*	*0.00*				
16	107		*–3.7*	*–19.0*	*–11.4*	*0.00*	*0.00*				
17	108		*–3.3*	*–9.8*	*–6.6*	*0.00*	*0.00*				
18	109		*–0.8*	*–6.3*	*–3.6*	*0.00*	*0.00*				
19	110		+0.3	–12.8	–6.19	0.00	0.00				9.08
20	111		+0.1	–8.8	–4.49	0.00	0.00				1.41
21	112		–3.4	–9.1	–6.04	0.00	0.00				3.06
22	113		+1.1	–14.1	–7.73	0.32	0.00				5.91
23	114		–4.9	–12.5	–8.68	0.00	0.00				16.27
24	115		–5.0	–11.7	–9.46	0.00	0.00				14.07
25	116		–3.9	–10.0	–6.04	0.00	0.00				13.65
26	117		+6.0	–6.1	–2.33	1.94	0.12				16.76
27	118		+4.9	–5.4	–1.12	1.43	0.00				7.95
28	119		+8.3	–2.6	+0.80	3.38	0.76				21.58
29	120		+3.9	–4.7	+0.81	1.11	0.00				11.93
30	121		+7.3	+0.9	+1.93	1.93	0.64				12.39

* NB! Precipitation (manual) recorded at 0700 hours on the next day; h = hail, r = rain, s = snow.
Notes: *Italics = Regression from Abisko data*

Month totals. **Precipitation:** .... ? ... mm **Global radiation** ∑R: ..... ? ....MJ/m^2
Temperature: max: + 8.3 °C min: – 19.0 °C mean : **– 6.26** ± 4.12 (SD) °C
∑TDD: 10.27 degree days > 0°C ∑GDD: 1.52 degree days > 5°C

Report form ITEX Climate Station

Site: **Latnjajaure** Country: **Sweden** Year: **1992** Month: **May**

Recording of precipitation (man/aut): man. (day 137–) Max and min temperatures (man/aut): aut.
Calculations of daily mean temp, TDD, and GDD
(from max-min amplitude [ampl] or hour means of logged data [integr]): integr.

Date	Day no.	Precip. mm*	Tmax °C	Tmin °C	Mean temp.	TDD	GDD	Wind max m/s	Wind mean m/s	Max. rad. W/m^2	Accum. rad. (R) MJ/m^2
1	122		+6.6	–2.0	+0.92	2.66	0.26				7.24
2	123		+6.3	–8.9	+0.53	1.82	0.15				8.27
3	124		+9.6	–1.6	+2.47	4.23	1.34				6.75
4	125		–1.8	–5.3	–3.78	0.00	0.00				11.64
5	126		+5.9	–4.0	+1.52	2.06	0.10				12.39
6	127		+8.5	+0.6	+2.96	2.96	1.03				9.47
7	128		+7.8	–5.6	+0.04	2.68	0.54				8.95
8	129		+2.5	–8.5	–3.15	0.55	0.00				19.15
9	130		+3.8	–5.6	–2.79	1.03	0.00				25.02
10	131		–1.6	–5.2	–3.36	0.00	0.00				19.45
11	132		+6.5	–6.4	+0.12	2.06	0.26				22.33
12	133		+5.9	–7.7	–3.00	1.77	0.14				21.88
13	134		+3.4	–8.4	–1.41	0.83	0.00				26.34
14	135		+6.4	–4.9	–1.41	2.15	0.23				18.15
15	136		+8.5	–1.7	+4.10	3.68	0.92				19.80
16	137	s 0.6	+9.1	–5.2	+3.81	3.43	1.00	16	8		11.93
17	138	s 8.5	+1.8	–5.0	–2.86	0.41	0.00	22	6		22.43
18	139	s 3.6	+1.7	–2.1	+1.65	0.49	0.00	17	3		16.07
19	140	s 2.6	+2.6	–0.8	+0.84	1.09	0.00	23	10		18.21
20	141	sr 8.4	+2.6	–4.0	+0.13	0.73	0.00	7	3		13.09
21	142	-	+4.4	+0.6	+2.90	2.90	0.00	7	2		10.91
22	143	-	+5.1	+1.2	+3.86	3.86	0.00	7	1		11.49
23	144	-	+10.8	+0.4	+4.04	4.04	1.98	4	1		25.92
24	145	s 0.1	+7.2	+0.5	+3.85	3.85	0.54	15	6		29.32
25	146	-	+6.0	–2.9	+2.06	2.23	0.18	5	1	1002	26.47
26	147	-	+10.5	+2.1	+5.72	5.72	0.92	9	4	999	27.98
27	148	-	+10.6	+3.0	+8.07	8.07	3.07	9	4	971	26.83
28	149	-	+13.3	+5.9	+9.22	9.22	4.22	10	3	959	26.66
29	150	-	+11.7	+5.5	+8.36	8.36	3.36	9	4	958	27.46
30	151	r 0.1	+11.4	+4.8	+8.15	8.15	3.15	7	1	923	25.31
31	152	r 0.0	+8.8	+1.2	+5.54	5.54	1.11	12	6	505	13.51

* NB! Precipitation (manual) recorded at 0700 hours on the next day; h = hail, r = rain, s = snow.

