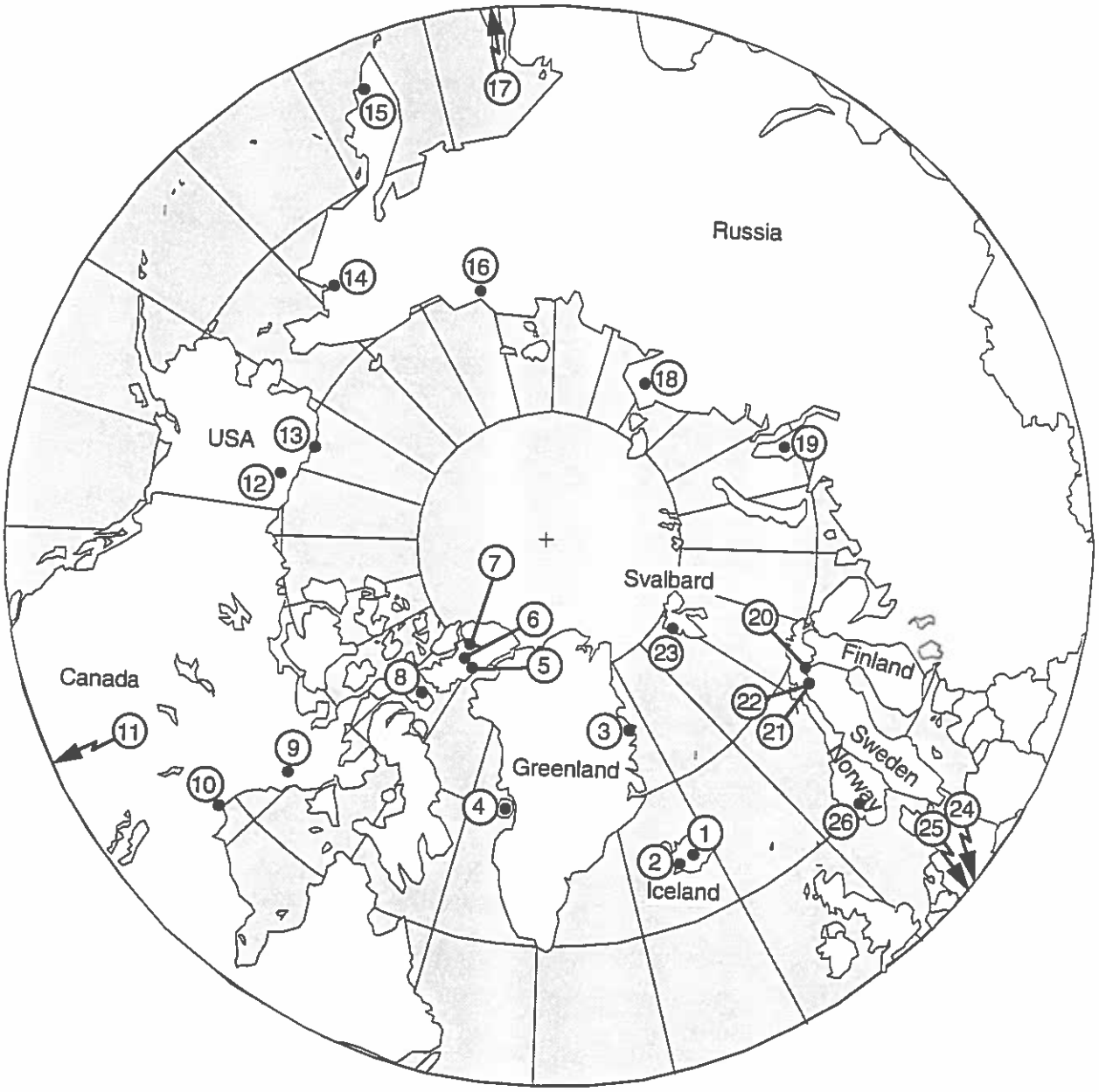
THE INTERNATIONAL TUNDRA EXPERIMENT

6TH ITEX WORKSHOP

University of Ottawa

Ottawa, Canada

7-11 April 1995



1 Hveravellir, Iceland
2 Mt. Skálafell, Iceland
3 Zachenberg, Greenland
4 Disko Island, Greenland
5 Alexandra Fjord, Canada
6 Sverdrup Pass, Canada
7 Hot Weather Creek, Canada
8 Truelove Lowland, 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

Marion-12

12·8·94

Report from the Swedish ITEX site (Latnjajaure) 1994/95

ITEX studies in operation:

Climate station (summertime 1990–, all year round 1992–); manual station in summer, automatic station equipped with Delta-T data logger; climate data from nearby Abisko station (subalpine) available since 1913.

Monitoring of snow-melt along north-facing slope (1991–)

Monitoring of lake ice break-up (1991–)

Monitoring of active layer depth (1993–)

Species manipulated and monitored:

Saxifraga oppositifolia	1990–	(OTCs 1993–)	Stenström, Molau
Cassiope tetragona	1991–	(OTCs 1993–)	Emanuelsson, Molau
Salix herbacea	1992–	(OTCs 1993–)	Nordenhäll
Eriophorum vaginatum	1992–	(OTCs 1993–)	Molau
Dryas octopetala	1992–	(OTCs 1993–)	Molau
Ranunculus nivalis	1992–	(OTCs 1993–)	Molau
Silene acaulis	1993–	(OTCs 1994–)	Alatalo
Carex bigelowii	1994–	(OTCs 1994–)	Lindskog, Jónsdóttir
Polygonum viviparum	1994–	(OTCs 1994–)	Molau, Bauert
Diapensia lapponica	1990–		Molau

Ongoing ITEX-related research:
Restrospective growth analysis in *Cassiope tetragona* (Havström)
Genetical variation in *Polygonum viviparum* (Bauert)
Genetical variation within and among populations of *Hylocomium* (Cronquist et al.)
Permafrost and patterned ground processes (Kling)
Long-term climatic variation (Holmgren)

Ongoing, non ITEX-related research:
Population fluxes in the twite, *Carduelis flavirsitris* (Molau)
Breeding ecology of the common ringed plover, *Charadrius hiaticula* (Wallander)
Home-range stability in the snow bunting, *Plectrophenax nivalis* (Molau)

New ITEX projects planned for 1995–97:
1. Seed flux. Seed rain plus potential seed bank monitored at stations at 100 m altitunal intervals along gradient from timber-line to high-alpine peaks (Molau).
2. Competitive responses. Community level, fully factorial experiment, focusing competition among resident and potentially immigrating plant species (manipulations = temperature, fertilization, and seed addition, replicated in nutrient-rich and -poor communities; Molau).
3. Snow regime and plant community composition (Hagmann)

Responses of two Dryas species to ITEX environmental manipulations: A synthesis with circumpolar comparisons.

Welker, J., Svoboda, J., Henry, G. Molau, U., Parsons, A., Wookey, P.

J. M. Welker & A. N. Parsons Natural Resource Ecology Laboratory Colorado State University Fort Collins, CO 80523 USA

J Svoboda Department of Botany, University of Toronto, Toronto, Ontario, Canada

G. Henry, Department of Geography, University of British Colombia, Vancouver, Canada

U. Molau, Department of Systematic Botany, Carl Skottsbergs Gata 22, 413 19 Gothenburg, Sweden

P. Wookey, Department of Biological Sciences, Hatherly Laboratories, University of Exeter, Exeter, United Kingdom

Developing broad-based ecological theorems regarding how tundra plants and ecosystems will respond to changing climates requires studies of the same species or genera in alpine, low and high arctic settings. There are, however, only a few tundra species or genera which have a circumpolar distribution and are also found in the alpine tundra of lower latitudes. *Dryas* is a wintergreen, dwarf shrub found as far south as the Front Range of Colorado and is circumpolar in its distribution in northern latitudes. This genus is thus an excellent example for comparative studies of how similar changes in conditions may modify plant and ecosystem processes across a range of tundra sites.

Recently field manipulations of temperature, water and in some cases even nutrients have been established in *Dryas* dominated tundra as part of the International Tundra Experiment(ITEX). *Dryas* species may, due to their wintergreen foliage, may respond more to a lengthened growing season compared with systems dominated by deciduous species. It can be hypothesized, for example, that photoperiodic controls over winter hardening or senescence of foliage may be weaker for *Dryas* than for deciduous dwarf shrubs, thus positive ecosystem carbon balance may be maintained later into the autumn, even under reduced irradiance. In addition, the wintergreen nature of *Dryas* may enable this genus to respond rapidly to early melting of snow, or warmer temperatures in spring by rapid maximization of carbon gain and accelerated phenologic development of reproductive structures.

In this paper we report on findings from four sites dominated by *Dryas* showing that organismic attributes such as seed mass do not always respond to warmer temperatures, that shifts in phenology are typically similar and that carbon dynamics may be modified at the end of the season under altered conditions when plants in ambient conditions are senescent.

Acknowledgements

We would like to thank the following agencies for providing funding for the 6th ITEX Workshop:

Ecological Monitoring Coordinating Office, Environment Canada, Ottawa
Office of Polar Programs, National Science Foundation, Washington
International Science Foundation, Washington
Dean of Arts, University of Ottawa, Ottawa
Dean of Science, University of Ottawa, Ottawa

Thanks also to Dr. Jeff Welker for organizing travel subsidies and accommodation for some of the overseas participants.

Finally, thankyou to Dr. Pat Webber for getting ITEX off the ground! We hope that this Workshop surpasses your expectations.

Au Nord de Notre Vie,

Greg Henry & Antoni Lewkowicz

THE INTERNATIONAL TUNDRA EXPERIMENT

6TH ITEX WORKSHOP

UNIVERSITY OF OTTAWA
OTTAWA, CANADA

PROGRAM

---

7 April, Friday

18:00 - 21:00 "Warming the Atmosphere" and Registration
Renaissance Room, Chateau Laurier

8 April, Saturday

Sessions held in Lamoureux 122

08:00 - 12:30 Registration

08:30 - 09:00 Official welcomes
Welcome and information (Greg Henry, Antoni Lewkowicz)
ITEX update 1994-95: Ulf Molau

09:00 - 09:20 Patrick Webber
A short history of ITEX: the founding vision

ITEX Site Reports 09:20 - 10:40

Sweden	Ulf Molau
Denmark	Per Molgaard
Norway	Ørjan Totland
Finland	Kari Laine
Iceland	Juha Alaltalo
Russia	Volodja Razzhivin
U.S.	Marilyn Walker
Canada	Greg Henry

New Alpine Sites

Switzerland	Felix Gugerli
Japan	Ulf Molau/Greg Henry

10:40 - 11:00 BREAK

Current ITEX Research: Climate and Warming Experiments. Chair: Greg Henry

11:00 - 11:20 Microclimatic responses in various open top chamber designs.
Giles Marion* et al.

11:20 - 11:40 Open discussion of experimental design: OTCs, snow manipulations, problems.

11:40 - 12:00 Poster previews

12:00 - 13:00 LUNCH

Poster Session:
13:00 - 14:00 (See the List of Posters, attached)

14:00 - 14:10 BREAK

Current ITEX Research: Evolution, Genetics and Systematics. Chair: Ulf Molau

14:10 - 14:30 Systematic considerations in ITEX vascular plants.
David Murray

14:30 - 14:50 Evolutionary response of arctic plants to climate change.
Kent Schwaegerle

14:50 - 15:10 Genetic variation in *Dryas octopetala*.
Karen Max

Current ITEX Research: Species responses to simulated warming.

15:10 - 15:30 *Salix arctica* at Alexandra Fiord, Ellesmere Island, Canada: responses to three seasons of ITEX experimental warming.
Michael Jones*, Greg Henry and S. Ellen MacDonald

15:30 - 15:50 Short-term responses to warming in *Salix herbacea*.
Urban Nordenhall

15:50 - 16:10 *Salix arctica* in a retrospective study.
Karen Christensen and Per Molgaard*

16:10 - 16:30 Establishment of an ITEX site at Barrow, Alaska, and short-term response of *Cassiope tetragona* and *Salix rotundifolia*.
Christian Bay

16:30 - 16:50 Differential growth and reproductive response of *Cassiope tetragona* to variations in growing season climate at Alexandra Fiord, Ellesmere Island, Canada.
Jill Johnstone* and Greg Henry.

ITEX Banquet: Le Chateau Montebello, Montebello, Québec
Featuring the ITEX movie: "ITEX: The Arctic Tundra in a Changing Climate," starring Ulf Molau.

Buses will take all to and from Le Chateau. Buses will leave the University of Ottawa campus at 18:00 and arrive back in Ottawa about 23:00.

9 April, Sunday

Sessions in Lamoureux 122

Current ITEX Research: Species responses to simulated warming II. Chair: Kari Laine

09:00 - 09:10 Information/schedule changes/etc.

09:10 - 09:30 Responses of two *Dryas* species to ITEX environmental manipulations: a synthesis with circumpolar comparisons.
Jeff Welker*, et al.

09:30 - 09:50 Short-term responses to warming in *Saxifraga oppositifolia*.
Mikael Stenstrom*, Felix Gugerli* and Saila Karinen

09:50 - 10:10 Effect of simulated climate warming on alpine and sub-arctic *Silene acaulis*, a pollen risk strategist.
Juha Alatalo*, Ørjan Totland and Ulf Molau.

10:10 - 10:30 Responses to temperature enhancement in *Ranunculus nivalis*, a perennial tundra herb. Ulf Molau

10:30 - 10:50 BREAK

10:50 - 11:10 Responses of *Polygonum vivparum* to simulated environmental change at a high arctic polar semi-desert, Svalbard.
Phil Wookey*, J.M. Welker, A.N Parsons, M.C. Press, T.V. Callaghan and J.A. Lee.

11:10 - 11:30 Responses of two *Eriophorum* species to tundra warming experiments.
Ulf Molau* and Greg Henry

11:30 - 11:50 ITEX activities on Disko Island in Greenland.
Karen Christensen and Per Molgaard*

Related species and studies

11:50 - 12:10 Leaf exsertion, leaf elongation, and leaf senescence in *Eriophorum vaginatum* and *Carex bigelowii* in northern Alaska.
Gaius Shaver* and James Laundre

12:10 - 12:30 Responses of *Acomastylis rossii* and *Bistorta bistortoides* to increased snow and summer temperature.
Marilyn Walker, Christine Cain, Skip Walker, Katherine Nash and Brad Lewis

12:30 - 13:30 LUNCH

Integration and Enhancement of ITEX Research. Chair: Giles Marion

1. Trophic level links.

13:30 - 13:50 Experimental snowdepth manipulations: effects on plant nutrients and implications for caribou.
Noreen Walsh, Thomas R. McCabe, Andy Parsons and Jeff W. Welker*.

2. Permafrost and active layer monitoring.

13:50 - 14:10 Circumarctic Active Layer Monitoring (CALM): an international contribution to ITEX.
Jerry Brown*, F.E. Nelson and D.A. Walker.

14:10 - 14:30 Monitoring of the active layer at the Kapp Linn area, Svalbard: 1972-1994. Jonas Åkerman.

14:30 - 14:50 Prospects for geomorphic monitoring at ITEX sites.
Toni Lewkowicz.

3. Effects of increased UV-B.

14:50 - 15:10 Effects of enhanced UV-B radiation on a subarctic heath ecosystem.
Ulf Johansson*, Carola Gehrke, Lars Olof Bjørn, Terry Callaghan and Mats Sonesson.

15:10 - 15:30 Effects of enhanced ultraviolet-B radiation on decomposition of organic matter in the Subarctic.
Carola Gehrke*, Ulf Johanson, Terry Callaghan, David Chadwick, and Clare Robinson.

15:30 - 15:50 BREAK

Data Management in ITEX. Chair: Marilyn Walker

15:50 - 16:00 Review of needs to create and manage an ITEX database.
Marilyn Walker

16:00 - 16:40 Database management and ITEX.
John Porter, LTER Program, U.S. National Science Foundation.

16:40 - 17:00 General discussion of data management and access for ITEX.
(Data access over the internet: Demonstrations on Monday morning in Geography GIS Lab., Room 021, Simard Hall.)

17:00 - 18:00 Outline of working groups and tasks.

Species Groups - Coordinators identified

Suggested Topics and Coordinators

Data analysis and Modelling - Ulf Molau/Greg Henry
Genetics / common gardens - Kent Schwaegerle/Kari Laine
Nutrient cycling - Gus Shaver/Josef Svoboda
Active layer monitoring - Jerry Brown/Toni Lewkowicz
Herbivory - Bob Jefferies/Anne Tolvanen
UV-B - Ulf Johanson/Carola Gerhke
Community dynamics - Marilyn Walker/Greg Henry
Animal Studies (insects) - Richard Ring/Dean Morewood
-Systematics - Dave Murray

10 April, Monday

Morning:	No formal sessions until 15:00. Morning free for sight-seeing and working group meetings.
09:00 - 10:30	Demonstration of data bases available over the Internet: GIS Lab, Room 021, Geography Department, Simard Hall.
09:00 - 14:00	Rooms available in Geography Department, Simard Hall, for meetings of Working Groups. (Access to computers and printers will be available).

Working Group Sessions - Alumni Auditorium

15:00 - 15:30	Outline and discussion of timetable for A&AR papers. Greg Henry and Ulf Molau
15:30 - 17:30	Meetings of species groups. Coordinators. Exchange of data, and assignment of analysis and writing.
19:00 - 21:00	To be announced.