Notes: Manual weather station opened 16 May. Electronic hand anemometer used.

Month totals. **Precipitation** (day 137–) 22.9 mm **Global radiation** ∑R: 570.42 MJ/m^2
Temperature: max: + 13.3 °C min: – 8.9 °C mean : **+ 1.91** ± 3.71 (SD) °C
∑TDD: 96.04 degree days > 0°C ∑GDD: 24.50 degree days > 5°C

Report form ITEX Climate Station

Site: **Latnjajaure** Country:**Sweden** Year: **1992** Month: **June**

Recording of precipitation (man/aut): man. Max and min temperatures (man/aut): aut.
Calculations of daily mean temp, TDD, and GDD
(from max-min amplitude [ampl] or hour means of logged data [integr]): integr.

Date	Day no.	Precip. mm*	Tmax ℃	Tmin ℃	Mean temp.	TDD	GDD	Wind max m/s	Wind mean m/s	Max. rad. W/m^2	Accum. rad. (R) MJ/m^2
1	153	-	+9.5	±0.0	+4.56	4.56	1.23	1	0	1043	29.02
2	154	-	+11.6	+1.0	+7.13	7.13	2.77	1	0	1034	28.43
3	155	-	+12.8	+3.7	+8.62	8.62	3.72	6	1	1006	27.88
4	156	r 0.0	+15.2	+3.9	+8.82	8.82	4.63	1	0	1040	28.57
5	157	-	+11.8	+2.3	+5.29	5.29	0.97	12.5	4.02	851	27.49
6	158	rs 0.4	+9.9	+2.4	+5.52	5.52	0.74	14.8	4.41	1001	18.17
7	159	r 0.9	+4.8	+0.2	+2.42	2.42	0.00	19.5	8.53	1263	27.06
8	160	-	+13.2	+0.3	+7.10	7.10	2.86	3.2	0.65	756	27.58
9	161	-	+16.3	+5.6	+10.59	10.59	5.59	1.8	0.61	769	28.14
10	162	-	+17.1	+7.7	+12.38	12.38	7.38	4.1	0.98	752	27.53
11	163	-	+15.7	+7.5	+11.88	11.88	6.88	4.0	0.89	745	27.48
12	164	-	+18.4	+7.5	+12.92	12.92	7.92	4.5	1.22	852	27.06
13	165	-	+16.4	+7.1	+12.41	12.41	7.41	8.0	2.23	829	26.79
14	166	r 2.7	+16.0	+4.7	+10.11	10.11	5.11	11.4	3.36	968	16.52
15	167	rs 0.1	+6.6	+3.6	+4.90	4.90	0.13	7.6	3.24	1147	15.63
16	168	s 0.8	+4.0	–2.6	–0.04	0.43	0.00	16.9	9.02	1053	16.96
17	169	-	+3.1	–2.9	–0.53	0.36	0.00	16.1	6.18	1070	23.08
18	170	s 0.0	+4.9	–0.5	+1.78	1.79	0.00	7.7	2.24	1047	23.33
19	171	-	+8.2	–1.1	+4.21	4.24	0.87	7.9	3.20	867	25.40
20	172	rs 3.1	+8.2	+0.1	+4.78	4.78	0.57	13.5	6.62	555	9.61
21	173	s 0.6	+0.8	–3.6	–1.16	0.00	0.00	12.6	5.54	1108	19.74
22	174	s 0.1	+1.4	–3.8	–1.54	0.01	0.00	10.2	4.94	1125	24.32
23	175	-	+1.8	–2.4	–0.26	0.47	0.00	13.4	7.70	1140	20.31
24	176	-	+9.6	–1.8	+3.88	4.05	0.91	5.1	1.65	776	28.54
25	177	-	+10.3	+1.8	+6.44	6.44	1.97	6.8	2.33	792	28.33
26	178	r 0.0	+15.3	+2.9	+9.39	9.39	4.56	4.7	0.95	762	25.87
27	179	r 17.0	+14.2	+3.4	+8.68	8.68	3.76	12.1	2.49	719	14.15
28	180	sr 0.9	+4.9	+1.1	+3.26	3.26	0.00	11.4	4.88	1160	22.52
29	181	-	+7.6	+1.0	+3.77	3.77	0.27	6.1	2.43	1006	26.07
30	182	sr 1.0	+6.8	+0.5	+3.28	3.28	0.05	7.0	2.86	1016	18.06

* NB! Precipitation (manual) recorded at 0700 hours on the next day; h = hail, r = rain, s = snow.

Notes: Logging anemometer installed 4 June.