11 April, Tuesday

09:00 - 09:30	Review and updating of ITEX Manual: Ulf Molau
09:30 - 11:30	Reports from Working groups on protocols and measurements for new studies.
11:30 - 12:00	Wrap-up & Pat Webber's review of the meeting.
12:00	Exchange of the ITEX Viking: Canada to Denmark.
12:00 - 13:00	LUNCH - Food for Goodbyes.

END of Workshop.

13:30 - 15:00	ITEX Steering Committee Meeting.

List of Posters

Poster Session: 8 April, 13:00-14:00. Posters will be up during all breaks on 8-9 April.

"Cape Rogozhny - a new ITEX site near Anadyr (South Chukotka)."
Vladimir Razzhivin, Anatoly Kotov and Ulf Molau

"ITEX research during the Swedish-Russian expedition: Tundra Ecology - 94."
Vladimir Razzhivin, Ingibjorg Svala Jonsdottir, Anna Lindskog, Mikael Stenstrom, Urban Nordenhall, Juha Alatalo

"Some effects of increased temperature on *Dryas octopetala* (Mountain Avens) at Kilpisjarvi, Finland."
Saila Karinen and Kari Laine

"Effects of climate change on sexual reproduction in the arctic clonal plant, *Carex bigelowii*."
Anna Lindskog and Ingibjorg S. Jonsdottir

"Reaction of tundra plants to climate warming."
Felix Gugerli

"Effects of shortened day length on tundra microcosms."
Steve Oberbauer

"Short-term responses in snowbed plants to experimental manipulation of growing season length."
Sunne Burmeister and Kari Laine

"Does Bilberry care about climate change?"
Anne Tolvanen

"To what extent do plant responses to natural variations in micro-environment predict responses to global climate change scenarios?"
Jacqueline Potter

"Little ice age temperature estimated by growth and flowering differences between subfossil and extant shoots of *Cassiope tetragona*, and arctic heather."
Mats Havstrom, Terry Callaghan, Sven Jonasson and Josef Svoboda.

"Long-term records of arctic vegetation from pollen diagrams."
Konrad Gajewski

"Impacts of enhanced ultraviolet-B radiation (280-320 nm) on growth of peat moss (*Sphagnum fuscum*) in a subarctic bog.
Carola Gehrke, Lars Olof Bjørn and Terry Callaghan

"The effects of enhanced UV-B radiation on stem and leaf growth of four arctic dwarf shrub species within a subarctic heath."
Ulf Johanson, Carola Gehrke, Lars Olof Bjørn and Terry Callaghan

"Temperature relations of arctic insects and potential effects of global warming: a case study of the arctic woolly bear caterpillar *Gynophora groenlandica* (Wocke)."
Dean Morewood

"Floral sex ratio in the arctic willow, *Salix herbacea* L., at Kilpisjarvi."
Mona-Anitta Lohiluoma

"A new vegetation map of the Kapp Linn area, Svalbard."
Jonas Åkerman et al.

"Shopping list for seeds of arctic plants."
Per Molgaard

"High-latitude research sites and biosphere reserves: A MAB-Northern Sciences Network Initiative."
C. Slaughter, J. Brown, P. Adams, K. Philip and M. Sonesson

ABSTRACTS

6TH ITEX WORKSHOP

UNIVERSITY OF OTTAWA

OTTAWA, CANADA

Note: Abstracts are arranged in order of appearance on the program, with those for posters listed first. The speaker and/or corresponding author is indicated with an asterisk (*).

CAPE ROGOZHNY - A NEW ITEX SITE IN THE ANADYR VICINITY (SOUTH CHUKOTKA)

Ulf Molau[1], Anatoly Kotov[2] & Vladimir Razzhivin[3]

1 Dept. of Systematic Botany, Göteborg University, Carl Skottbergs Gata 22, S-413 19 Göteborg, Sweden
2 Scientific Center "Chukotka", ul. Energetikov 15, Anadyr, 686710 Russia.
3 Dept. of Vegetation of the Far North, Komarov Botanical Institute ul. Prof. Popova 2, St. Petersburg, 197376 Russia

The new Cape Rogozhny field station of the Scientific Center "Chukotka" (Anadyr) is situated on the northern shore of Onemen Bay (mouth of Anadyr River). The area belongs to south Hypoarctic tundra of Anadyr lowland. *Eriophorum vaginatum* tussock tundra is the dominating community type in the landscape. Dwarf shrub communities with *Betula exilis, Salix pulchra, Ledum decumbens, Vaccinium uliginosum*, and *V. vitis-idaea* and *Carex lugens* are typical for the relatively rare hills. Wet sedge meadow tundra with dominance of *Eriophorum polystachyon* and *Carex stans* is common for depressions with small creeks. Snowbed vegetation of slopes of terraces is represented by herb-prostrate shrub communities dominated by *Salix chamissonis, Empetrum subholarcticum, Rhododendron aureum*, and *Artemisia arctica*.

Eriophorum vaginatum, Carex stans and *Salix chamissonis*- dominated community types were selected for ITEX monitoring. Three OTCs were set up in *Eriophorum vaginatum* tussock tundra in July 1993. The peculiarity of OTC's is metallic skeleton made of rod 5-7 mm in diameter covered by polyethylene. Using polyethylene leads to increasing of continentality inside of OTC's, i.e. day temperature is 3-5 degrees higher and night temperature is 2 degrees lower than outside. Monitoring of active layer shows significant growth of permafrost depth.

ITEX RESEARCH DURING THE SWEDISH-RUSSIAN EXPEDITION "TUNDRA ECOLOGY - 94"

Juha Alatalo[1], Ingibjorg S. Jonsdottir[1], Anna Lindskog[1] Urban Nordenhall[1], Vladimir Razzhivin*[2] and Mikael Stenström[1]

1 Dept. of Systematic Botany, Göteborg University, Carl Skottbergs Gata 22, S-413 19 Göteborg, Sweden

2 Dept. of Vegetation of the Far North, Komarov Botanical Institute ul. Prof. Popova 2, St. Petersburg, 197376 Russia

Seventeen sites were visited in Russian Arctic from Kola Peninsula to Wrangel Island during June-August 1994 by expedition "TUNDRA ECOLOGY - 94" based on the scientific vessel "Academic Fedorov". ITEX research by the joint Swedish-Russian botanical team was mostly focused on study of genetic and phenetic variation of arctic and arctic-alpine plants over a large geographic area. Approximately 1100 plant specimens were collected for transplantation mainly to Tromso and Oulu botanical gardens for further experimental study (among them *Carex ensifolia* s.l. - 180, *C. lugens* - 41, *Saxifraga oppositifolia* - 116, *S. caespitosa* - 106, other *Saxifraga* - 169, *Papaver* species - 66). Specimens of *Carex ensifolia* complex, *Saxifraga oppositifolia* and other *Saxifraga* species, *Salix herbacea* and *Salix polaris*, *Oxyria digyna*, *Eriophorum vaginatum*, and others, were collected for isozyme electrophoresis to study genetic variation. Specimens of almost all *Saxifraga* species of the Russian Arctic and of the *Carex ensifolia* complex were collected for morphological and life-form analysis to study phenetic and life-form plasticity according to environment and especially to climate. Variation in reproductive ecology especially the relationship between sexual and vegetative reproduction according to climate was studied in the *Carex bigelowii* complex and for some *Saxifraga* species.

SOME EFFECTS OF INCREASED TEMPERATURE ON *DRYAS OCTOPETALA* (MOUNTAIN AVENS) AT KILPISJARVI, FINLAND

Saila Karinen and Kari Laine

Department of Botany, University of Oulu, FIN-90570 Oulu, Finland

The main object in this experiment is to find out the effects of experimental warming on some vegetative and reproductive traits of *Dryas octopetala*.

The phenology of summer-green and calciphilous Dryas octopetala has been observed in the Malla nature reserve at Kilpisjarvi, Finland (69°03'N, 20°50'E) in subarctic area in 10 OTCs and 10 controls (plot-size 0.25 m^2). The OTCs were set up in summer 1993. The observations have mainly been monitored during summer 1994. The experimental site is situated on the east side of fell Pikku-Malla on 620 m a.s.l. In this site the growth pattern of *Dryas octopetala* is matted. Most of the flowers were perfect in 1994, but also both male-sterile and female-sterile flowers were found in the experimental site. The flowers were pollinated mainly by flies.

Every flower was monitored as individuals in the plots during the whole growing season. Phenological events, such as flower bud swelling, flower opening, last petal shedding, were observed daily, and every second day after the active growth and flowering period. At the time when seeds were maturing, the plants were monitored daily again. Quantitative measurements (length of the longest leaf blade, pedicel length, seed number) were carried out at the same time as the respective phenological events were observed. Seed weight and germination were measured later in autumn.

Temperature was measured every hour in four OTCs and in four control plots during 10.6-26.9.1994 by a data logger with eight censors. The mean temperature was about 1.5°C higher in the OTCs (ΣGDD: 668°C) than in the control plots (ΣGDD: 525.8°C).

The effect of the OTCs on the vegetative traits such as the occasion of the first flower bud swelling, the first flower opening, the last petal shedding, the first twisting of maturing styles and the first seed dispersal was statistically significant. Concerning the first seed dispersal, it may have been affected by different wind conditions between OTCs and controls. There were no significant differences between OTCs and controls in length of the longest leaf blade and the pedicel length. Difference in seed number was significant, but that result remains uncertain because of the effect of the wind. Differences between the OTCs and the controls in seed weight and germination were significant.

EFFECTS OF CLIMATE CHANGE ON SEXUAL REPRODUCTION IN THE ARCTIC CLONAL PLANT, *CAREX BIGELOWII*

Anna Lindskog* and Ingibjorg S. Jonsdottir

Department of Botany, University of Göteburg, Carl Skottbergs Gata 22, S-413 19 Göteburg, Sweden

Carex bigelowii is a circumpolar rhizomatous sedge and is widely used as a model-plant for arctic clonal plants. It is common in the Swedish mountains and is an important species for many herbivores. This study aims at answering the following questions: How is sexual reproduction in *Carex bigelowii* affected by climate change? Is there a trade off between sexual and vegetative reproduction and how is that trade off affected? What will the consequences be for seed set and thereby dispersal and genetic variation within the populations?

Field experiments are conducted at Latnjajaure field station, 15 km west of Abisko, Swedish Lappland. The field station is owned by Abisko Research Station and is the Swedish ITEX-site. In Latnjajaure we have ten OTCs (open-top chambers) and two control plots two each OTC, one pollinated and one untreated. The OTCs were put up in June 1994. Already after one season the phenology was accelerated. The female spikes started to flower three days earlier in the OTCs and the male spikes started to realese pollen four days earlier. The vegetative characters measured were not significantly affected after one season.

REACTION OF TUNDRA PLANTS TO CLIMATE WARMING

Felix Gugerli

Institute for Systematic Botany, University of Zurich, Zollikerstr. 107, CH-8008 Zurich
e-mail: fgugerli@systbot.unizh.ch

ITEX Open Top Chambers (OTC) have been used for *Saxifraga oppositifolia* in Val Bercla, a high-mountain valley of the Central Alps of Switzerland. Air and soil temperatures during the growing season were raised by 0.9 degrees C and 1.6 degrees C, respectively, inside the OTCs. Generally, air temperature inside the chambers was higher than outside during the day, while nighttime temperature was below the control. Phenology and reproduction of *S. oppositifolia* were affected by the experimental treatment. However, only the Relative Reproductive Success (RRS) showed a significant, though not expected result, namely a reduced mean RRS for plants under elevated temperature. This effect is attributed to a lower visitation rate of pollinators. Propositions for changes in monitoring and additional experimentation are made.

EFFECTS OF SHORTENED DAY LENGTH ON TUNDRA MICROCOSMS

Steve Oberbauer
Dept. of Biological Sciences, Florida International University, Miami, FL 33199 U.S.A.
tel: 305-348-2580; fax: 305-348-1986

Global warming will substantially increase the length of the active season for high latitude ecosystems, but many plant species in these areas have phenological patterns genetically adapted to short growing seasons. Some, but not all, of the cues that affect phenological stages will change with global warming. Those species constrained by cues that will be unchanged with global warming, such as photoperiod, will be unable to respond to extended season length. As a result, species composition, productivity, and carbon fluxes from these ecosystems may change. The objective of this study was to test for daylength effects on phenology and carbon balance of tundra microcosms under controlled environmental conditions. Microcosms of tussock tundra from Toolik Lake, Alaska were collected in the end of July and returned to the lab where they were immediately placed on a temperature regime of 20 hr at 15 C and 4 hr at 12 C. Plants in the daylength treatment were subjected to a 1 hr reduction in daylength per week starting from 24 hr daylight. Phenology of individuals ramets and system carbon balance were monitored weekly. The results revealed significant changes in microcosm carbon flux rates in response to decreasing daylength. These changes were associated with changes in the phenological state of important species.

SHORT-TERM RESPONSE OF SNOW-BED PLANTS TO EXPERIMENTAL MANIPULATION OF GROWING SEASON LENGTH

Suenne Burmeister*[1] and Kari Laine[2]
1 Spezielle Botanik, University of Tuebingen, Auf der Morgenstelle 28, D-72076 Tuebingen, Germany
2 Botanical Gardens and Dept. of Botany, University of Oulu, FIN- 90570, Oulu, Finland

Timing of snowmelt is considered one of the most important factors controlling phenology and distribution of alpine plants. A snow removal and snow addition experimemt was carried out at Kilpisjaervi, Finnish Lapland, between May and September 1994. Three 35-m long transects were established in snow-bed vegetation along a slope above a long-lasting snow patch. The pattern of snow melt was observed, and phenology of *Salix herbacea* (Salicaceae), *Cassiope hypnoides* (Ericaceae) and *Gnaphalium supinum* (Asteraceae) was monitored. Phenological data were recorded for leaf development and flowering traits. Reproductive success was assessed by calculating seed:ovule resp. fruit:flower ratios.

The phenological development showed a clear response to the time of release from the snow. Delaying snowmelt led to a decrease in the time required to reach any phenological stage (accelerated phenology). The effects on reproductive success were less obvious. Seed:ovule/fruit:flower ratios did not differ significantly between treatments. But advancing snowmelt resulted generally in a significantly earlier seed dispersal. Thus, although the plants with the earlier date snowfree needed on average more time, they could still benefit from the prolonged growing season.

LITTLE ICE AGE TEMPERATURE ESTIMATED BY GROWTH AND FLOWERING DIFFERENCES BETWEEN SUBFOSSIL AND EXTANT SHOOTS OF *CASSIOPE TETRAGONA*, AN ARCTIC HEATHER

Mats Havström*[1], Terry V. Callaghan[2], Sven Jonasson[3] and Josef Svoboda[4]

1 Botanical Institute, University of Göteborg, Carl Skottsbergs Gata 22, S-413 19 Göteborg, Sweden
2 Sheffield Centre for Arctic Ecology, University of Sheffield, Sheffield S10 2UQ, U.K.
3 Botanical Institute, Department of Plant Ecology, Øster Farimagsgade 2D, DK-1353, Copenhagen, Denmark
4 University of Toronto, Erindale College, 3359 Mississauga Road North, Mississauga, Ontario L5L 1C6, Canada

* Corresponding author: fax: +46-31 773 26 62; E-mail: mats.havstrom@systbot.gu.se

1. A unique opportunity to study conditions for plant growth at the onsetof glaciation was offered as a retreating glacier at Ellesmere Island, Canada revealed well-preserved, subfossil plants (411-170 radiocarbon years old) of *Cassiope tetragona*, an arctic dwarf-shrub previously used tostudy climate-related growth of modern plants.
2. Growth and flowering of the ancient and modern shoots of *C. tetragona* from the same locality were examined retrospectively. The ancient shoots produced leaves in each, and flowers in each except one, of the last 26 years before they died, although this production was significantly lower and less variable among years than in the modern shoots.
3. Predictions based on regression between modern plant performance and climatic data from the study site imply that the mean July temperature of the period immediately preceding the glaciation of the area was about 0.7°C lower than today. This estimate is independently supported by the correlation between growth and mean July temperature seen today among different sites.
4. The results support the idea that the pre-Little Ice Age plants were killed suddenly by permanent snow embedment, and not by glacial movements or temperature limitations as such.

IMPACTS OF ENHANCED ULTRAVIOLET-B RADIATION (280-320 NM) ON GROWTH OF PEAT MOSS (*SPHAGNUM FUSCUM*) IN A SUBARCTIC BOG

Carola Gehrke*[1], Lars Olof Bjørn[2], Terry V. Callaghan[3]

1 Dept. of Plant Ecology, Ecology Building, Lund University, S-223 62 Lund, Sweden, and Abisko Scientific Research Station, Royal Swedish Academy of Sciences, S-98107 Abisko, Sweden
2 Sect. of Plant Physiology, Lund University, Box 117, S-221 00 Lund, Sweden
3 Sheffield Centre for Arctic Biology, University of Sheffield, Tapton Gardens, Taptonville Road, Sheffield S10 2TN, U.K.

A steady thinning of the ozone layer above the northern hemisphere during the last years has lead to an increase in UV-B radiation (280-320 nm) of 1 % per year at the earth's surface. High latitude ecosystems are not adapted to a high UV-B regime and thus expected to be particularly susceptible to UV-B enhancement. One polar ecosystem of particular importance concerning carbon sequestration from the atmosphere, water budget and carbon dioxide and methane release to the atmosphere are peatlands.