Month totals. **Precipitation** 27.8 mm **Global radiation** ∑R: 709.64 MJ/m^2
Temperature: max: + 18.4 °C min: – 3.8 °C mean : **+ 5.69** ± 4.26 (SD) °C

∑T**Report form** **ITEX Climate Station**

Site: **Latnjajaure** Country: **Sweden.....** Year: **1992** Month: **July**

Report form ITEX Climate Station

Site: **Latnjajaure** Country: **Sweden** Year: **1992** Month: **July**

Recording of precipitation (man/aut): man. Max and min temperatures (man/aut): aut.
Calculations of daily mean temp, TDD, and GDD
(from max-min amplitude [ampl] or hour means of logged data [integr]): integr.

Date	Day no.	Precip. mm*	Tmax °C	Tmin °C	Mean temp.	TDD	GDD	Wind max m/s	Wind mean m/s	Max. rad. W/m^2	Accum. rad. (R) MJ/m^2
1	183	s 1.2	+3.1	+1.0	+1.75	1.75	0.00	7.6	4.99	973	15.93
2	184	sr 0.6	+4.2	+0.5	+1.86	1.86	0.00	8.9	3.60	1125	21.13
3	185	s 1.1	+1.9	–0.8	+0.44	0.54	0.00	17.7	8.88	812	15.70
4	186	r 0.0	+7.0	+0.5	+3.51	3.51	0.12	18.6	8.39	1062	21.62
5	187	s 0.6	+7.6	+1.9	+4.85	4.85	0.61	9.0	4.89	775	28.25
6	188	s 3.2	+2.5	+0.2	+1.23	1.23	0.00	12.0	6.56	989	14.80
7	189	sr 0.5	+3.1	+0.1	+1.31	1.31	0.00	13.6	6.99	1060	24.09
8	190	r 7.7	+6.1	+1.2	+3.86	3.86	0.08	5.9	2.80	205	4.98
9	191	r 0.5	+5.0	+2.3	+3.56	3.56	0.00	9.3	3.53	836	9.16
10	192	r 0.0	+8.3	+2.4	+4.56	4.56	0.47	6.5	2.67	966	17.50
11	193	r 2.6	+7.7	+2.3	+4.17	4.17	0.24	11.0	3.52	1106	17.92
12	194	r 0.1	+10.6	+1.7	+5.82	5.82	1.88	9.1	3.01	987	24.69
13	195	r 0.2	+13.4	+6.5	+9.61	9.61	4.61	10.4	3.27	918	14.16
14	196	r 4.0	+11.2	+3.5	+8.16	8.16	3.19	4.9	1.51	832	14.44
15	197	r 43.1	+8.6	+4.3	+7.03	7.03	2.03	8.7	2.74	278	6.84
16	198	r 10.1	+7.2	+1.9	+4.80	4.80	0.44	12.9	6.42	331	8.01
17	199	s 0.3	+2.7	–0.1	+1.26	1.26	0.00	13.5	7.54	780	12.71
18	200	-	+10.5	–1.0	+4.93	5.08	1.72	5.2	1.73	796	25.70
19	201	-	+13.4	+3.5	+8.68	8.68	3.70	5.6	1.40	898	23.70
20	202	r 1.9	+12.4	+4.0	+8.49	8.49	3.50	5.6	1.65	929	15.11
21	203	r 0.2	+12.0	+6.2	+9.01	9.01	4.01	5.2	1.50	920	16.98
22	204	r 1.1	+11.2	+7.2	+9.92	9.92	4.92	11.9	4.12	289	4.80
23	205	r 17.5	+8.3	+2.0	+5.42	5.42	1.02	15.4	8.19	665	7.14
24	206	r 1.1	+10.0	+2.1	+5.90	5.90	1.57	11.6	3.34	930	14.50
25	207	r 0.4	+9.4	+5.2	+7.39	7.39	2.39	9.2	2.16	639	8.31
26	208	r 0.6	+14.0	+3.8	+8.80	8.80	3.93	6.0	2.18	886	15.76
27	209	r 9.2	+10.7	+6.5	+9.09	9.09	4.09	7.6	1.99	332	5.35
28	210	r 0.3	+8.8	+4.6	+6.16	6.16	1.16	10.3	4.01	962	12.56
29	211	r 0.4	+6.9	+3.9	+5.28	5.28	0.35	10.1	4.02	919	13.71
30	212	r 11.1	+9.7	+4.2	+6.99	6.99	2.04	5.3	1.94	926	12.09
31	213	rs 3.4	+6.7	+2.6	+4.54	4.54	0.10	10.5	4.89	240	6.94

* NB! Precipitation (manual) recorded at 0700 hours on the next day; h = hail, r = rain, s = snow.

Notes:

Month totals. **Precipitation** 133.0 mm ! **Global radiation** ∑R: 454.62 MJ/m^2
Temperature: max: + 14.0 °C min: – 1.0 °C mean : **+ 5.43** ± 2.77 (SD) °C
∑TDD: 169.33 degree days > 0°C ∑GDD: 48.17 degree days > 5°C

Report form ITEX Climate Station

Site: **Latnjajaure** Country: **Sweden** Year: **1992** Month: **August**

Recording of precipitation (man/aut): man. Max and min temperatures (man/aut): aut.
Calculations of daily mean temp, TDD, and GDD
(from max-min amplitude [ampl] or hour means of logged data [integr]): integr.