In the Subartcic (Abisko, Sweden, 68.35°N, 18.82°E) an ombrotrophic peat bog, dominated by *Sphagnum fuscum*, was exposed to enhanced UV-B radiation corresponding to 15% ozone depletion under clear sky conditions. Before the experiment, shoot density and biomass partitioning in *S. fuscum* were investigated. These parameters will be studied again at the end of the experiment in order to estimate any changes in productivity due to enhanced UV-B radiation. For the whole investigated period (July until September 1994) the height increment in *S. fuscum* exposed to enhanced UV-B was significantly
decreased by 20%. Ecological implications are discussed.

* corresponding author: tel. -46-10 93 11; fax -46-10 44 23;
e-mail:carola.gehrke@planteco.lu.se

THE EFFECTS OF ENCHANCED UV-B RADIATION ON STEM AND LEAF GROWTH OF FOUR DWARF SHRUB SPECIES WITHIN A SUBARCTIC HEATH

Ulf Johanson[1], Carola Gehrke[2], Lars Olof Bjørn[1], Terry Callaghan[3]
1 Dept. of Plant Physiology, Lund University, Box 117, S-221 00 Lund, Sweden
2 Dept. of Plant Ecology, Ecology Building, Lund University, S-223 62 Lund, Sweden and Abisko Scientific Research Station, Royal Swedish Academy of Sciences, S-981 07 Abisko, Sweden
3 Sheffield Centre for Arctic Ecology, University of Sheffield, Sheffield S10 2UQ, U.K.

In a field irradiation experiment UV-B radiation was enhanced to simulate 15 % ozone depletion under clear sky conditions in northern Sweden. This was accomplished by using UV-B fluorescent lamps mounted on metal frames raised over a naturally growing plant community. The investigated area consisted of a dwarf shrub heath mainly composed of the four species *Vaccinium vitis-idaea, V. myrtillus, V. uliginosum* and *Empetrum hermaphroditum*. The absolute annual stem growth, relative stem growth and absolute leaf growth were recorded for different years. The relative growth was significantly reduced by UV-B enhancement in the two evergreen species *V. vitis-idaea* (29 % after two years of enhanced UV-B) and *E. hermaphroditum* (14 % after one year and 33 % after two years). The two deciduous species also showed a tendency for decreased relative growth under enhanced UV-B, but this effect was not statistically significant. The leaf thickness of *V. vitis-idaea* increased both during 1992 (9 %) and 1993 (4 %). In contrast, the two deciduous species *V. myrtillus* and *V. uliginosum* developed thinner leaves under enhanced UV-B both during 1992 (4 % for *V. myrtillus*, 6 % for *V. uliginosum*) and 1993 (9 % for *V. myrtillus*, 10 % for *V. uliginosum*).

TEMPERATURE RELATIONS OF ARCTIC INSECTS AND POTENTIAL EFFECTS OF GLOBAL WARMING: A CASE STUDY OF THE ARCTIC WOOLLY-BEAR CATERPILLAR, *GYNAEPHORA GROENLANDICA* (WOCKE)

Wm. Dean Morewood
Department of Biology, University of Victoria, Victoria, B.C. V8W 2Y2 Canada

The arctic woolly-bear caterpillar, *Gynaephora groenlandica*, is abundant in the polar oasis at Alexandra Fiord, Ellesmere Island, and plays an important ecological role there as both a dominant herbivore and a very significant food source for breeding birds as well as insect parasitoids. This population of *G. groenlandica* is thought to be limited by parasitoid-induced mortality rather than by the extreme conditions of the physical environment. Because insect development and activity are strongly temperature-dependent, increased temperatures that are predicted to occur with global warming could alter development rates and/or activity patterns of *G. groenlandica* and its parasitoids, disrupting the balance between populations. Temperature relations of *G. groenlandica* and its parasitoids are being investigated both in the field at Alexandra Fiord and in the laboratory at the University of Victoria, with the ultimate goal of estimating the responses of these insects to predicted global warming. This study was initiated in 1994 and is expected to continue for at least two more field seasons.

FLORAL SEX RATIO IN DWARF WILLOW, *SALIX HERBACEA* L., AT KILPISJARVI, NW FINLAND.

Lohiluoma, M-A.,[1] Nordenhall, U.[2] and Laine, K.[3]

1 University of Oulu, Department of Botany, Linnanmaa, FIN-90570 Oulu, Finland
tel. +358 81 554 5862; fax. +358 81 553 1500
e-mail: malohilu@phoenix.oulu.fi
2 University of Göteborg, Department of Systematic Botany, Carl Skottbergs gata 22, S-41319 Göteborg, Sweden
tel. +46 31 773 2677; fax. +46 31 773 2677
e-mail: urban.nordenhall@systbot.gu.se
3 University of Oulu, Department of Botany, Linnanmaa, FIN-90570 Oulu, Finland
tel. +358 81 553 1571; fax.+358 81 553 1584
e-mail: klaine@cc.oulu.fi

Floral sex ratio of arctic dwarf willow, *Salix herbacea* L., was studied at Kilpisjarvi, NW Finland, during summer 1994. The study was carried out at two transects, at the fjelds Jehkats and Pikku-Malla (altitudes 650 m a.s.l. and 850 m a.s.l.). The floral sex ratio was strongly male biased (70:30) at both sites. The effect of topography, snow-melt, soil nutrient stage (Ca, K, Mg, P and N), soil moisture and pH was studied. Studied variables did not correlate significantly with the floral sex ratio. However, correlation between nutrients and proportion of female catkins is positive at Jehkats, and negative at Pikku-Malla Male plants seemed to have higher flowering frequency than female plants. The effect of studied variables on individual sex ratio will be observed during the coming season.

SHOPPING LIST FOR SEEDS OF ARCTIC PLANTS

Per Molgaard(*)
Dept. of Botany and Pharmacognosy, Royal Danish School of Pharmacy, Univeritetsparken 2, DK 2100, Copenhagen, Denmark.

From the literature it seems that species in Greenland have smaller seeds than plants from the same genus outside Greenland Polunin 1959: Circumpolar Arctic Flora). Seeds from Kilen in North Greenland were comparatively smaller than seeds from the same species outside Greenland. To throw further light on hypothesis I should very much like seed samples from all ITEX SITES of selected species:

Draba bellii, D: gredinii/oblongata, D. subcapitata
Cerastium arcticum/alpinum
Minuartia rubella
Pedicularis hirsuta, P.lanata/dasyantha
Papaver radicatum s.l.
Potentilla hyparctica

EVOLUTIONARY RESPONSE OF ARCTIC PLANT POPULATIONS TO CLIMATE CHANGE

Kent Schwaegerle

Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks, AK 99775 U.S.A.

The persistence of arctic plant populations in their present geographic locations depends in part on their ability to adapt in a changing environment. We will assess the potential for evolutionary change in *Salix pulchra*, *Eriophorum vaginatum*, and *Dryas octopetala* by characterizing genetic variation within and among populations. These studies will reveal patterns of evolutionary change that have occurred in the past as local populations adapted to different geographic conditions and will reveal genetic constraints on adaptive evolution in the present. Because climate change will primarily affect plant populations by altering the spatial and temporal availability of plant growth resources, these studies will focus on morphological and physiological traits associated with acquisition of growth resources.

SALIX ARCTICA AT ALEXANDRA FIORD, ELLESMERE ISLAND, CANADA: RESPONSES TO THREE SEASONS OF ITEX EXPERIMENTAL WARMING.

Michael H. Jones[1], Greg H.R. Henry[2], and S. Ellen MacDonald[1]

1 Dept. of Renewable Resources, University of Alberta, Edmonton, AB, T6G 2H1 Canada
2 Dept. of Geography, University of British Columbia, Vancouver, B.C. V6T 1Z2 Canada

The high arctic, dioecious willow *Salix arctica* (Pall) was subjected to experimental warming at Alexandra Fiord, Ellesmere Island, beginning in June 1992. This research was conducted as part of the International Tundra Experiment (ITEX), and the results reported here are for data collected from 1992-1994, the first three years of a long-term experiment. We found that the strength of the warming effect was strongly dependent upon habitat, and that male and female willows generally differed little in the magnitude of their responses. In a relatively dry community, warming consistently, if not significantly, resulted in greater catkin and leaf fascicle lengths, annual stem increments, specific leaf areas, and female reproductive success. In contrast, willows in a wet-mesic meadow were affected little by warming. The timing of phenological events was not affected by the warming treatment in either habitat, although growth reates of leaf fascicles was enhanced signficantly in male willows in the meadow. Reproductive effort, measured in the third year, did not differ by warming treatment, habitat, or sex. Field trials indicated that germination rates may be slightly enhanced by warming. Although the effect of the experimental treatment was not pronounced, there is evidence that warming had a cumulative effect on plants in the dry habitat over three seasons.

SALIX ARCTICA IN A RETROSPECTIVE STUDY

Karen Christensen & Per Molgaard(*)

Dept. of Botany and Pharmacognosy, Royal Danish School of Pharmacy, Univeritetsparken 2, DK 2100, Copenhagen, Denmark.

A female biased distribution pattern in *Salix arctica* is presented in relation to herbivory and annual growth pattern. With increasing age of the population a more pronounced female bisaed sqewness is observed. In general the annual growth is similar in male and female plants, but highly variable with the habitat. Herbivory is most severe to male plants, which may explain the sexual distributional pattern. Preliminary results will be presented and discussed in relation to the ITEX program.

ESTABLISHMENT OF AN ITEX SITE AT BARROW, ALASKA AND THE SHORT-TERM RESPONSES OF *CASSIOPE TETRAGONA* AND *SALIX ROTUNDIFOLIA*

Christian Bay

Botanical Museum, University of Copenhagen, Gothersgade 130, DK-1123 Copenhagen, Denmark
fax: +45 35322210; e-mail: chrisb@bot.ku.dk

During the growing season of 1994, an ITEX site was established and monitored at Barrow, Alaska. Twenty-four open top chambers (OTCs) and 24 controls were placed randomly in a population of *Cassiope tetgragona*(L.) D.Don and *Salix rotundifolia* Trautv.

Temperature and humidity were measured in OTC and control plots and recorded by data loggers every 1.2 hours over the entire growing season. An additional 13 data loggers and sensors were added in August. The mean temperature difference between OTCs and controls was 1.75°C in those plots measured throughout the season.

The phenological monitoring was conducted mostly on a daily basis over 69 days from mid June to the end of August. Selected ramets of *Cassiope tetragona* were used, whereas the monitored unit of *Salix rotundifolia* was plants within a 100 cm^2 area. All other vascular plant species (total=23) found in the plots were monitored accoring to phenological parameters most relevant for each species.

The experimental manipulations of *Cassiope tetragona* had a significant impact on all phenological parameters. The early phenological stages started *ca.* 3 days earlier in OTCs compared to controls, whereas the differences between the later phenological stages were *ca.* 8 days. The length of the period when flowers were open and exposed to pollinators was only prolonged by *ca.* 1 day in the OTCs, although flowering started *ca.* 8 days earlier than controls. There was no significant difference in annual growth increment between plants in OTCs and controls.

There was a significant difference in early phenological stages of *Salix rotundifolia* between plants in experimental and control plots. The emergence of leaves and stigmas was *ca.* 5 days earlier, and the onset of seed dispersal was *ca.* 6 days earlier in OTCs. The total length of the growing season was prolonged by *ca.* 5 days in experimental plots.

There was a significant difference in the weight of the largest leaf and length of the longest leaf between female plants in OTCs and controls. The ratio of mature:immature catkins was significantly larger in OTCs, indicating that the temperature enhancement has a positive effect on the survivability of young catkins.

The onset of pollen dispersal and the time when all pollen was released was significantly earlier in the OTCs: averaging 5.5 days and 3.0 days, respectively. The period of pollen release was 34% longer in OTCs.

Although there was a significant difference in the length of longest leaf of male plants between OTCs and controls, there was no difference in leaf weight.

DIFFERENTIAL GROWTH AND REPRODUCTIVE RESPONSE OF *CASSIOPE TETRAGONA* TO VARIATIONS IN GROWING SEASON CLIMATE AT ALEXANDRA FIORD, ELLESMERE ISLAND, CANADA

Jill Johnstone* and Greg H.R. Henry

Department of Geography, University of British Columbia, Vancouver, B. C. V6T 1Z2 Canada
email: jill@unixg.ubc.ca; Greg.Henry@mtsg.ubc.ca

The short-term response of *Cassiope tetragona* to experimental manipulations of surface temperature and snowmelt timing was monitored at Alexandra Fiord, Ellesmere Island, in 1992 and 1993. Phenological timing appears to be an important factor governing the growth response of this species, and may indicate important environmental or genetic constraits which determine more long-term responses to climate variations. In general, *C. tetragona* shows a conservative growth response to experimental manipulations and natural variations in environmental conditions. Reproduction of this species, in contrast, appears to be highly sensitive to increases in growing season temperatures.

The statistical relations between growth and reproduction of *Cassiope tetragona* and natural variations in climate were examined using retrospective analysis of two 35-year growth chronologies and one 25-year flowering chronology developed from plants sampled from one of the temperature manipulation sites. The three chronologies show strong correlations with concurrent July temperatures recorded at Alexandra Fiord and summer temperatures recorded at Eureka, Ellesmere Island. Statistical analysis of the *Cassiope* chronologies supports the conclusions taken from the warming experiments, suggesting that growth is moderately sensitive, and reproduction highly sensitive, to variations in growing season temperatures.

SHORT-TERM RESPONSES TO WARMING IN *SAXIFRAGA OPPOSITIFOLIA*

Mikael Stenström*[1], Felix Gugerli*[2] and Saila Karinen[3]

1 Department of Systematic Botany, University of Göteborg, Carl Skottsbergs gata 22, S-413 19 Göteborg, Sweden.
E-mail: mikael.stenstrom@systbot.gu.se
2 Institute for Systematic Botany, University of Zurich, Zollikerstr. 107, CH-8008 Zurich, Switzerland.
E-mail: fgugerli@systbot.unizh.ch
3 Department of Botany, University of Oulu, Linnanmaa, SF-905 70 Oulu, Finland.
E-mail: sjk@phoenix.oulu.fi

The response to warming in *Saxifraga oppositifolia* (a long-lived, evergreen, herbaceous perennial, dependent on insects for full seed set) was assessed by Open-top chambers (OTCs) at Latnjajaure, Sweden (2 seasons) and Val Bercla, Switzerland (1 season). ITEX Corners were used at Kilpisjaervi, Finland (2 seasons). The species appears to be very conservative, and the only significant effect consistent among sites was a shortened prefloration period (time from snowmelt to flowering) for experimental plants at both Val Bercla and Latnjajaure in 1994. Temperature increase in the ITEX Corners at Kilpisjaervi was only 0,4 degrees C, and none of the response variables were significantly affected in 1994. At Val Bercla, the flowering period was extended in the OTCs; a similar, however not significant effect was seen at Latnjajaure. The relative reproductive success was lower in the OTCs at Val Bercla,
possibly due to a low pollinator visitation rate. Pollination was not significantly affected at Latnjajaure; instead, there was a trend of fruit set being higher in the OTCs in both years of the study.

RESPONSE TO SIMULATED CLIMATE WARMING BY ALPINE AND SUB-ARCTIC *SILENE ACAULIS*, A POLLEN RISK STRATEGIST.

Juha Alaltalo[1], Orjan Totland[2], and Ulf Molau[1]

1 Dept. of Systematic Botany, University of Göteborg, Carl Skottsbergs Gata 22, S-413 19 Göteborg, Sweden
2 Botanical Institute, University of Bergen, Allengaten 41, N-5007 Bergen, Norway

To test whether early flowering species can respond in the same positive manner to climatic warming as is predicted for late-flowering seed-risk strategists, experimental climatic warming was applied to an alpine and sub-arctic population of *Silene acaulis*. The experiment was run for two years at the sub-arctic site (LFS) and one year at the alpine site (Finse).

The two year temperature enhancement had a marked effect on the phenology at LFS. Cushions inside the open top chambers (OTCs) started flowering significantly earlier than in the controls. Both the male and female phases developed significantly earlier in the OTC, as did the start of seed dispersal. The response in quantitative reproductive traits differed partly between the different sites. There was no significant difference between OTCs and controls in numbers of flowers or capsules, or fruit/flower ratio at either site. Plants in OTCs produced significantly more mature seeds at LFS, but not at Finse. At LFS, seeds from controls were significantly heavier than those from OTCs. This was in direct contrast to results at Finse, where heavier seeds were produced in OTCs. Plants in OTCs at LFS had significantly higher seed/ovule ratios, whereas there was no significant difference at Finse. At both sites, the abortion rate was significantly less in OTCs than controls. There was a significant negative correlation between number of seeds and mean seed weight at LFS, but not at Finse.

The results show that early flowering alpine and sub-arctic species can respond in a positive way to climatic warming. If they will not respond in a similar manner as late-flowering species, the composition of the vegetation could change. The response differences between sites may be due to the fact that the alpine site only experienced one season of warming. It could also be that temperature is a limiting factor at the sub-arctic site, but not at the alpine site. If this is true, then climatic warming can be expected to have greater effects at the northern limit of a species range.

RESPONSES TO TEMPERATURE ENHANCEMENT IN *RANUNCULUS NIVALIS*, A PERENNIAL TUNDRA HERB.