Date	Day no.	Precip. mm*	Tmax °C	Tmin °C	Mean temp.	TDD	GDD	Wind max m/s	Wind mean m/s	Max. rad. W/m^2	Accum. rad. (R) MJ/m^2
1	214	rs 4.9	+4.7	+2.2	+3.28	3.28	0.00	14.4	7.40	883	11.86
2	215	r 0.3	+9.3	+1.7	+5.67	5.67	1.55	7.4	2.14	498	9.16
3	216	r 0.3	+11.0	+6.2	+8.37	8.37	3.37	4.4	1.23	851	7.86
4	217	r 11.5	+11.0	+5.6	+8.47	8.47	3.47	10.2	2.99	715	9.29
5	218	r 1.0	+8.3	+5.5	+6.81	6.81	1.81	12.9	5.14	701	8.86
6	219	r 0.9	+10.0	+4.7	+7.16	7.16	2.16	5.2	1.62	865	11.77
7	220	r 0.8	+7.2	+3.0	+5.27	5.27	0.57	12.2	3.90	818	10.32
8	221	s10.4	+5.4	–0.6	+2.06	2.09	0.00	15.5	5.69	888	10.97
9	222	s 2.3	+1.6	–1.1	+0.09	0.22	0.00	14.1	5.66	951	14.06
10	223	r 3.5	+8.6	–0.9	+4.27	4.36	1.01	5.9	1.90	793	13.35
11	224	r 7.6	+7.7	+4.1	+5.66	5.66	0.80	6.0	1.93	260	5.10
12	225	r 0.4	+5.1	+0.5	+3.25	3.25	0.00	8.6	4.82	322	4.41
13	226	r 1.6	+6.3	–0.2	+2.57	2.57	0.03	5.3	2.21	776	10.24
14	227	r 0.6	+8.1	+1.8	+4.18	4.18	0.30	5.5	1.78	826	12.17
15	228	-	+9.9	+2.9	+5.50	5.50	1.13	4.1	1.49	905	12.70
16	229	r 1.0	+7.6	+1.8	+5.84	5.84	1.23	6.4	2.69	466	6.03
17	230	r 3.5	+9.6	+5.2	+6.52	6.52	1.52	4.4	1.35	880	8.59
18	231	r 0.8	+10.0	+5.2	+6.73	6.73	1.73	4.7	1.22	727	9.20
19	232	r 0.1	+8.9	+4.7	+6.94	6.94	1.94	4.1	1.12	428	9.25
20	233	r 0.6	+8.6	+5.2	+6.77	6.77	1.77	5.0	1.26	323	6.64
21	234	-	+10.6	+4.3	+6.77	6.77	1.83	5.1	1.45	766	15.44
22	235	-	+12.4	+4.2	+7.73	7.73	2.79	4.5	1.40	606	14.46
23	236	-	+11.4	+3.6	+7.19	7.19	2.25	6.7	2.38	716	15.34
24	237	-	+9.5	+2.5	+5.45	5.45	0.98	5.6	2.15	605	9.38
25	238	-	+10.0	+2.9	+5.64	5.64	1.06	5.1	2.07	559	10.21
26	239	-	+8.1	+3.4	+5.56	5.56	0.86	5.4	2.21	517	9.13
27	240	r 0.0	+8.8	+2.3	+5.18	5.18	0.86	4.8	1.77	478	8.58
28	241	r 0.4	+7.3	+3.9	+5.57	5.57	0.73	6.3	2.97	381	7.09
29	242	r 0.2	+7.8	+5.0	+6.12	6.12	1.12	7.5	2.42	478	6.57
30	243	r 0.1	+9.3	+4.9	+6.44	6.44	1.44	6.7	2.12	497	9.06
31	244	r 0.6	+8.9	+4.4	+6.67	6.67	1.67	5.8	3.16	664	10.22

* NB! Precipitation (manual) recorded at 0700 hours on the next day; h = hail, r = rain, s = snow.

Notes: Manual weather station closed 1 September.

Month totals. **Precipitation** 52.0 mm **Global radiation** ∑R: 307.31 MJ/m^2
Temperature: max: + 12.4 °C min: – 1.1 °C mean : **+ 5.60** ± 1.88 (SD) °C
∑TDD: 173.90 degree days > 0°C ∑GDD: 39.98 degree days > 5°C

ITEX **Snow depth transect form**

Site:..... **Transect no./name:……**

Year: 19..... **Date:**...../..... **Day number:** .....

Point on transect	Probe 1 (cm)	Probe 2 (cm)	Probe 3 (cm)	Probe 4 (cm)	Probe 5 (cm)	Mean depth (cm)	± SD
0 m							
5 m							
10 m							
15 m							
20 m							
25 m							
30 m							
35 m							
40 m							
45 m							
50 m							
55 m							
60 m							
65 m							
70 m							
75 m							
80 m							
85 m							
90 m							
95 m							
100 m							

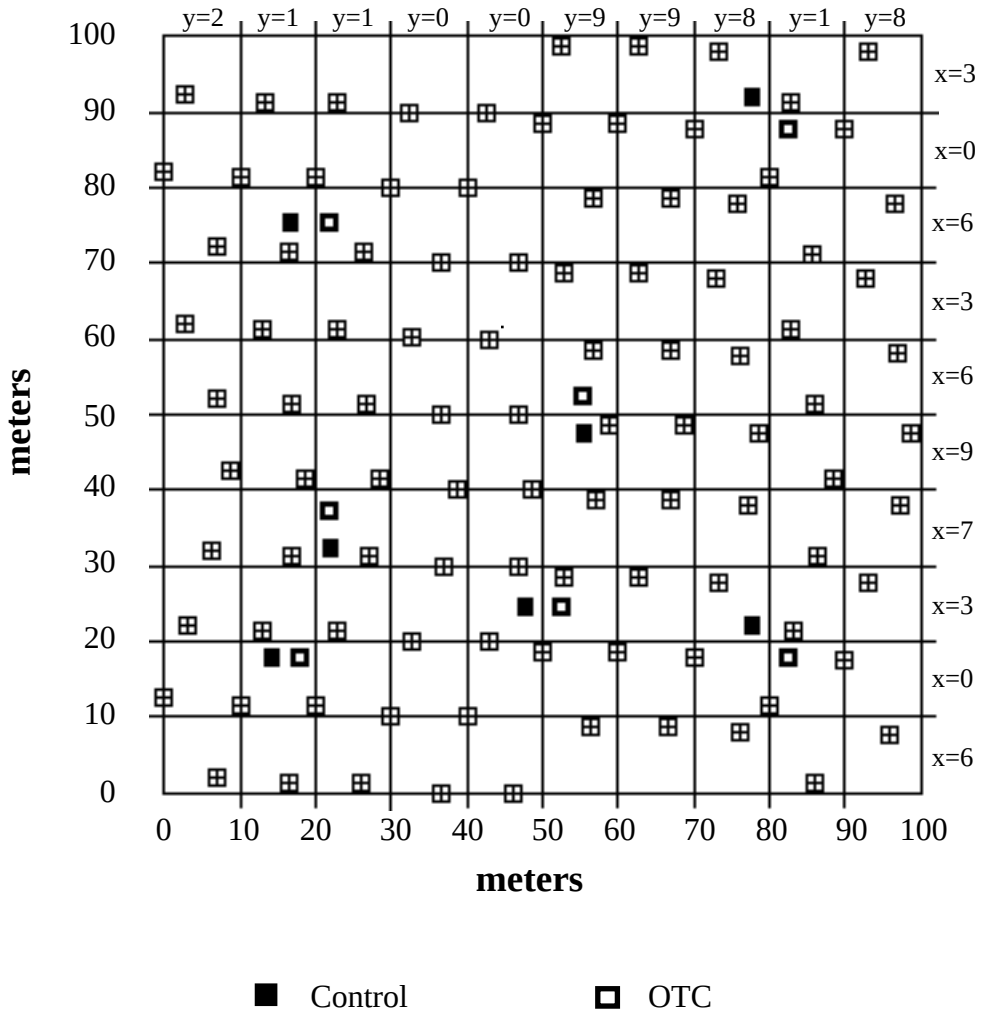
Present position of snow front along transect: ..... m from 0 point.
Repeat sonding every third day until completed snow-melt.
Note flowering fronts for plant species: species front (m from 0 point)

_____ _____ m
_____ _____ m
_____ _____ m
_____ _____ m
_____ _____ m
_____ _____ m
_____ _____ m
_____ _____ m

ITEX-IPA active layer grid form

DATE: (month)_____/(day)_____(year) 19____

LOCATION: (site)_____(country)_____



AVERAGE THAW CALCULATIUON:

A= TOTAL NUMBER POINTS MEASURED:

B= CUMULATIVE SUM OF ALL ACTIVE LAYER THICKNESS (CM):

B/A= AVERAGE THAW:_____

ITEX ACTIVE LAYER/OCT CONTROL FORM

DATE: (month) /(day) /(year) 19

OTC identifer	OTC center	CONTROL POINTS 1	2	3	4	Average	Notes
Average							

Frost Tube: (1)_____(cm); (2) _____(cm)
Date Recorded (m)_____(d)_____(y) 19___

Page _____(use additional forms as necessary)

ITEX Lake Monitoring Protocol

ITEX Site: ..... Country: .....Year: 19..... Month: .....

Lake: ..... Co-ordinates: .....