Ulf Molau

Department of Systematic Botany, University of Göteborg, Carl Skottsbergs Gata 22, S-413 19 Göteborg, Sweden, and Institute of Arctic Biology, University of Alaska Fairbanks, P.O. Box 757000, Fairbanks AK 99775-7000 USA

Responses to experimental warming in *Ranunculus nivalis*, a tundra herb with perennial rhizomes, were studied during two consecutive seasons (1993-94) at the Latnjajaure Field Station in northernmost Swedish Lapland. Temperature enhancement was brought about by using open-top chambers (OTCs) according to the ITEX design. Contrary to the findings from evergreen perennials, an experimental increase in temperature by 3°C on average had no significant impact on reproductive phenology (pre- and postfloration time spans) in this species. Climatic differences between the seasons, however, yielded significant differences in these respects. The main reason is believed to be that in 1994 the area experienced a very early thawing, but after that the phenological development of most species was retarded by recurrent blizzards. When temperatures finally grew favorable for continuation of the *R. nivalis* annual flowering cycle, it was facing much stronger a competition from other species (from shading) than during more normal years when the species flowers very early, escaping that competitive pressure.

Quantitative traits, on the other hand, showed the opposite kind of response. The width of the basal (rosette) leaves, and thereby leaf area, increased highly significantly in the experimentally warmed plots, and there were hardly no differences between the years in this respect. Shoot height showed a similar, significant response, and there was a large overall increase in biomass in the species in heated plots. The most striking and highly significant differentiation is obtained in seed weight and germinability between OTCs and control plots (14-33 % increase in seed weight). There was no detectable trade-off between seed number and seed weight.

In concluson, *R. nivalis* is performing much better when it is allowed to start its annual flowering cycle at an early date. It also exhibts the general trend that deciduous tundra plants respond to increased temperature by increased growth and production, accompanied by little or no phenological response, whereas evergreen species react the other way.

RESPONSES OF *POLYGONUM VIVIPARUM* TO SIMULATED ENVIRONMENTAL CHANGE AT A HIGH ARCTIC POLAR SEMI-DESERT, SVALBARD.

P.A. Wookey*[1], J.M. Welker[2], A.N. Parsons[2], M.C. Press[3], T.V. Callaghan[3] & J. A. Lee[3]

1 Department of Biological Sciences, University of Exeter, Hatherly Laboratories, Prince of Wales Road, Exeter EX4 4PS U.K.
2 Natural Resource Ecology Laboratory, Colorado State University Fort Collins, CO 80523-1499 USA
3 Department of Animal & Plant Sciences, University of Sheffield, Sheffield S10 2UQ U.K.

Polygonum viviparum - a perennial rhizomatous geophyte of circumpolar, northern temperate and alpine distribution - is successful in habitats ranging from high arctic fellfields / polar semi-deserts to the closed plant communities of the sub-arctic herb meadows. Distinct individuals make up the population at any one site, and the growth form is non-clonal. *P. viviparum* proliferates mainly by asexual reproduction involving the formation of bulbils on a flowering spike: the production of viable seeds is rare. *P. viviparum* offers an excellent opportunity to record the effects of simulated environmental change on plant growth, development and biomass allocation to reproductive structures (bulbils, spikes and flowers) compared with vegetative (leaves and corms). The large proportion of below-ground biomass present as a single corm also enables below-ground allocation to be readily quantified.

Growing season temperatures and precipitation, and soil nutrient (N, P and K) status, were increased in situ at a polar semi-desert site in northwestern Spitsbergen to simulate the possible impacts of climate change. During the second growing season of manipulations, biometric analyses were made of vegetative and reproductive structures, together with measurements of instantaneous net photosynthesis (Pn).

P. viviparum responded most strongly to the addition of nutrients (N, P and K, at rates of 5, 5 and 6.3 g m^{-2} yr^{-1}), both in terms of vegetative and asexual reproductive development. By contrast, increasing the mean growing season air temperatures by 3.5°C above ambient (3.6°C for June, July and August at this site) - a treatment equivalent to ITEX temperature manipulations - exerted a significant impact on allocation to asexual reproductive structures (bulbil numbers and weights, and spike length) alone, but did not influence leaf or corm development. Pn, expressed per unit leaf area, was similar in all treatments, although greater leaf development in the nutrient-amended treatments can be expected to have maintained greater CO2 assimilation per individual plant. Water additions were not significant as a main effect for any of the measured parameters of plant performance.

Elevated growing season temperatures at the polar semi-desert may alter the population structure and increase the numbers of individuals of *P. viviparum*, and the overall biomass, by enabling increased recruitment of individuals from bulbils. The poor nutrient status of the site, however, together with a lack of suitable microsites for establishment of plants from bulbils, may constrain recruitment in the longer term. Increased investment of photosynthate and nutrients in bulbils may also constitute a significant reproductive cost and reduce the longevity of parent plants.

ITEX ACTIVTIES ON DISKO ISLAND IN GREENLAND

Karen Christensen & Per Molgaard*
Dept. of Botany and Pharmacognosy, Royal Danish School of Pharmacy, Univeritetsparken 2, DK 2100, Copenhagen, Denmark.

ITEX CORNERS are placed around *Papaver* and *Salix arctica*. The 1994-season was unusual in the way that snow melt was very early, and afterwards the weather was wet and cool. This created a prolonged season with subnormal performance of the plants. Adverse effects were especially seen on the plants in ITEX CORNERS. They were more severely affected than the controls and did not grow as well as in the previous years.

LEAF EXSERTION, LEAF ELONGATION, AND LEAF SENESCENCE IN ERIOPHORUM VAGINATUM AND CAREX BIGELOWII IN NORTHERN ALASKA

Gaius R. Shaver* and James Laundre

The Ecosystems Center, Marine Biological Laboratory, Woods Hole, MA, USA 02543
Telephone: 508-548-3705, x492
Email: Gshaver@lupine.mbl.edu

The seasonal patterns of leaf exsertion, elongation, and senescence were described and compared for two of the most abundant graminoid species of Alaskan moist tussock tundra, *Eriophorum vaginatum* and *Carex bigelowii*. In addition the responses of both species to NPK fertilizer and to variation in site fertility (water track versus non-track areas) were also assayed and compared. The research was done over two full growing seasons at two sites near Toolik Lake, Alaska, where other aspects of the ecology of both species have been the subject of intensive and ongoing research.

Both species showed the typical graminoid pattern of sequential leaf production, in which the exsertion and elongation of new leaves is coincident with the senescence of old leaves. However, the rates of these processes were much slower and steadier in *Eriophorum* than in *Carex*, with much greater overlap in the life histories of individual leaf cohorts. The total and green leaf lengths of whole tillers in *Eriophorum* were also less variable over the entire year than in *Carex*. The conclusion is that *Carex* should depend more on external storage of leaf metabolites and structural components than *Eriophorum*, with a much greater seasonal variation in demands on storage and retranslocation to and from leaves.

The effects of fertilizer and the water track on leaf growth dynamics and turnover rates were largely nonsignificant, despite major effects on total tiller size and productivity. This is in contrast to previous research on evergreen leaf dynamics, but similar to results of previous research on overall production and biomass regulation in *Eriophorum*. We conclude that the graminoid response to increased nutrient availability in the Arctic is to dilute the greater amounts of nutrient uptake by greater growth, so that nearly the same metabolic homeostasis is achieved as under low nutrient availability, but at a higher biomass.

EXPERIMENTAL MANIPULATIONS OF SNOWDEPTH: EFFECTS ON PLANT NUTRIENT CONTENT AND IMPLICATIONS FOR CARIBOU.

N. E. Walsh[1], T. R. McCabe[1], A. N. Parsons[2] and J. M. Welker*[2]

1 National Biological Service, 101 12th Ave., Box 15, Fairbanks, AK 99701 U.S.A.
2 Natural Resource Ecology Laboratory, Colorado State University Fort Collins, CO 80523-1499 USA

Predictions suggest that winter snowfall in northern latitudes will be altered by increasing concentrations of greenhouse gases. The ecological consequence of either increases or decreases in snowfall are however unclear, especially effects across trophic levels, *i.e.* plants to herbivores. In this study we have manipulated snow cover on the summer range of the Porcupine caribou herd in northern Alaska and examined forage mineral nutrition. Snow fences were used to increase snow pack and produce a later snowmelt than controls and black mesh netting placed on the snow surface to increase the rate of snow melt, lengthing the growing season. Peak season sampling was conducted and carbon and nitrogen contents were examined from ambient snow conditions, increased snow pack and from increased snowmelt. C and N contents for *Betula nana*, *Eriophorum vaginatum* and *Salix planifolia* were studied. We found that increasing the snow cover on caribou summer range resulted in higher peak season N contents for *B. nana* and for *E. vaginatum* with no change in leaf C-content. This resulted in lower C/N ratios of both species at peak season. When snowmelt was accelerated with netting it caused no effect on the carbon or the nitrogen content of *E. vaginatum*, but a slight increase in N content was observed for *B. nana*. Higher leaf N contents in plants from the increased snowpack may be due to the delayed phenology and the temporal displacement of the seasonal patterns of changes in mineral nutrition. However, nitrogen input from snow may also have contributed to higher tissue N in the higher snowpack sites. Increased nutrient content of caribou forage would have positive implications for caribou populations, at least in the short-term as higher forage nutrition would mean higher animal nutrition, improved body conditions, higher conception rates and greater overwinter survival of individuals.