Altitude: ..... m Surface size: ..... km^2 Depth: ..... m

Date	Day Number	Ice Stage *	Ice Cover (%)	Surface Water Temp. (℃)	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					

* **Break-up:** B0 No sign of break-up
B1 Open water on shore
B2 Open water offshore
B3 Ice in movement
B4 Final break-up

Freeze-up: F0 No ice formation
F1 Ice formation on shore
F2 Ice cover on bays
F3 Ice within visible range
F4 Final freeze-up

Species: ***Bistorta vivipara***

Site: Year:

Devices: OTCs / corners Co-ordinates: Altitude (m):

Replicates are genets / ramets Observation period (day ##): –

Experiment plants

No.	P1	P2	P3	P4	P5	P6	P7	P8		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
E 1																	
E 2																	
E 3																	
E 4																	
E 5																	
E 6																	
E 7																	
E 8																	
E 9																	
E 10																	
E 11																	
E 12																	
E 13																	
E 14																	
E 15																	
E 16																	
E 17																	
E 18																	
E 19																	
E 20																	
C 1																	
C 2																	
C 3																	
C 4																	
C 5																	
C 6																	
C 7																	
C 8																	
C 9																	
C 10																	
C 11																	
C 12																	
C 13																	
C 14																	
C 15																	
C 16																	
C 17																	
C 18																	
C 19																	
C 20																	

Control plants

Phenological dates (day numbers):

P1: Snow-free
P2: First leaf unrolls (original set of plants)
P3: Inflorescence app. between sheath (ochrea; orig. set of plants)
P4: First flower open (original and supplementary plants)
P5: First bulbill shed (drops off when touched; orig. and supp. plants)
P6: First seed dispersal (optional, since rarely obs. sexual reprod.)
P7:
P8:

Quantitative measurements:

Q1: Length of inflorescence stalk (at full flower; in mm)
Q2: Width of largest leaf (in mm)
Q3: Number of leaves per individual
Q4: Number of bulbils per shoot
Q5: Number of flower per shoot
Q6: Relative proportion of bulbils (Q4/Q4+Q5)
Q7: Colour of bulbils
Q8: Mean bulbil weight (mean±SD, in µg); optional

ITEX Plant Response Variables

Species: ***Carex stans***

Site: Year:

Devices: OTCs / corners Co-ordinates: Altitude (m):

Replicates are genets / ramets Observation period (day ##): –

Experiment plants

No.	P1	P2	P3	P4	P5	P6	P7	P8		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
E 1																	
E 2																	
E 3																	
E 4																	
E 5																	
E 6																	
E 7																	
E 8																	
E 9																	
E 10																	
E 11																	
E 12																	
E 13																	
E 14																	
E 15																	
E 16																	
E 17																	
E 18																	
E 19																	
E 20																	
C 1																	
C 2																	
C 3																	
C 4																	
C 5																	
C 6																	
C 7																	
C 8																	
C 9																	
C 10																	
C 11																	
C 12																	
C 13																	
C 14																	
C 15																	
C 16																	
C 17																	
C 18																	
C 19																	
C 20																	

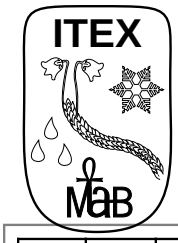
Control plants

Phenological dates (day numbers):

P1: Snow-free
P2: Emergence of first new leaf
P3: First stigmas visible
P4: First anthers exposed
P5: First yellowing of leaves
P6: First seed shed
P7:
P8:

Quantitative measurements:

Q1: Age class of shoot in flower
Q2: Length of flowering stem to base of terminal spike (1 cm)
Q3: Number of green leaves (at full flower)
Q4: Length of longest leaf (accuracy 1mm)
Q5: Total green leaf length per tiller (mm)
Q6: Utricles weight (Acc. 0.1 mg, mean ±SD;optional)
Q7:
Q8:



ITEX Plant Response Variables

Species: ***Cassiope tetragona***

Site: _____ Year: _____

Devices: OTCs / corners Co-ordinates: _____ Altitude (m): _____

Replicates are genets / ramets Observation period (day ##): – _____

	No.	P1	P2	P3	P4	P5	P6	P7	P8		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Experiment plants	E 1																	
	E 2																	
	E 3																	
	E 4																	
	E 5																	
	E 6																	
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	E 20																	
Control plants	C 1																	
	C 2																	
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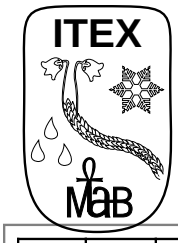
	C 20																	

Phenological dates (day numbers):

P1: Snow-free
P2: First colouring of flower buds (whitish-yellow, protruding)
P3: First elongation of pedicels
P4: First open flower
P5: First corolla drop
P6: First capsule splits open - if possible
P7:
P8:

Quantitative measurements:

Q1: Total number of flowers per ramet
Q2: Total number of developing capsules per ramet
Q3: Fruit:Flower Ratio (Q2 / Q1)
Q4: Annual growth increment (main shoot, acc. 1 mm)
Q5:
Q6:
Q7:
Q8:



ITEX Plant Response Variables

Species: ***Dryas***

Site: Year:

Devices: OTCs / corners Co-ordinates: Altitude (m):

Replicates are genets / ramets Observation period (day ##): –

Experiment plants

No.	P1	P2	P3	P4	P5	P6	P7	P8		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
E 1																	
E 2																	
E 3																	
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C 20																	

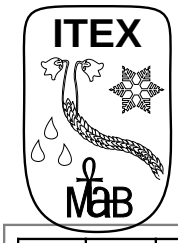
Control plants

Phenological dates (day numbers):

P1: Snow-free
P2: First leaf erected
P3: App. of first colour (white tip) of flower bud (=bud break)
P4: First open flower
P5: Last petal shed (pull gently if needed)
P6: First twisting of maturing styles (or ods. of no. twist at all)
P7: First seed dispersal (pull the elongate, barbed style gentyly)
P8: First yellow or brown leaves (summer-green forms)

Quantitative measurements:

Q1: Dimension of clone or plot
Q2: Total number of flowers (clone/plot)
Q3: Length of longest leaf blade (mm)
Q4: Pedicel length (plot mean ± SD; mm)
Q5: Number of seeds per flower
Q6: Mean seed weight (±SD) in µg (optional)
Q7: Seed yield per flower (Q5 x Q6; optional)
Q8: No. of flowers (of total) destroyed by caterpillars



ITEX Plant Response Variables

Species: ***Eriophorum*** _____

Site: _____ Year: _____

Devices: OTCs / corners Co-ordinates: _____ Altitude (m): _____

Replicates are genets / ramets Observation period (day ##): – _____

	No.	P1	P2	P3	P4	P5	P6	P7	P8		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Experiment plants	E 1																	
	E 2																	
	E 3																	
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Control plants	C 1																	
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Phenological dates (day numbers):

P1: Snow-free
P2: Appearance of first inflorescence bud
P3: First open flower (=first anthers exposed)
P4: First seed shed
P5:
P6:
P7:
P8:

Quantitative measurements:

Q1: Tussock diameter to tips of leaves (cm)
Q2: Number of flowering stalks per tussock
Q3: Mean length of 10 longest leaves (mean ± SD; mm)
Q4: Tiller growth (tot. ann. leaf prod. per tiller, mm opt.)
Q5: Seed: Ovule ratio (optional
Q6: Seed weight (mean±SD; accuarcy 0.01 mg; optional)
Q7:
Q8:

Species: ***Oxyria digyna***

Site: Year:

Devices: OTCs / corners Co-ordinates: Altitude (m):

Replicates are genets / ramets Observation period (day ##): –

Experiment plants

No.	P1	P2	P3	P4	P5	P6	P7	P8		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
E 1																	
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E 3																	
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Control plants

Phenological dates (day numbers):

P1: Snow-free
P2: First leaf unrolls
P3: First inflorescence bud
P4: First open flower
P5: First seed dispersal
P6:
P7:
P8:

Quantitative measurements:

Q1: Number of inflorescences per clone (0, 1, 2, ect.)
Q2: Length of inflorescence stalk(s) at full flower (mm)
Q3: Width of largest leaf (mm)
Q4: Number of mature fruits per plant.
Q5: Mean fruit weight (mg)
Q6:
Q7:
Q8:

Species: ***Ranunculus nivalis***

Site: Year:

Devices: OTCs / corners Co-ordinates: Altitude (m):

Replicates are genets / ramets Observation period (day ##): –

	No.	P1	P2	P3	P4	P5	P6	P7	P8		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Experiment plants	E 1																	
	E 2																	
	E 3																	
	E 4																	
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Control plants	C 1																	
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Phenological dates (day numbers):

P1: Snow-free
P2: Flower open (attaining bowl-shaped)
P3: Last petal shed
P4: First seed dispersal (NB! Start harvesting nutlets at this point)
P5: First yellowing of leaves
P6:
P7:
P8:

Quantitative measurements:

Q1: Height of flowering shoot (mm)
Q2: Width of largest basal leaf (mm)
Q3: Number of nutlets per flower (harvest in seed bags)
Q4: Mean nutlet weight (µg±SD; optional)
Q5: Seed yield (Q3 x Q4)
Q6: Seed: Ovule Ratio
Q7:
Q8:

ITEX Plant Response Variables

Species: ***Salix*** _____ **females**

Site: _____ Year: _____

Devices: OTCs / corners Co-ordinates: _____ Altitude (m): _____

Replicates are genets / ramets Observation period (day ##): – _____

	No.	P1	P2	P3	P4	P5	P6	P7	P8		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Experiment plants	E 1																	
	E 2																	
	E 3																	
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Control plants	C 1																	
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Phenological dates (day numbers):

P1: Snow-free
P2: First leaf bud burst
P3: First stigma visible
P4: Onset of seed dispersal
P5: First yellowing of leaves
P6: Last green leaf turning yellow
P7: All leaves shed (optional)
P8: Onset of seed dispersal (Capsules split open, wool visible)

Quantitative measurements:

Q1: Total no. of flowering catkin per monitured branch
Q2: Ann. growth increment (1 cm in *S.arctica*, otherwise 1 mm)
Q3: Length of longest leaf (including petiole) in mm
Q4: Weight of largest leaf (with petiole) in mg
Q5: Total number of mature catkins per branch
Q6: Catkin length *or* Capsule number (mean mm± SD)
Q7: Fruit:Flower Ratio (mean ± SD)
Q8: Seed: Ovule ratio (mean ± SD)