CIRCUMARCTIC ACTIVE LAYER MONITORING (CALM): AN INTERNATIONAL CONTRIBUTION TO ITEX

Jerry Brown*[1] , F.E. Nelson[2] and D.A. Walker[3]

1 International Permafrost Association, Arlington VA 22219-0200 U.S.A.
2 Department of Geography and Planning, State University of New York-Albany, Albany, NY 12222 U.S.A.
3 Institute of Arctic and Alpine Research, Uinversity of Colorado, Boulder, CO 80309-0450 USA

Measurement of the thickness of the active layer (thaw depth) over permafrost is an important and relatively easy observation to incorporate in any ecological or permafrost investigation. There is, however, no single method for measuring this parameter over an area of interest. Employment of standardized measurement method and sampling design are important for interannual comparisons at single sites, for intersite comparisons and to avoid inaccurate estimates in complex terrain or landscape units. The objectives of this report are two-fold: (1) to report on the status and results of our common international active layer measurements; and (2) to propose a modified ITEX program of measurement for monitoring the active layer. These activities are being undertaken in cooperation with both the International Tundra Experiment (ITEX) and International Permafrost Association (IPA). Results are also reported in the IPA news bulletin Frozen Ground.

During the 1994 St. Petersburg workshop it was agreed that active layer measurement programs should be established at ITEX sites as soon as possible, to facilitate effective site comparison and detection of long-term trends. The measurement program at each site should obtain both (1) progression of thaw including its onset; and (2) maximum end-of-season thaw, as an indicator of interannual variation in climatic parameters and the moisture and thermal regimes of the soil. Observations of supplemental soil moisture and daily soil temperature data in the upper 50 cm are also desirable when continuous data cannot be obtained. We proposed establishment of a fixed grid for active layer measurements; the optimal size is 1 km x 1 km, subdivided into 100 m x 100 m sections and chosen to be representative of a variety of local or regional landscape units. The best sampling design at this scale employs both systematic and random components. Owing to time and other constraints, most grids established in 1994 were substantially smaller ranging from 60 to 200 meters on a side. Thaw measurements using a gridded sampling design were made at 13 locations in four countries. Average thaw ranged from a minimum of 30 cm at a Devon Island location to 86 cm on southern Yamal Peninsula, to 111 cm in drier sites in Svalbard.

Detailed recommendations for sampling and instrumentation, and a draft data form are presented for incorporation into the ITEX manual.

MONITORING OF THE ACTIVE LAYER, AT KAPP LINN, SVALBARD 1972-1994.

H. Jonas Åkerman

Dept. of Physical Geography, Lund University, Sølvegatan 13, S22362 LUND, Sweden.
tel: 46-46 2128693; fax: 46-46-2124417
E-mail: Jonas.Akerman@natgeo.lu.se

The active layer, or depth of thaw, has been monitored within 100x100 m squares at ten sites in the vicinity of Kapp Linn', (78°03'42"N, 13°37'07"E) Svalbard during the period 1972 -1994. The ten sites differs in elevation, distance from the sea, vegetation cover, substrate and active periglacial processes. The sites has been monitored by random sampling within the squares by the use of small-diameter metal probes and supplemented by thermistor profiles. One site is equipped with an automatic datalogger covering levels form 2 m above to 7 m below the ground. From the field season 1994 the probing method follows the proposed ITEX-standard for active layer monitoring. The mean active layer varies between 1.92 m and 0.38 m with the deepest being the exposed, well drained raised beach ridges and the shallow sites being the bogs. The inter-annual variability is fairly similar for all the sites (coefficient of variation 11-14%) except for the bog site where it is 21%. The summer mean air temperature for the monitoring period 1972-1994 is 3.6°C with is the same as for the entire climatic record period 1912-1994. The summer air temperature (June-August) has a range of 2.8°C during the study period with a maximum of 5.1°C and a minimum of 2.3°C. The inter annual variability of the active layer as monitored during the observation period do not correlate with the MAAT or with the individual summer months but very well with the total summer climate (June - Aug.). There is no clear over-all trend in the summer climate during the monitoring period but a clear division between the period from 1972 to 1983 which had a decreasing summer temperature and 1984 to 1994 which show an increase in the air temperature. The active layer depths follows the same general pattern. The observed changes in the depth of the active layer during the period 1984 -1994 can be correlated with an increased amount of soil water in the active layer - especially at the bog site and the sorted net site. The well drained raised beach ridges and the areas with soil wedges are not affected very much. The active layer variations during the investigation period has not yet reached a depth at with the ice wedges are influenced. The marginal is however only a few centimetres. A majority of the earlier fairly common palsa-like mounds found in the bogs of the area have disappeared. There are also several observations of an increased thermokarst activity within the study area.

THE EFFECTS OF ENHANCED UV-B RADIATION ON A SUBARCTIC HEATH ECOSYSTEM

Ulf Johanson*[1], Carola Gehrke[2], Lars Olof Bjørn[1], Terry Callaghan[3], Mats Sonesson[2]

1 Dept. of Plant Physiology, Lund University, Box 117, S-221 00 Lund, Sweden
2 Dept. of Plant Ecology, Ecology Building, Lund University, S-223 62 Lund, Sweden and Abisko Scientific Research Station, Royal Swedish Academy of Sciences, S-981 07 Abisko, Sweden
3 Sheffield Centre for Arctic Ecology, University of Sheffield, Sheffield S10 2UQ, U.K.

Due to anthropogenic releases of certain gases, especially chlorofluorocarbons (CFCs), the stratospheric ozone layer is under threat. The consequence of a thinner ozone shield is an increase in biologically harmful ultraviolet-B radiation (UV-B, 280-320 nm) reaching the biosphere. To investigate the effects of increased UV-B radiation on a subarctic heath ecosystem a field irradiation experiment was established at Abisko, northern Sweden (68 °N). UV-B was supplemented with fluorescent tubes to simulate 15% ozone depletion. The vegetation in the plots consists of a dwarf shrub layer with mosses and lichens beneath. Many response variables of the vegetation are measured in these plots, e.g. growth, phenology, photosynthesis, changes in species composition and decomposition. The annual stem growth of dwarf shrubs was lower under enhanced UV-B. This was more pronounced in evergreen than in deciduous species and tended to increase over time. Leaf thickness of dwarf shrubs was changed by UV-B. The leaves of the evergreen *Vaccinium vitis-idaea* were thicker, while those of the two deciduous species *V. myrtillus* and *V. uliginosum* were thinner. Further effects on ecosystem level will be discussed.

EFFECTS OF ENHANCED ULTRAVIOLET-B ON DECOMPOSITION OF ORGANIC MATTER IN THE SUBARCTIC

Carola Gehrke*[1], Ulf Johanson[2], Terry V. Callaghan[3], David Chadwick[4], Clare H. Robinson[3]

1 Dept. of Plant Ecology, Ecology Building, Lund University, 223 62 Lund, Sweden
2 Dept. of Plant Physiology, Lund University, Box 117, 221 00 Lund, Sweden
3 Sheffield Centre for Arctic Biology, University of Sheffield, Tapton Gardens, Taptonville Road, Sheffield S10 2TN, U.K.
4 AFRC Institute of Grassland and Environmental Research, North Wyke, Okehampton, Devon EX20 2SB, U.K.

Decomposition of organic matter is particularly important in extreme terrestrial environments such as polar regions where nutrient cycling is slow and limits biomass production. Any modification of decomposition resulting from environmental change such as increase in ultraviolet-B radiation (UV-B, 280-320 nm) due to a thinning of the stratospheric ozone layer may have impacts on ecosystem structure and function.

We investigated how UV-B radiation will affect: 1) the quality of plant litter grown under different UV-B levels in the Subarctic; and 2) decomposition under different UV-B levels. The deciduous dwarf shrubs *Vaccinium uliginosum* and *V. myrtillus* grew under ambient and enhanced UV-B (corresponding to 15 % ozone depletion) in a natural heath ecosystem in the Subarctic. After two growing seasons senesced leaves were collected and decomposed in a 2 x 2 factorial experiment under both laboratory conditions for 62 days (*V. uliginosum*: no UV-B and 10 kJ m-2 day-1 UV-B_{BE}) and under field conditions for 24 months (*V. myrtillus*: ambient and enhanced UV-B corresponding to 15 % ozone depletion).

The enhanced UV-B during growth changed the litter quality. Subsequently, the microbial respiration was decreased. A lower relative mass loss due to treatment was found both after 62 days decomposition in the laboratory and after 24 months decomposition in the field.

The UV-B during decomposition decreased the proportion of lignin in the plant residues. Total microbial respiration decreased. The litter decomposed under UV-B was less colonized by fungal decomposers. There are strong indications of changes in decomposer fungal community structure due to UV-B.

Ecological implications and feedback effects on global climate change are discussed.