ITEX Plant Response Variables

Species: ***Salix*** _____ **males**

Site: _____ Year: _____

Devices: OTCs / corners Co-ordinates: _____ Altitude (m): _____

Replicates are genets / ramets Observation period (day ##): – _____

	No.	P1	P2	P3	P4	P5	P6	P7	P8		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Experiment plants	E 1																	
	E 2																	
	E 3																	
	E 4																	
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Control plants	C 1																	
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Phenological dates (day numbers):

P1: Snow-free
P2: First leaf bud burst
P3: First pollen shed
P4: All pollen shed
P5: First yellowing of leaves
P6: Last green leaf turning yellow
P7: All leaves shed
P8:

Quantitative measurements:

Q1: Total number of catkin buds
Q2: Annual growth increment (main shoot)
Q3: Length of longest leaf (including petiole) in mm
Q4: Weight of largest leaf (with petiole) in mg
Q5:
Q6:
Q7:
Q8:

Species: ***Saxifraga oppositifolia***

Site: Year:

Devices: OTCs / corners Co-ordinates: Altitude (m):

Replicates are genets / ramets Observation period (day ##): –

	No.	P1	P2	P3	P4	P5	P6	P7	P8		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Experiment plants	E 1																	
	E 2																	
	E 3																	
	E 4																	
	E 5																	
	E 6																	
	E 7																	
	E 8																	
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Control plants	C 1																	
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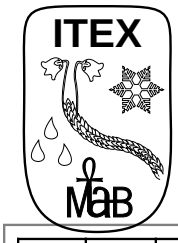
Phenological dates (day numbers):

P1: Snow-free
P2: First open flower (= onset of flowering)
P3: First pollination (orange pollen on stigma)
P4: First open anther dehiscence (orange pollen exposed)
P5: First petal fading
P6: Last petal fading (= end of flowering)
P7: First opening capsule (slit at top)
P8:

Quantitative measurements:

Q1: Vegetative growth (5 shoots/genet,mm; mean ± SD)
Q2: Total number of flower buds (at beginning of season)
Q3: Total number of flowers per individual
Q4: Number of pollinated flowers when 1st anther opens
Q5: Number of mature fruits
Q6: Number of seeds per capsule (mean ± SD)
Q7: Total number of flower per capsules (mean ± SD)
Q8:



ITEX Plant Response Variables

Species: ***Silene acaulis***

Site: Year:

Devices: OTCs / corners Co-ordinates: Altitude (m):

Replicates are genets / ramets Observation period (day ##): –

	No.	P1	P2	P3	P4	P5	P6	P7	P8		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Experiment plants	E 1																	
	E 2																	
	E 3																	
	E 4																	
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Control plants	C 1																	
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Phenological dates (day numbers):

P1: Snow-free
P2: First open flower
P3: First open anther
P4: First stigma receptive
P5: First capsule cracks open (at top)
P6:
P7:
P8:

Quantitative measurements:

Q1: Size of cushion (accuracy 1 cm)
Q2: Number of flowers
Q3: Number of capsules
Q4: Fruit : Flower Ratio (Q3/Q2)
Q5: Number of seeds per capsule (mean±SD)
Q6: Seed : Ovule Ratio (mean per clone±SD, optional)
Q7: Flowers female (F) or hermaphrodite
Q8:

Group 1B species

ITEX Plant Response Variables

Species:

Site: Year:

Devices: OTCs / corners Co-ordinates: Altitude (m):

Replicates are genets / ramets Observation period (day ##): –

Experiment plants

Control plants

No.	P1	P2	P3	P4	P5	P6	P7	P8		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
E 1																	
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Phenological dates (day numbers):

P1: Snow-free
P2:
P3:
P4:
P5:
P6:
P7:
P8:

Quantitative measurements:

Q1:
Q2:
Q3:
Q4:
Q5:
Q6:
Q7:
Q8:

ITEX Insect **ITEX Plant Response Variables**

Species: ***Gynaephora groenlandica/G. rossii***

Site: Year:

Devices: OTCs / corners Co-ordinates: Altitude (m):

Replicates are individuals Observation period (day ##): –

	No.	P1	P2	P3	P4	P5	P6	P7	P8		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
On experiment plants (*Salix*)	E 1																	
	E 2																	
	E 3																	
	E 4																	
	E 5																	
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On control plants (*Salix*)	C 1																	
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Phenological dates (day numbers):

P1: Snow-free
P2: First Caterpillar
P3: First *S*alix leaf bud burst (male/female)
P4: First flower out (pollen/stigma)
P5: First pupae
P6: First adult (male/female)
P7: First mating
P8: First egg count
Additional observation of parasitism

Quantitative measurements:

Q1: Length of caterpillar, mm (or stage)
Q2: Orientation of basking caterpillar (compass)
Q3: Colour (yellow/brown/black)
Q4: No. of caterpillars feeding on male *Salix*
Q5: No. of caterpillars feeding on female *Salix*
Q6: No. of caterpillars feeding on other plants
Q7: Estimated density of caterpillar/m^2 (or high/low)
Q8: Orientation of pupae (use compass if possible)